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LITTORAL HERMIT CRABS (Decapoda: Anomura) FROM PORT MOMBASA

P.J. REAY

Department of Biological Sciences
Plymouth Polytechnic, Plymouth PL4 8AA, U.K.

ABSTRACT

Ten species of hermit crabs belonging to the genera *Coenobita* (2 species), *Calcinus* (2), *Clibanarius* (5) and *Dardanus* (1) were collected and identified from the supralittoral and intertidal zones of Port Mombasa during February and March 1983. A key to the identification of the species is presented. The species pair, *Calcinus laevimanus* and *Clibanarius virescens* were numerically co-dominant and occurred throughout the intertidal area. Actual densities of up to 82 crabs m⁻² were recorded, but aggregations of *Clibanarius virescens* (eg. 74 in a 10 cm² area) could give rise to much higher density values locally. The two dominant species were small in size (up to 14 mm total carapace length), and samples contained up to 36.2% ovigerous females. They occurred in 14 different shell types, and there was evidence of both species- and size-related shell selection. I also concluded, from the scarcity of empty shells and from the behaviour of crabs provided with empty shells, that suitable shells were a scarce resource for hermit crabs in the area. Compare to the dominant species, the other eight were either rare, or restricted to a particular habitat. For example, *Coenobita* species were mostly found in the supralittoral zone of sandy beaches. Both *Dardanus lagopodes* and *Calcinus latens* were restricted to the shallow sublittoral or lower shore pools, whereas all other species were usually found out of water at low tide. The results are compared with those from other areas, and some suggestions for further work are made.

INTRODUCTION

In spite of being conspicuous and often abundant members of the intertidal and supralittoral communities, hermit crabs do not appear to have been studied along the Kenya coast. Even in the Indian Ocean as a whole, little more than species lists occur in the literature, and studies on the semi-terrestrial *Coenobita rugosus* from Somalia and Aldabra (eg. Vannini 1976, Vannini and Chelazzi 1981) appear to be the only detailed work undertaken. Species lists, either of crabs or of intertidal marine fauna including hermit crabs, have been given for the Red Sea by Hughes (1977); for Aldabra by Taylor (1971a); for Diego Garcia by Taylor (1971b); for Madagascar and the Comores by Dehancé (1964); for Tanzania by Hartnoll (1976); for Pakistan by Tirmizi and Siddiqui (1982); for South Africa by Barnard (1950), and for Somalia by Lewinsohn (1982). The latter is the most relevant paper as far as Kenya hermit crabs are concerned, and provides information on habitat, distribution and diagnostic features.

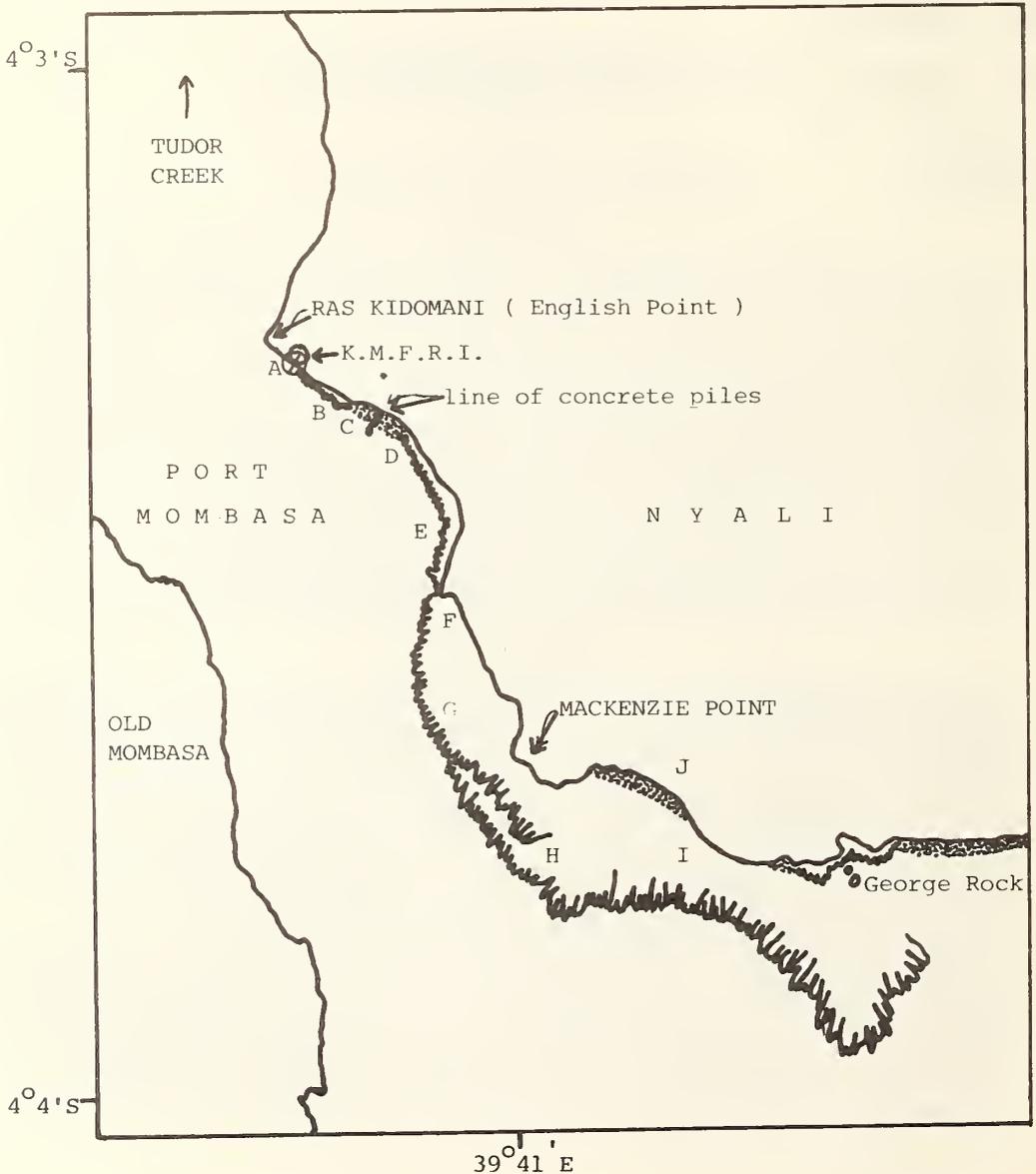
Outside of the Indian Ocean area, and particularly around the coasts of North and Central America, the ecology and behaviour of hermit crabs has been extensively studied. Much of this work has concentrated on the mechanics and implications of the shell selection behaviour (eg. Fotheringham 1976, Spight 1977), agonistic behaviour (eg. Hazlett 1970, Dunham 1978) and interspecific co-existence (eg. Vance 1972a, Bertness 1981). General reviews have been provided by Reese (1969) and Scully (1983), and the broader role of gastropod shells in benthic communities is discussed by McLean (1983).

Hermit crabs are of no direct commercial importance, but their abundance in some areas suggests

that they may play an important role in littoral communities, and they are potentially in direct competition with man for empty gastropod shells. Indeed, they are referred to in this context in a poster issued by the Kenya Ministry of Tourism and Wildlife which advises that one reason for not gathering empty shells is that it deprives hermit crabs of a home.

With this application in mind and, in the absence of any published data on Kenya hermit crabs, the present paper seeks to bring together observations made during February and March 1983 from the littoral zone of Port Mombasa.

Figure 1 The study area on the eastern shore of Port Mombasa, showing specific area A — J referred to in text.



STUDY AREA, MATERIALS AND METHODS

The study area, with major features, is shown in Figure 1. Hermit crabs were observed and collected at low tide from exposed intertidal rock surfaces, pools, and the shallow sublittoral, and from the supralittoral zone of sandy beaches. Some samples were taken to the laboratory for examination and measurement, and some were maintained alive in captivity. All crab measurements refer to total carapace length (from rostrum tip to one of the posterior tips of the posterior carapace). Gastropod shell measurements refer to the maximum linear dimension. Further details of methods are given in the appropriate section below.

RESULTS

The Species Present and Their Identification

From Barnard (1950) and Tirmizi and Siddiqui (1982), it is clear that four genera are represented in the study area. These are all from the superfamily Coenobitoidea, as the bases of the third maxillipeds are proximate (close together); in the other pagurid superfamily, the Paguroidea, they are widely separated. Within the Coenobitoidea, two families are represented: the Coenobitidae (with genus *Coenobitus*) and the Diogenidae (with genera *Calcinus*, *Clibanarius* and *Dardanus*).

A key to the identification of the ten species found in this study is given as Appendix 1, and some of the key features are illustrated in Figure 2. A list of the species is as follows:

<i>Coenobita rugosus</i>	H. Milne Edwards
<i>Coenobita cavipes</i>	Stimpson
<i>Calcinus laevimanus</i>	(Randall)
<i>Calcinus latens</i>	(Randall)
<i>Clibanarius virescens</i>	(Krauss)
<i>Clibanarius merguiensis</i> *	de Man
<i>Clibanarius longitarsus</i> *	(de Haan)
<i>Clibanarius eurysternus</i>	Hilgendorf
<i>Clibanarius laevimanus</i>	Buitendijk
<i>Dardanus lagopodes</i>	(Forsk.)

All identifications have been confirmed by Professor L.B. Holthuis, who also provided primary identification on species marked with an asterisk.

Distribution and Abundance

The different species were distributed as follows (referring to areas denoted in Figure 1):

Coenobita rugosus and *Coenobita cavipes*. Restricted to the strand-line and above, on sandy beaches and the maritime (terrestrial) habitats on cliff-tops. Most specimens are obtained from area J and the beaches towards, Nyali, and *Coenobita rugosus* was the more common of the two species.

Calcinus laevimanus. Widespread and abundant throughout the littoral zone and on most flat, rocky substrates within the study area. It was particularly characteristic of shallow pools and ridges towards the top of the shore, where algal growth was sparse (eg. areas B, C and I). This was the most widespread species encountered and, with *Clibanarius virescens*, was also the most abundant.

Calcinus latens. Restricted to pools low on the shore and the shallow sublittoral. Nowhere common, but it was most consistently found in areas G and H.

Clibanarius virescens. Widespread and abundant, probably the most abundant species overall. Present throughout the littoral zone and on most flat, rocky substrates within the study area, it was most closely associated with those sites having a turf of macro-algae, eg. area D and I. Here, unlike most of the other species it often formed dense aggregations.

Clibanarius merguiensis. Present in very small numbers among *Clibanarius virescens* in area D.

Clibanarius longitarsus. Only one specimen recorded, in area E, but probably more common on muddy substrates associated with mangroves.

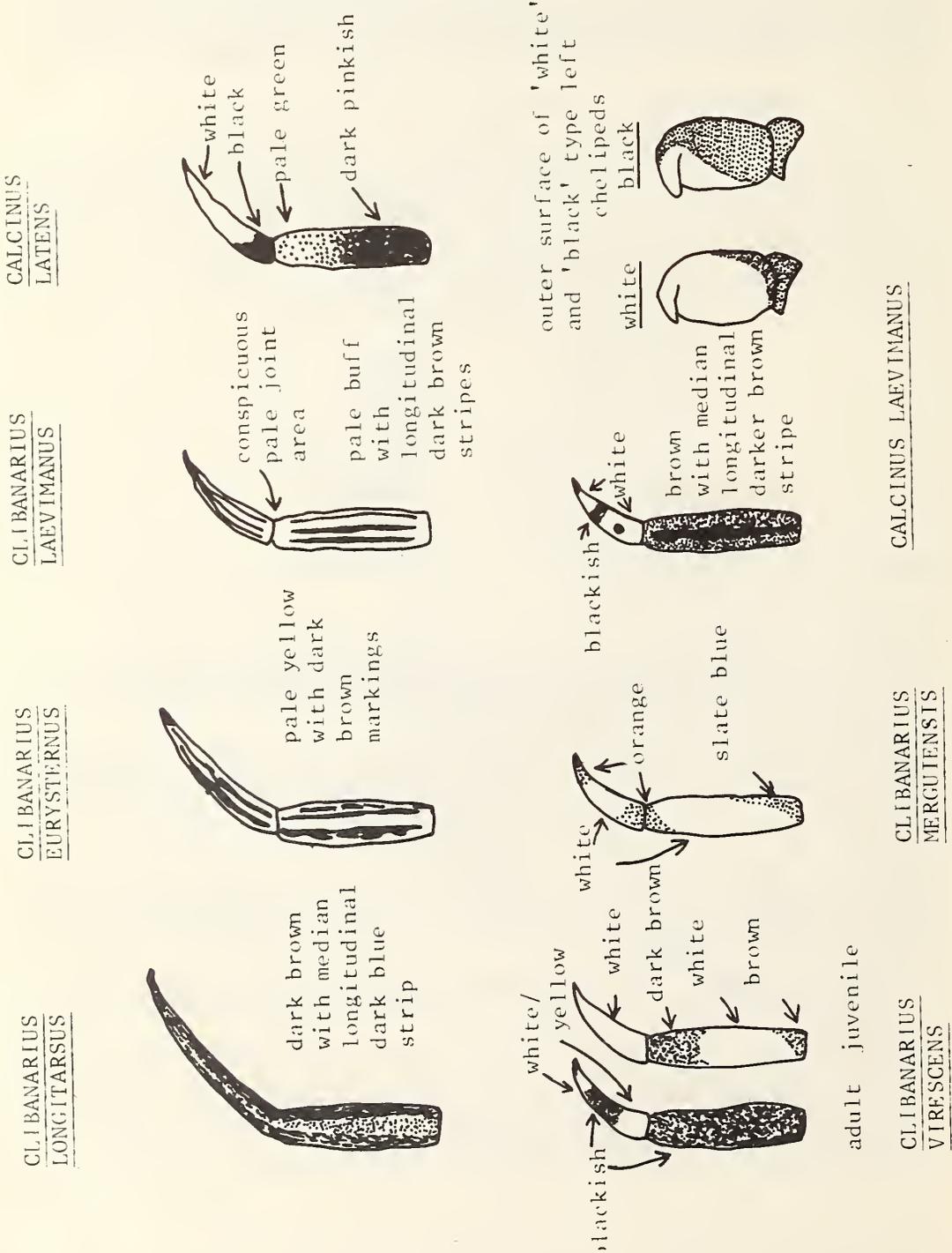
Clibanarius eurysternus. Widespread, but nowhere common, usually occurring singly in areas dominated by the other species, particularly in area I.

Clibanarius laevimanus. Only recorded from the upper shore in areas E and F, but here it was the most common species, occasionally forming loose aggregations. Its habitat was distinctive and consisted of limited algal growth, shallow silty pools and irregular rocky projections.

Dardanus lagopodes. Two specimens were found, one in the shallow sublittoral of area A and one in

Figure 2

Schematic diagrams (based on freshly dead material) to show colour patterns on the outer surfaces of third right pereiopods of *Calcinus* and *Clibanarius* species, and on the left chela of *Calcinus laevimanus*. Bristles on pereiopods have been omitted, and only propodus and dactylus are shown.



a deep pool in area H, but *Dardanus* species are primarily sublittoral and are therefore not likely to be common on the shore.

A limited amount of information on the relative abundance and density of *Calcinus laevimanus* and *Clibanarius virescens* was collected. This can be summarised as follows:

1. In a 1m² quadrat set adjacent to one of the pilings in area D, repeated counts were carried out on 8, 14 and 18 February. As the hermit crabs were removed from the area on each occasion, the latter two counts reflect invasion rates. The results were:

February 8	64	<i>Calcinus laevimanus</i>
	16	<i>Clibanarius virescens</i>
	2	<i>Clibanarius merguensis</i>
February 14	24	<i>Calcinus laevimanus</i>
	10	<i>Clibanarius virescens</i>
February 28	35	<i>Calcinus laevimanus</i>
	14	<i>Clibanarius virescens</i>

The quadrat was selectively placed in an area known to be favoured by *Calcinus laevimanus*, and the initial count can be used as a rough approximation to the maximum density observed for this species.

2. A second 1m² quadrat was selectively placed in an area of algal turf in a typical *Clibanarius* habitat of area D. In this quadrat, on February 11, 59 *Clibanarius virescens*, 12 *Calcinus laevimanus* and 1 *Clibanarius merguensis* were counted. This is typical of the densities encountered in such areas, but dense aggregations of the former species can result in much higher values. For example, an aggregation of *Clibanarius virescens* in area D occupied 10 cm² and contained 74 individuals. Such aggregations were quite common, and occurred on open surfaces as well as under small overhangs, and occasionally under stones.

3. In two transect lines set parallel to and, respectively, 2m and 5m from, and to the west of, the pilings (area C), a mean density of 17.3 hermit crabs m⁻² was found between low water mark and the sandy beach. The distribution was very patchy with many of the 0.25m² quadrats containing no crabs and with the maximum number per quadrat being 117.

Population Structure

The population structure is described only in terms of size, but the proportion of berried females was also noted. Data on population structure are restricted to the species *Calcinus laevimanus* and *Clibanarius virescens* from samples obtained in area D (Figure 3).

In *Calcinus laevimanus* I noticed that berried females had a smaller area of white on their enlarged left chelae compared to those taken to be males, which were occasionally entirely white (see Figure 2). This was assumed to be a straightforward sexual difference, but an isolated captive individual which moulted showed a 'white' pattern on the moulted chela, but a 'black' pattern on the new one. Such apparent changes in chela pattern require further investigation.

Shells Inhabited

The inhabited shells were characterised by the gastropod species, by shell size and by the intactness of the shell. It is relevant to ask: (a) whether there is any selection for preferred shell types by different species or sizes of hermit crabs; (b) whether shells are a limited resource, and (c) whether shell selection and availability are relevant to the competition and coexistence of species within the hermit crab guild.

The following observations have some bearing on these questions:

1. A wide range of shell species is used, as shown by the genera recorded for *Calcinus laevimanus* and *Clibanarius virescens* in two m² quadrats (Figure 4).

2. Very few empty shells were found in the areas inhabited by hermit crabs. The few empty shells found were usually either broken, blocked or belonging to the opisthobranch genus *Bulla* (the latter were sometimes occupied by crabs, but were probably not ideal because of the thinness of the shell and the large aperture).

3. There were some indications of species differences in shell selection. Although both *Clibanarius virescens* and *Calcinus laevimanus* were commonly found in *Carithium* spp. shells, *Cypraea* spp. and *Pyrene* spp. shells were almost always occupied by *Clibanarius*, and *Nerita* spp. by *Calcinus* (Figure 4). *Coenobita* spp. also seemed to favour *Nerita* spp., whereas the very flattened *Clibanarius eurystrernus* was typically found in *Conus* spp. shells which have a long narrow aperture.

4. There is a general relationship between the size of the crab and the size of the shell, particularly if the data are analysed species by species (Table I).

Table 1 *The relationship between shell length (SL) and crab (carapace) length (CL).*

	Regression Equation	Correlation coefficient
<i>Clibanarius virescens</i> in <i>Cerithium</i> spp.	$SL = 3.21 + 2.60 CL$	$r = 0.92$
<i>Clibanarius virescens</i> in <i>Cypraea</i> spp.	$SL = 6.48 + 2.06 CL$	$r = 0.87$
<i>Calcinus laevimanus</i> in <i>Cerithium</i> spp.	$SL = 4.45 + 2.53 CL$	$r = 0.67$
<i>Calcinus laevimanus</i> in <i>Nerita</i> spp.	$SL = 3.11 + 1.97 CL$	$r = 0.80$

5. Hermit crabs kept in captivity showed little tendency to change their shells when presented with empty shells. One of the few to change was a *Clibanarius virescens* in a damaged *Cerithium* sp. shell, which it exchanged for the intact *Nerita* sp. shell presented to it in its individual container. Another experiment demonstrated that *Calcinus laevimanus* is capable of interspecific shell exchange by force. This involved removing two individuals (one larger and behaviourally more dominant than the other, with a correspondingly larger shell) from their shells by gentle heating. The smaller crab was then given the larger shell and the larger crab the smaller one in separate containers. Within two minutes of being placed together again, the larger crab had removed the smaller from its shell by a series of violent jerking movements, thus effecting a shell exchange which resulted in the two crabs occupying their original homes.

6. Fourteen empty *Nerita* sp. and *Cerithium* sp. shells were marked with a spot of red paint on 13th March and added to one of the small pools in area B occupied by at least 24 *Calcinus laevimanus* and 13 *Clibanarius virescens*. Immediate interest was shown by the hermit crabs in these shells and, within five minutes, all the new shells were occupied, but only by *Calcinus laevimanus*.

These diverse and very limited observations suggest some evidence for crab-specific shell preferences, for a shortage of suitable shells in the natural environment, and for the ability of crabs to occupy empty shells and to rob shells from other individuals.

Diurnal Behaviour Patterns

A conspicuous feature of the distribution of species other than *Calcinus latens* and *Dardanus lagapodes* was their occurrence on open rock and algal turf substrates during the intertidal period. Not only were the crabs often out of rock pools, but they were commonly found lying with the aperture of the shell uppermost and facing the sun. It appeared that at least some of the rock pools provided an unfavourable environment, and that exposure to the air best enabled the animals to survive the hazards of the intertidal period. Whether the stress factor was increasing temperature or decreasing oxygen content was not determined, but a single set of observations on a small pool (c. 0.3m in diameter) containing *Clibanarius virescens* showed a clear movement onto the rim of the pool as the temperature increased (Table I). In addition to moving out of pools, *Clibanarius virescens* also formed aggreg-

Table 2. *Movement of Clibanarius virescens onto the rim of a small pool in area C on 18th February, the tide left the pool at about 10.15h and returned at 16.00h (low water at 13.16h; air temperature 29.5°C). air temperature 29.5°C).*

Time	Pool Temperature (°C)	Number of <i>Clibanarius virescens</i> on pool rim
10.00	30.0	0
11.15	31.5	7
12.15	36.0	32
13.15	37.5	68
15.15	37.0	82
16.15	31.0	2

Figure 3

Length-frequency histograms for *Calcinus laevimanus* and *Clibanarius virescens* (hatched area = ovigerous females). Samples 1 and 2 describe the hermit crabs obtained from the two m² quadrats in area D on 8th and 11th February (see text). Sample 3 describes those collected from a 10 cm² aggregation in area D on 18th February.

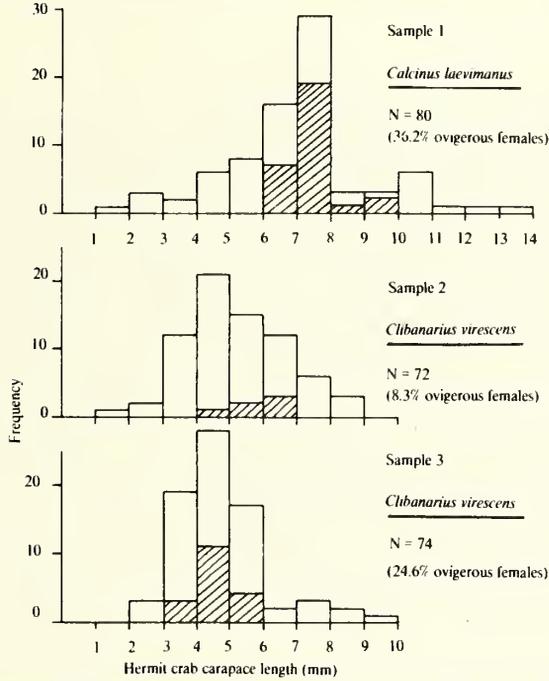
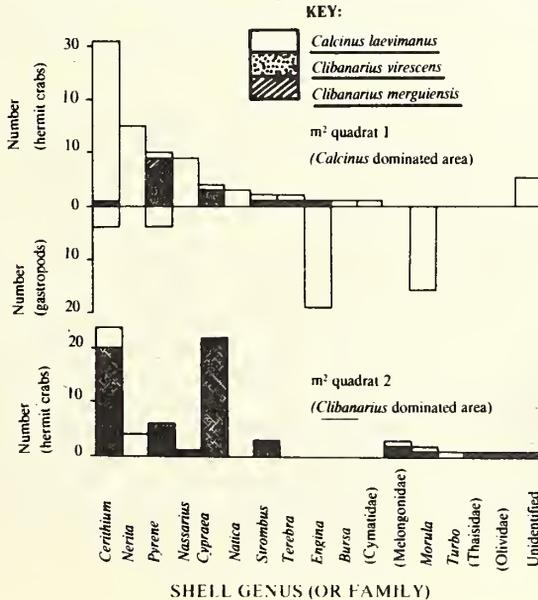


Figure 4

The frequency of shell genus (or family) occupancy in hermit crabs from the two m² quadrats in area D on 8th and 11th February (see text). Also shown below x-axis are the numbers of living gastropods in quadrat 1 (none were present in quadrat 2).



tions several individuals deep, as previously described. Some low-tide aggregations were also found under stones in area A, but throughout most of the study area, large loose stones were scarce.

When the intertidal area was flooded by the incoming tide, underwater observation revealed very few exposed hermit crabs in their intertidal positions, but they were clearly present among the bases of the macroalgae and in crevices. Limited observations suggest that they begin to emerge again on the late ebb tide.

DISCUSSION

The species of intertidal hermit crabs identified in the present study were also recorded by Lewinsohn (1982), apart from *Clibanarius merguensis*. In addition, *Clibanarius eurysternus* and *Clibanarius laevimanus* appeared to be less uncommon at Mombasa than Lewinsohn (1982) deduced from his Somalian material. However, he recorded 26 species in total, and the list included one species of *Coenobita*, six of *Calcinus*, two of *Diogenes*, five of *Dardanus*, one of *Paguristes* and three of *Pagurus* which were not recorded in the present study. The discrepancy between this list, and that of only ten species for Port Mombasa, can at least in part be explained by the wider latitudinal range sampled, and the closer attention paid to pools and areas of coral rubble in the Somalian study. It can, however, be deduced from Lewinsohn's (1982) work that, as on the Kenya coast, *Calcinus laevimanus* and *Clibanarius virescens* formed a dominant species pair over at least part of his study area.

The species of intertidal hermit crabs identified from rocky substrates at Mombasa have been recorded from other areas in and beyond the western Indian Ocean. Thus *Clibanarius virescens* is present from Pakistan (Tirmizi and Siddiqui 1982), to Australia (Abrams 1982) and South Africa (Barnard 1950). *Calcinus laevimanus* is present in both Hawaii (Reese 1969) and South Africa (Bernard 1950) as well as Tanzania (Hartnoll 1976), Aldabra (Taylor 1971a) and Diego Garcia (Taylor 1971b). *Calcinus latens* occurs in the Red Sea (Hughes pers. comm.), Pakistan (Tirmizi and Siddiqui 1982) and South Africa (Barnard 1950). The three species mentioned so far have also been recorded from Madagascar and the Comores by Dechancé (1964), as have *Clibanarius eurysternus*, *Clibanarius laevimanus*, *Clibanarius longitarsus*, *Clibanarius merguensis* and several other species. *Coenobita* species are widely recorded from the Indo-Pacific region (eg. Taylor 1971b, Dechance 1964, Page and Willason 1982), both *Coenobita rugosus*, *Coenobita perlatus* and *Coenobita cavipes* could all be expected to occur on the Kenya coast.

So far, the precise hermit crab guild, or community of species, found at Port Mombasa has not been recorded elsewhere, but this is most likely to be a simple reflection of the lack of comparable studies. The results have already been compared with Lewinsohn (1982), but Hartnoll's (1976) study at Dar es Salaam was more comparable because of its geographical proximity and restricted study area. However, this author probably overlooked several species in recording only *Calcinus laevimanus* in his list of littoral fauna.

From the discussion so far, it is perhaps sufficient to conclude that: (a) the genera identified from the present study are typical of intertidal rocky shore habitats in the Indian and Pacific Oceans, and (b) the dominance of the guild by a *Calcinus/Clibanarius* species-pair is not unexpected (Bertness 1982). The habitat and general behavior of the species at Mombasa is similar to that described for the same or related species elsewhere but, as Bertness (1982) has clearly shown in his comparison of *Calcinus/Clibanarius* pairs from the Pacific and Caribbean coasts of Panama, abiotic (in his case, tidal amplitude) and biotic (type and intensity of predation) factors can act as important modifiers to the basic pattern. In the studies of species pairs reported by Bertness (1981, 1982) and Reese (1969), it appears that *Clibanarius* spp. occur high on the shore, are behaviourally subordinate, and are most active as the tide comes in. Although there is a broad overlap in distribution, *Calcinus* spp. occur somewhat lower on the shore, are more dominant, and, at least where tidal amplitude is low, tend to follow the water's edge. Overall, *Clibanarius* spp. spend more time emerged than *Calcinus* spp., and this may also be correlated with the aggregating tendencies which, as Snyder-Conn (1981) has suggested, appear to have some advantage in relation to the problems of desiccation and thermal stress. To a large extent, the present study supports the above conclusions but, *Calcinus laevimanus* appeared to occur more towards the top of the shore than *Clibanarius virescens*. The habit of lying emerged well above the water line of rock pools with the shell aperture uppermost, was commonly observed, as it was in Hawaii by Reese (1969). Clearly, however, more precise observations on

distribution, separating the effects of tidal height and substrate characteristics, and including the remaining species, are required before definite conclusions can be drawn.

Although Reese (1969) concluded that hermit crabs had relatively few predators other than a few specialised crabs (such as *Calappa* and *Eriphia* species) and octopus, it is clear that certain fish of the order Tetraodontiformes are capable of crushing even the hardest shells inhabited by hermit crabs, and that this may influence their distribution and behaviour underwater. Thus, Levings and Garrity (1983) estimated that 20% of nerites (*Nerita* species) in an open microhabitat in Panamanian waters would be eaten within 24 hours by fish such as *Diodon* sp. (porcupine fish). Similar conclusions were reached by Bertness (1982) and, in relation to hermit crabs, he found that on the Pacific coast of Panama, where fish predation is intense, *Nerita* sp. shells are not preferred by either *Calcinus obscurus* or *Clibanarius albidigitus*, in spite of their wide availability. This appears to be due to the fact that *Nerita* sp. is the preferred prey of *Diodon* and that these low-spire shells also offer hermit crabs little resistance from thermal stress. *Nerita* sp. shells do, however, provide good protection against stomatopods, the main predators in the Caribbean, and on this coast *Nerita* shells are preferred by *Calcinus tibicen*, but not by *Clibanarius antillensis*. The latter requires a tall-spire shell in its upper shore habitat, where thermal stress is the major factor. In the light of these findings, the apparent preference for *Nerita* sp. shells by *Calcinus laevimanus* at Mombasa could be associated either with the more limited tidal range compared with the Pacific coast of Panama, with other habitat differences, with a lower fish predation rate, or with real differences between the relevant hermit crab species. It would be rewarding to investigate this further.

The maximum density figures recorded for both *Calcinus laevimanus* and *Clibanarius virescens* at Mombasa were of the same order as those for intertidal hermit crabs reported in the literature (Hazlett 1970, Hughes 1977, Abrams 1982). It is generally accepted that gastropod shells are a limiting resource for many hermit crab populations. The evidence and implications are discussed, for example, by Fotheringham (1976) and Scully (1983). Much of the evidence, as in the present study, comes from the scarcity of empty shells in areas inhabited by hermit crabs, although Spight (1977) has drawn attention to the fact that empty shells are rapidly removed by physical processes anyway, and soon become inaccessible to most hermit crabs. Vance (1972a), however, succeeded in increasing the density of hermit crabs by supplying empty shells to wild populations. The implications of shells being a scarce resource are that (a) there will be a discrepancy between actual shell size and preferred shell size, and (b) there may be interspecific competition affecting the structure and dynamics of the hermit crab guild.

It is well established that hermit crabs in shells above or below the optimal size are disadvantaged with respect to predation (Vance 1972b), reproduction (Fotheringham 1976) and tolerance to desiccation (Taylor 1981), and of course the extreme effects will be either zero mobility or zero protection. It was not possible to establish preferred shell sizes for the hermit crabs found at Mombasa, but the rapid shell exchanges recorded in the natural environment suggests that at least some of these crabs were in less than preferred shells.

Several studies have been carried out on habitat and niche separation in sympatric hermit crab species. Kellogg (1977), for example, working on sublittoral species off California, concluded that co-existence was made possible by a combination of habitat differences, shell size partitioning and shell species partitioning in descending order of importance. To some extent, this would also seem to apply to the Mombasa species. Bertness (1981) found that, in the *Calcinus obscurus*/*Clibanarius albidigitus*/*Pagurus* sp. guild of the Pacific Panama coast, active competition for a limited supply of shells directly influenced shell quality and spatial distribution. *Clibanarius* inhabited less than preferred shells in sympatric populations of *Clibanarius* and *Calcinus* and showed distinct avoidance responses when encountering *Calcinus obscurus*. It also had a superior ability to locate and therefore exploit empty shells.

Shell exchanges between individuals have been extensively documented (Scully 1983). The extent to which they occur is known to depend on the species (Hazlett 1970) and shell adequacy (Abrams 1982), but most exchanges appear to be intraspecific rather than interspecific. Certainly, no interspecific interaction was observed in mixed groups kept in captivity in the present study, whereas intraspecific interactions in both *Clibanarius virescens* and *Calcinus laevimanus* were common. In the case of the former species, the interactions were more aggressive, and casual observation supported the conclusion of Dunham (1978) that the relative amount of white on the right chela was of considerable social significance. The observation that the patterning could change abruptly over one moult appears to be a new one, but further data are needed to confirm this and assess its significance.

It is clear that the two dominant species at Mombasa differ not only in their habitat and shell

preferences, but also in their activity patterns and social behaviour. Further work is likely to reveal other differences, and provide some indication of how these two species are able to live sympatrically at similar density levels.

CONCLUSIONS

This study provides only a preliminary account of hermit crab biology on the Kenya coast, and it should also be noted that only a limited range of habitats was examined. Thus, collections from soft substrates and sublittoral regions would undoubtedly reveal different species. The species found on intertidal rocky substrates were, however, similar to those reported in the literature from other tropical areas, and the limited amount of data collected indicates that the biology of these Kenyan hermit crabs is also similar to their counterparts in other study areas. Much work remains to be done, and fortunately hermit crabs provide a very convenient and rewarding subject for marine ecological and behavioural research. The most productive approach would be to carefully repeat recent studies such as those of Bertness (1981, 1982). This would be a valuable contribution both to rocky shore ecology in Kenya, and to hermit crab biology worldwide, since there appears to have been no substantial work carried out in the Indian Ocean area.

The crabs studied are small and the shells they inhabit are not normally those utilised by shell collectors. Nevertheless, both they and their shell resources are intertidal, and thus are particularly vulnerable to human interference; this should be recognised in the context of their likely importance in rocky shore ecological processes. This importance, including a study of feeding biology, would also be a useful topic for research.

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APPENDIX I

A KEY TO THE IDENTIFICATION OF HERMIT CRABS FOUND AT MOMBASA

- 1 — Antennular peduncle longer than carapace; antennular flagellum blunt at tip; terrestrial and semi-terrestrial hermit crabs (Family: Coenobitidae; Coenobita) 2
 — Antennular peduncle shorter than carapace; antennular flagellum ending in a filament; littoral and sublittoral hermit crabs (Family: Diogenidae) 3
- 2 — Carapace and pereopods red or with red markings. No stridulating mechanism (row of teeth) on outer surface of manus of left cheliped *Coenobita cavipes*
 — Carapace and pereopods pale to dark grey, without red markings, stridulating mechanism on outer surface of manus of left cheliped *Coenobita rugosus*
- 3 — Tips of chelipeds pointed and calcareous (white); left cheliped markedly larger than right *Calcinus 4*
 — Tips of chelipeds spoon-shaped and corneous (black); both chelipeds usually of the same size 5
- 4 — Left cheliped with sharply-contrasting black and white areas; right cheliped without strongly-serrated dorsal margin *Calcinus laevimanus*
 — Left cheliped pale distally, gradually darkening towards base of the propodus; right cheliped with strongly-serrated dorsal margin *Calcinus latens*
- 5 — Fingers of chelipeds opening and closing obliquely or nearly vertically; left cheliped larger than right; very bristly *Dardanus lagopodes*
 — Fingers of chelipeds opening and closing horizontally; chelipeds equal or sub-equal *Clibanarius 6*
- 6 Pattern on walking legs includes longitudinal stripes 7
 — Pattern on walking legs does not include longitudinal stripes 9
- 7 — Basic colour pale with brown or reddish-brown markings; dactylus of walking legs equal to, or shorter than the propodus 8
 — Basic colour dark blue/green (but may be pale pink in juveniles); dactylus of walking legs longer than the propodus *Clibanarius longitarsus*
- 8 — Thorax markedly flattened; longitudinal pattern on walking legs of irregular shapes; joints on walking legs not conspicuously pale *Clibanarius eurysternus*
 — Thorax not markedly flattened; longitudinal pattern on walking legs of regular stripes; joints on walking legs conspicuously pale *Clibanarius laevimanus*
- 9 — Walking legs with white (or yellow) and black (or brown) bands *Clibanarius virescens*
 — Walking legs with white, orange and blue colouration (this may only be a juvenile pattern, *Clibanarius merguensis*

- NB 1. Walking legs 1 and 2 = Pereiopods 2 and 3.
 2. The Diogenid genera, *Paguristes* and *Diogenes*, may also be encountered in the area. In *Paguristes* the fourth pereiopods (first pair of reduced thoracic appendages) are simple, not chelate. In *Diogenes*, which shares pointed, calcareous-tipped chelae with *Calcinus*, the rostrum is replaced by a moveable scale or spine, and the antennal flagellum is setose rather than bare.
 3. As a result of the work of Lewinsohn (1982) it is clear that up to six additional species of *Calcinus* and five of *Dardanus* could occur on the Kenya coast.

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Cyclic sequences of vegetation in the plant communities of the Aberdares Mountains, Kenya

A D Q Agnew

University College of Wales, Aberystwyth.

ABSTRACT

Cycles of vegetation change are described for two vegetation types on the Aberdares Mountains, Kenya. The shrubby *Alchemilla argrophylla* undergoes a cycle of growth and degeneration rather similar to *Calluna vulgaris* in Western Europe; that is the phases are not synchronous unless forced to be so by fire or disturbance. Bamboo (*Arundinaria alpina*) however is monocarpic, patches of stems 0.5 to 5 hectares in extent flower synchronously and thus initiate a series of vegetation changes characterised by *Sambucus africana* which eventually lead back to Bamboo forest. These cycles are of importance in management of montane game reserves in East Africa. The nature of cyclic successions is discussed.

INTRODUCTION

There is no doubt that all vegetation is unstable in the short term. Individual plants die and are replaced; herbivores remove parts of selected species and these species must maintain their numbers by different strategies compared with unpalatable ones; geomorphological and geochemical processes impose slow cycles and trends on the plant cover of the earth. Grubb (1977) draws attention to the overall importance of cyclic change-over of species composition in many plant communities as an explanation of the diversities of species populations. Some plant communities predictably fluctuate around the life-history of the dominant whose death leads to a cycle of events which finally repeats itself. It is possible to refer to these as cyclic sequences and their appreciation gives insight into the dynamics of such communities as well as help in management problems.

In East Africa, plant communities are seldom dominated by one species unless disturbed by man's activities. In the montane zone, however, dominance becomes more and more pronounced and Hedberg (1964) delimits zones of characteristic species up to the alpine zone above the forest level. In general the progression of physiographic vegetation types can be said to pass from montane mixed forest to gymnosperm forest (*Juniperus procera* or *Podocarpus latifolius**) thence into bamboo (*Arundinaria alpina*). Above the tree line there is tussock grassland (of *Festuca pilgeri*, *Andropogon amethystinus* and *Carex monostachya*) which alternates with what is clearly heath vegetation of various types. It is the purpose of this paper to describe cyclic changes in the bamboo, and the heath vegetation dominated by the Rosaceous *Alchemilla argrophylla*.

The following account is based on floristic analyses made in 1976, while investigating the boundary zones between plant communities. Two line transects of 30 contiguous 50 cm x 50 cm quadrats were taken at right angles to the boundary between easily discernible plant communities. Analysis of these data by reciprocal averaging allowed identification of the quadrats from the homogeneous ends of the transects. These were then taken as representative of the communities, and mean cover could be assigned to each species, as well as to the pH of surface soil from each quadrat. Clearly this resulting figure is akin to a phytosociological releve, and since it is based on non-random sampling the citation of confidence bands would be meaningless.

In the case of the bamboo analyses, 10 l m x 1 m quadrats were roughly randomised to give a basis for the stem variance figures.

Nomenclature of flowering plants follows Agnew (1975).

* Formerly *P. milanjanus*.

THE ALCHEMILLA ARGYROPHYLLA CYCLE

Description

This shrubby silvery-leaved *Alchemilla* is one of the characteristic plants of the heath vegetation of the moorlands about 3000 m on Mount Kenya and the Aberdares (replaced by *Alchemilla elgonensis* on Mount Elgon). It occurs in burnt bushland edges as well as heathland but in the latter it frequently dominates. The shrub grows from 20 to 70 cm tall in a complex community in which a mosaic of mounds and hollows may be associated with small open patches of grassland and herbs, and in which mole-rats (*Tachyoryctes* spp.) disturb large areas.

Alchemilla heath can burn, but these heathlands of the central Aberdares plateau do not seem to have been burnt for some time, and it is possible to find stands of apparently differing ages. I have made the general observation that on the extensively burnt shrubland of Mt. Kenya (Sirimon track head, 3700 m) the regeneration in 1976, two years after burning, included a dense population of *Alchemilla argyrophylla* seedlings. There was no extensive stand of *Alchemilla* heath at that altitude before the fire and it is possible that fire stimulates widespread germination. Figure 1 is a diagram of the supposed course of the *Alchemilla* cycle and incorporates part of a measured transect through a bush, and Table 1 gives the floristic composition of sample areas of the proposed sequence.

Cross-sections of representative stems from three stages in the cycle are shown in Fig. 2. The growth zones are rather tantalizing, for young stems appear to be ageable but the oldest stem seems to have no clear growth zones towards the older wood. The rainfall pattern on the Aberdares is of two principal rainy periods (as in the rest of Kenya to the East of the Rift Valley) but they are hardly separated at higher altitudes. Indeed there were heavy showers during the period of my observations in July 1976 which in the lowlands is invariably dry. The main dry period is January and February and under this regime recognisable annual growth zones could be expected, but note how the new "spring" wide-vessel growth seems to have recently started on these sections. Obviously the phenology of growth on these equatorial mountains would repay investigation.

In the following account of cyclic events the recognisable growth zones are used as indices of annual growth to estimate the duration of various stages of the cycle, but future work should check this against long-term observations.

Pioneer (3-4 years). The establishment phase takes place either as colonisation after disturbances by fire, mole-rats, human interference or as part of the cycle within a mosaic of phases of *Alchemilla* heathlands. Growth rates are unknown but measurements gave a mean of 10 cm of new shoot, leafy to ground level. The flora of this phase depends on its origin. If the result of disturbance, grasses and ruderals are abundant. Creeping plants such as *Carex conferta*, *Oxalis corniculata* and *Uebelinia crassifolia* are common when the full cycle of growth phases is present.

Building (4-7 years). Here there are erect shoots with naked woody bases, showing 30 cm of new growth of the current year, with abundant flowering. The flora consists typically of abundant bryophytes, and a very diverse assemblage of flowering plants which are frequently creeping or rhizomatous.

Mature (4-8 years). The older shoots lean and finally fall, and the basal bark peels in scales, while new growth averages 25 cm with abundant flowering. Maximum floristic diversity is present but bryophytes are reduced and grasses may be abundant between the spreading bushes of *Alchemilla*.

Degenerate (possibly 10 years). Fallen shoots surround the base of the old plant, while the 10-20 cm of new growth attest the decreased performance here. The ground may be covered with bark scales from the stem bases and the flora is greatly reduced, particularly in bryophytes and grasses.

In general there seems to be no difference between the soils of the study areas exemplified in Table 1 in so far as they were investigated.

Discussion of the heathland cycle

Cyclic sequence in vegetation are characteristic of heaths, where a dominant woody plant has a limited life span; the best known example is that of *Calluna* in Britain (Gimingham, 1972), the study of which was part of research into ecological management for grouse stocking.

The principal heath species of the Aberdares range in Kenya are *Erica arborea* and *Philippia excelsa* which form woodland, and the low shrubby *Alchemilla argyrophylla*. This woodland is dominated by true members of the heath family, and although its soils are sufficiently acid and peaty for it to be regarded as a heathland community its long term dynamics are still unknown. Possibly there is a cycle involved but if so it must be so interrupted by fire, and by invasion by pyrophilic plants such as *Stoebe kilimandscharica* that there can be little evidence remaining as to its characteristics today. Possibly intensive investigation of such sites of pure *Erica arborea* as remain will reveal a cycle. However, the heath shrub *Alchemilla argyrophylla* does give evidence of a cyclic behaviour very analogous to that described for *Calluna vulgaris* in Scotland.

It is difficult to ascribe any evolutionary advantage to the shrub consequent on the development of the cyclic vegetation pattern described. It is possible that this is another feature of the effect of the important mole-rat populations in alpine Africa, as described by Hedberg (1975).

There are numerous afro-alpine plant species capable of rapidly colonising bare ground and these may have evolved as much in response to selection by solifluction as by mole-rat disturbance.

THE BAMBOO CYCLE

Description

Bamboo occurs from 2750-3500 m over extensive areas of all East African mountains (Hedberg 1964). Wimbush (1947) has described the bamboo cycle in general terms. It is a dominant, monocarpic plant which flowers and dies back in patches throughout the forest. Flowering tends to be almost synchronised over large areas. For instance it was easy to find flowering specimens in 1966 over wide areas of the Aberdares bamboo forests but flowering had apparently taken place in the previous decade on Mt. Kenya and flowering specimens were not found there although flowered patches with dead bamboo were common. By 1969 it was difficult to collect herbarium specimens on the Aberdares but a flight over the Mau forest revealed extensive areas of current flowering. Observations in 1968 and 1976 allow the following account to be prepared. Floristic stages are easy to observe and are described below; they are summarised in Tables 2 and 3 and Fig. 3.

Pioneer

Regeneration of bamboo appears to take place from the rare revitalisation of a section of fallen culm or even part of the rhizome system. Very occasional small living shoots can be found even within the dead tangle of stems 2-4 years after flowering but take a long time to become conspicuous clumps. I have not been able to find seedlings in the field, and on the Aberdares at least, I have not found viable seeds, although Dr. P.J. Greenway (pers. comm.) has assured me that they do exist. The tussocks of bushy growth which result from this revitalisation grow slowly for 3-5 years forming thickets of many-stemmed plants 1-3 m tall amongst the *Sambucus* of the previous phase. pH is at its highest and litter cover of the soil is low. The bushes of bamboo enlarge until they join up when the Building Phase begins.

Building

I define this as the stage when the height of the growing stems exceeds the general height of the stand. In fact a rapid increase in general height is obtained and this phase appears to last but a short time, from 5-7 years, and the stems retain the clumped pattern imposed during the pioneer stage. Floristically this period is the poorest, for the light-demanding species of the pioneer stage have been eliminated and the shade-loving species of the mature phase apparently migrate and invade only slowly. I suspect that most of the shade-loving species that are found are survivors from the previous cycle and examination of Table 2 shows this to be true of *Pteris catoptera* and *Cyperus dereilema*, for instance. Even *Sanicula* and *Selaginella kraussiana* can survive in odd pockets in the *Sambucus* stage.

Floristic changes are accelerated by a change in pH of the soil during this period. Since the major event is a fast increasing bamboo biomass, more and more plant nutrients become locked into it and are not available for circulation. We also have to consider the effects of a change in the litter type from predominantly broad-leaved to the strongly sclerenchymatous leaves of the bamboo. Both these events are reflected in a lowering of pH during this period.

Table 2 gives an analysis of sampled stem densities during this and subsequent stages. The dense clumping of this building phase can be seen and needs no further comment.

Mature

As soon as the annual new growth of stems equals the height of the stand (no further overall height increase taking place), the stands can be said to be mature and only slow changes take place for the next 10-15 years. These changes are:

- a) the separation of bamboo culms on the forest floor until a more regular, less clumped, pattern is produced;
- b) the final change of the forest floor species to those of deep shade, and the elimination of many lianas which were established during the *Sambucus* and Pioneer stages;
- c) soil pH continues to decline but not to very low levels. There is often heavy grazing of young bamboo shoots by rhinoceros and elephants, which could be important in hastening or delaying the onset of flowering.

Flowering and *Sambucus* stage:

Flowering takes place during one season only but 2-3 years pass before the culms fall, and this is most important for the whole system. The culms fall in a haphazard way, making flowered areas extremely difficult to enter. There is a sudden increase in light-demanding broad-leaved species and climbers, dominated by *Sambucus africana*, so that from this to the thicket pioneer stage can be called the *Sambucus* stage. Herb diversity increases slowly, the initial invasion leading to rampant single-species patches of vegetation, particularly climbers, but this is soon broken up by the entry of large mammals. They break the vegetation down into small patches between which trails meander allowing entry of ruderal plants.

Soil pH increases but not immediately because the bamboo culms may take a number of years to rot away. However, as the process continues, more and more of the total nutrient pool is returned to the soil and thence to a much more rapid cycle within the soft-leaved dicotyledonous plants of the *Sambucus* stage, so that by the end of this period the maximum pH is reached.

Ultimately, just before the thicket (pioneer) bamboo stage with which this account began, there is maximum heterogeneity in the vegetation because of the network of large trails which breaks it up, and the persistence of large bamboo culms, some of which may even be upright. The diversity is further increased by uneven invasion by opportunistic ruderal species, and uneven elimination of the old forest floor flora.

Tree species such as *Nuxia*, *Podocarpus* and *Dombeya goetzenii* have their greatest opportunity for establishment and growth during the *Sambucus* phase, for their saplings are suppressed under the high bamboo canopy but are able to grow more quickly after this has flowered. I have not been able to show that the present distribution of these trees is associated with past flowering sites but it is clearly a possibility which could repay investigation.

The possibility of internally operated cycles must be borne in mind when discussing vegetation changes through any cause, and in the National Parks of Kenya today a principal preoccupation is with environmental damage by elephant. This is well documented in Tsavo (Glover 1963), but not so well in the Aberdares where there is considerable evidence of recent elephant damage, which was not there in 1969. It is increasingly difficult to find undisturbed stands of bamboo at low or high altitudes, and some *Cliffortia*, or even *Hagenia* trees on the moorland woodlands are beginning to suffer as well. This is despite the very great area of bamboo/*Sambucus* edge which now exists and which was probably not available before 1965. The *Sambucus* areas of the bamboo cycle hold high potential for grazing and browsing animals and are heavily used so that feeding trails of rhino and elephant form a network within them, and there is nearly always a distinct marginal trail either for passage or for feeding on the marginal bamboo fronds. The stands of bamboo which I visited in July 1976 on the West of the escarpment (Kinangop side) were under great pressure from elephant. Large culms had been pulled down and trampled and I could find very few undamaged emerging bamboo shoots. Conditions on the East (Mweiga and Nyeri) side were much better. There was less damage to mature bamboo and new shoots were plentiful.

In the relatively non-seasonal climate of the tropics, biological events are based on obscure triggers. Tweedie (1965) has documented periodic flowering in upland Kenya Acanthaceae, but we are a long way from an understanding of the phenomenon. The bamboo cycle creates a very high heterogeneity in the area as a whole and is of central importance to its carrying capacity, and so reserve management would gain from knowledge of the physiology and ecology of flowering. Therefore the bamboo cycle itself is a worthwhile subject for conservation, so that if the main flowering area of the bamboo became totally disturbed by big

game pressure or by exploitation through agriculture or forestry, a sufficient area for the full development of the natural cycle should be set aside lest an outstanding example of a natural biological process be lost.

Janzen (1976) discussed periodic bamboo flowering and its evolutionary significance which he suggests could be due to a need for overcoming seed predation by spasmodic over-production. In my observation of bamboo regeneration, I have never seen a seedling. All regenerating plants have been traceable to fallen culms, and Wimbush (1947) agrees with this observation. This of course does not argue against Janzen's thesis, but may simply be a feature of a species marginal to the central range (East Asia) of that genus. In any case my observations suggest that the young shoots are the most grazed part of the life cycle. Excessive predation of these could possibly eliminate the bamboo. To follow Janzen and suggest an alternative evolutionary potential for the cycle of bamboo regeneration is not difficult. For surely the diversification of the habitat into mosaics, where the *Sambucus* patches hold prime browse material, would reduce pressure on those very vulnerable 60 cm spikes of high nutrient content on the bamboo woodland floor.

The bamboo is part of a more diverse woody vegetation at the lower part of its range. Groves of *Podocarpus latifolius*, *Dombeya goetzenii* and *Nuxia congesta* grow amongst the bamboos in favoured sites. Based on my general observation I tend to regard those favoured sites as also the sites of most frequent flowering of bamboo, although I have no quantitative evidence for this. I have also observed seedlings of these tree species most frequently at the edges of bamboo flowered areas, and it is not unlikely that tree species distribution is indeed associated with the flowering pattern of the bamboo.

GENERAL DISCUSSION

Cyclic successions have been recognised for some time, Watt (1947) drew attention to their presence in certain British vegetation, while Kershaw (1973) dealt with them at length and extended the ideas to many situations where a plant species shows a cycle of performance at any one spot without affecting the vegetation as a whole. More recently Grubb (1977) has suggested that this process is responsible for a great deal of the diversity in plant communities in that the "regeneration niche", which is made available on the decline of an individual after its cycle of growth and maturity, is the major potential site for invasion of a closed community.

It is clear that communities which are characterised by cyclical successions are simply those where dominance is such that the major plant species eventually replaces itself but during this process the entry of many different species constitutes an alternating community structure. In the examples presented in this paper the bamboo cycle is more impressive in this respect than the *Alchemilla* because there is a far greater disparity between environments in that cycle than in the *Alchemilla*. But it may be that there is a general principle involved here because long lived dominants must show a certain synchrony in their phases of growth for the cycle to be recognized. If the bamboo culms on the Aberdares flowered and died one or two at a time, replacement by *Sambucus* for a few years would be unremarkable and the whole community would present the aspect of mixed *Arundinaria alpina*/*Sambucus africana* with abundant lianas. It is the synchrony which gives the major effect and this is lacking in the *Alchemilla*, where the recognition of the various phases in the stands reported on here is probably due to differing ages since their last firing or burning; old stands show a mixture of recognisable phases. This is very similar to the situation in *Calluna vulgaris* in Scotland (Gimingham 1972) where burning is a recognized management tool and even-aged stands are therefore produced which can be said to be predominantly pioneer, building or mature. It is clear therefore that longevity of the dominant and synchrony of life cycle behaviour are both responsible for elevating the diffuse "regeneration niche" into a definite cycle of community events. The ultimate may be the type of cycle imposed on soil nutrient conditions within the ecosystem as suggested by Florence (1965) for Douglas Fir and oak woodland with a time scale of c. 2000 years. Obviously such cycles must be increasingly hard to recognise as more natural vegetation becomes disturbed by man's influence.

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TABLE I

Mean cover percentage of species in three stands of dominant *Alchemilla argyrophylla* in the Aberdares Moorland.

Only species with 4 or more records are cited. Others (with stand number in parentheses) are: *Anagallis serpens* (2), *Ardiansandra wetsteinii* (1), *Carduus chamaecephalus* (1), *Carex greenwayii* (3), *Haplosciadium abyssinicum* (2), *Helichrysum ellipticifolium* (1), *Helictotrichon milanjanum* (3), *Heracleum abyssinicum* (2), *Hypericum lanceolatum* (3), *Lobelia duripratii* (1), *Lysimachia ruhmeriana* (3), *Mariscus kerstenii* (2), *Ranunculus oreophytus* (2), *Sambucus africana* (3), *Senecio schweinfurthii* (2).

Stages of Cycle Present in Stand	1	2	3
	Pioneer and Building	Building and Mature	Mature and Degenerate
No. of Quadrats	23	20	16
Forbs:			
<i>Alchemilla argyrophylla</i>	28.73	35.0	56.24
<i>A. johnstonii</i>	10.22	12.75	
<i>A. rothii</i>	4.13		
<i>Ajuga remota</i>		0.25	0.94
<i>Carduus keniensis</i>	2.83	0.75	
<i>Cerastium afromontanum</i>		1.50	
<i>Conyza subscaposa</i>	0.87		
<i>Dichondra repens</i>	3.70	3.25	
<i>Euphorbia schimperiana</i>	5.22	3.75	
<i>Galium kenyanum</i>	0.43	0.25	
<i>Geranium arabicum</i>		0.50	1.87
<i>Helichrysum cymosum</i>	0.65	2.00	
<i>Hypericum peplidifolium</i>	2.83	1.00	0.62
<i>Luzula johnstonii</i>	4.78	1.00	0.94
<i>Oxalis corniculata</i>	4.78	4.25	7.50
<i>Pimpinella keniensis</i>	5.00	3.75	
<i>Polygonum afromontanum</i>		0.25	0.93
<i>Satureia kilimandschari</i>	0.86	1.00	
<i>Sibthorpia europaea</i>	0.60	0.25	4.07
<i>Sonchus afromontanus</i>	0.22	0.25	
<i>Stachys alpigena</i>		5.25	3.75
<i>Swertia crassiuscula</i>	0.80	1.00	
<i>Tolpis capensis</i>	1.09	0.75	
<i>Trifolium burchellianum</i>	3.69	4.00	
<i>T. cryptopodium</i>	0.43		
<i>Uebelinia crassifolia</i>	1.08	0.75	
<i>Veronica glandulosa</i>	1.74	1.75	
<i>Viola eminii</i>			3.13
<i>V. nannae</i>	5.00	2.00	
Grasses and Sedges:			
<i>Agrostis kilimandscharica</i>	5.87	1.75	1.24
<i>Anthoxanthum nivale</i>			3.12
<i>Carex conferta</i>	5.00	3.00	4.69
<i>Festuca abyssinica</i>		8.25	
<i>F. pilgeri</i>		4.00	
<i>Koeleria capensis</i>	13.91		1.24
<i>Mariscus sp.</i>		2.75	
<i>Pentaschistis borussica</i>	5.21	15.0	0.31
<i>Poa leptoclada</i>	3.05	3.0	2.18
Other species (Number)	2.39(4)	3.00(7)	2.87(5)
Bryophytes:			
<i>Acrocarpus mosses</i>	8.70	2.0	
<i>Pleurocarpus mosses</i>	2.17	1.75	1.25
Leafy liverworts	3.04	1.75	2.19
Mean pH (aq.)	4.62	4.67	4.65
Diversity (H)	3.039	2.732	1.746
Cover Total	138%	137%	99%

TABLE 2

Features of successional stages in the Aberdares Bamboo (Arundinaria alpina)

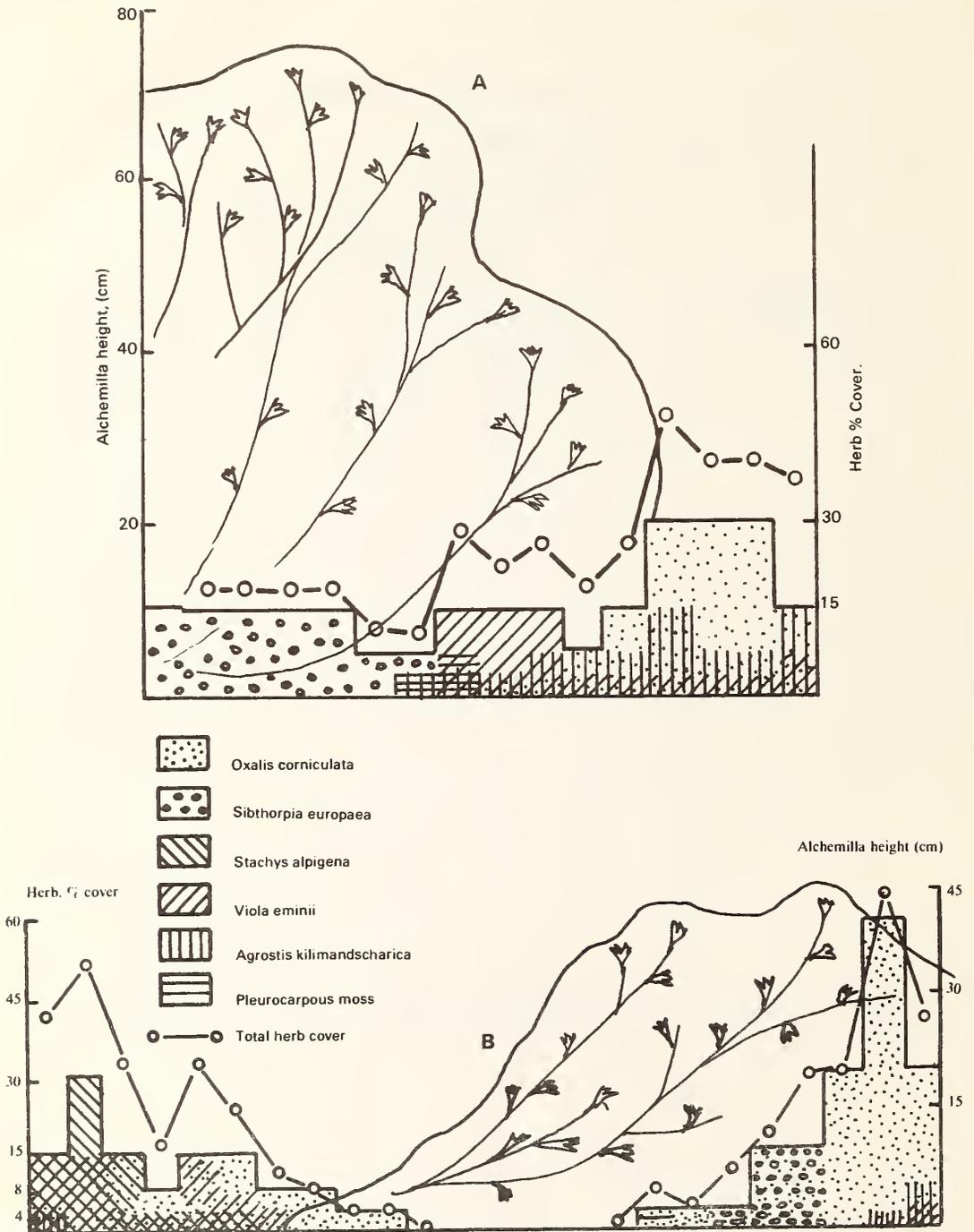
	Pioneer bamboo	Building bamboo	Mature bamboo young Sambucus	Flowered bamboo-	Mature Sambucus	Old Sambucus
<i>Arundinaria alpina</i> (culms. m ⁻²)	3.7	3.4	1.1	trace		
<i>Arundinaria</i> culm variance	4.14	1.76	1.20			
pH mean	5.66	5.24	5.13	5.07	5.06	6.38
<i>Acalypha cf. volkensii</i> S	0.20			0.73	0.36	
<i>Acritochaete volkensii</i> W	2.20	8.71	11.80	14.73	9.00	
<i>Australina acuminata</i> W		1.71				0.67
<i>Cardamine africana</i> W		1.14	2.80	0.36		0.67
<i>Cynoglossum lancifolium</i> S	0.40	0.40		2.45		4.50
<i>Cyperus dereilema</i> W	1.55	5.00	10.40	4.73		
<i>Cyphostemma kilimandscharicum</i> C	0.40				1.45	3.83
<i>Dichrocephala integrifolia</i> S					3.45	0.67
<i>Droguetia iners</i> W	0.20		0.40			
<i>Galium chloroionanthum</i> C		1.14				0.67
<i>Geranium arabicum</i> S			5.64		2.0	
<i>Girardinia bullosa</i> W	0.40				0.36	
<i>Hydrocotyle mannii</i> W		1.14				0.67
<i>Mikaniopsis clematoides</i> C	0.60				3.27	
<i>Oxalis corniculata</i> S				2.91		4.67
<i>Pilea spp.</i> W	0.60	2.29			0.36	
<i>Poa schimperiana</i> S					0.72	0.67
<i>Polystichum fuscopaleaceum</i> I	0.60					0.67
<i>Pseudocarum eminii</i> C	0.60	0.57	8.10	9.36	3.27	14.50
<i>Pteris catoptera</i> I	0.20	5.57	1.50	0.73	3.18	2.67
<i>Sambucus africana</i> S	1.00	1.71		5.27	20.82	42.50
<i>Sanicula elata</i> W	0.20	2.86	13.00			0.67
<i>Selaginella kraussiana</i> W		6.71				0.67
<i>Senecio moorei</i> S				0.36	0.36	2.50
<i>Senecio syringifolius</i> C	1.80	1.14	2.40	12.55	4.18	2.00
<i>Solanum terminale</i> I		1.71	0.80		2.18	
<i>Veronica abyssinica</i> S				2.18	0.73	3.83
<i>Viola abyssinica</i> I	4.0	0.80	1.1		3.83	
No. of quadrats	20	7	10	11	11	6
Additional species (number)	3	2	2	1	7	9
Additional species (Cover)	1.0	4.57	1.60	0.36	8.89	26.00
Total Ground Flora Cover	11.95	49.97	53.6	63.46	62.58	118.86
<i>Assemblage diversity</i> (\bar{H})	2.581	2.581	1.923	2.201	2.385	2.465

Mean cover is given for species occurring in more than one stand; data are given for six characteristic stands. The major habit of each species is given as: C, climber; I, indeterminate; S, ruderals of disturbed ground, W, woodland floor herbs. These categories have been decided from general observation and herbarium specimens.

TABLE 3.

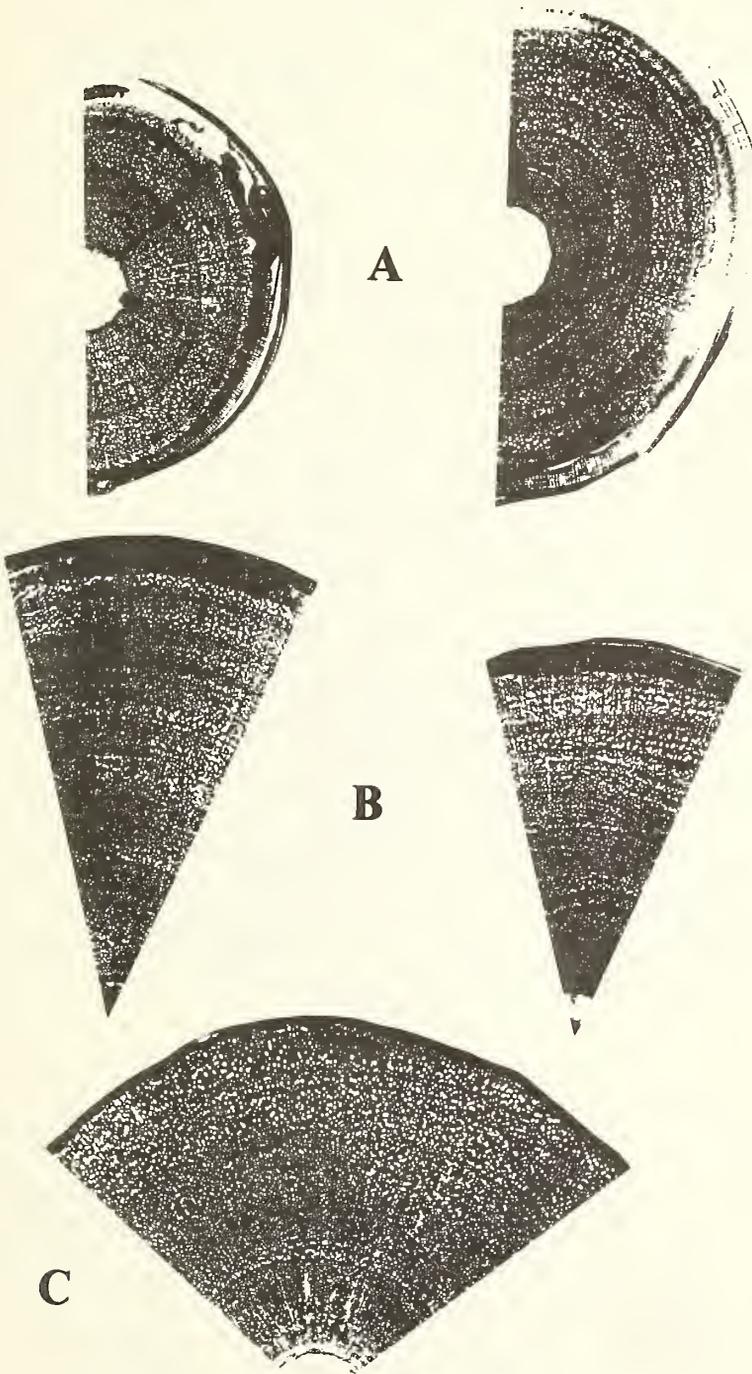
Cover contributions (as percent of total herbaceous cover) of 4 habitat classes from Table 2.

	Successional stage					
	Pioneer bamboo	Building bamboo	Mature bamboo Young Sambucus	Flowered bamboo	Mature Sambucus	Old Sambucus
Woodland Flora plants (W)	43.1	59.1	71.6	31.2	15.5	2.8
Plants of disturbed ground						
(a) including <i>Sambucus</i>	13.4	3.4	0	30.8	53.7	67.2
(b) excluding <i>Sambucus</i>	11.7	0	0	22.5	20.6	31.5
Climbing plants (C)	28.4	5.7	19.6	34.5	19.5	17.7
Azonal species (1)	6.7	22.68	5.8	8.6	2.8	6.0



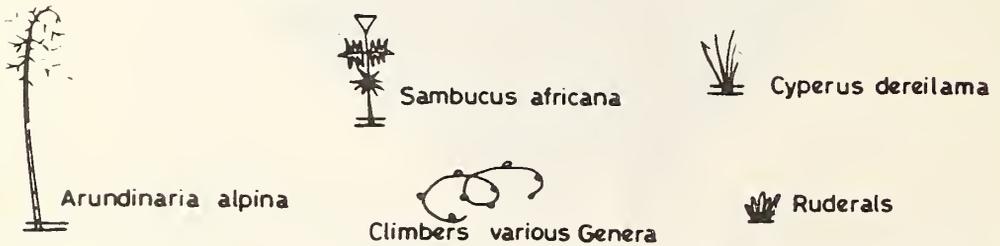
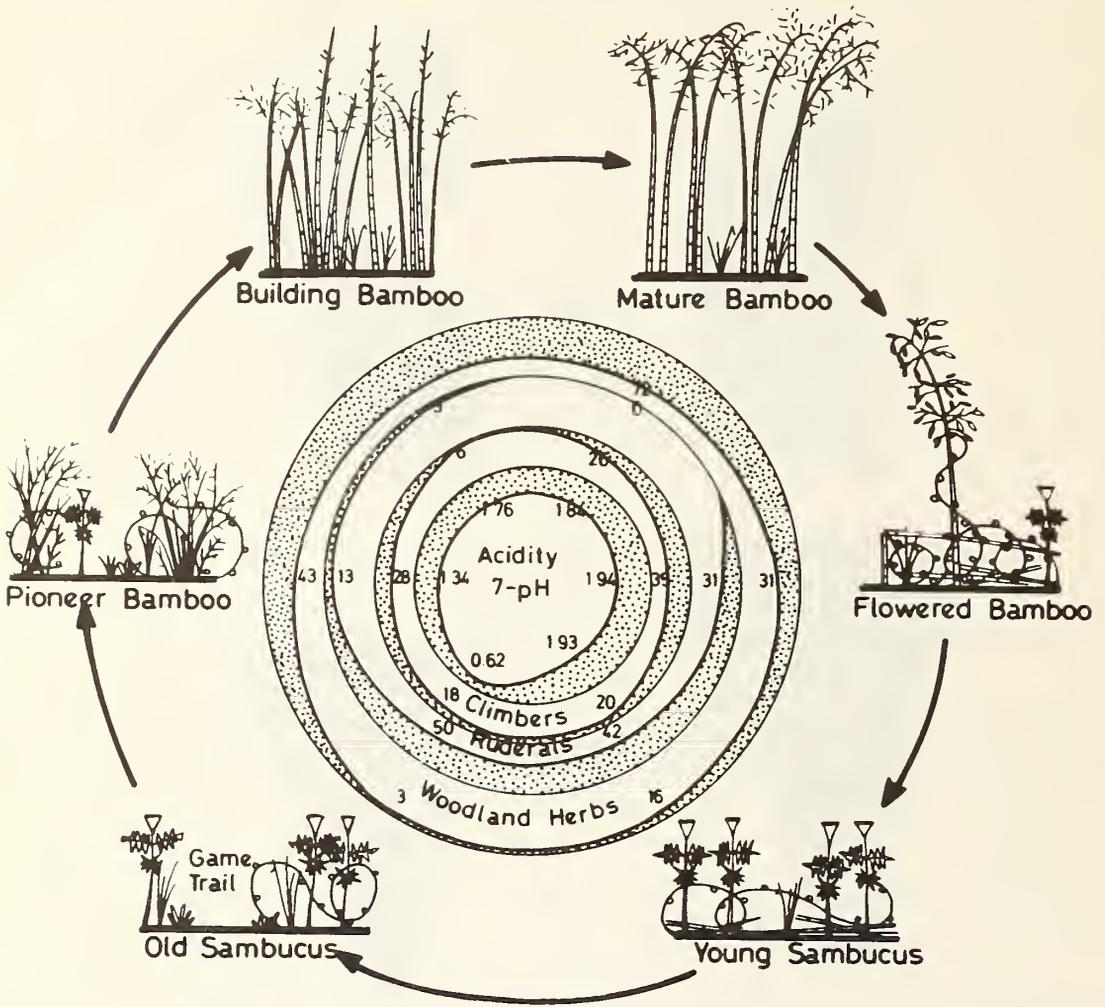
Two diagrammatic representations of transects through changing phases of the *Alchemilla argyrophylla* cycle. In A, a mature bush is suppressing *Agrostis* and *Oxalis* in favour of the shade tolerant *Sibthorpia*. In B, a degenerating bush is allowing entry of *Oxalis* and *Agrostis* both in the centre, where perennial herbs (*Viola*, *Stachys*) are establishing, and at the margin where *Sibthorpia* is being replaced.

Fig. 1



Sections through stems of *Alchemilla argyrophylla* taken at ground level from (A) pioneer and building, (B) mature and (C) degenerate phases of the successional cycle.

Fig. 2



A diagrammatic illustration of the successional cycle associated with the bamboo (*Arundinaria alpina*) on the Aberdare Mountains. The six phases illustrated do not exist for similar time periods. The course of change of acidity (observed pH subtracted from 7) and the percentage cover of three floristic elements are shown as concentric plots. Values from Tables 2 & 3.

Fig. 3

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Ectozoochory by Hares (*Lepus crawshayi*) in Queen Elizabeth National Park, Uganda

Asaph A. Ogen-Odoi*

and

T.G. Dilworth

Department of Biology and Fire Science Centre
University of New Brunswick
Bag Service # 45111
Fredericton, New Brunswick
Canada, E3B 6E1

ABSTRACT

Ninety-six hares, *Lepus crawshayi*, were shot and examined for plant propagative disseminules. Sixty-four of them carried plant disseminules belonging to 22 species. A total of 436 disseminules were extracted by vigorously combing the furs. Three hundred and twenty-three of the disseminules belonging to 14 plant species were on 36 female hares and 110 disseminules belonging to 8 species came from 26 males, and an account of the females' importance in carrying disseminules is discussed. More disseminules were recorded in the dry than in the wet seasons. Female hares showed nonsignificant seasonal differences in number of disseminules as well as nonsignificant differences in the number of species of plant disseminules they carried. The males showed no seasonality in their zoochory activity. The significance of climatic, vegetative, edaphic and other environmental factors in influencing the seasonality and magnitude of plant propagules and its bearing on zoochory is reported.

More grass disseminules than herbaceous ones were carried by hares, and *Hyparrhenia filipendula* and *Tribulus terrestris* were the grass and herb species most frequently carried. The amount of ectozoochory was found to be influenced by the presence of zoochory features other than abundance of disseminules.

INTRODUCTION

The requirement for plants to disperse from the parent stock and the various methods and mechanisms of plant dispersal were discussed by Ridley (1930). The mechanisms whereby animals may effect the dispersal of seeds are many (Grime 1979). Ridley (1930) and later, van der Pijl (1972) described and classified seeds and fruits which are adapted for dispersal by animals.

Grime (1979) discussed the large number of adaptations of many different plants which facilitate transport of the seed by particular animals. He differentiated between dispersal mechanisms (e.g., burrs, hooked fruits, glutinous seeds) which involve attachment to the exterior of the animal (ectozoochory) and those in which the disseminule is attractive and eaten by the animal (endozoochory).

*Current Address: Uganda Institute of Ecology and Uganda National Parks
P.O. Box 22, Lake Katwe Uganda, East Africa

In the course of studies of general ecology of the hares and the effects of prescribed burning of grassland habitat on them, we found that hares were carrying plant disseminules externally. Because information on the role of mammals in zoochory is rather scanty (McClintock 1965), we decided to investigate this aspect of the hare's ecology.

The hare zoochory literature deals primarily with temperate species (Watt cited by McClintock 1965, Flux 1967, Ridley 1930, Tomich *et al.* 1968). All these investigations reported low incidences of ectozoochory by the hares studied. Agnew and Flux (1970) found higher levels of ectozoochory by Cape hare (*Lepus capensis* L.) in Kenya than reported in the temperate regions (Flux 1967, Ridley 1930, Tomich *et al.* 1968). They attributed this to differences in the flora rather than fauna in the study areas. This paper reports on the role of *Lepus crawshayi* de Winton (Eltringham and Flux 1971) in ectozoochory in Queen Elizabeth National Park, Uganda. The study was conducted from October 1981 to the end of September 1982.

STUDY AREA

Queen Elizabeth National Park (formerly Ruwenzori National Park), 1978 km² in area, is found in the extreme southwestern corner of Uganda between latitudes 29° 45' E and 30° 15' E and longitudes 0° 30' S and 0° 15' N. It occupies the floor of the western arm of the Great East African Rift Valley. The Park has an undulating topography that varies from 900 m to 1450 m a.s.l. The climate is equatorial with bimodal rainfall peaks, with 2 wet (March-May — long wet and September-November — short wet) and 2 dry (December-February — long dry and June-August — short dry) seasons. Detailed information on the climate of the Park is given in Lock (1967) and Spinage (1968). The vegetation comprises several grassland mosaics ranging from the hippo-grazed *Sporobolus* mosaics along the lakes and Kazinga Channel shores to the tall fire-adapted *Hyparrhenia-Themeda* grasslands (Edroma 1975). The grasslands are dotted with bushes of *Capparis* spp., and in some places bushes of *Acacia* spp. have thickened into woodlands. In the south central portion of the Park which receives high rainfall, is the Maramagambo tropical rain forest. Further details of the vegetation have been given by Langdale-Brown *et al.* (1964), Osmaston (1971), Lock (1967) and Field (1968).

MATERIALS AND METHODS

The hares were collected monthly at night by shooting with a .410 calibre shotgun using a hand-held 100-watt spotlight. The dead hares were packed separately in polythene bags with tags bearing the number, date, time, location and habitat and then transported to the laboratory. In the laboratory, the hares were emptied onto large sheets of white absorbent paper to mop up any dew on the fur, then vigorously combed using a fine fur comb and thoroughly searched for any plant materials on the body. The disseminules were put separately into labelled vials for identification and counting.

The hares were then sexed, and weighed and standard body measurements were taken before dissecting for other studies. As many of the different habitats as possible were sampled, which included open, short, and tall grasslands, woodlands, and forest edges.

Data were gathered on the number and sex of hares carrying disseminules, total number of disseminules, and disseminule species diversity. The number of months a particular species was observed is referred to as the frequency of occurrence of that species. The statistical analyses were based on Steel and Torrie (1960), and $P \leq .05$ was accepted as significant.

RESULTS

Throughout the 12 months, 96 hares were examined and 62 (64.6%) of them had disseminules on their fur (Table 1). The number of disseminules on the hares in the dry season was significantly greater than in the wet seasons, accounting for 74.0% of the annual total of 434. In the wet season, 109 disseminules were collected, 25.1% of the total. The greatest monthly total of disseminules was recorded in February, at the end of the first long dry season, and the lowest occurred in the middle of the first long wet season (April 1982) with only 9 (2.1% of total).

The highest number of disseminules, 13 out of a total of 23 (56.3%) was recorded in the middle of the second short wet season (October 1981) and the lowest, with only 3 species (13.0%), was in May 1982 in the first long wet season. However, there was no seasonal trend in the total number of species represented ($X^2 = 1.27$, d.f. = 3, $P > 0.05$) (Table 1).

Table 1. Seasonality of ectozoochory by hares in Queen Elizabeth National Park, Uganda, October 1981 — September 1982. Each season had three sampling periods.

Seasons	Total Number of Hares Examined	Number of Hares Carrying Disseminules	Total Number of Disseminules	Mean Disseminule Per Hare 'S.E.	Total Plant Species Represented
1. Short Wet	28	10	70	2.6±0.0	15
2. Long dry	21	19	181	9.9±3.2	12
3. Long wet	22	9	39	2.0±0.7	7
4. Short dry	25	24	144	5.7±0.8	12
TOTALS	96	62	434	4.5±1.5	23

The incidence of disseminules on the hares was 93% in the dry seasons and 38% in the wet seasons (Table 1). There was a nonsignificant relationship between the number of hares examined and those that carried disseminules per month ($r = 0.33, P > 0.05$). This meant that the dispersal of disseminules by hares was density independent. There was also nonsignificant relationship between mean number of disseminules per hare per month and number of species represented per month ($r = 0.55, P > 0.05$). This showed that some plant species are better adapted for hare dispersal or that some species produced more disseminules than others (Table 3).

Table 2. Numbers and species of plant disseminules by seasons, on female and male hares in Queen Elizabeth National Park, Uganda, October 1981-September 1982.

	MALES			FEMALES		
	Number of Hares Carrying Disseminules	Total Number of Disseminules	Total Disseminule Species	Number of Hares Carrying Disseminules	Total Number of Disseminules	Total Disseminule Species
1. Short wet	5	31	6	5	39	9
2. Long dry	5	17	2	14	163	10
3. Long wet	6	29	3	3	10	4
4. Short dry	10	33	5	14	111	7
TOTALS	26	110	8	36	323	14

Table 3. Plant species, number and type of disseminules involved in ectozoochory with their frequency of occurrence based on 96 hares shot in Queen Elizabeth National Park, Uganda, October 1981 - September 1982. The nomenclature of shrubs and herbs follows Lind and Tallantire (1975) and for grasses, Clayton (1974).

Plant Species	Frequency of Occurrence of Species (Months)	Number of Disseminules	Type	% of Total Number of Disseminules
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A. GRASSES

1. <i>Hyparrhenia filipendula</i> (Horst) Stapf	5	65	seeds	15.0
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2. <i>Tragus berteronianus</i> Schult.	6	54	seeds	12.4
3. <i>Cenchrus ciliaris</i> L.	7	44	seeds	10.1
4. <i>Themeda triandra</i> Forssk.	5	29	seeds	6.7
5. <i>Heteropogon contortus</i> (L.) Roem. & Schult.	5	28	seeds	6.5
6. <i>Eragrostis cilianensis</i> Lutati	3	26	seeds	6.0
7. <i>Chloris gayana</i> Kunth	4	19	seeds	4.4
8. <i>Brachiaria platynota</i> (K. Schum.) Robyns.	4	17	seeds	3.9
9. <i>Aristida adoensis</i> A. Rich.	1	11	fruits	2.5
10. <i>Eragrostis tenuifolia</i> (A. Rich) Steud.	3	8	inflorescence	1.8
11. <i>Harpachne schimperi</i> Hochst. ex. A. Rich.	1	7	spikelet + seeds	1.6
12. <i>Eragrostis exasperata</i> L.	2	4	seeds	0.9
13. <i>Panicum brevifolium</i> L.	1	3	inflorescence	0.7
14. <i>Microchloa runthaii</i> Dev.	4	4	inflorescence	0.2

B. HERBS/SHRUBS

15. <i>Tribulus terrestris</i> L.	3	43	fruits	9.9
16. <i>Oxygonum sinuatum</i> (Meisn.) Dammer	4	39	fruits	9.0
17. <i>Alysicarpus rugosus</i> (Willd.) DC.	2	14	seeds	3.2
18. <i>Achyranthes aspera</i> L.	2	7	seeds	1.6
19. <i>Clematis hirsuta</i> Guill. & Perr.	3	7	seeds	1.6
20. <i>Urena lobata</i> L.	1	4	fruits	0.9
21. <i>Triumfetta macrophylla</i> K. Schum.	1	2	fruits	0.5
22. <i>Sanicula elata</i> D. Don	1	1	seeds	0.2

Forty-five female hares made up 46.9% of the total collected. These carried 324 disseminules accounting for 74.7% of the total (Table 2). The highest number of disseminule species on an individual hare was 10, 43.5% of the total number of species, on a female hare in the long dry season. Twenty percent of the females carried no disseminules as compared to 49% of the males. Females show nonsignificant ($\chi^2 = 3.7, P > 0.5$) seasonal differences in number of disseminules as well as non-significant differences ($\chi^2 = 3.3, P > 0.05$) in the species of plant disseminules they carried (Table 2).

Fifty-one (53.1%) of the hares collected were males, and these carried 110 disseminules, accounting for 25.3% of the overall total (Table 2). The highest number of disseminules recorded on a male hare was 17 at the end of the short dry season and the highest number of disseminule species was 6 accounting for 26.1% of the total annual disseminule species ($n = 23$) at the beginning of the long wet season of 1982.

Twenty-two plant species were identified on the hares, with a total of 436 disseminules. Fourteen of the species were grasses which made up 64% of the species involved with a total of 319 disseminules or 73% of the disseminules recorded. Herbs and shrubs made up 36% of the species involved with 8 species represented. The herbs and shrubs totalled 117 or 27% of the disseminules (Table 3).

Among the grass species, *Hyparrhenia filipendula* was the most common, with 65 seeds (15% of the total disseminules) found in 5 months. *Cenchrus ciliaris* was found in 7 months, *Tragus berteronianus* in six and *Panicum brevifolium*, *Aristida adoensis* and *Harpachne schimperi* each occurred in only one month (Table 3).

Tribulus terrestris, a grassland herb, was the most common of the herbaceous plant disseminules encountered, with 43 fruits representing 10.0% of total disseminules and occurred in 3 months of the study. The commonest herb, *Oxygonum sinuatum* occurred in 4 months and contributed 39 fruits, 9% of the total disseminules (Table 3).

DISCUSSION

Ectozoochory by hares as demonstrated in this study could have tremendous impacts on local distribution of some plant species in the Park. Sixty-four percent of the hares examined carried disseminules on their fur regardless of the season. These disseminules are dropped off daily as the hare grooms its fur. Some areas of the Park at certain seasons of the year carry from 5-12 hares/ha, and thus their role in the dynamics of the vegetation could be significant.

The hares in this study area carried a higher number of species than those studied by Agnew and Flux (1970) in Kenya savannahs, although the Kenyan animals carried a higher total number of disseminules

than those from this Park. The higher number of species reported here could be because of differences in plant communities (and possibly soils and climate) in the two areas, and more important still are the behavioural and niche differences between *Lepus capensis* and *Lepus crawshayi* (Agnew and Flux 1970). *Lepus crawshayi* prefers thicker bush as well as grassland (Eltringham and Flux 1971), therefore it is capable of picking up and transporting disseminules within the ranges of the two or more habitats. The presence on *L. crawshayi* of disseminules of herbs, e.g., *Triumfetta macrophylla*, common only along swamp edges, and *Sanicula elata*, a forest herb (Lind and Tallantire 1975), suggests that this species may have a large home range or wide habitat preferences.

The high frequency of *Hyparrhenia filipendula* corresponds to its wide distribution in the Park and its adaptive features for zoochory. The less commonly observed species, e.g., *Harpachne schimperi* (Table 3) were not rare in the Park, but rather lacked the modifications for ectozoochory such as barbs or hooks. This finding agrees with that of Friedman and Stein (1978) who reported the seed dispersal mechanisms of *Anastatica hierochuntinca* to have profound influence on its ecological dispersion through zoochory. Herbs like *Tribulus terrestris* and *Oxygonum sinuatum* are very highly modified for zoochory life and are seasonally abundant.

The highest incidences of the disseminules on hares occurred in the dry seasons and the lowest registered in the wet seasons (Table 1). The most logical explanation for these seasonality effects is that most annual and perennial plants in the region that have their growth cycles synchronized with the wet and dry seasons, thus have more mature and abundant disseminules in the dry season (Lind and Tallantire 1975).

Possibly the disseminules are removed only "accidentally" as the hare scratches off itching ectoparasites from its body. Studies have reported that burning (which in this Park occurs extensively in the dry seasons) in dry seasons reduces the intensity and extent of infestations of ectoparasites (Bendell 1955, Flux 1972, Clifford *et al.* 1976). Fewer parasites in the dry seasons as a possible result of bush fires, could mean that hares groom less and hence accumulate plant disseminules on the body. Flux (1967) reported that moulting in *Lepus europaeus* Pallas in New Zealand occurs in seasons similar to the rainy seasons in the tropics, and later Agnew and Flux (1970) reported that *Lepus capensis* and *Lepus crawshayi* in the tropics moult in the wet seasons. If this is the timing for moulting of savannah hare, this could further explain the seasonality of the number of disseminules observed.

The species of the disseminules were found to vary little with seasons. This could have been because of the widely scattered collection locations in the Park or due to the local variation in microclimate, vegetation and soils (Langdale-Brown *et al.* 1964).

The higher incidence of disseminules on female hares of *Lepus capensis* reported by Agnew and Flux (1970) was also the case in *Lepus crawshayi* in this study. The explanation put forward by Agnew and Flux (1970), i.e., that the female hares have less time to groom or tend to live in thicker cover as they tend the young where they encounter more burrs, is plausible but it is open to further investigation. A further explanation could be that females tend to range farther afield, especially when breeding and lactating, to acquire enough food.

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VEGETATIVE KEY TO THE ALPINE VASCULAR PLANTS OF MOUNT KENYA

Truman P. Young
Department of Biology
University of Miami
Coral Gables, Florida, USA
and
Mary M. Peacock*
Department of Botany
University of California
Davis, CA, USA

INTRODUCTION

In recent years there has been an increasing interest in several aspects of plant biology in the alpine zone of Mount Kenya. To my knowledge, at least a dozen research projects were carried out between 1977 and 1984. Fortunately, the flora of the region has been the subject of a fine monograph by Hedberg (1957), and the currently available volumes of the Flora of Tropical East Africa (FTEA hereafter) contain a majority of the alpine species. Although reproductive individuals are generally more prevalent on the mountain throughout the year when compared to the drier lowlands, many species are only rarely found in the reproductive state (personal observations). As part of a comprehensive study of the vegetation of the upper Teleki Valley on Mount Kenya, we produced this key based on vegetative characters. It has since proven useful (in manuscript form) in studies by various other researchers. It is hoped that its publication will facilitate and encourage future biological research on Mount Kenya.

A lower elevational limit of 3500 meters was chosen to eliminate a number of forest species that occur sporadically above the timberline. Several species not listed by Hedberg are included. These represent either new records for Mount Kenya, such as *Helictotrichon umbrosum* and *Cystopteris diaphana*, or new altitudinal ranges discovered in our studies, such as *Kniphofia thomsonii* and *Asplenium E* (Agnew 1974). A separate paper will document the distribution, frequency, and ecology of the approximately 70 species found in the upper Teleki Valley.

As an additional aid to identification, three short reproductive keys for difficult groups are appended to the main vegetative key. The first of these covers three species of *Helichrysum*, the second covers herbs with opposite entire leaves, and the third covers the grasses. For three genera (*Poa*, *Colpodium*, and *Cerastium*) of two species each, no reliable vegetative distinguishing traits could be found. These genera are included in the reproductive keys.

One other genus deserves special mention. Hedberg (1957) and Clayton (1970) distinguished *Pentaschistis minor* and *P. borussica* by panicle shape. The former reportedly has a linear panicle, and the latter an open panicle. In addition, their altitudinal distributions on Mount Kenya were thought to be disjunct (Hedberg 1957). We have found that not only can *Pentaschistis* spp. be found at intermediate elevations, but that panicle shape in *P. minor* varies with plant age and air temperature (T.P.) Young, personal observations). In addition, Clayton (1970) reports the existence of intermediates between *P. minor* and *P. borussica*. We have found no consistent vegetative differences, and both key out here as *P. minor*.

*present address: Department of Biology, University of Nevada, Reno, NV, USA

Hints to Using the Key

It is particularly helpful to use this key in conjunction with Hedberg (1957), Agnew (1974), and relevant volumes of the Flora of Tropical East Africa (cf. Clayton 1970), sections of whose keys we have used here. After reaching one or more possible species identities in the key, compare your specimen to the descriptions in these texts, paying attention also to habitat and elevation. Unfortunately, the first two of these references are difficult to obtain at this time in East Africa. One hopes that this will not always be the case.

This key is designed for use with living vegetative material. Dry material may differ, especially in color. Reproductive material is often very different from vegetative material; for example, several small rosette species produce long leafy stems at reproduction, and leaves on reproductive stems may differ from those on vegetative plants. As in any vegetative key, there is likely to be some confusion concerning seedlings and young plants. For example, very young shaded *Lobelia telekii* individuals look similar to mature *Limosella africana* plants. In this case the latex of the former is indicative, but in others it must be left to the reader's own development of a 'feel' for the species. In particular, young plants of woody or shrubby species often appear herbaceous. We have tried in this key to reduce such ambiguities, relying on invariable characters as much as possible.

In order to make this key accessible to as broad a readership as possible, we have tried to minimize the use of botanical jargon. Nonetheless, some specialized terminology is unavoidable, particularly for the grasses.

- 1) Plant a fern; leaves (fronds) thin, compound, glabrous (but may have scales); ultimate segments dentate; leaves arising from a rhizome; plant not a rosette 2
Plant not a fern; if leaves compound and glabrous, then ultimate segments entire or the vegetative plant a rosette 3
- 2) Leaves multipinnate; final frond segments (pinnae) fan-shaped; rachis with coppery scales
. *Asplenium* sp. E. (Agnew)
Leaves pinnate; pinnae lanceolate, rachis without scales
. *Cystopteris diaphana* (syn. *C. fragilis*)
- 3) Plant glabrous; erect stems densely covered by numerous single-veined leaves less than 2 cm long (a nonseed plant that often has sporangia in its leaf axils) *Lycopodium saururus*
Plant not as above — if leaves small, glabrous and entire, then not densely covering erect stems (Angiosperms) 4
- 4) Leaves with parallel venation, entire, simple, often grasslike, not succulent, >2 cm long; if <2 cm long, then with distinct ligules (Monocotyledons) 5
Leaf veins net-like; leaves entire to deeply lobed, simple or compound, if somewhat grasslike, then succulent or woody or with liguleless leaves <2 cm long (Dicotyledons) 32
- 5) An aquatic plant with long internodes and leaves >1 cm broad *Potamogeton schweinfurthii*
Plant terrestrial, or with narrow leaves and short internodes 6
- 6) Leaves >1.5 cm wide 7
Leaves <1.0 cm wide 9
- 7) Leaves often >3 cm wide, always narrowing near the base. *Disa stairsii*
Leaves 1.5 to 2.5 cm wide, linear 8
- 8) Leaves with a raised midvein on both upper and lower surfaces; leaf blades flat
. *Gladiolus watsonoides*
Leaves without a raised midvein, or only on the lower surface; leaf blades often V-shaped
. *Kuiphofia thomsouii*
- 9) Leaves triangular to rectangular in cross section, with notched corners (in cross section)
. *Romulea keniensis*
Leaves flat, folded, rolled, round, or V-shaped, not notched 10
- 10) Leaves >4 mm wide, tinged red and densely long hairy. *Luzula abyssinica*
Leaves <4 mm wide, if greater, then not tinged red and densely long hairy 11
- 11) Leaves with a distinct ligule, either membranous or a fringe of hairs (Graminae) 14 (see also 134)
Ligule indistinct or absent (*Carex*) 12

- 12) Leaves (culms) round *Carex runssoroensis*
 Leaves flat to V-shaped 13
- 13) Leaves <4 mm wide, strongly V-shaped *Carex monostachya*
 Leaves >4 mm wide *Carex* sp. (prob. *bagaertii*)
- 14) Ligule a fringe of hairs 15
 Ligule membranous 16
- 15) Backs of leaves with single raised midveins *Pentstemon minor*
 Backs of leaves with a number of equal ribs *Andropogon amethystinus*
- 16) Leaf forming two right angles between the sheath and the blade *Koeleria capensis*
 Leaf forming a single acute angle at the ligule 17
- 17) Leaves flat or folded, not readily rolled between the fingers 18
 Leaves (tightly) rolled or subulate, readily rolled between the fingers 28
- 18) Leaves >20 cm long, >5 mm wide *Andropogon amethystinus* (incl. *A. longipes*)
 Leaves <20 cm long, if longer then <5 mm wide 19
- 19) Leaves flat 20
 Leaves folded; if open, then with a distinct crease. 23
- 20) At least some leaves >4 mm wide 21
 All leaves <3.5 mm wide 22
- 21) Leaves glabrous or (sparsely hairy) when crushed not having a distinct aromatic smell or taste *Colpodium* spp. (see 139)
 Leaves usually long hairy; when crushed smelling and tasting of coumarin
 *Anthoxanthum nivale*
- 22) Leaves sparsely pubescent; some hairs >2 mm long *Helictotrichon umbrosum*
 Leaves glabrous or with a few hairs <1.5 mm long *Agrostis quinqueseta*
- 23) Folded leaf >1.5 mm wide 24
 Folded leaf <1.5 mm wide 26
- 24) Stem with distinct internodes >2 cm long *Calamagrostis hedbergii*
 Plant tufted; internodes <1 cm long 25
- 25) Upper leaf sheath of two distinct parts—a membranous extension of the ligule inside, and a green leafy lip outside *Colpodium* spp. (see 139)
 Upper leaf sheath not of two distinct parts *Poa* spp. (see 146)
- 26) Ligule <1.5 mm long with dark glands at its base, especially in older leaves. *Festuca abyssinica*
 Ligule > 1.5 mm long, without dark glands at its base 27
- 27) Leaf bases, sheathes, or blades tinged red; blades flexuous *Deschampsia flexuosa*
 Plant not tinged red; leaf blades straight *Agrostis sclerophylla*
- 28) Leaves smooth or only slightly rough to the touch 29
 Leaves scabrous, distinctly rough to the touch 30
- 29) Culm bases white, not grey or brown or reddish *Agrostis gracifolia*
 Culm bases grey or brown or reddish 30
- 30) Ligules <1.5 mm long; culm bases often reddish *Festuca pilgeri*
 Ligules >1.5 mm long; culm bases not reddish 31
- 31) Leaves striate *Agrostis volkensisii*
 Leaves estriate *Agrostis trachyphylla*
- 32) Leaves producing a milky latex 33
 Leaves not producing a milky latex 35
- 33) Latex white; leaves never >4 cm long; leaves entire, often emarginate . . . *Dianthoseris schimperii*
 Latex cream colored; leaves usually >4 cm long; leaves shallowly crenate, not emarginate . . .
 (*Lobelia*) 34
- 34) Midvein glabrous in smaller plants; in larger plants, rosette
 retaining a reservoir of water. *Lobelia deckenii* ssp *keniensis*
 Lower midvein pubescent on the underside, rosette not retaining a reservoir of water (note: hybrids
 between these two species occur rarely) *Lobelia telekii*
- 35) Leaves or stem armed with stout spines, not merely barbed 36
 Plant not armed with spines, although some leaves may have weak barbs 38

- 36) Only stems armed; plant a woody shrub *Helichrysum citrispinum*
 Leaves armed, plant a rosette (*Carduus*) 37
- 37) Leaves compound; undersides white with pubescence *Carduus keniensis*
 Leaves dentate, undersides green *Carduus chamaecephalus* (syn. *C. platyphyllus*) (note:
 hybrids occur rarely)
- 38) Leaves distinctly compound and plant herbaceous or woody only at the base 39
 Leaves simple, entire to deeply lobed; or if leaves compound, then plant distinctly shrubby (see 106)
 49
- 39) Leaves with three leaflets; leaflets entire or minutely toothed *Trifolium multinerve*
 Leaves with more than three leaflets, or if three then distinctly dentate 40
- 40) Leaflets ovate, with acuminate teeth *Cardamine obliqua*
 Leaflets dentate, lobed, entire, sometimes filiform; not ovate 41
- 41) Leaves <10 cm long and leaflets >5 mm wide (*Ranunculus*) 42
 Leaves >10 cm long; or if less, then leaflets <5 mm wide 44
- 42) Leaves multipinnate *Ranunculus oreophytus*
 Leaves trifoliate 43
- 43) Leaflets deeply lobed *Ranunculus keniensis*
 Leaflets merely dentate *Ranunculus aberdaricus*
- 44) Leaflets <2 mm wide, filiform (*Peucedanum*) 45
 Leaflets >3 mm wide, dentate 46
- 45) Leaf rachis glabrous *Peucedanum friesiorum*
 Leaf rachis sparsely pubescent *Peucedanum kerstenii*
- 46) Leaves densely pubescent, white to silvery in appearance 47
 Leaves sparsely pubescent, greenish 48
- 47) Leaflets pinnately lobed or leaves bipinnate *Anthemis tigrensis*
 Leaflets entire to 1-2 lobed *Cotula abyssinica*
- 48) Leaflets <5 mm wide *Haplosciadium abyssinicum*
 Leaflets >7 mm wide *Heracleum inexpectatum* (syn. *Heracleum elgonense*)
- 49) Plant a rosette, internodes <5 mm long (although leafy stolons or reproductive shoots may be
 present) 50
 Vegetative plant with distinct internodes 73
- 50) Leaves entire 51
 Leaves dentate to deeply lobed 58
- 51) Leaves spatulate, >1.5 cm long 52
 Leaves not distinctly spatulate; if slightly so then <1.5 cm long 54
- 52) Leaves <5 mm wide, not purple tinged *Limosella aquatica* (syn. *Limosella africana*)
 Leaves >5 mm wide, or purple tinged (*Swertia*) 53
- 53) Plants producing stolons *Swertia crassiuscula*
 Plants not producing stolons *Swertia volkensis*
- 54) Leaves succulent *Subularia monticola*
 Leaves not succulent 55
- 55) Leaves glabrous 56
 Leaves pubescent 57
- 56) Leaves >3 mm wide *Dianthoseris schimperii*
 Leaves <3 mm wide *Sagina afroalpina*
- 57) Underside of leaf apex with a distinct gland; leaf hairs not glandular *Myosotis keniensis*
 Underside of leaf apex without a white gland; leaf hairs glandular *Cerastium* spp. (see 133)
- 58) Leaves dentate to lobed less than halfway to the midvein 59
 Leaves lobed more than halfway to the midvein 70
- 59) Leaves robust, thick (1 mm), with stout midveins and incurved margins, dentate 60
 Leaves thin, with thin margins, dentate or not 66

- 60) Leaves white woolly underneath 61
 Leaves green underneath, sometimes light green due to a thin layer of hairs 62
- 61) Upper leaf surfaces relatively smooth, plant becoming megaphytic *Senecio brassica*
 Upper leaf surfaces rugulose; plant a small flat rosette *Haplocarpha rueppellii*
- 62) Leaves <1 cm wide; plant not becoming megaphytic (see 121) 63
 Leaves >2 cm wide; plant becoming megaphytic 64
- 63) Plant glandular sticky *Senecio schweinfurthii*
 Plant not glandular sticky *Senecio keniophytum*
- 64) Leaves green beneath *Senecio keniodendron*
 Leaves greenish-white beneath, due to a thin layer of hairs 65
- 65) Megaphytic rosette plant growing to several meters; absent from the Teleki Valley, occurs along rocky courses elsewhere *Senecio battiscombei*
 Megaphytic rosette plant never reaching much taller than 1 m; only found along the ecotone between adjacent *Senecio brassica* and *Senecio keniodendron* populations, not uncommon in these situations *Senecio keniodendron* x *S. brassica* hybrid
- 66) Leaves lobed or crenate, >2 cm long 67
 Leaves toothed, <2 cm long 68
- 67) Leaves >5 cm long, often deeply lobed *Scabiosa columbaria*
 Leaves <5 cm long, crenate *Conyza subscaposa*
- 68) Hairs simple or leaves glabrous *Wahlenbergia pusilla*
 Hairs forked or stellate 69
- 69) Leaves densely covered by stellate hairs usually <.5mm long; (silique >.7 mm broad).
 *Arabis alpina*
 Leaves sparsely to moderately covered by stellate and simple hairs, some hairs at the bases of leaves up to 7 mm long; (silique <.7mm broad) *Arabidopsis thaliana*
- 70) Basal leaves usually thrice ternately lobed *Anemone thomsonii*
 Leaves pinnately, bipinnately, or palmately lobed 71
- 71) Leaves palmately lobed; not longer than wide; sometimes reddish (*Geranium*) 112
 Leaves pinnately to bipinnately lobed; longer than wide; not reddish. 72
- 72) Leaves >5 cm long *Scabiosa columbaria*
 Leaves <5 cm long *Oreophyton falcatum*
- 73) Leaves succulent 74
 Leaves not succulent 77
- 74) Plant woody at base *Sedum ruwenzoriense*
 Plant herbaceous 75
- 75) Leaves alternate *Sedum crassularia*
 Leaves opposite (*Crassula*) 76
- 76) Plant restricted to shallow soil on dry ledges; leaves distinctly succulent, nearly spherical.
 *Crassula alba*
 Plant of seasonal boggy flats; leaves weakly succulent *Crassula granvikii*
- 77) Leaves entire or with barbs or small acuminate teeth 78
 Leaves distinctly dentate to lobed to compound 104
- 78) Plant woody, at least at the base 79
 Plant herbaceous throughout 93
- 79) Leaves broader than 7 mm, never sticky 80
 Leaves narrower than 5 mm, or glandular sticky 81
- 80) Leaves opposite *Hypericum keniense*
 Leaves alternate *Protea kilimandscharica*
- 81) Leaves clasping the stem (*Helichrysum*) 82
 Leaves petiolate, not clasping the stem 85
- 82) Leaves >8 mm wide, glandular sticky *Helichrysum formosissimum*
 Leaves <5 mm wide, not glandular sticky 83 (see also 125)
- 83) Stems usually >6 mm in diameter; upper and lower leaf surfaces distinctly different in color; plant a shrub to 2m *Helichrysum chionoides*
 Stems <5 mm in diameter; upper and lower leaf surfaces similar; plant >.5m high 84

84) Leaves on young vegetative stems appressed, spreading when older; dark apical glands inconspicuous *Helichrysum cymosum*
 Leaves on vegetative stems spreading; dark apical glands conspicuous *Helichrysum brownei*

85) Leaves >1 cm long 86
 Leaves <1 cm long 87

86) Leaf bracts on uppermost leafless parts of stems large, dense, covering most of the stem
 *Euryops brownei*
 Leaf bracts small, sparse; the stem clearly visible
 *Hebenstretia angolensis* (previously *H. dentata*)

87) Leaves in clusters, silvery grey, linear *Stoebe kilimandscharica*
 Leaves not in clusters, if linear, then deep green (Ericaceae) 88

88) Young leaves densely pubescent, <3 times long as broad (*Blaeria*) 89
 Young leaves glabrous or nearly so, >3 times long as broad 90

89) Leaf hairs >.5mm; plant sparsely branched, the side branches much weaker than the main stem, leaves usually >3 mm long *Blaeria filago*
 Leaf hairs <5mm long; plant richly branched; leaves usually <2.5 mm long
 *Blaeria johnstonii*

90) Young stems densely pubescent 91
 Young stems glabrous or nearly so 92

91) Leaf blade <5 times the length of the petiole, petiole >1mm long *Philippia trimera*
 Leaf blade >5 times the length of the petiole, petiole usually <1mm long *Erica arborea*

92) Leaves <5mm long; plant a shrub to several meters *Philippia excelsa*
 Leaves >5mm long; plant a small woody herb to .5m *Erica whyteana*

Note: The genera *Erica* and *Philippia* can be distinguished most reliably in flower by the relative size of the dry stigma:
 Dry stigma >3 times the width of the style *Philippia*
 Dry stigma <3 times the width of the style *Erica*

93) Leaves in whorls of four or more (*Galium*) 94
 Leaves opposite or alternate 96

94) Leaves 4-6 in a whorl *Galium glaciale*
 Leaves (6-)8-10 in a whorl 95

95) Leaves barbed *Galium ruwenzoriense*
 Leaves not barbed *Galium ossirwoense*

96) Leaves alternate 97
 Leaves opposite 98 (see also 127)

97) Leaves >4 times long as broad *Senecio jacksonii*
 Leaves <3 times long as broad *Anagallis serpens*

98) Leaves distinctly spatulate and some >2 cm long 99
 Leaves not distinctly spatulate, or less than 2 cm long 100

99) Leaves >1.5cm wide *Swertia kilimandscharica*
 Leaves <1.5cm wide *Swertia subnivalis*

100) Leaves with thickened margins (*Satureja*) *Satureja biflora* (inc. *S. punctata*)
 Leaves without thickened margins 101

101) Stem with glandular hairs (*Cerastium*) 133
 Stem without glandular hairs 102

102) Opposite leaf bases united *Crassula granvikii*
 Opposite leaf bases not united 102b

102b) Stems succulent, reddish; leaves rarely >3 times long as broad *Anagallis serpens*
 Stems non-succulent, not reddish if alive; leaves often >3 times as long as broad 103

103) Leaves narrowing at the base *Callitriche stagnalis*
 Leaves broad at the base *Montia fontana*

104) Leaves with distinct stipules 105
 Leaves exstipulate 113

105) Plant woody, at least at the base 106
 Plant herbaceous 109

- 106) Leaves bipinnate *Artemisia afra*
 Leaves trifoliolate or simple 107
- 107) Leaves bipinnate *Adenocarpus niannii*
 Leaves or leaflets dentate or serrate 108
- 108) Leaves densely pubescent, usually trifoliolate; stipule membranous, with undivided apex
 *Alchemilla argyrophylla*
 Leaves sparsely to moderately pubescent, simple; stipule foliaceous, with a dentate apex
 *Alchemilla johnstonii*
- 109) Leaves with stinging hairs *Urtica massaica*
 Leaves without stinging hairs 110
- 110) Stipules dentate; plant erect *Cineraria grandiflora*
 Stipules entire; plant spreading 111
- 111) Leaves sharply dentate *Alchemilla cyclophylla*
 Leaves without acute teeth (*Geranium*) 112
- 112) Leaf blades reniform (kidney shaped) *Geranium kilinandscharica*
 Leaf blades pentagonal *Geranium arabicum*
- 113) Leaves opposite, at least near the base 114
 Leaves alternate 120
- 114) Leaves more than twice as long as broad 115
 Leaves less than twice as long as broad 117
- 115) Leaves deeply lobed toward base, entire at apex *Valeriana kilinandscharica*
 Leaves crenate-dentate throughout (*Bartsia*) 116
- 116) Leaves usually <3 times long as broad, rarely rolled (flowers purple) *Bartsia abyssinica*
 Leaves usually >3 times long as broad, often rolled (flowers yellow)
 *Bartsia decurva* (syn. *Bartsia kilimandscharica*)
- 117) Leaves minty, stems hairy (*Satureja*) 118
 Leaves not minty, stems glabrous (*Veronica*) 119
- 118) Leaf bases cordate *Satureja kilimandscharica*
 Leaf bases cuneate to truncate *Satureja simensis*
- 119) All stems prostrate *Veronica gunae*
 Some stems ascending to erect *Veronica glandulosa*
- 120) Leaves glabrous *Hebenstretia angolensis* (see at 86)
 Leaves pubescent (*Senecio*, see Hedberg 1957, page 225) 121
- 121) Plant glandular sticky 122
 Plant not glandular sticky 123
- 122) Plant woody at the base *Senecio roseiflorus*
 Plant herbaceous *Senecio purtschelleri*
- 123) Plant woody, at least at the base *Senecio schweinfurthii*
 Plant herbaceous 124
- 124) Leaves petiolate, dentate *Senecio keniophytum*
 Leaves apetiolate, mostly entire *Senecio jacksonii*

SPECIAL REPRODUCTIVE KEYS TO DIFFICULT GROUPS

Unarmed *Helichrysum* spp.

- 125) Involucre bracts appressed, inconspicuous; capitula diameter <4mm ... *Helichrysum cymosum*
 Involucre bracts open, showy; capitula diameter >15mm 126
- 126) Heads 1-5 in each corymb, 2.5-3.0cm wide, white with faint reddish tinge in bud
 *Helichrysum brownnei*
 Heads usually 5-10 or more in each corymb, 1.5-2.5cm wide, pure white or with a brownish tinge
 *Helichrysum chionoides*

Herbs with opposite, entire, glabrous leaves

- 127) Ovary of four separate carpels 128
 Carpels united 129
- 128) Flowers unisexual *Callitriche stagnalis*
 Flowers bisexual *Crassula granvikii*

- 129) Flowers irregular *Satureja biflora*
 Flowers regular 130
- 130) One style and stigma 131
 3-5 styles or stigmas 133
- 131) Petals small, <4mm long *Montia fontana*
 Petals longer than 6mm 132
- 132) Petals with indistinct nectaries without ciliation *Swertia subnivalis*
 Petals with distinct ciliate nectaries *Swertia kilimandscharica*
- 133) Petals often inconspicuous, with a narrow slit at apex; capsule teeth erect with reflexed margins
 *Cerastium octandrium*
 Petals emarginate at apex, capsule teeth backwards or spirally *Cerastium afro-moutanum*
- Gramineae**
- 134) Inflorescence [two to] several digitately arranged spikes *Andropogon amethystinus*
 Inflorescence an open or contracted panicle 135
- 135) Ligule a fringe of hairs *Pentaschistis minor*
 Ligule inembraneous 136
- 136) Spikelets with one floret 137
 Spikelets with more than one floret (sometimes only one fertile, but then with more than one awn per spikelet) 144
- 137) Floret with long hairs longer than the spikelet (sometimes deciduous upon drying) *Calamagrostis hedbergii*
 Floret without hairs or with only short hairs 138
- 138) Leaves >3mm wide; florets awnless (*Colpodium*) 139
 Leaves <3mm wide, if greater then florets awned (*Agrostis*) 140
- 139) Spikelets 4-6.5mm long; leaves to 12cm long *Colpodium chionogeiton*
 Spikelets 2.5-3.5mm long; leaves to 6.5cm long *Colpodium hedbergii*
- 140) Florets awnless *Agrostis sclerophylla*
 Florets awned 141
- 141) Leaves flat, >2mm wide *Agrostis quinqueseta*
 Leaves rolled, <2mm wide 142
- 142) Leaves smooth *Agrostis gracifolia*
 Leaves rough 143
- 143) Leaves striate *Agrostis volkensii*
 Leaves estriate *Agrostis trachyphylla*
- 144) Florets awnless 145
 Florets short to long awned 147
- 145) Glumes enclosing the florets *Koeleria capensis*
 At least the upper florets exserted (*Poa*) 146
- 146) Panicle contracted *Poa leptoclada*
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- 147) Upper florets distinctly exserted; lemma straight-awned from the tip (*Festuca*) 148
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- 148) Leaves rough *Festuca pilgeri*
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- 149) Spikelets enclosed by the glumes, 2-8mm long *Deschampsia flexuosa*
 Spikelets exserted from the glumes, 8-16mm long 150
- 150) Leaves usually >4mm wide, smelling of cumarin *Anthoxanthum nivale*
 Leaves <4mm wide, without a distinctive smell *Helictotrichon umbrosum*

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REPORT ON ACTIVITY IN THE NORTHERN CRATER OF OL DOINYO LENGAI, 24TH JUNE TO 1ST JULY 1988

Celia Nyamweru, Department of Geography, Kenyatta University,
P.O Box 43844, Nairobi, Kenya.



INTRODUCTION

Ol Doinyo Lengai, the only active volcano in the Gregory Rift Valley of East Africa, is also the only active carbonatite volcano in the world. Several times this century it has erupted lava and ash composed largely of sodium carbonate minerals. Early accounts of its eruptive activity were given by Hobley (1918) and by Reck and Schulze (1921); later accounts were provided by Richard (1942), Guest, (1956), Dawson (1962) and Dawson, Bowden and Clark (1968). The most recent widely known eruption was the explosive eruption that occurred between August and October 1966. Few people, whether in East Africa or elsewhere, are aware that the volcano erupted in early 1983, and that small scale activity in the northern crater has continued since then. A report on the activity from 1983 to 1987 has been published by the present author (Nyamweru 1988), and several short accounts have appeared in the Scientific Event Alert Network Bulletin between 1983 and 1988. The account that follows is the record of activity between 24th June and 1st July 1988, during which period the author was a member of a party that camped in the inactive (southern) corner of the north crater (area S in figures 1, 2 and 3).

DIARY OF ERUPTIVE ACTIVITY

24-06-88, 1630 hours: First view into the crater when party members arrived on the crater rim. No lava flowing out on crater floor. Liquid lava present in two (connected) small lava lakes in the area T4T7 (see figures 1, 2 and 3). The larger lake lies to the east, and is about 8 to 10 metres in diameter, with overhanging sides 2 to 3 metres high. The liquid lava is black, with very low viscosity and bubbling actively, breaking in bubbles over 50 cm in diameter which throw 'spray' over 4 metres high. Small drops of lava fall outside the vent and form lapilli on the surrounding slopes. Plate I is of this lava lake and shows two bubbles of lava breaking on the lake surface, below the overhanging north wall of the vent. The second lava lake lies about 20 metres to the west, and is also active; a vertical fan-shaped spray of lava is rising from a narrow pinnacle in the centre of the lake, building it up. At

1630 hours there is no other activity visible in the crater, although steam and sulphurous fumes are emitted from a number of vents on the crater floor, its walls and its rim (see figure 1).

24-06-88, circa 1800 hours: lava begins to overflow from the southern side of the eastern lava lake of T4T7, and flows rapidly southwards; Flow 1 in figure 4.

24-06-88, between 1900 and 2000 hours: The flow (mainly of a lava) reaches the southern wall of the crater and is stationary but still hot at 2000 hours. During this period lava probably also flows eastwards, where it reaches the base of the crater wall. After dark there is an intermittent orange-yellow flare of burning gas from the top of the western vent of T4T7, and a dull red glow of lava from the eastern lava lake and its outflow.

25-06-88, 0700 hours: no new flows during the night: whitening of rock by chemical change beginning to occur around the margins of Flow 1. Lava is bubbling gently in the eastern lake of T4T7 but not splashing high or flowing out. The western lake is quiet, with little or no bubbling sound.

25-06-88, circa 1200 hours: lava begins to spill over the lip of the eastern lake, rapid flow begins towards the south, very liquid black lava flowing in a stream about 1 to 1.5 metres wide, spreading out and slowing down as it flows (Flow 2 in figure 4).

25-06-88, 1345 hours: liquid lava overflowing to the east in a very narrow layer, probably less than 5 cm thick but several metres wide; this 'sheetflow' lasts only for a few minutes (Flow 2 in figure 4).

25-06-88, 1400 hours: active outflow has largely ceased.

25-06-88, 1630 hours: lava moving in the lava lakes on T4T7 but not flowing out or bubbling over the edges of the lakes.

26-06-88, 0730 hours: small outflow of lava from the southeast side of T4T7, escaping from a little crack below the rim of the lava lake. This has ceased before 1000 hours, when the lava is solid but still very hot (Flow 3 in figure 4).

26-06-88, 1000 hours: lava bubbling actively in both lava lakes, but not spattering out or overflowing.

26-06-88, 1030 hours: small tricklings of fluid lava emerging from within the edge of Flow 2, near the northeast crater wall. Thickness of edge of flow is 50 to 60 cm; surface is solid but still warm.

26-06-88, 1600 to 1730 hours: no flowing lava on crater floor but lava bubbling at a relatively low level in T4T7 east. During this period, the noise of moving lava is heard from the open holes on the upper slopes of T5, from which shimmering heat and steam are rising; looking deep into the holes, it is possible to see liquid lava moving around below. At 1630 hours a small patch of pahoehoe lava is still warm on the north slope of T5 and probably formed within the last one or two days, though it was not observed flowing; this little flow appears to have originated from a crack low down on the slope of T5.

27-06-88, 0800 hours: lava is bubbling at a very high level in the lava lake T4T7 east.

27-06-88, circa 0900 hours: a crack opens on the lower southwest side of the T4T7 ridge and very fluid lava flows out in a narrow stream; Flow 4 in figure 4.

27-06-88, 0940 hours: lava has spread along a bearing of about 210 degrees from its source, towards the southwest corner of the crater. Black, smoothly flowing lava is in a stream about 50 cm wide, spreading out into tongues with a small-scale a surface; it cools to a dark chocolate brown colour.

27-06-88, 1000 hours; flow is about 112 metres long and reaches to within 27 metres of the southern crater wall at the western end of the saddle. Its thickness is about 20 to 30 cm on the lobes at its lower end. During this period the lava remains bubbling actively at a high level in T4T7 east.

27-06-88, 1115 hours: flow is continuing, spreading out between T1 and T2 but not extending further south.

27-06-88, 1145 to 1200 hours: flow continuing, lava lake in T4T7 east bubbling actively.

27-06-88, 1300 hours: lava bubbling actively in T4T7 east. At the head of the new flow (F4) a hornito (H1) about 50 to 70 cm high has formed within about the last hour, by bubbling of highly gaseous lava from a narrow slit near its top. The hornito (see Plate II) is being built up by wrinkled cords and tiny lobes of smooth lava, while below it lava is still flowing out rapidly in streams 30 to 60 cm wide. In places the liquid lava disappears into a tunnel and then emerges further downstream; at this stage steady movement over quite a wide front is continuing towards the lower end of the flow. Slabs of pahoehoe form on top of the flowing lava, then are carried on by the moving rock, broken and tilted; lines of tilted slabs mark the flow lines (see Plate III).

27-06-88, 1340 to 1350 hours: hornito still bubbling; volume of lava escaping from beneath it is gradually decreasing, as the flow is contained within the limits of the earlier flows.

27-06-88, 1430 hours: hornito no longer bubbling but flow continues.

27-06-88, 1515 hours: flow continuing in a narrow (20 to 30 cm wide) channel within the earlier channels. Flow is on surface near source, then goes into a tunnel.

27-06-88, 1615 hours: source of flow has moved a few metres downstream, bubbling out under a narrow corded skin of lava that is few hours older. There is a gentle spattering in the west side of T4T7, and more active bubbling in T4T7 east.

27-06-88, 1700 hours: flow is continuing; there is active bubbling in T4T7 east and a gentle noise of moving lava deep below T5.

27-06-88, later that night: flow ceases along F4; bubbling continues in T4T7 east. The central pinnacle in T4T7 west, which was emitting a spray of lava on the evening of 24-06-88, collapses.

28-06-88, 0800 hours: no new flows on crater floor, no outflow of lava, but lava bubbling actively in T4T7 east.

28-06-88, 1630 hours: active continuous bubbling from T4T7 east, little or no sound from any other vent.

29-06-88, 0750 hours: a new large flow has formed in the night, overflowing from a groove cut in the lip around the lava lake, T4T7 east; this is Flow 5 which has gone mostly towards the south and southwest (Figure 5).

29-06-88, 0810 hours: flow very active from the vent, with overflow from two places on the rim of the lava lake; lava has also flowed round to the east and northeast and has reached the north wall of the crater below the rim cone C1. On the northwest side of T4T7 there is spattering of very gas-rich lava from the top of one of the little cones that border the vent; new trails of dark lava are forming down the pale grey slopes of the cone.

29-06-88, 1010 hours: lava bubbling in both the eastern and western lakes of T4T7; overflow still continuing from the south side of T4T7 east.

29-06-88, 1100 hours: lava bubbling in both lakes; occasional spattering from the top of the western cone.

29-06-88, 1230 hours: active bubbling and overflowing from T4T7 east; line of small hornitos building up along the line of flow where liquid lava is breaking out of tunnels below the older surface.

29-06-88, 1400 hours: lava bubbling and overflowing; southwestern corner of flow has reached within 16 metres of the southeast corner of T2.

29-06-88, 1430 to 1530 hours: spray of highly gaseous lava from the top of a hornito, the highest of a line of about 7 hornitos that lie along the axis of Flow 5; the spray from the hornitos has stopped by about 1530 hours but extension of the lava flow further downstream continues until later in the day.

29-06-88, 2000 hours: surface outflow of lava has ceased before this, but the lava lake on both sides of T4T7 is bubbling actively, with a dull orange glow and an occasional pale orange flare of gas. When the molten lava spatters on the rim of the vent, it glows dull red for some seconds before it cools.

30-06-88: active bubbling and splashing of lava from both the eastern and western sides of T4T7 continues throughout the day, but there is no surface overflow during daylight hours.

30-06-88, approx. 1949 hours: a new vent opens on the east side of T4T7 and lava begins to flow rapidly to the east and southeast, quickly reaching the east wall of the crater (figure 5).

30-06-88, 2030 hours: the lava has spread to the east of T5, covering the earlier (Flow 1) lava in this area. A lava cone is soon built up at the source of the lava (T8) which at this time appears to be 2 or 3 metres high and about 10 metres in diameter. A spray of dull red lava is thrown a further 3 metres above the top of the cone. At this time the level of lava in T4T7 has fallen by as much as 10 metres and it is possible to see a large hollow below the arch that joins the two lava lakes (east and west sides of T4T7).

30-06-88, 2200 hours: lava from T8 fountaining from the cone and flowing actively.

01-17-88, 0230 hours: occasional spattering from the top of T8.

01-07-88, 0630 hours: occasional spattering from the top of T8. The cone is now about 10 to 12 metres high, with a smooth slope to the southeast, a break in slope on its northwest side. The lava below T4T7 can be heard moving around, though at some depth. The last members of the party left the crater rim at about 0700 hours.

LIST OF LAVA FLOWS (see figures 4 and 5)

Flow 0: This was not observed actually flowing but at noon on 25-06-88 was still warm and had undergone very little whitening; it had originated from the northwest slope of T4T7 and had flowed to within a metre of the north crater wall; see figure 4. This flow probably formed on 24-06-88; according to M. Krafft it was already in existence when he visited that part of the crater late that day. The flow was about 35 metres long, width at downstream end (across 3 lobes) circa 30 metres, width near base of cone circa 14 metres. Thickness between 30 to 50 cm. It was largely composed of a lava, but it was overlain with little lobes of pahoehoe that seem to have resulted from the closing stage of the eruption.

Flow 1: This flow came from the eastern lava lake of T4T7 and formed between about 1800 to 1900 hours on 24-06-88. Its dimensions were as follows: from the vent to the east-northeast crater wall, about 50 metres long; from the vent to the southern crater wall, about 180 metres long; maximum thickness 50 to 70 cm (see figure 4; this flow is also visible in the centre of Plate IV).

Flow 2: This flow formed between about 1200 and 1400 hours on 25-06-88, by overflow of very liquid lava from the rim of the eastern lava lake. Its dimensions were not measured but it was a much smaller flow than Flow 1 and only covered parts of it, within a few tens of metres of the vent (see figure 4).

Flow 3: This formed between about 0730 and 1000 hours on 26-06-88, it was another very small flow which escaped from a crack on the southeast side of T4T7, below the rim of the lava lake (dimensions not measured, but see figure 4).

Flow 4: This flow started at about 0900 hours on 27-06-88 from a crack that opened low on the southwest slope of T4T7. It continued to flow in gradually narrower channels until after 1700 hours on the same date; between about 1200 and 1430 hours a small hornito formed at its upper limit, by effusion of highly gaseous lava. The final dimensions of the flow were: length about 120 metres; width ranging from 1 metre close to its source to about 40 metres at its downstream end; thickness maximum 50 cm. At its final extent, the toe of the flow reached to within 12 metres of the south wall of the crater (see figure 4; this flow is also visible in Plate IV, where it is the narrow, dark flow on the left side of the crater floor).

Flow 5: This flow probably started during the early hours of 29-06-88; by our first visit to the crater at 0750 hours that day, the flow had extended far to the south of its source; it was overflowing actively from a notch cut in the southern rim of the eastern lava lake of T4T7. The flow also extended to the east and northeast of its source, covering a distance of about 80 metres from the vent to reach the crater wall (see figure 5). Flow continued until about 1600 hours and at its final extent the flow was over 150 metres long and had reached to within 20 metres of the south crater wall at the saddle, and to within 6 metres of the north side of T1.

Flow 6: This flow began to form at about 1940 hours on 30-06-88, from a new vent low on the east side of T4T7. Movement was very rapid in the early stages and by 2033 hours the new flow had extended round the slopes of T5 and reached the eastern crater wall (see figure 5). The thickness of the flow ranged from 20-30 cm to a maximum of about 50 cm. At the source of the flow, lava fountaining built up a new cone (T8; see figure 5) which by 0630 hours on 01-07-88 was about 10 to 12 metres high. The flow of lava probably ceased soon after 2200 hours, but spattering from the top of the cone continued throughout the night and was still taking place at a reduced level the following morning.

DIMENSIONS OF CRATER

Pacing from west to east on a diameter just to the north of T2, between T4T7 and T5: 244 metres.

Pacing from north to south on a diameter to the west of T4T7, past the eastern corner of T1: 222 metres (average of 2 pacings).

Pacing on a diameter at bearing 136 degrees, from the base of D, passing just to the south of T5: 253 metres.

Height of northeast wall (estimated) 40 to 50 metres. Northwest wall could be slightly higher (but not more than 60 metres). East wall is slightly lower (30 to 40 metres).

The level of the crater floor around T5 and T4T7 is markedly higher than the level to the south, at the base of the saddle, and may even be higher than the lowest point of the saddle.

DESCRIPTION OF THE CRATER; THE ERUPTIVE CENTRES (see figures 1 to 3).

Southern crater: this feature, to the south of the central summit, was a shallow, gently sloping depression floored by rather coarse grey ash, with patches of green vegetation on its floor and sides.

T1: (the 'igloo') inactive and largely unchanged since April 1988 and even December 1987; rounded pale grey slope (length about 45 metres around base of slope) facing southwards towards the saddle. Overhang facing northwards into the crater; distance across base of overhang was about 10 metres. Occasional slight emission of steam from base of its inner slopes.

T2: this collapsed centre also largely unchanged since April 1988; in plan it was approximately circular, about 33 metres in diameter, with inward facing walls (best preserved on its north and south sides) and a central cone with an open hole on its south side. This hole was more than 6 metres deep and inside it was a jumble of blocks of rock; some warm fumes were rising from it. Considerable sulphur staining was visible on its inner slopes and fumes were emitted from the central holes from the base of the outer walls. There were 'stalactites' along the base of the inner walls.

T5: little change in this group of pinnacles since April 1988. When first seen at 1630 hours on 24-06-88 there was no steam visible, no sound of molten rock at depth, but later during the week there

was emission of steam, and shimmering heat rising from the holes that were still open towards the top of the pinnacles.

At 1630 hours on 26-06-88 a member of the party heard and saw liquid lava moving around deep below T5, and at mid-day on 30-06-88 it was possible to hear moving lava below this feature. A small flow of pahoehoe lava was still hot on the north slope of T5 at circa 1600 hours on 26-06-88, and may have formed within the last 24 to 48 hours, though it was not actually observed flowing. T5 is visible on the right of the crater floor in Plate IV.

T4T7: this was the centre of activity throughout our stay. It changed greatly after December 1987 (when there were two quite small separate vents, T4 and T7) and according to D. Peterson also changed noticeably between his visit on 27-05-88 and the end of June 1988. By then it had developed into a continuous ridge, broadly aligned east-west, with an uneven crestline rising to a series of grey lava pinnacles; its length (parallel to its long axis) was about 80 metres. The two lava lakes (eastern and western) were connected under an arch of older lava, which supported a lava pinnacle over 3 metres high. When the level of lava was low (as it was late on 30-06-88) it was possible to look through and under the arch from one lake to the other. The lava pinnacle in the centre of the western lava lake that was emitting a spray of lava on 24-06-88 collapsed on 27-06-88. T4T7 can be seen on the far (north) side of the crater floor in Plate IV.

A3: these inactive vents, small cones and lava flows were still clearly visible on the crater wall, though rather paler in colour than they had been in late 1987; largely grey or white, with a crumbled, rather powdery surface; erosion by running water had begun to cut little gullies down parts of this slope. There were at least 5 small vents on the northern slope, as well as others to the west and (possibly) the east. The cones were of basically the same form and dimensions as comparable features on the crater floor; the three larger ones stood between 3 to 6 metres above the crater wall and there were two smaller ones. The largest cone lay to the west of the cluster, and had a steep top with an open vent, though the bottom of the hole was not visible.

A4: on the northern wall of the lowest part of the saddle, just behind T1, there was an area of soft, powdery pale grey/brown material, with two or three small, partly in filled pits which appear to be heavily weathered small vents comparable to those on the north wall of the crater, opposite them. The top of the saddle for several metres was made of soft powdery pale grey/brown material rather than of the mid-grey, harder and coarser material (which includes pieces of rock up to 10 cm long) that made up the rest of the saddle and much of the upper rim and summit of the volcano.

D: this inactive vent, with a small lava flow below it, was still clearly visible on the crater wall, though pale brown and heavily weathered. There was possibly an equally old, smaller vent to the south of D, close to the top of the western crater wall.

C1: when first seen at 1630 hours on 24-06-88, was not emitting steam. The cone rose over 4 metres above the crater rim and had steep slopes of soft, crumbly grey material. An estimate of its dimensions was 10 metres long and 8 metres high. Later during the week occasional emission of steam from this cone was observed. C1 lies at about 1 o'clock on the crater rim in Plate IV.

Crater floor: the areas not covered by very recent flows were various shades of pale grey, pale brown and white; different generations of flows could be distinguished by overlapping lobes and tongues of weathered lava. Despite the intensive weathering of the lava surfaces, the pahoehoe and aa structures, as well as some lines of small hornitos, were clearly distinguishable. For example the tilted slabs of pahoehoe and the small hornito observed forming on Flow 4 on 27-06-88 could be recognized in a weathered state on nearby older flows. Figures 1 and 2 show FF, two medium grey

flows which had longitudinal blackened fissures following their long axes. The blackening marked a line of fumaroles and was due to chemical activity of the fumes. Viewed from the summit on 28-06-88, the oldest parts of the crater floor appeared to be on its southeast side (beyond T5; here there was a small alluvial fan of material brought down from the slopes above, overlying the weathered lava) and on the southwest side beyond T1.

M: the saddle was very low on its north side; its height there was about 4 metres. To the south, towards the inactive southern section of the crater, there was a drop of about 12 metres; thus the floor of the southern section was at a lower elevation than that of the active northern part of the crater.

DESCRIPTION OF THE CRATER; THE FUMAROLES (marked xxx on figure 1; not marked on the other figures)

East rim: Strong sulphurous smell, fumes and yellow staining along cracks on rim.

West and northwest rim: deeply cracked in many places, both parallel to the rim and across it. Some cracks emit mainly steam and support local patches of vegetation, including mosses and lichens; others emit sulphurous fumes and the surrounding areas are largely bare of vegetation.

T1: occasional gentle emission of steam and slight smell of sulphur.

T2: sulphurous smell, yellow staining, fumes from inner slopes on both sides.

T5: occasional emission of steam (see notes above).

Northeast wall: patches of bright yellow sulphur, local gentle emission of steam.

M: the saddle; the east side of the saddle, where it begins to rise steeply, is heavily altered and there is emission of sulphurous fumes. On the west side of the saddle, at a rather lower elevation, there is an open crack (less than 5cm wide) that crosses the saddle, with active emission of fumes and some sulphur staining (see note b. below).

Southern section of the crater: the crack referred to above crosses the saddle and extends into the southern 'inactive' section of the crater. Occasional emission of steam was also observed from a spot near the centre of the southern section of the crater.

GENERAL OBSERVATIONS AND CONCLUSIONS

- a. Over the period that we observed the crater, activity was concentrated in the area T4T7, where there was a lake of liquid lava over 40 metres long (including the eastern and western lakes and the connection between them). However liquid lava was also seen and heard moving around deep below T5 and there was evidence of recent small flows from the northern slope of T5, so this centre is not entirely extinct. Broadly, however, it appears that most activity is concentrated towards the northeastern and eastern sides of the crater.
- b. A line of weakness seems to cross the whole crater, on a bearing about 42 degrees to 222 degrees. On the northeast wall it is marked by a small grey vent near the top of the wall, with grey material below it. On the crater floor it is marked by fumaroles that have formed long lines of black staining that run to the west of T1. On the saddle it is marked by the big crack which emits sulphurous fumes. The new cone (T8) that formed the night of 30-06-88 lay very slightly to the northwest of this line. This line of weakness could well form the site of future eruptive vents.

- c. Eruptions have taken place at several locations on the crater walls, in particular on the north wall (A3 and C1), but also apparently along the saddle (A4). Considering the fumaroles that extend across the saddle, and the high level of the floor of the northern section, it seems quite possible that lava could in the future reach the surface in the 'inactive' southern section of the north crater. Equally, it is quite possible that future eruptions could occur on the crater walls or even on its rim.
- d. The newly erupted lava weathers extremely rapidly, changing colour almost completely; the surface goes from dark grey or dark chocolate brown on newly cooled lava to pale grey within less than 48 hours. This makes it virtually impossible to recognize a 'new' lava flow unless one observes it within one or two days of its formation and thus creates serious limitations to the detailed picture of changes in the crater that may be drawn. The rate of change of the lava may depend to some extent on the weather conditions; when the atmosphere is very moist (and windy) one might expect the change to be more rapid than when it is still, hot and dry. However even the flows that erupted on the sunny days that we were in the crater (e.g. Flow 4) changed colour very rapidly.
- e. During the seven days during which observations were made, liquid lava was always present close below the surface; at least 4 quite substantial flows were produced and a cone over 10 metres high was built up. It is not possible to tell whether this represents the general level of activity over the last five years or not, since no other continuous observations over seven days have been made. However the intermittent observations made over the years since 1983 indicate that liquid lava was frequently present, bubbling close below the surface if not actually flowing out. The topography of the crater floor and walls has changed strikingly over this period, evidence of the emission of quite a large volume of lava.
- f. In particular the northern 'pit-crater' that existed in the late 1960's and during the 1970's has become much shallower; shallower even than it was before the explosive eruption of 1966. One may ask how much shallower it will get before another major explosive eruption occurs and recreates a deep, vertical walled pit crater at the summit of Ol Doi Ny Lengai?

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GLOSSARY

AA a lava flow with a rough, jagged, clinkery surface. (A term of Hawaiian origin). See the lava in the foreground of Plate III.

HORNITO a small mound built up on top of a lava flow by clots of very fluid rock escaping from openings in the roof of an underlying lava tube. Two hornitos are shown to the right of the standing figure in Plate II.

PAHOEHOE a lava flow with a smooth, billowy or ropy surface. (A term of Hawaiian origin). See the lava in the foreground of Plate II.

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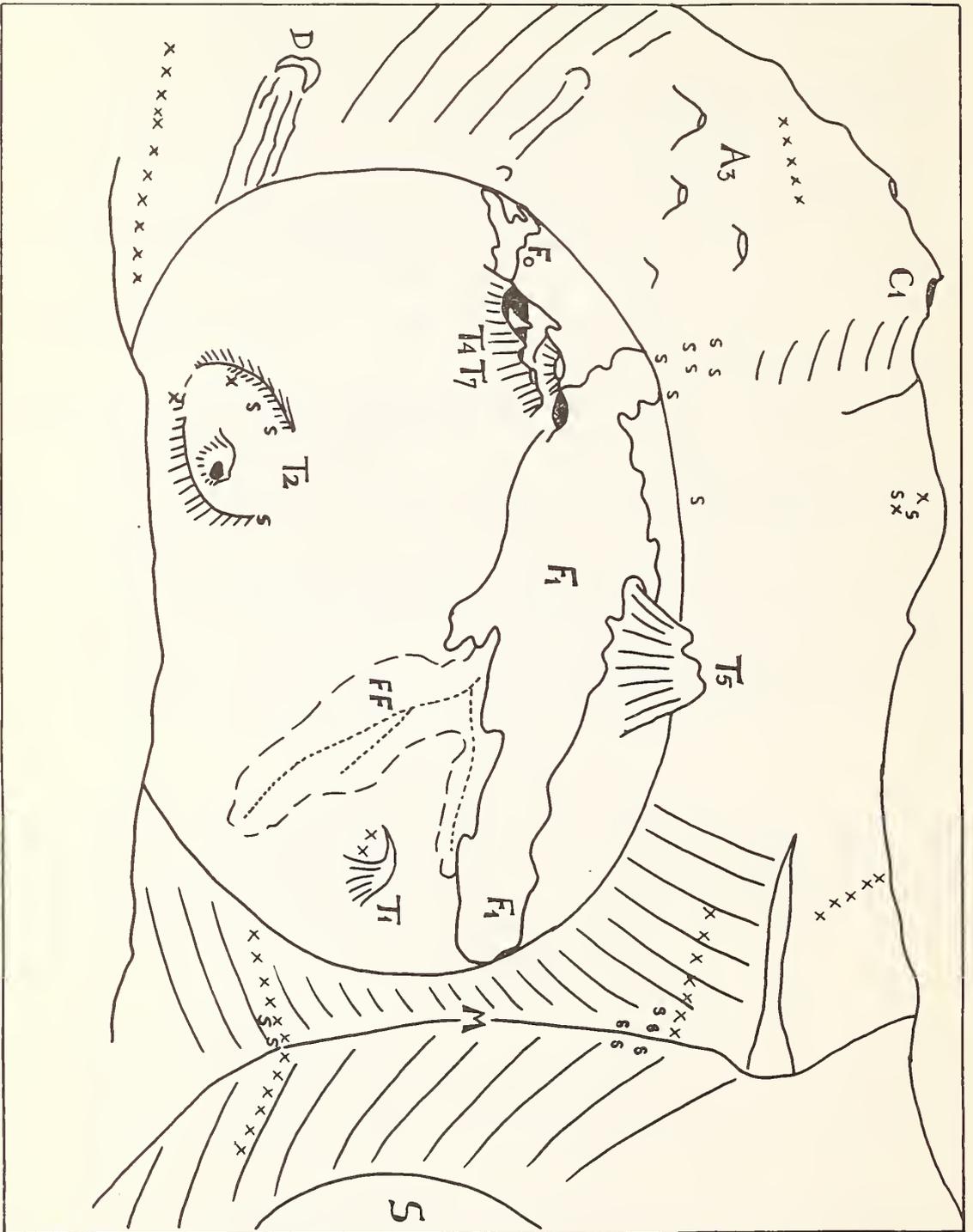


Figure 1 : The crater of Ol Doiyo Lengai sketched from a point on its southwest rim at 1520 hours on 25th June 1988. xxx: fumaroles; sss: Sulphur. For other letters and numbers, see text.

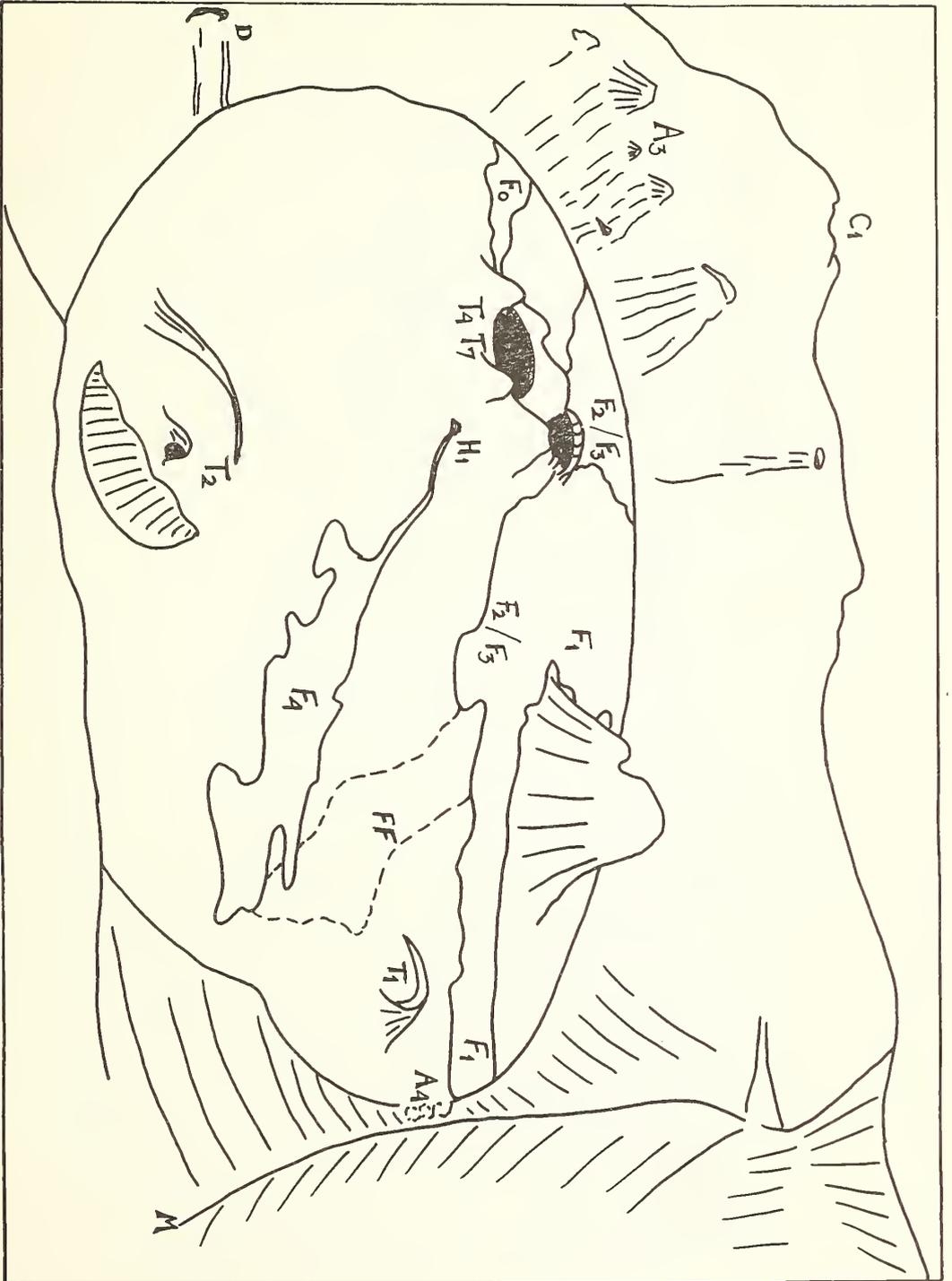


Figure 2: The crater sketched from the same point as figure 1 at 1600 hours on 28th June 1988.

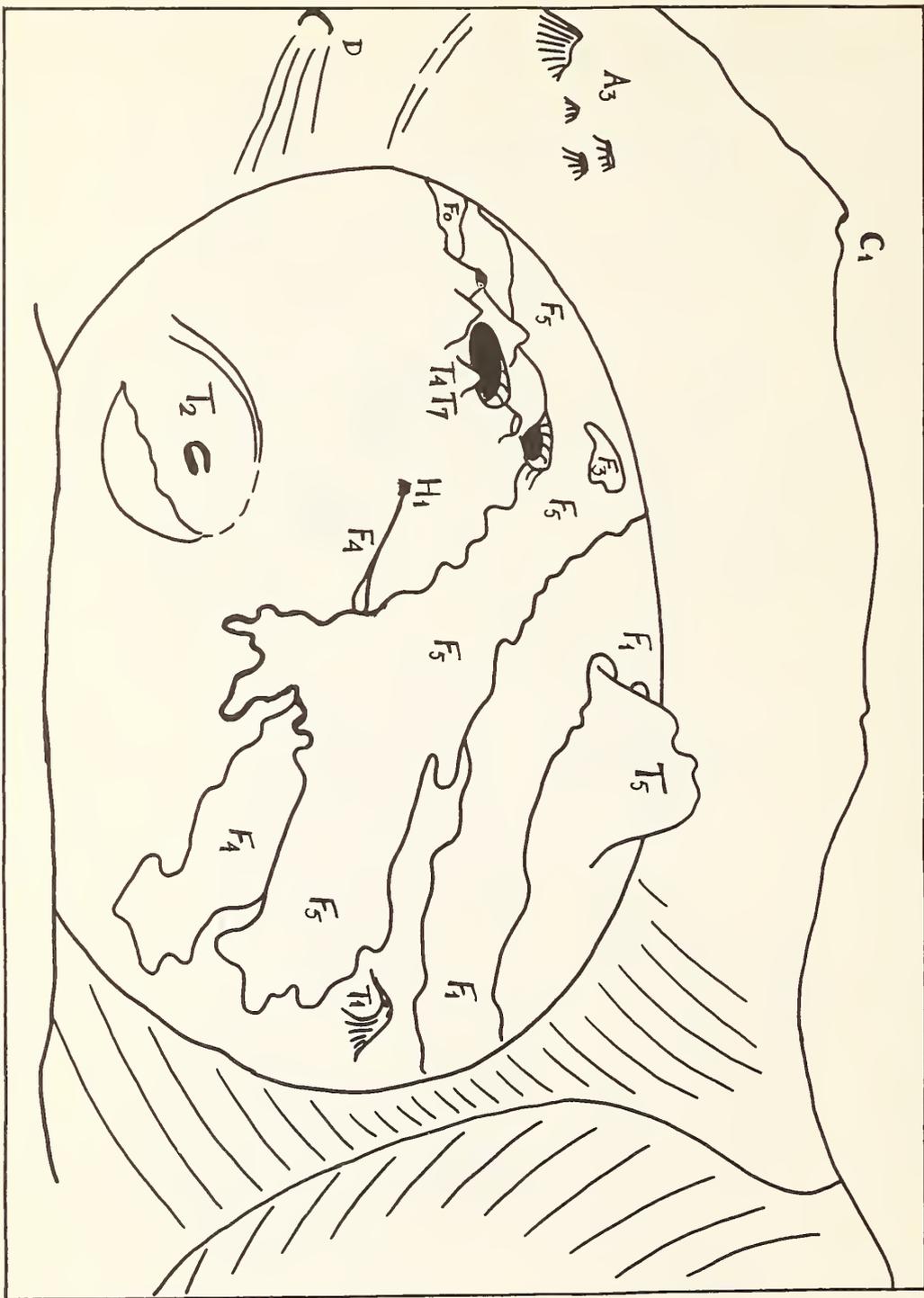


Figure 3: The crater sketched from the same point as figures 1 and 2 at 1545 hours on 29th June 1988.

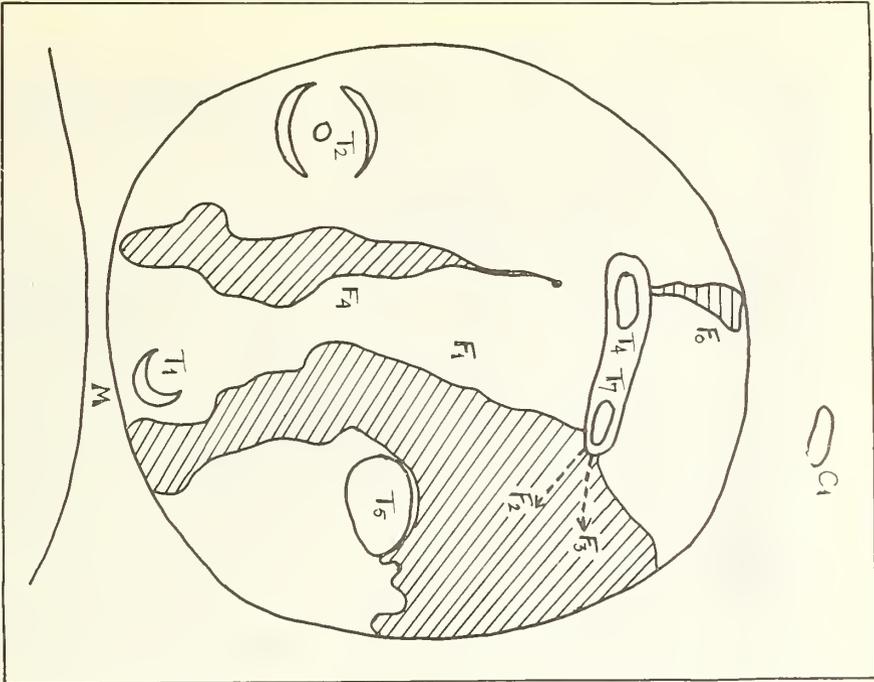


Figure 4: Plan of the crater of Ol Doinyo Lengai showing the approximate positions of flows F0, F1, F2/F3 and F4. Approximate diameter of crater is 240 metres.

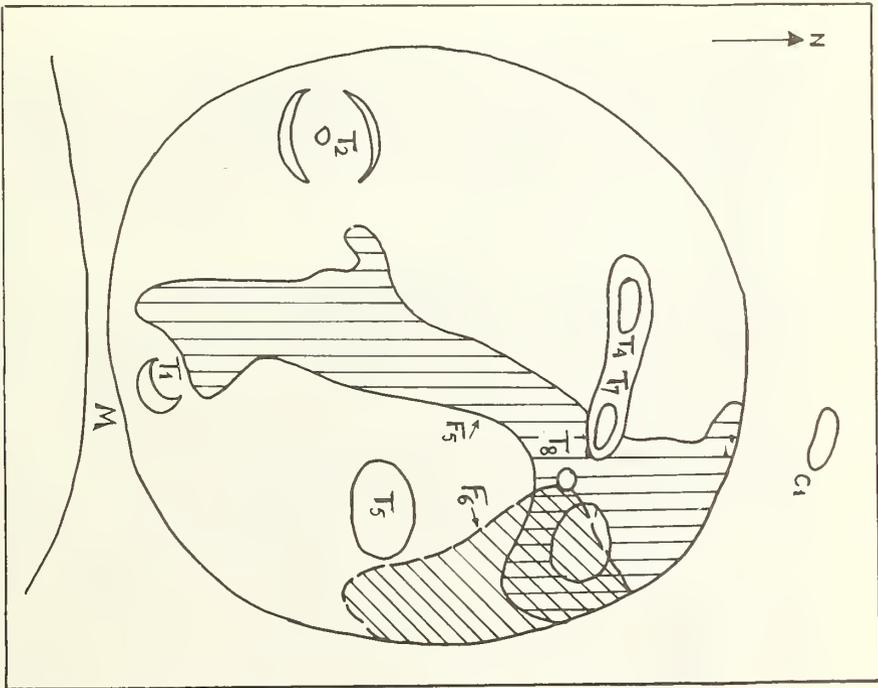


Figure 5: Plan of the crater of Ol Doinyo Lengai showing the approximate position of flows F5 and F6.



Plate I: Lava bubbles breaking in the eastern lava lake of T4T7. In the background is the crater wall with the cones labelled A3 in figures 1 to 3.



Plate II: The source of Flow 4 at 1615 hours on 27th June 1988; two hornitos and several small channels of pahoehoe lava. Behind the standing figure are the pinnacles forming T4T7 and in the background stands the crater rim with the rim-cone C1.



Plate III. Surface of Flow 4 on 30th June 1988; tilted slabs of lava already turning white. The broken wall of the old vent T2 is in the background.



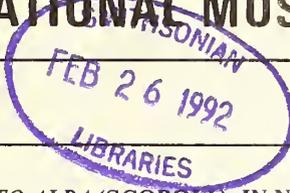
Plate IV: View of crater from the southeast on 28th June 1988, showing the saddle to the left, the rim-cone slightly east of north and the eruptive vents T1, T2, T4T7 and T5 on the crater floor.
(all photographs taken by the author)

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THE DIET OF THE BARN OWL, *TYTO ALBA* (SCOPOLI), IN NAIROBI, KENYA.

Cecilia M. Gichuki, Department of Ornithology, National Museums of Kenya, P.O. Box 40658, Nairobi.

ABSTRACT

The food of the Barn Owl, *Tyto alba* (Scopoli), was studied by the analysis of undigested remains of prey found in regurgitated pellets. About 1200 pellets were obtained from a nest site at Karen (36° 12'E; 1° 21'S), in Nairobi, during the period January 1977-July 1979. Analysis of the skeletal remains found in the pellets revealed that rodents made up 63.8% of the diet, with the multimammate rat *Mastomys natalensis* being the principal single species. Anurans made up 18.8%, crocoiduras 12.7% and birds 4.6% of the total prey items. Bats, lizards and invertebrates formed a minor proportion. Thus, diverse and varying quantities of non-rodent prey were taken by Barn Owls at Karen. Consequently, it appears that the owl would readily switch from the preferred rodent prey to other items during difficult periods. The owl seemed to be an opportunistic feeder with a relatively small hunting range and a preference for hunting in open habitats.

INTRODUCTION

The diet and ecology of the Barn Owl, *Tyto alba* (Scopoli), has been extensively studied in southern Africa (Kolbe 1946, Davies 1959, Hanney 1962, Winterbottom 1966, Vernon 1972). In East Africa, Barn Owls are reident and widely distributed in urban and peri-urban areas (Britton 1980), but little detailed research has been carried out on their food. Laurie (1971) investigated their diet in Serengeti National Park (Tanzania) and found that rodents were the principal prey. According to Norris (1972), pellets collected in Nairobi National Park (Kenya) were found to contain a wide range of prey items, with rodents predominating. Apart from vertebrate prey, pellets in Nairobi and Serengeti were found to contain diverse but minor invertebrate prey items.

Apart from the work of Norris (1972), there seems to have been no serious study on the food of Barn Owls in Kenya. The purpose of the present study was to determine the prey taken by a pair of Barn Owls at Karen (36° 12'E, 1° 21'S), 13 kilometres west of Nairobi. Since Karen is near Nairobi National Park, this work supplements the previous study reported by Norris in 1972.

STUDY AREA

Nairobi lies on the northern edge of the Athi-Kapiti plains and at an average elevation of 1770m above sea level. The distribution pattern of rainfall is bimodal, with the long and short rains occurring in the periods March-May and November-December, respectively. The mean annual rainfall is 1048mm, with a maximum of 1077mm and a minimum of 1018mm.

Karen is a residential area with medium human population density. Prior to the establishment of human settlement, the area was covered by a dry type of tropical semi-evergreen forest, with tall trees such as *Croton megalocarpus* and *Shrebera alata* dominating. Greenway (1943) reported that understory shrubs and lianes are abundant in this type of forest, but the actual number of tree species is quite limited. Except for scattered patches, most of the original forest at Karen has been cleared and replaced with residential plots ranging in sizes from 5 to 7 hectares. A wide range of exotic species of trees, shrubs and herbs have been planted in the plots amongst the remaining native vegetation. Hedges of Kei Apple (*Aberia caffra*), *Cupressus* spp. and other ornamental shrubs enclose the plots.

In Fig. 1, the principal habitats in which Barn Owls are likely to hunt for prey are shown relative to the position of the owls' nest site at Karen. There is a golf course and other areas of open land where various grasses grow, mainly grazing and farmland species. There are also semi-permanent swamps and man-built ponds which serve as breeding sites for amphibians. Typhaceae (bulrushes) and Cyperaceae (reeds) overgrowing areas with stagnant water were inhabited by rodents and served as suitable roost sites for many bird species, particularly ploceids. Some plots at Karen had livestock, open paddocks and stables which were attractive to rodents and grain-eating birds.

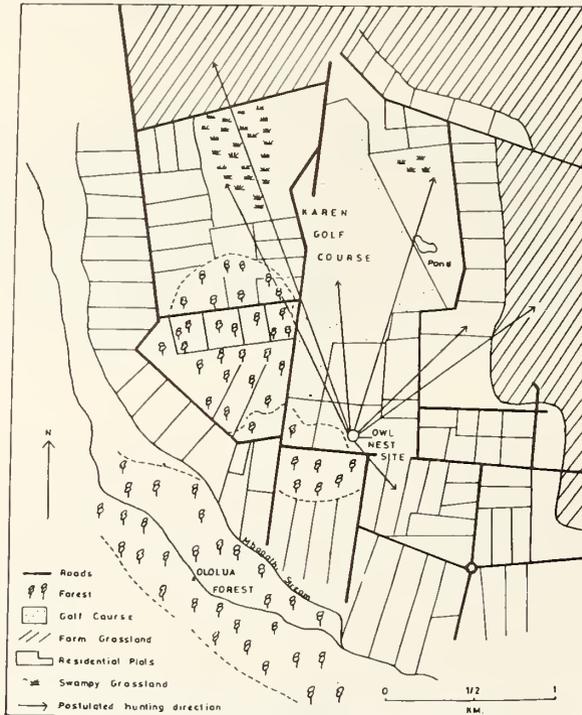


Figure 1. Karen area showing environs of owl's nest site.

MATERIALS AND METHODS

Barn Owl pellets were collected from an attic of an occupied building at Karen during the period January 1977-July 1979. A pair of owls had been intermittently nesting in the attic since 1976. The pellets were not obtained regularly, but were collected during the general cleaning of the house by the owner.

Measurements of complete and compact pellets were taken using sliding calipers, after which the pellets were carefully broken up using a scalpel. The skeletal remains obtained from the pellets were placed in water to which some detergent had been added. After a day, the skeletal material was rinsed in clean water and later bleached in hydrogen peroxide for a period of 24-48 hours. Bleaching of the skeletal material facilitated their identification by comparison with standard museum specimens.

A total of 1200 Barn Owl pellets were obtained from the nest site at Karen. They ranged in size from 49 x 25 mm to 26 x 16 mm, and except for a few loose ones, most of them were coated with dried saliva and were therefore compact. There was a tendency for pellets to contain complete skulls of the prey, however some contained no skulls at all. Some of the pellets analysed contained a single prey item but the bulk of them contained skeletal remains of different prey species.

Out of the 1200 pellets, 4470 prey fragments were recovered, however only 2262 prey items were identified. The balance, consisting of 231 cranial fragments, 1042 right and 935 left mandibles of vertebrate prey, were not identified due to excessive fragmentation and loss of specific diagnostic characters.

Table 1 shows the numerical percentages of the identified prey items and fragments excluding the unidentified material. Rodents were the principal prey, with frogs and shrews making secondary constituents in the diet. The main prey groups will be dealt with in more detail in the following sections.

Prey Group	Number of Items	% total items
Rodentia	1499	66.3
Insectivora	269	11.9
Chiroptera	1	.04
Aves	97	4.3
Reptilia	1	.04
Anura	395	17.5
Arthropoda	+	+
Total	2262	100.1
Note: + = Present but not counted		

Table 1. The composition of the diet of the Barn Owl at Karen, based on identified items and fragments of the major prey groups.

Arthropoda

Some arthropod prey remains were found but were not counted. Insect remains were found in the form of limbs, elytra, mandibles and fragments of the cuticle. There was evidence of termites (Order Isoptera), beetles (Order Coleoptera) and crickets (Order Orthoptera). Some of the insects may have been taken by prey species such as amphibians, shrews and birds that were subsequently killed by the owl.

Anura

Frogs were detected in the pellets by their characteristic astragalus, and by the pelvic and pectoral girdles, but most anurans were identified from skulls. The identity of *Xenopus* spp. was confirmed from the examination of the pelvic girdles. Anurans formed 18.8% of the total prey and, as shown in Table 2, *Hemismus guineensis* was the most common. This species was also common at Karen. It burrows in the ground feeding on the surface at night and appearing in large numbers at the onset of the rains. *Bufo gutturalis* is also widespread at Karen but no specimen was recovered from the pellets. The species is known to be very toxic to mammals (Duff-Mackay pers. common.), and this may also be the case for birds. Because 40.5% of the anuran prey were unidentified (Table 2), the number of species eaten by the owl may have been more than four.

Prey species	Number of items	% total items
<i>Hemismus guineensis</i>	221	55.9
<i>Pyxicephalus delalandii</i>	5	1.3
<i>Ptychadena</i> spp.	1	0.3
<i>Xenopus borealis</i>	8	2.0
Unidentified fragments	160	40.5
	395	100

Table 2. The frequencies of anuran (frog) prey, based on the identified skulls, pelvic girdles and the unidentified fragments.

Aves

Bird remains found in the pellets mainly consisted of skulls, skull fragments and feathers. As an overall element of the diet, birds represented 4.3% of the total prey. As shown in Table 3, the bird prey was diverse, with 12 genera identified. Diversity may have been higher if all the bird prey fragments were

identified to species level. Most of the bird genera belonged to the family Ploceidae, which may have been preyed upon whilst in their communal roosts. The skeletal remains of other bird families were occasionally found.

Prey species	Number of items	% total items
<i>Colius</i> spp.	11	10.1
<i>Pycnonotus</i> spp.	2	1.8
<i>Mirafra</i> spp.	1	0.09
<i>Lonchura</i> spp.	6	5.5
<i>Malaenornis</i> spp.	1	0.9
<i>Lanius</i> spp.	1	0.9
<i>Zosterops</i> spp.	1	0.0
<i>Passer</i> spp.	11	10.1
<i>Ploceus</i> spp.	14	12.8
<i>Quelea</i> spp.	13	11.9
<i>Euplectes</i> spp.	5	4.6
<i>Vidua</i> spp.	2	1.8
Unidentified spp.	41	37.6
Total	109	99.8

Table 3. The frequencies of avian prey, based on identified skulls and the unidentified skull fragments.

Chiroptera and Reptilia

Bat and lizard remains were infrequent in the pellets, with only one fragment each. Because of the loss of specific diagnostic characters, I could not identify the fragments further.

Insectivora

Shrews (family Soricidae) were third in abundance among the animals taken by Barn Owls at Karen. They were an easy prey for the owl since they are slow-moving and nocturnal. The bulk of skulls and mandibles of shrews recovered from the owl's pellets were apparently from young animals and were thus difficult to identify to species level with certainty because according to Dr. Weib Spitzenberger (pers. comm.) the cranial characteristics do not provide a definite diagnosis and external features and measurements are necessary.

Rodentia

Rodents were the commonest prey. Two families, Muridae and Rhizomyidae, both with a total of 14 different species, were identified, but there may have been a few rodent species that could not be positively identified. The Muridae formed the greater proportion of the diet of the Barn Owl. A total of 442 skulls (including their mandibles) were recovered from the pellets. The skulls of individual rodent species were of varying sizes, indicating that small rodents of varying ages and sizes were preyed upon by the owl. Table 4 shows the percentage composition of rodent prey taken.

Of the murid rodents that were positively identified from skull and dental characters, *Otomys angoniensis* made up 36.2% of the total number of skulls, *Mastomys natalensis* made up 29.2% and *Dendromus* sp. and *Mus* sp. combined made up 24.7%. Other rodent species made up only 9.9% of the skulls. However, skulls alone would not show a complete picture of the total rodent prey taken.

Prey species	Number of skulls	Total number of items	Skulls all items	% grand total
<i>Rattus rattus</i>	1	7	0.2	0.5
<i>Rhabdomys/Lemniscomys</i> spp.	6	40	1.4	2.7
<i>Mastomys natalensis</i>	129	855	29.2	57.0
<i>Dendromus/Mus</i> spp.	109	109	24.7	7.3
<i>Otomys angoniensis</i>	160	325	36.2	21.7
<i>Oenomys hypoxanthus</i>	1	7	0.2	0.5
<i>Dasymys incomtus</i>	1	7	0.2	0.5
<i>Arvicanthis niloticus</i>	12	79	2.7	5.3
<i>Gammomys dolichurus</i>	6	40	1.4	2.7
<i>Pelomys fallax</i>	1	7	0.2	0.5
<i>Tatera</i> spp.	0	7	0	0.5
<i>Tachyoryctes splendens</i>	16	16	3.6	1.1
Total	442	1499	100	100.3

Table 4. The composition of the rodent prey of the barn owl based on (a) skulls alone and (b) all the identified items.

Apart from the skulls, there were 1057 loose mandibles, some of which were similar to those of the identified skulls. Also, there were teeth and other cranial fragments, some of which matched the skulls already identified. As shown in Table 4, combination of whole skulls and loose skulls fragments resulted in an increased number of prey items and gives a better picture of the rodent prey than skulls alone.

When all the identified skeletal fragments are considered *M. natalensis* made up 57.0% of the total rodent prey. This species was widespread in the study area, especially in open grassland and cultivated areas. *Otomys angoniensis* was the next most important rodent species, constituting 21.7% of the total rodent prey. This rodent is crepuscular and inhabits swampy areas, and its habit of feeding in open sites might have made it vulnerable to predation despite of its low density in the study area. *Arvicanthis niloticus* was a common species in grassland and cultivated areas at Karen, but only a few remains of the species were recovered from the pellets, probably due to its largely diurnal nature.

Dendromus spp. and *Mus* spp. are small rodents and as many as four skulls were recovered from a single pellet. *Dendromus* spp. were identified from their characteristic grooved incisors, while those of *Mus* spp. are ungrooved and have a notched surface. Because their skulls were fragile, these were excessively fragmented and the incisors were in most cases lacking. Loose teeth might also have been damaged or lost during the cleaning of the material. Without the incisors, only 4 skulls of *Dendromus* spp. and 3 of *Mus* spp. were positively identified. The balance of 102 skulls could have belonged to either genus.

The Root-rat *Tachyoryctes splendens* was common at Karen but it formed a very low percentage of the Barn Owls' diet. Only 16 skulls were recovered from the pellets, and all of them belonged to young animals. An adult Root-rat may weigh up to 250 g (Kingdon 1974), and may therefore be too large for the owl to kill or carry. Creek Rats (*Pelomys fallax*) are both diurnal and nocturnal feeders, and though suitable habitats for them were available at Karen, only one specimen was recovered from the pellets. Similarly, only one specimen of the Rusty-nosed Rat *Oenomys hypoxanthus* was obtained from the Barn Owl pellets. The Swamp Rat (*Dasymys incomtus*) occupied tall grasses growing in and adjacent to semi-permanent swamps at Karen. However, only one specimen of the species was found in the pellets.

Other rodent species of minor importance in the diet included the Black Rat, *Rattus rattus*, probably associated with stables and farm buildings, which was uncommon in the pellets. *Tatera* spp. were uncommon at Karen, but their numbers probably increase in dry periods of the year. A few skeletal parts belonging to this genus were present. Both grass mice *Lemniscomys* spp. are diurnal feeders and were abundant in the Karen area. They were present in the pellets, but could not be identified to species level because the specimens were apparently old and their dental cusps heavily worn out. According to Kingdon (pers. comm.), such old specimens with worn out dental cusps are difficult to differentiate with certainty. However, it is likely that most of the skulls were those of the more common species *Lemniscomys* spp.

DISCUSSION AND CONCLUSIONS

The size of the Barn Owl pellets collected at Karen were comparable to those of pellets collected in different localities in southern Africa by Skead (1963) and Vernon (1972). The pellets collected at Karen

tended to contain complete skulls of one or more species, but this appeared to depend on the size of the prey animals. However, as Brooke (1967) reported, not yet pellet contained whole skulls. The skeletal remains of some prey animals, especially *Praomys* spp., *Dendromus* spp. and *Mus* spp. were often so fragmented that only the molar teeth could be detected in the pellets. Similarly, the molar teeth and incisors of young animals were more frequently recovered than whole skulls.

Analysis of the pellets indicated that a wide range of small vertebrates was preyed upon by the owl, which appears to be well adapted to feeding on rodents and shrews that are nocturnal or crepuscular. Other prey groups, notably arthropods, bats, frogs and lizards seem to be supplementary components in its diet. The relative abundance of bird and frog skeletal remains in the pellets implies that Barn Owls readily switch to them if shrews and rodents are not easily available.

The multimammate Rat (*Mastomys natalensis*) is abundant at Karen (Gichuki 1978), and was the dominant single prey item in the diet. The species may have been preferred and easily available in the owl's hunting range. Further, this prevalence may be ascribed to the semi-commensal nature of both this rat and the owl with man. In South Africa (Vernon 1972) and Nigeria (Demeter 1978), the Barn Owl has been reported feeding almost exclusively on the multimammate rat in areas where the latter was abundant and easily available.

The Swamp Rat *Otomys angoniensis* was second in abundance to the Multimammate Rat as Barn Owl prey. Both *O. angoniensis* and *Dasymys incomtus* occupy similar habitats. The two rodent species were present in semi-permanent swamp vegetation and in reeds bordering man-made ponds and dams at Karen. However, only one specimen of *D. incomtus* was recovered from the pellets, compared with 160 specimens of *O. angoniensis*. Misonne (1963) compared trapping records of the two rodent species with their skeletal remains recovered from Barn Owl's pellets obtained at Kigezi (Uganda) and concluded that *O. angoniensis* displaces *D. incomtus* from its optimum habitat. My study showed a similar situation at Karen where 0.5% of *D. incomtus* and 21.7% of *O. angoniensis* were recorded from Barn Owl's pellets.

A wide range of other rodent species were taken, but in small numbers. Creek Rats (*Pellomys fallax*) and the Rusty-nosed Rat (*Oenomys hypoxanthus*) occupy swampland and forest edges (Delany 1975), but were only minor components in the diet of the owl at Karen. In West Africa, Heim de Balsac and Lomotte (1958) reported that Barn Owls seemed to select against Creeks Rats and Rusty-nosed Rats, though the two species were widespread within its hunting range. The two rat species and the Root Rat (*Tachyoryctes splendens*) may have been selected against by the pair of Barn Owls at Karen. Furthermore, no forest rodents found at Karen, such as *Graphiurus* spp. and *Lophuromys* spp., were recovered from the owl's pellets. It would thus appear that the owl avoided hunting for prey in well wooded areas, preferring less enclosed habitats.

Hunting by the Barn Owl is a function of its food requirements and the difficulties involved in procuring the food. Thus the owl compensates for poor conditions by hunting for a longer period and in a larger range (Smith and Marti 1976). In an Israeli desert, Bodenheimer (1949) estimated Barn Owl hunting range to be 2-25km². At Karen, the habitat conditions favour establishment of a rich small mammal fauna, so that there was probably an abundant food supply in the area. Therefore, the hunting range of the owls was likely to be small. From the distribution of the identified prey species, both recovered from the pellets and trapped in the Karen area, it would appear that the hunting range of the pair of Barn Owls was probably not greater than 5km². The hunting range of the studied pair of Barn owls may have overlapped with the range of at least two other pairs known to have roosted and nested in the Karen area (Eric Risley, pers. comm.). Competition from the other two pairs and the changes in the abundance and availability of suitable prey may have caused the pair studied to alter their hunting range from time to time.

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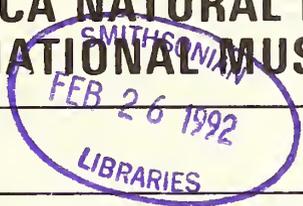
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THE DISTRIBUTION AND ECONOMIC IMPORTANCE OF THE MANGROVE FORESTS OF KENYA

J.O. Kokwaro

Department of Botany, University of Nairobi

ABSTRACT

The mangroves form a group of higher plants which form a unique ecosystem, in that they grow in that part of land which is neither in demand for human settlement nor for agricultural use. They are also unique in their adaptation to both soil and water conditions. They are useful as a source of timber, for building poles, fuel, dyes, tannins, and are also known to provide both shelter and food for part of the marine fauna. Their value to the country, therefore, calls for proper utilization and conservation of all the available mangrove forests along the coast. The demand for forest products, including those from the mangroves in Kenya, is greater than the available resources from the forests, and unless proper and prompt planning for their protection is implemented our mangroves will soon be among the endangered ecosystems in the country.

INTRODUCTION

The Kenyan coast runs from the Somali border at 1°40' S southwest to 4°40' S at the border with Tanzania (Map 1). It lies in that hot tropical region where the weather is primarily controlled by the great monsoon air currents of the Indian Ocean. It is the southeast monsoon which brings the long rains from April to June, when most of the annual precipitation is received. The short rains begin around October or November, and both long and short rains occur mainly in the morning or mid-day hours.

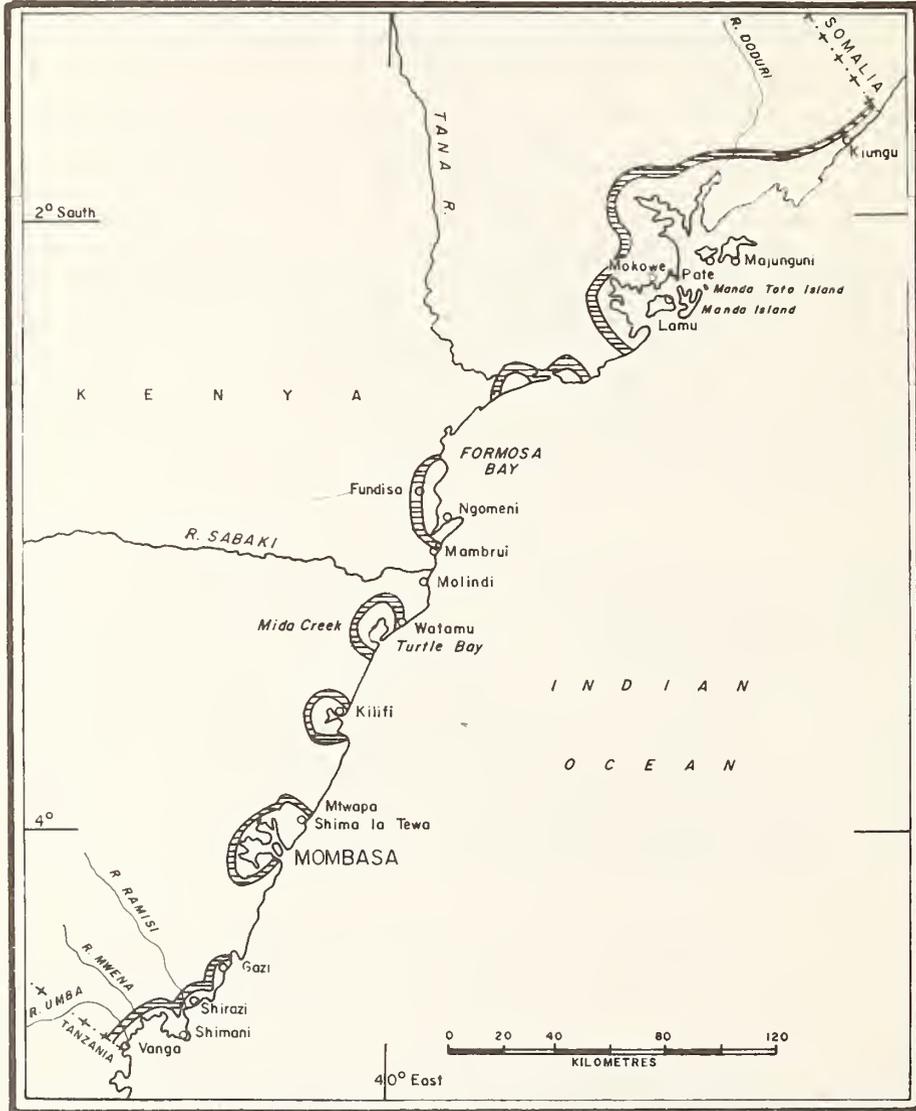
The mangroves form the type of vegetation collectively referred to as mangrove swamps, mangrove forests or mangrove thickets. They are a common feature of tropical shores and are usually formed around the mouths of rivers and creeks where there is a gradual slope of the land towards the sea as well as a large tidal range resulting in a broad inter-tidal zone, consisting of a mixture of sand and silt. These communities are generally confined to tidal estuaries and lagoons, as they are protected from the force of the open sea in these localities. The supporting soil is primarily heavy mud which is mostly saline, though frequently influenced by freshwater streams and rivers. Though the mangroves can withstand seawater with high salinity, their communities are usually most prolific in areas not far from the mouths of coastal streams.

ADAPTATION TO A UNIQUE ENVIRONMENT

Lagoons behind tropical shores as well as creeks influenced by freshwater streams contain brackish water, and their shores are mostly muddy. Such shores may support a growth of mangroves, which are adapted to this habitat — an environment which is unique due to the following factors:

- (1) **Fluctuating salt content.** The mangrove swamp is essentially tidal, receiving water of low salinity from the river and water of high salinity from the sea at different times each day. The plants and animals in the mangrove system will thus have to be adapted to withstand such changes in salinity.
- (2) **Aeration.** The soil in the mangrove swamp is saturated by water and hence almost completely lacks the oxygen required by the plants for root respiration.
- (3) **Mobility of the soil.** The soil level is unstable, as the streams bring down alluvial soil which is deposited, only to be washed away again by sea currents. This makes it difficult for seedlings to establish themselves.

To be able to withstand the fluctuations in salt content most plants of the mangrove swamps are halophytes, i.e. plants with high osmotic pressure in their cell-solutions. In order to obtain oxygen for respiration some of the plants have pneumatophores (breathing roots or aerial roots); and by means of stilt roots they are able to withstand the mobility of the soil.



MAP 1
Distribution of Mangrove forests along the Kenya Coast line
DISTRIBUTION

The mangrove swamps along the Kenyan coast cover approximately 52,980 hectares (Table 1). The largest stands occur in the Lamu area including the islands of Manda and Patta, and also along the Vanga-Funzi system near the Kenya-Tanzania border. The former area receives its low-salinity water from the Doduri and Tana rivers, while the latter receives this from the Ramisi, Mwena and Uмба rivers.

Other areas along the coast with less extensive mangrove stands are Mtwapa, Kilifi and Mida creeks to the north of Mombasa; the Mombasa-Port Reitz area; Gazi to the south of Mombasa; and the Ngomeni-Fundi Isa area to the north of Malindi (Map 1). The border between the mangroves and the non-halophytic vegetation is found to be well-defined everywhere along the coast, except where fresh-water from the rivers comes into the ocean. Where natural vegetation is disturbed, an impenetrable, evergreen, usually thorny bush dominated by Baobab trees (*Adansonia digitata*) is found. However, since most land adjacent to the mangroves is cultivated, plantations, especially of coconut, are prevalent.

TABLE 1:
Distribution of the Mangroves
(from Doute et al. 1981)

LOCALITY	DISTRICT	AREA IN HECTARES
Kiunga	Lamu	3,025
Lamu	Lamu	30,475
Kipini (Witu)	Tana River	1,595
Mto Tana (Witu)	Tana River	250
Mto Kilifi (Formosa Bay)	Kilifi (1,515), Tana River (820)	2,335
Mto Fundisa (Formosa Bay)	Kilifi	330
Ngomeni	Kilifi	1,815
Mida Creek (Malindi)	Kilifi	1,600
Takaungu (Malindi)	Kilifi	30
Kilifi Creek	Kilifi	360
Mtwapa Creek	Kilifi (410), Mombasa (115)	525
Tudor Creek	Mombasa	1,465
Port Reitz	Mombasa (380), Kwale (1195)	1,575
Maftaha Bay	Kwale	615
Ras Mwachema	Kwale	5
Funzi Bay	Kwale	2,715
Vanga	Kwale	4,265
<i>Distribution by districts:</i>		
	Lamu District	33,500
	Tana River District	2,665
	Kilifi District	6,060
	Mombasa District	1,960
	Kwale District	8,795
		Total 52,980

ECONOMIC IMPORTANCE

Small trees and shrubs are the most important plants of the mangrove swamps. There are five important genera of widely distributed woody plants in the mangrove vegetation of the Kenyan coast, each genus containing one species. *Bruguiera gymnorrhiza*, *Ceriops tagal* and *Rhizophora mucronata* belong to the family *Rhizophoraceae*, *Sonneratia alba* to the *Sonneratiaceae* and *Avicennia marina* to the *Verbenaceae*. They are all viviparous except *Sonneratia*, and often have stilt roots and pneumatophores (breathing roots). *Avicennia* and *Sonneratia* are the first colonizers of the swamps. Once established, mud can accumulate among their breathing roots, producing conditions favourable for *Ceriops* and *Rhizophora*. *Rhizophora* is the commonest and most important constituent of the mangrove swamps. It usually occupies the most favourable sites between *Sonneratia* and *Avicennia* on the creek edge, and *Ceriops* on the landward side. *Bruguiera* is normally found scattered in *Rhizophora* stands.

For a long time, the Coastal Kenyans have exploited the rich natural products of the mangroves to supplement their marginal producing agricultural land. They use the mangrove plants in many ways, and these are discussed below and listed in Table 2.

Poles

The most important product of the mangroves is poles for export and for local house-building. Annually, half a million poles were exported from Kenya during the 1930s. About 300,000 headloads of withies were obtained from the mangrove forest annually during the same period (Rawlins 1957). The majority of poles and withies are from *Rhizophora mucronata*.

Vegetable Tannins

These are generally considered as minor forest products in Kenya. However, during the mid-1950s, the mangroves were yielding tan bark exported at the rate of 3,500 tons per annum (Rawlins 1957). In many ways the mangrove bark is a unique tanning material, the supply of which is virtually inexhaustible. There is no need for planting or weeding, as the mangrove trees propagate themselves and no other trees are able to establish themselves in this special environment. The common tannin-yielding genera of the mangroves are *Avicennia*, *Bruguiera*, *Ceriops*, *Heritiera*, *Rhizophora*, *Sonneratia* and *Xylocarpus*. Of all these, *Rhizophora mucronata* is the easiest to strip and prepare for both local use and for export, and the tannin content of its bark (12-50 %) is among the highest. There are several reasons why tannin from mangroves has not come to the forefront in Kenya as a tanning material. Firstly, the mangrove forests of Kenya are not very extensive, compared to those of Tanzania. The second reason is the difficulty in collecting the bark from the swamps. Finally, the differences in tannin content between the various genera precludes indiscriminate felling of trees if a product of consistent quality is to be obtained. A possible additional disadvantage is that of the unwillingness of leather-buyers to use dark-coloured sole leather — and mangrove tannin is dark red. Research aimed at removing or bleaching the coloured components of the mangrove tannins will definitely increase their use and consequentially the commercial value of Kenyan mangroves.

Fuel

Coastal Kenyans have for a long time used different mangrove species as a source of fuel. We find that the kind of raw material used in traditional fuel depends more on accessibility than on the quality of the plants used. Those who live close to the mangrove forests therefore have the tendency to use the wood, frequently as firewood and occasionally for charcoal production. Charcoal produced along the coast is generally exported to the Middle East and was an extremely lucrative trade until the late 1970s when the Kenya Government had to intervene to prevent the complete destruction of forests, including the mangroves. It was estimated that the charcoal export from Kenya to Kuwait alone was at a rate of 35,000 tons a year (East African Standard 08.03.1971). The bulk of charcoal for export is still produced from the coastal forests.

Apart from *Bruguiera gymnorrhiza* and *Rhizophora mucronata* whose poles (boriti) and bark (for tanning) are of high value commercially, the rest of the mangrove species are utilized in one way or another as a source of fuel. Both firewood and charcoal are obtained from *Avicennia*, *Ceriops*, *Heritiera*, *Lumnitzera*, *Sonneratia* and *Xylocarpus* species, and most of these yield high quality fuel since they have hard and compact wood.

For the coastal people, charcoal is a major source of income whenever they can produce and export it, as the Middle Eastern demand for Kenyan charcoal is ever present; charcoal, even when imported, is cheaper than oil as a source of energy, and certain industrial work is better done by using charcoal as fuel than by electric or oil energy. Fortunately, the rate of regeneration of the mangroves is high when they have been harvested, since most of the species produce fruits and seeds which easily establish themselves. In Malaya, mangrove seedlings are collected as they drop, and planted in rows after the trees have been harvested and the swamps cleared. Proper planting has the advantages of ensuring that the seedlings are not washed away by the sea currents; of making harvesting easier, since the trees grow in lines; and of making increases in production possible as required.

It is clear that the demand for charcoal will continue to rise in Kenya. It is therefore the responsibility of the Forestry Department to encourage plantation of mangroves for the production of tannin, building poles, charcoal and firewood for both local consumption and export. It should be noted that most mangroves do not coppice when felled; this in itself will create some employment in fields like tanning, charcoal production and timber, primarily for export. The production of charcoal can be carried out by using modern and more economical methods such as the CUSAB charcoal kiln.

TABLE 2:
Summary of Economic Use of Mangroves

SPECIES	LOCAL NAMES	POLES (BORIFI)	FANNIN/ DYE	DHOW MASTS, ETC.	VARIOUS	FUEL	MEDICINAL, ETC.
1. <i>Avicennia marina</i>	Mchu, Mtu		Dye, 6% Tannin	Dhow ribs canoes, drums, carts, beds			Aphrodisiac, contraceptive
2. <i>Bruguiera gymnorhiza</i>	Muia, Mchofi, Mkifu, Msindi	Boriti, nguzo, telephone poles	Dye, 53% Tannin			Firewood	
3. <i>Ceriops tagal</i>	Mkandaa	Fito, mapau, nguzo	24-42% Tannin			High quality firewood & charcoal	
4. <i>Heritiera littoralis</i>	Msikundazi Mkokoshi, Mkukushu		14-15% Tannin			Good firewood & charcoal	
5. <i>Lumnitzera racemosa</i>	Kikandaa, Mkandaa-mwitu, Muyanywa, Mtuitui	Building poles				Good firewood	
6. <i>Rhizophora mucronata</i>	Mkoko	Majority of the building poles	Dye, 12-50% Tannin				
7. <i>Sonneratia alba</i>	Mililana, Mpia, Mkoko-mpia		15% Tannin	Boat ribs	Carpentry		Camel/fodder condiments medicaments
8. <i>Xylocarpus granatum</i>	Mkomafi, Mtonga	Poor quality building poles	33% Tannin	Dhow masts, carts		Firewood	Fruit infusion aphrodisiac
9. <i>Xylocarpus moluccensis</i>	Mkomafi			Dhow masts	Joinery, Sandals.		

Feeding ground for fishes

Mangrove swamps are of great importance as feeding grounds for marine fishes. Most prawns, lobsters and crabs especially the juveniles use the mangrove swamps as their feeding ground. Breeding ponds as part of the mariculture programme has been set up at Ngomeni mangrove swamps for the breeding of prawns. They are also favourable habitats for various other kinds of marine fauna.

USES OF INDIVIDUAL PLANT SPECIES

Avicennia marina (Forssk.) Vierh. (*Verbenaceae*)

PLATE 1

Mchu (Standard name, Swahili); Mtu (Vanga Swahili); Mutu (Bajun); Mtswi (Giriama).

A spreading willow-like tree with a wide-spreading root system which sends up numerous asparagus-shaped pneumatophores to ca. 45 cm long.

A brown dye is produced by pounding and mashing the bark in cold water. Both the bark and the leaves contain up to 6% tannin, which is considered low.

The timber is used for making ribs of dhows, small dugout canoes, chairs, drums, carts and bedsteads. A bitter and somewhat aromatic resin which oozes from the bark is claimed to be both an aphrodisiac and a contraceptive. The roots are also claimed to have aphrodisiac properties.

Bruguiera gymnorrhiza (L.) Lam. (*Rhizophoraceae*)

PLATE 2

Muia (Standard name); Msindi, Muia or Mkifu (Swahili); Mchofi (Digo & Gazi-Swahili).

A slender glabrous tree to 25 m high, with buttresses and knee-like roots acting as pneumatophores arising from near the base of the trunk.

The bark contains up to 53% tannin and also yields a black dye which, when processed, turns orange-red, brown or violet. The dye is prepared by pounding the bark in a mortar and mixing it with cold water; the fabric or leather is soaked in this liquid for 3 days and then hung in the shade to dry.

Poles are used locally as boriti and nguzo for building and construction, for telephone poles or as firewood. The wood is seasoned by leaving the poles in seawater for some weeks, and thereafter becomes very hard and durable.

Ceriops tagal (Perr.) C.B. Robinson (*Rhizophoraceae*)

Mkandaa (Standard name, Swahili).

A shrub or mediumsize tree, with buttresses and knee-like roots acting as pneumatophores. This is the real Mkandaa although the name is sometimes loosely applied to mangroves in general.

The bark contains 24-42% tannin. The poles are used for building local houses and are called fito, mapau or nguzo. The wood is widely used as firewood and for charcoal production, and yields a high-quality fuel.

Heritiera littoralis Dryand. in Ait. (*Sterculiaceae*)

Msikundazi (Swahili); Mkokoshi or Mkukushu (Vanga-Swahili).

An evergreen tree up to 25 m high, boles often with plank buttresses. Normally grows at the site in the mangrove swamp where fresh water intermingles with seawater, and the best stands in Kenya occur on the Ramisi River. It also used to be common on the Tana River below Kau, but the amount has dwindled due to heavy utilization and other factors.

The bark yields 14-15% tannin. The wood is used for dhow masts, and is reported to be good for firewood and for charcoal production.

Lumnitzera racemosa Willd. (*Combretaceae*)

Kikandaa (Standard name, Swahili); Mkandaa-mwitu, Mtuitui (Swahili); Mnyanywa (Vanga-Swahili)

Shrub or tree to 9 m high with dark rough bark, although red and smooth when young. Roots bending to form 'knees'.

Poles are used in building or as firewood, producing good fuel.

Rhizophora mucronata Lam. (*Rhizophoraceae*)

PLATE 3

Mkono (Standard name, Swahili)

The commonest and most important mangrove, growing up to 25 m high, and developing stilt roots adventitiously from the upper stem nodes.



Plate 1: *Avicennia marina* (*Verbenaceae*)
Note the numerous breathing roots (pneumatophores) (Photo: J.O. Kokwaro, Vanga, 1969).



Plate 2: *Bruguiera gymnorhiza* (*Rhizophoraceae*)
Msindi, Muia, Mkifu (Swahili). Note that the pneumatophores are distinctly kneed or knee-shaped. (Photo: J.O. Kokwaro, Gazi, 1969).



Plate 3: *Rhizophora mucronata* (*Rhizophoraceae*)
Mkoko (Swahili). Note the numerous branched stilt-roots with root caps at the end, tap root abortive. The leaves are fairly similar to those of *Bruguira*. (Photo: J.O. Kokwaro, Gazi, 1969).

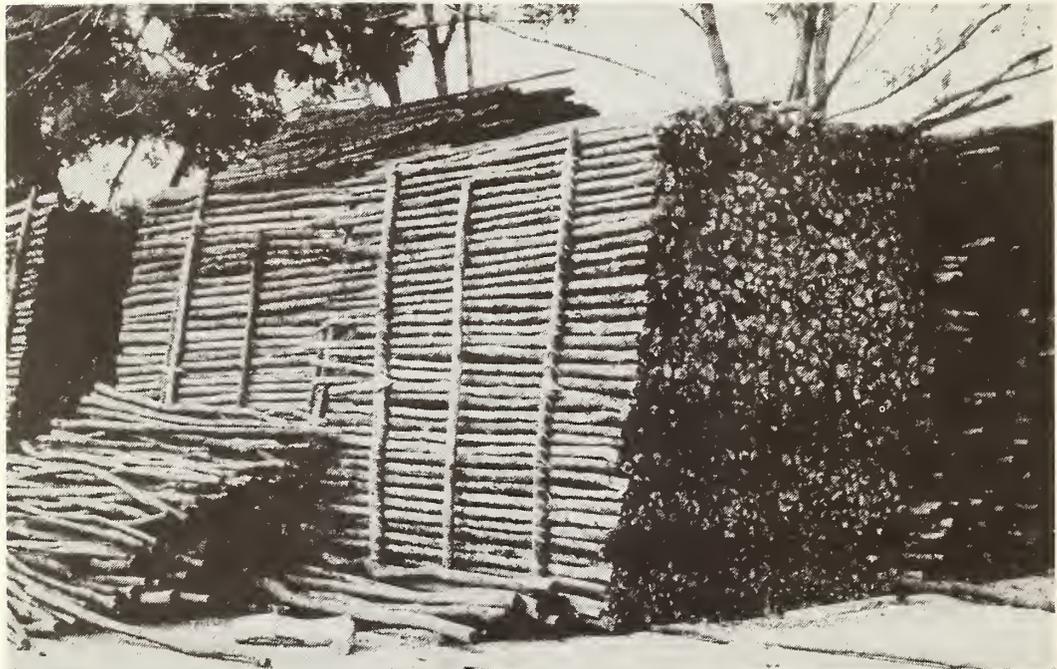


Plate 4: Mangrove poles, seasoned and arranged in stacks at Lamu Island ready for shipment overseas. (Photo: J.O. Kokwaro, Lamu, 1978)

The bark contains 12-50% tannin and is much used. The bark is pounded in a mortar until soft and mixed with cold water. The fabric or leather to be treated is soaked in the infusion for three days and then hung in the shade to dry; the resulting colour is reddish brown. This species provides the majority of building poles for export as well as for local use.

Sonneratia alba Sm. (*Sonneratiaceae*)

Mlilana, Mkokompia or Mpia (Swahili)

Evergreen shrub or tree 3-15 m high, occasionally to 20 m. The roots are wide-spreading, sending up many finger-like pneumatophores which are up to 75 cm high.

The light wood is used in carpentry work, for building native huts, to support fishing nets and to make boat ribs. The bark contains up to 15% tannin. The leaves are used, mainly by the Bajun and the Boni, as camel fodder. The fruits are edible and yield both condiments and medicaments. "Mpia" comes from "pia", a top, as the fruit somewhat resembles this.

Xylocarpus granatum Koen. (*Meliaceae*)

Mkomafi (Swahili); Mtonga (Vanga-Swahili)

A tree up to 6 m high, with green or brown smooth or flaking bark. This tree does not possess "breathing" roots, and is common on creek banks and in pure saltwater creeks.

The bark contains up to 33% tannin, and the timber is known to make good masts for dhows although the trunks are seldom of the right shape. The wood is also used for making handcars, in building construction and for firewood. The grapefruit-sized fruits are crushed in water and the infusion drunk as an aphrodisiac.

Xylocarpus moluccensis (Lam.) M.J. Roem. (*Meliaceae*)

Mkomafi or Msikundazi (Swahili)

A spreading tree up to 12 m high, without "breathing" roots. Common in sites only occasionally wetted by seawater.

The timber is used for dhow masts, in joinery, for making sandals and for firewood.

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OBSERVATIONS ON *SALVINIA* AND ITS ENVIRONMENT AT LAKE NAIVASHA (KENYA)

Nils Tarras-Wahlberg

Nydala, 570 03 Vrigstad, Sweden

ABSTRACT

Lake Naivasha is a freshwater lake in the Rift Valley of Kenya. It was infested in the 1960s by the floating fern *Salvinia molesta* Mitchell. This fern is indigenous to Brazil where it is apparently harmless. At lake Naivasha, as in several other inland waters of the tropical Old World, it is capable of an explosive population increase, and it can occupy the surface of calm nutrient-rich waters very quickly. By forming a surface-mat, it stops sunlight from reaching submerged plants and so it kills the submerged vegetation. This has resulted in serious setbacks to the local fishing industry.

It is shown that in nutrient-rich waters young *Salvinia* has a doubling time of 4.5 days. Optimal growing conditions exist near Papyrus stands. Old mats of *Salvinia* may be invaded by vascular plants, and so a formation of sudd may start.

INTRODUCTION

The project to study *Salvinia*, of which this paper is one of the results, was carried out in 1974-75 and was followed up during a brief period in 1981. The project was sponsored by SIDA.

Lake Naivasha is situated 100 km NW of Nairobi at an altitude of 1890 m. Its surface area is 160 km². It is a relatively shallow lake of recent geological origin, surrounded by extinct or dormant volcanoes. Two major rivers, Malewa and Gilgil, drain into the lake, bringing rainwater from the Nyandarua (Aberdare) Range. This is an important factor in keeping the lake fresh as evaporation from the lake is more than twice as much as the local rainfall (Ase 1983). At the northern side of the lake these rivers have formed the 11.7 km² large North Swamp. As shown by Fig. 1 there are several other fringing, floating swamps on the lake. These were formed during periods of low water when papyrus (*Cyperus papyrus* L.) started to grow on the exposed mud at the shore. The following periods of high water changed the cultivated land near the shore into a shallow part of the lake, now separated from open water by papyrus. A lagoon was thus formed with optimal growing conditions for submerged and floating vegetation. In 1975 a waterlily, *Nymphaea coerulea* Savigny was dominant; in 1985, during a brief visit to the lake, only eight flowers of this species were observed.

Survey methods

For the survey, the following instruments were used: two battery-powered pH and electrical conductivity meters (Esselte 1973 model), an albedo-meter (Kipp & Zoonen model), a portable oxygen meter (Beckman Fieldlab) and during the last period of work a Hach Fieldlab with a spectrophotometer (Dr-El 2).

The growth rate of *Salvinia* in its natural environment was measured inside floating culture-cages of various design. The arrangement with floats proved to be the best in situations where the water suddenly rises after heavy rains.

History of *Salvinia* on Lake Naivasha

The occurrence of *Salvinia* on Lake Naivasha is a relatively recent phenomenon. In the early 1960s it was introduced (certainly by man) to the lake and in 1964 it covered 60 ha at the eastern part of the lake. Steps

for control were organized, resulting in spraying with the herbicide paraquat and in mechanical removal by volunteers and landowners. In the late 1960s eradication was considered to have been achieved, but isolated individuals were alive inside the northern swamp, and started to spread into the lagoon inside the swamp. In October 1970 a strong wind from the north broke the palisade of papyrus and *Salvinia* was spread all over the lake (Gaudet 1976). *Salvinia* infestation of the spawning grounds of *Tilapia* fish caused concern at the Fisheries Department, as the fishing industry faced a severe setback.

Taxonomy of *Salvinia*

Mitchell (1973) described the new species *Salvinia molesta* from inland waters in Africa, Indonesia, Australia and from a pond in Rio de Janeiro, Brazil. Before that, the "African pile" was believed to be *S. auriculata* Aubl. Mitchell suggested that the new species was a hybrid between *S. biloba* and *S. auriculata*, also found in the same pond. It has been shown subsequently (Forno & Harley 1979, Forno 1983) that *S. molesta* grows naturally in several districts of South America and is one of four closely related species forming the *S. auriculata* group. The growth of *S. molesta* in Brazil seems to be very modest and creates no problems. Forno and Harley suggest that the reason for this is the presence of natural enemies. *Salvinia molesta*, from here on just called *Salvinia*, is probably a hybrid as it is sterile. It seems to show hybrid vigour and is able to multiply by means of vegetative propagation. Today it has a worldwide distribution, and the clone will possibly number billions of individuals! It is causing much harm and has therefore been in focus nearly as much as *Eichhornia crassipes* Mart., the water hyacinth. Actions for the control of *Salvinia* have been expensive and nearly always without lasting results, as has been the case at Lake Naivasha.

Life-cycle of *Salvinia* at Lake Naivasha.

Mitchell (1969, 1974, 1976) has published findings on the autecology of *Salvinia*. He distinguishes three stages of growth:

- 1) The primary invading form with small leaves, not exceeding 1.5 cm in width, floating on the water surface.
- 2) The open water colonizing form with long internodes and keeled leaves of about 2 cm width.
- 3) The mat form of the plant with short internodes and of a compressed shape. This form has leaves of up to 6 cm in width, which are folded upwards and have lost direct contact with the water. Sporocarps are present, but sterile.

All three forms have a submerged leaf at each node. This leaf has the shape of a root and its function is nutrient absorption and stabilization. The submerged parts of *Salvinia* tend to elongate when nitrogen is deficient (Gaudet 1973).

At low water in 1974-75, many single *Salvinia* plants were transported by the NE monsoon to the western side of the lake and got stranded. Others died on the open lake where conditions of waves together with a superabundance of oxygen proved fatal. These effects were reported by Kariuki (1974, typewritten report at KSTC). When drifting *Salvinia* plants became stranded on wet exposed mud in the shade of papyrus they started to disintegrate. Old plants were however able to start a new generation by means of extensive budding in the mud. Mitchell (1969) has shown that the number of lateral buds is dependent on the amount of nitrogen available, i.e., the more nitrogen the more buds. Gaudet (1976) laid stress upon the great importance of the exposed mud being extremely rich in nutrients, and especially in nitrogen, for the growing new generation of *Salvinia*. At the end of the long rains in April the reflooding of the lake will add still more nutrients. These are washed out from the mud at the shore as the process of oxydation has set them free during the process of exposure and drying. Nutrients may also be brought in from fields nearby, where hippos and cattle have deposited their dung. Fertilized farmlands may also supply additional nutrients.

In the nutrient-rich shallow water young *Salvinia* will grow and start the explosive population increase which is well-known from laboratory experiments by Gaudet (1973) and Mitchell & Tur (1976). The *Salvinia* from Lake Naivasha is rich in mineral salts which is indicated by its use as a fertilizer (Gaudet 1973). The same authority suggests *Salvinia* as an agent for the removal of nutrients from waters. Accordingly it can be used for the reversal of eutrophication in recipient water bodies (Toerien et al. 1983). The young *Salvinia* will rapidly spread over the water surface. In the shade of papyrus *Salvinia* will sometimes associate with *Ricciocarpus natans* L.

Experiments arranged at Fishermans Camp (see Fig. 1) in cages, have shown that young *Salvinia* have a speed of growth which is close to what was observed in laboratory conditions such as those of Gaudet (1973) and Mitchell & Tur (1976). The result of the experiments is presented in fig. 2. This result was

observed in a cage with 50% cover after heavy rains. It is assumed that an increased supply of nutrients was caused by these rains.

One can suggest that the growth of *Salvinia* is density-dependent. The explanation for this would be competition for nutrients or for space. In the laboratory, under optimal conditions, Gaudet (1973) using *Salvinia* from Lake Naivasha found a weight doubling time of 4.6 days. Mitchell & Tur (1976) found a similar result in the laboratory, but under field conditions in Lake Kariba the growth rate was much more modest (Mitchell & Tur 1976).

While growing in the natural environment the plants float into deeper water with less shade. The agent for transportation is either rising water, wind or man. The growing *Salvinia* now passes into the third phase and mats will develop. Its weight (wet weight, gravity water removed by centrifuging) will now exceed 10kg/m². After the formation of mats growth is very slow. In the midst of the wide mats an additional increase of weight per unit of area is probably entirely dependent on an increase of nutrients which may be conveyed by hippos, currents or man.

Agitation may set *Salvinia* afloat to reach new localities. Infestation may easily occur where submerged vegetation is thick and close to the surface. This seems to be a normal condition where *Ceratophyllum demersum* is growing. This locality will then be taken over by *Salvinia* which can make the *Ceratophyllum* turn yellow and die because of its shading effect. Photosynthesis and productivity will thus occur in the layer just above the water surface. In places where the nutrient conditions are good the old *Salvinia* can live for a very long time, growing at one end, dying at the other. The optimal conditions for such old *Salvinia* mats may be found where slightly moving water is transporting nutrients to the submerged leaves. The river outlets into the lake provide such an environment. As was shown by Gaudet (1979) these areas will also produce additional nitrogen by fixation within the papyrus swamps. The nitrogen fixed is deposited in the sludge below the swamp or directly added to the lake through decomposition, which is as high as a yearly loss of one-third of the total biomass of the papyrus.

The nitrogen-rich sludge below the swamp shows a seasonal pattern of being flushed into the lake. In this way *Salvinia* is nourished as well as nursed by the papyrus at Lake Naivasha. The two plants are closely associated. At the river outlets and outside the north papyrus swamp huge *Salvinia* localities were found at places where irrigation pumps created currents towards the land. Near such places one can also expect nutrient input from fertilizers. Places where hippos are frequent also make good growing spots for *Salvinia* (Diedrichs 1976).

The *Salvinia* sudd of Lake Naivasha

The term sudd derives from the Sudd swamp on the upper White Nile, where floating papyrus islands are big and firm enough to carry both man and cattle (Beadle 1974). The term sudd has also been used to denote floating islands in general when they are made of dense vegetation. Mitchell (1969) uses the name sudd for the old mats of *Salvinia* which are colonized by vascular plants on Lake Kariba. Gaudet (1973) claims that sudd is absent on Lake Naivasha whilst Tarras-Wahlberg (1984) uses the term mini-sudd for floating islands of *Salvinia* and others plants which were found to be the environment of a new species of *Oribatei* (mites or *Acar*i). Sudd was certainly present on Lake Naivasha in 1974 and 1981 on the large papyrus-fringed lagoon outside the mouth of the river Gilgil. According to Mr. Hopcraft, a land-owner living near the place where the infestation of *Salvinia* started, it occurred here as early as the 1960s. The *Salvinia* in that region of the lake has, after the early failure of control, been allowed to grow nearly undisturbed, in which respect that part of the lake is unique. The large mass of *Salvinia* outside the Malewa river mouth was sprayed with herbicide at the end of the 1970s and disappeared completely after the rise of the water level. Hopcraft's lagoon can still, and actually should be, researched! As it is very difficult to penetrate Hopcraft's lagoon, preliminary research was started instead at Mennell's lagoon, the wide lagoon on the NW side of the lake.

Salvinia got into this lagoon in the 1970s through a man-made canal through the fringing papyrus swamp. At this lagoon, which had quite a different shape in 1981 compared to that of 1975, it was possible to find sudd formations of different ages and constitution.

The *Salvinia* sudd is composed of the remnants of several generations of *Salvinia* which have succeeded each other and which have interweaved into a permanent turf. At Mennell's Lagoon in 1981 the sudd was 30-40 cm thick, consisting of dead *Salvinia* at the bottom and living *Salvinia* on top; this mat was invaded by the common vascular plants of the shore. The pioneer of this invasion was *Hydrocotyle ranunculoides* L., being the only plant apart from *Salvinia* in most places on the sudd. Older sudd mats also had the following species: *Cyperus* sp., *Sphaeranthus suaveolens* (Forssk.) DC, *Senecio moorei* RE Fries, *Ludwigia stolonifera* (Guill. & Perr.) Raven and *Gnaphalium* sp.

Animals related to *Salvinia*

A species of *Oribatei* (Mites or *Acari*), *Hydrozetes lemnae* Coggi is very common in young and mature mats of *Salvinia*. This is an amphibious species of mite with a world-wide distribution. It has been reported to occur on *Salvinia molesta* in Florida, USA (Krantz & Baker 1982). When the *Salvinia* mats change into sudd this species disappears and is replaced by another oribatid mite, *Trimalconothrus scimitarum*, which was described as a new species in a separate paper (Tarras-Wahlberg 1984). This species is also common among roots of papyrus on Lake Naivasha. *Rhopalosiphon nymphae* was a numerous and conspicuous aphid on *Salvinia* outside Mennell's Lagoon in 1981. As a potential vector to a still unknown virus disease this aphid might be of importance for biological control of *Salvinia* in the future.

Earthworms are frequent in older mats of *Salvinia* and they seem to compose the only detected suitable food for birds feeding there. Among the birds the Lily-Trotter and the Long-toed Lapwing are restricted to floating vegetation for their breeding. As has been pointed out earlier (Tarras-Wahlberg 1981) the *Salvinia* areas of Lake Naivasha can apparently bear a denser population of the Lily-Trotter than the earlier Water-lily vegetation. The first breeding record of the Long-toed Lapwing for Lake Naivasha was on *Salvinia* in 1975.

Other species of birds observed on *Salvinia* come there for shelter and food. The African clawed toad, *Xenopus mulleri* Peters, both as adult and as tadpole, thrives below *Salvinia* and is taken by the Squacco Heron as it comes to the surface for breathing. Hadada Ibis were seen taking earthworms. Crayfish (*Procambarus clarkii*) are caught by the African Fish Eagle as well as by others when they occur near a *Salvinia* mat. Nymphs of dragonflies are taken by the Malachite Kingfisher.

The following records of birds made at two different *Salvinia* localities are characteristic of its richness in species and individuals.

1. Wide *Salvinia* mat outside Malewa River Mouth, 15.11.1974
Observer: Evert Bengtsson
Lily-trotter 30, Long-toed Lapwing 38, Blacksmith Plover 15, Wood Sandpiper 50, Greenshank 10, Marsh Sandpiper 10, Ruffs and Reeves 150, Curlew Sandpiper 5, Little Stint 300, Ringed Plover 15, Glossy Ibis 5, Saddle-bill Stork 1, Moorhen 15, Black Crake 4, White Pelican 6, Pink-backed Pelican 10, African Skimmer 2, White-winged black Tern 50, Whiskered Tern 8.
2. Wide *Salvinia* mat outside Gilgil River mouth, 27.02.1975
Observer: Nils Tarras-Wahlberg
Lily-trotter 2, Long-toed Lapwing 6, Blacksmith Plover 2, Greenshank 1, Little Stint 300, Sacred Ibis 3, Glossy Ibis 122, Hadada Ibis 2, Little Egret 25, Yellow-billed Egret 2, Grey Heron 1, Squacco Heron 5, Purple Gallinule 2, Black Crake 3, Egyptian Goose 2, Yellow-billed Duck 10, Little Grebe 1, Pink-backed Pelican 1, Woodland Kingfisher 2.

These lists of birds include a great number of migrants from Northern Europe. A possibility exists that they transport minute animals from the mires there to Tropical Africa. A few mysterious findings of single individuals of *Oribatei* (*Nothrus pratensis* Sell., *Tectocephus velatus* Mich.) from *Salvinia* outside the northern swamp might be explained this way, as they are both typical species of Scandinavian mires!

The rich bird-life on *Salvinia* at Lake Naivasha is a positive aspect of an otherwise negative situation. In general animal life in connection with *Salvinia* is still a neglected subject.

Abiotic environmental factors

A limited collection of environmental chemical and physical data was made, and the results are presented here. Publications by Gaudet (1973, 1977, 1979) give further information.

In 1975 large mats of *Salvinia* occupied the lake surface in front of the river-mouths at the NE side of the lake. Apparently conditions there were optimal. On an albedometer very high readings of solar radiation were recorded, as well as an albedo for *Salvinia* of 0.15-0.20.

Later disturbance by hippos forced me to move the instrument to the Fisheries Department inside the Crescent Island. Records were obtained of the global radiation for the first six months of 1975. Figure 3 gives the mean readings of every hour during the day over the whole observation period, and includes the positive and negative standard deviations. The shape of the curve reflects the usual weather pattern: a sunny morning, followed by soaring cumulus clouds at noon; towards the afternoon, thunderstorms are normal. Wind may then come from any direction as indicated by the wind compass in Fig. 1. The mean

daily global radiation for one cm² at Lake Naivasha was 577 ± 202 gram calories. The radiation naturally influences the temperature of the *Salvinia* mats. Room & Derr (1983) have made an interesting study of the microclimate in a *Salvinia* mat in Australia. In general the temperature of the mat was higher than that of the air above it. *Salvinia* was also shown to be able to self-regulate its temperature. A detailed study of the microclimate must precede any transfer of organisms for control of *Salvinia* from one area to another (Room & Derr, 1983).

Old and dense mats of *Salvinia* allow very little light to penetrate them. Mitchell (1969) gives the record 0 (nil) for mats at Lake Kariba, Zambia. A few measurements made at Lake Naivasha in January 1975 also show no light penetrating to the water surface below the mat. Because of this, no photosynthesis can occur. A few oxygen measurements from below *Salvinia* mats at Lake Naivasha show very low values.

It is obvious that a scarcity or lack of oxygen strongly influences the ecology of the Lake within the *Salvinia* areas. Anaerobic conditions like this are well-known from tropical floating swamps. Gaudet (1979) reports on his studies on the northern papyrus swamp at Lake Naivasha. As the vast *Salvinia* mats during the period of his observations (1974-75) were immediately outside his research area, a lot of relevant information on *Salvinia* ecology can be deduced from his studies.

Two points relating to the quality and quantity of the water of Lake Naivasha are of interest:

- fluctuations of water level, i.e. the relation between inflow and evaporation of water
- the salinity of the water as indicated by records of electrical conductivity and pH.

As regards the fluctuations of water-level, it can be regarded as certain that seepage out of the lake occurs (see Ase 1983). Gaudet (1979) has studied the fluctuation of the water level and its impact on the vegetation of the lake. He has pointed out the great importance of the fluctuations on the growth of papyrus. As *Salvinia* is dependent on papyrus, it too is affected by the fluctuations.

In 1974 the water level was very low, and the lake, at least on its eastern edge, had nearly turned into a soda lake. The pH was about 10, and the electrical conductivity was as high as 1000 microS (readings taken at Crescent Island, 17.09.1974). At the same time the lesser Flamingo was seen in hundreds near Naivasha town, apparently feeding in the shallow water. This low water exposed large areas of wet mud, on which papyrus (and consequently *Salvinia*) established itself. When the water was at its lowest level, no *Salvinia* survived in the culture cages inside Crescent Island, presumably because of the high water pH and high electrical conductivity values. Fig. 4 shows the great variation of these values in both space and time, recorded over a 10-day period at the end of 1974. The most likely factor behind this variation is the photosynthetic action of the planktonic algae which consume nutrients and carbon, causing electrical conductivity to increase and the pH to decrease. This is most likely to occur at sampling station 4.

Another possible reason for these abrupt changes could be the underground inflow of salty water, postulated by Thomson and Dodson (see Ase 1983). A core taken by Ase at the Lake to the north of Hell's Gate revealed several porous zones. These parts of the core also became coated with salt crystals when they dried (Ase, pers. comm.). An underground seepage into the lake might well be salty.

In 1974 when the lake was at its lowest level the author observed swirls from the bottom in the northeastern part of the lake. Some months later no swirls were seen but water samples from the same area showed a pH of 9.8 and an electrical conductivity of 500 microS. Probably an underground supply of salty water only happens when the water level is extremely low. However, such a salty upwell may explain the extreme values of pH and electrical conductivity recorded from the northeastern part of the lake. The capricious values recorded may well be explained by the variable wind-directions. Crescent Island is the rim of an old crater, which continues below the surface of the water. In situations of very low water the inside of the crater will form a separate lake, which will quickly turn into a soda lake through evaporation. This would raise the values of pH and electrical conductivity.

One more explanation has to be discussed. Close to the lake shore near Naivasha town a vegetable dehydration plant has been built. In 1975 the spill water from the factory was channelled into the maize fields as fertilizer, but before this was done the whole amount went into the lake, via the shore. Measurements of the electrical conductivity of this effluent showed a value of 1500 microS. During the same period as the very high pH and electrical conductivity were registered in the lake, the values of samples from Gilgil and Malewa Rivers were low (Gilgil R. 75 microS, Malewa R. 50 microS on 31.10.1975). Daily samples taken for 30 consecutive days from the Malewa River at a point near the outlet gave a mean value of 48.8 microS.

pH values for this study were taken on many occasions. The *Salvinia* areas of the lake had a mean pH of 7.1, those areas without *Salvinia* a mean of 8.5. This difference can probably be explained by the lack of photosynthesis below the *Salvinia*, as no removal of CO₂ and consequent decrease of pH can occur.

Synopsis:

In 1974-75, during the end of a period of very low water, values of electrical conductivity and pH in Lake Naivasha were higher than normal, and showed great variations in time and space. *Salvinia* areas of the Lake gave lower values of these factors, at least where the growth was luxuriant. The absence of *Salvinia* from waters inside Crescent Island is probably related to the high values of pH and electrical conductivity there.

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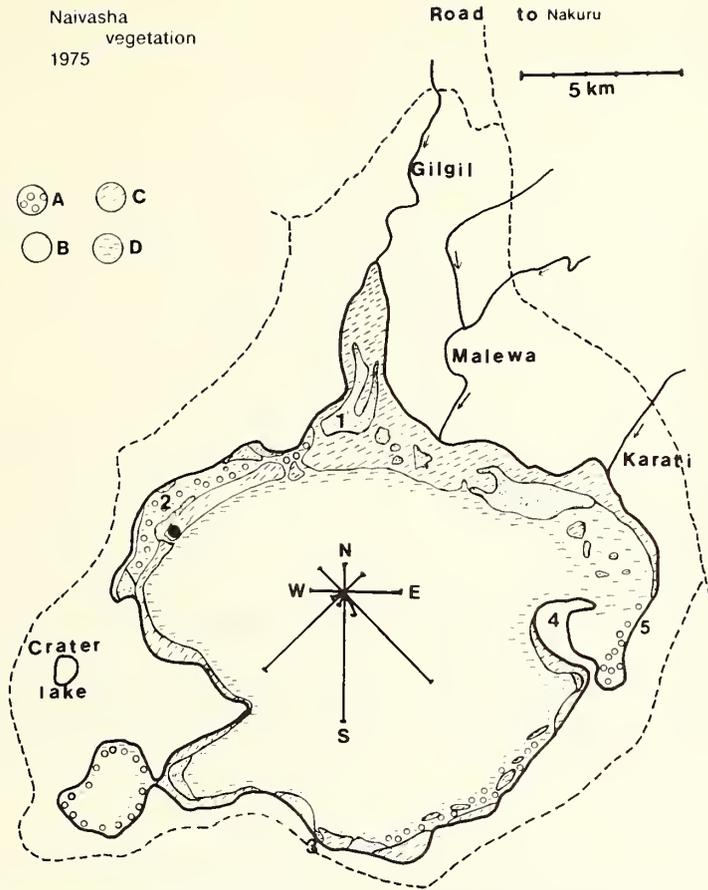


Fig. 1 Lake Naivasha, vegetation in 1975 and the main localities mentioned in the text. A - water lilies, B - *Salvinia*, C - *Papyrus*, D - submerged vegetation.
 1 - Hopcraft's lagoon, 2 - Mennells lagoon, 3 - Fishermen's Camp, 4 - Crescent Island, 5 - Fisheries' Department.

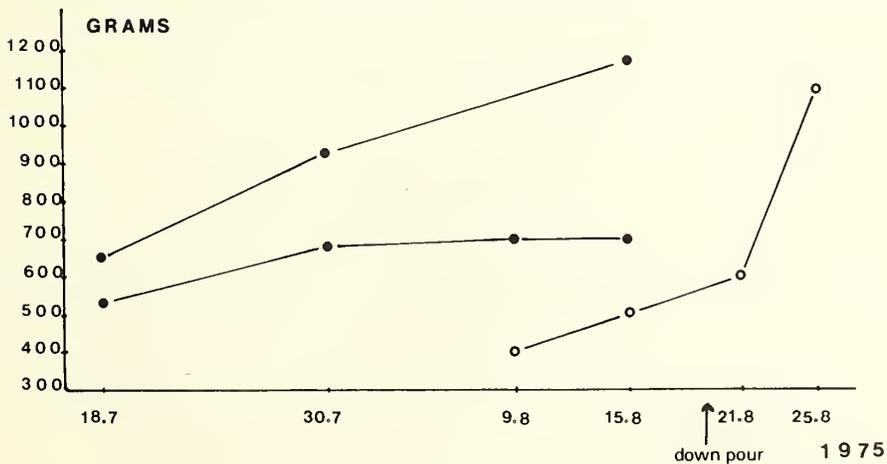


Fig. 2 Weight of *Salvinia* (wetweight - gravity water removed by centrifuging) during a period in 1975 at the shore of Fisherman's Camp. Notice the remarkable rate of growth after a downpour, which is supposed to have brought nutrients to the place of experiment.

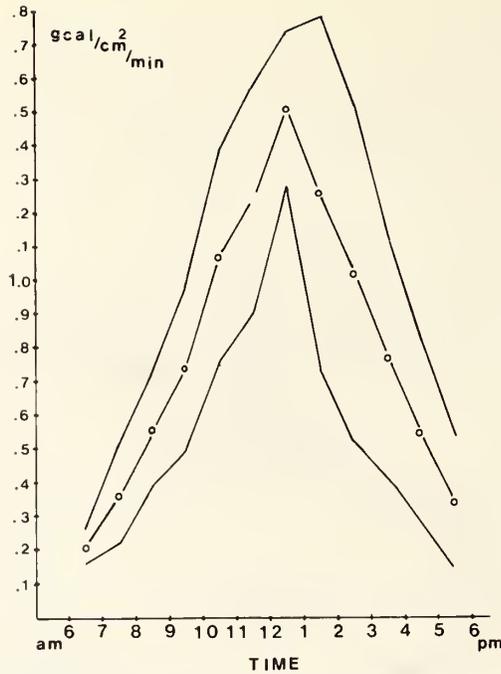


Fig. 3 Global radiation at the Fisheries' Department inside Crescent Island during the first half of 1975. The graph shows the mean values of each hour during the period with the standard deviations included at the adjacent curves. Notice the high deviations from noon onwards which are caused by the random occurrence of cumulus and cumulonimbus clouds.

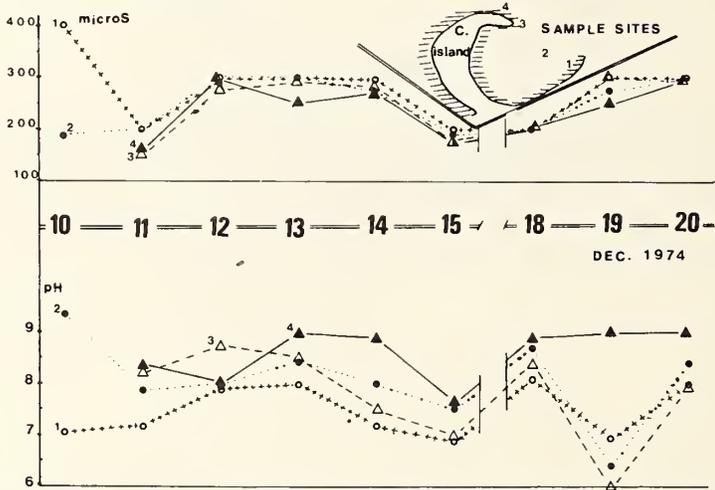


Fig. 4 Short-period variations of pH and electrical conductivity at 4 stations near Crescent Island during a period at the end of 1974.

hour	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18
number of records	11	34	57	31	39	53	33	44	34	59	33	70
mean gcal/cm ² /min	0.21	0.36	0.56	0.74	1.07	1.24	1.51	1.26	1.02	0.77	0.54	0.34
standard error ±	0.10	0.10	0.14	0.16	0.24	0.31	0.34	0.23	0.53	0.50	0.35	0.26

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ALPINE PLANT COMMUNITIES OF MT. ELGON. — AN ALTITUDINAL TRANSECT ALONG
THE KOITOBOSS ROUTE

E. Beck¹, H. Rehder², E.D. Schulze³ and J.O. Kokwaro⁴

ABSTRACT

The afroalpine vegetation of Mt. Elgon was studied along an altitudinal transect ranging from the montane forest up to the summit of Koitoboss (13,880 ft.).

Since, due to recurrent fires, the boundary between the lower Ericaceous and the alpine belt is an interlocking one, both vegetation girdles were encompassed in the studies. The Ericaceous belt can be divided into a woodland and bush storey. The former, with respect to the species encountered represents a transition zone from the montane forest to the microphyllous bush vegetation. The latter was designated as Ericaceous bush and exhibits various indications of former fires, thus rather reflecting different stages of regeneration than a climax vegetation. Within the alpine belt tussock grassland and two types of *Carex* bog form a lower storey. The vegetation of the upper zone is characterized by a field layer of predominantly *Alchemilla elgonensis* and thus could be addressed as *Alchemilla* scrub. However, according to the accompanying species several types of this scrub were distinguished: a *Helichrysum scrub* which was found on shallow soil covering volcanic rock slabs; an *Euryops bush*, bordering the so-called *Dendrosenecio* woodland vegetation. The latter was divided into a *Dendrosenecio elgonensis*-Community on moist soil and a *Dendrosenecio barbatipes*-Community covering the well-drained steeper slopes of the caldera rim.

INTRODUCTION

Mt. Elgon (14,178 ft.) is one of the seven East African high mountains exhibiting alpine vegetation. As described in detail by Hedberg (1951) the vegetation characteristic of the alpine belt is usually found above the so-called Ericaceous belt, i.e. above 11,000 to 11,500 ft. However, probably due to recurrent burning, a broad altitudinal zone exists at Mt. Elgon, in which alpine grassland or scrub vegetation has penetrated into the Ericaceous belt thus narrowing that girdle considerably and even bordering the montane forest belt in a small area south of the caldera (Hamilton, 1981). In the present communication this zone of mutual interference was included in the alpine belt. With respect to the upper border of this belt, Mt. Elgon is not high enough to exhibit a nival zone; therefore the summits, too, are covered by alpine vegetation. Since this paper describes the plant communities along the Koitoboss route, i.e. along the access from the south-east, it should be mentioned that the East of Mt. Elgon gains considerably less precipitation than the South

¹ Lehrstuhl für Pflanzenphysiologie, Universität Bayreuth
D-8580 Bayreuth, Postfach 101251

² Institute für Botanik und Mikrobiologie, TU München, Arcisstraße 21,
D-800 München

³ Lehrstuhl für Pflanzenökologie, Universität Bayreuth, Postfach
101251

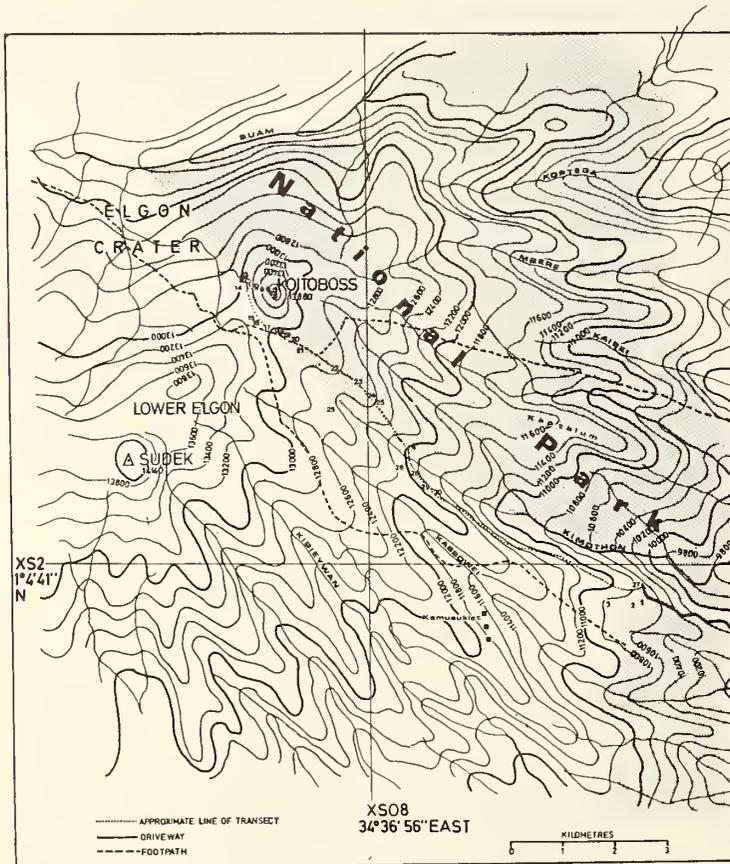
⁴ Botany Dept. University of Nairobi, P.O. Box 30197
Nairobi, Kenya.

and especially West (Hamilton 1981). Thus the southeastern slopes may be intermediate with respect to humidity and rainfall. Although no exact data were available, there is no doubt that the maximum of rainfall occurs in the montane forest belt (Hamilton 1981), and that the alpine region, although more often covered by clouds than the montane girdle, gains considerably less precipitation.

The soils along the Koitoboss route are mostly of the alpine Brown Soil or Brown Soil-Gley type which have been described for Mt. Kenya (Beck et al. 1981), but mires and boggy areas outside and inside the caldera were also recorded. The soil of these swamps consists of a material classified as "radicellous peat", i.e. an organic soil which had developed predominantly from roots and rhizomes of higher plants as well as from mosses, but without any contribution of Sphagnum species. Hedberg (1964) also stated that he could not find one Sphagnum plant at Mt. Elgon. In particular close to the caldera rim, and also at the summit of Koitoboss, large slabs of volcanic rock crop up which are covered by an only very shallow humus layer.

TOPOGRAPHY

Easy access to the alpine region of Mt. Elgon is provided by a driveway leading from the Kitale Gate of Mt. Elgon National Park to an altitude of about 10,800 ft. It ends about 260 ft. above the sharply notched Kimothon valley. From that point a faint foot tract which enters the caldera rim between Koitoboss and Lower Elgon was used to establish the altitudinal transect. From the saddle the tract turns eastward to climb Koitoboss summit via its W face. Some bogs of the caldera, in particular the so called Koitoboss swamp were included in the transect. For mapping the route and localizing the plots the Sheet NA-36-12 (Kapenguria), Series Y 503, printed by Survey of Kenya was used and a sketch of the relevant area was drawn magnifying the pertinent area (Fig. 1).



CLASSIFICATION OF THE VEGETATION

Conspicuous, repeatedly occurring combinations of plant species were listed and species quantification was performed according to the method of Braun-Blanquet (Mueller-Dombois and Ellenberg, 1974). Unknown plant species were collected and identified using the "Flora of Tropical East Africa" (Hubbard and Milne-Redhead), "Upland Kenya Wild Flowers" (Agnew 1974), "Kenyan Trees and Shrubs" (Dale and Greenway 1961) and "Afroalpine Vascular Plants" (Hedberg 1957). To the Dendrosenecios the nomenclature proposed by Nordenstam (1978) was applied. Identification of difficult species was confirmed by comparison with material of the East African National Herbarium at Nairobi. Unfortunately, the mosses have not yet been identified. For abstraction of vegetation units, the proposals of Hedberg (1964) were used as guiding principle.

THE VEGETATION FORMATIONS

Ericaceous belt

Having passed several types of dense montane forest along the driveway to the Koitoboss area, an open type of *Ericaceous woodland* is entered at an altitude of about 10,200 ft. This woodland is characterized by tree-like representatives of the Ericaceae as are the broad-leaf species *Agauria salicifolia* and the microphyllous species *Philippia keniensis* (and *excelsa*) and *Erica arborea*. It still comprises montane forest species, too. Typical representatives of the latter are the trees of *Olea kilimandscharica*, *Juniperus procera*, *Rapanea rhododendroides*, *Hagenia abyssinica* and *Hypericum keniense* as well as some herbs, e.g. *Viola eminii*. This lower storey of the Ericaceous belt thus may be regarded as natural transition from the forest to the Ericaceous bush, the latter representing the upper storey of this belt. Two analyses of such a woodland vegetation are provided by Table 1 (plots 1 and 2). Clearing on rocky outcrops exhibit an open vegetation type which, in analogy to Klötzli's classification on Mt. Kilimanjaro (1958) might be described as *Exothea abyssinica* - *Agrostis* spp. - Community (plot Nr. 3). Apart from the replacement of *Agrostis volkensis* at Kilimanjaro by *A. gracilifolia* and *A. kilimandscharica* at Mt. Elgon, this community differs from that described by Klötzli in that mosses are dominating on the rocky soil instead of grasses.

In contrast, e.g. to the western part of Mt. Kilimanjaro (Beck et al. 1983) the Ericaceous bush on Mt. Elgon is an open vegetation, appropriately characterized by Cotton (1932) as "subalpine grasslands with scattered Ericaceous bushes and suffruticose plants of temperate genera". There is no distinct border between the lower storey of the Ericaceous belt and the upper one. In the latter the trees are more and more replaced by bushes of microphyllous species, such as *Philippia keniensis*, *Anthospermum usambarense* and *Stoebe kilimandscharica*. In the visited area between Kimothon and Kasswei (Fig. 1) the Ericaceous bush more or less everywhere exhibits signs of burning, such as charred *Philippia* stems, from the basis of which new shoots had developed. Another direct indication of former fire is the absence of the cylinders of dry leaves around the stems of *Dendrosenecio elgonensis*. Thus the plant communities found in these areas (plots 28 to 30) on the one hand by the absence of the tree-like differential species listed in Table 1 can already be distinguished from those of the Ericaceous woodland, but on the other hand rather appear to reflect regeneration stages of the bush than the climax plant community. According to Hedberg (1964) luxuriant growth of *Carduus keniensis*, as it is indicated by plots 29 and 30 can be taken as to show recolonization of burnt-over areas. According to our own observations on Mt. Kilimanjaro (Beck et al. 1983) the same is true for the predominance of *Artemisia afra* (plots 28 to 30).

Alpine belt

The vegetation formations and plant communities typical of the alpine belt are shown in Table 2.

a) Tussock grassland

In the Koitoboss area the upper boundary of the Ericaceous belt varies between 10,800 and 11,800 ft (cf. Hamilton 1981). Usually it extends to the higher altitudes merely on steep slopes and rocky crests while on the valley floors it is replaced by a tussock vegetation. According to Hedberg (1951) tussock grassland is the most important vegetation type of the alpine belt of Mt. Elgon, covering more than half of the area. This author further emphasized (1964) that fires are at least partly responsible for the large extension of the tussocks inside and outside the crater and that it is in particular the frequency of burning that favours the spread of grassland at the cost of the scrub vegetation. This is undoubtedly true for grassland covering well-drained soils, especially in the lower zone of the alpine belt. In plots 24 and 25 such plant communities

have been analyzed. The herb layer is dominated by the tall tussocks of *Festuca pilgeri*, the gaps in between being occupied by other grass species as *Pentstemon borussica*, *Agrostis kilimandscharica* and *Koeleria capensis*. The inconspicuous occurrence of Everlastings in such tussock grasslands may indicate the above mentioned fire-triggered competition of grassland with scrub communities. A dense moss layer was found covering patches of bare soil in between the grass tussocks.

b) *Carex* bogs

Another type of tussock vegetation is represented by the so-called *Carex* bogs (Hedberg 1964) which cover water-soaked peaty soils on flat depressions without any or with reduced drainage. Naturally those bogs occur more frequently at lower elevations than in the upper alpine regions. At Mt. Elgon two types of *Carex* bogs may be differentiated by the presence (plots 23 and 26) or absence (plots 13 and 14) of tree-like groundfels. *Carex* bogs (type 2 in Table 2) characterized by the latter (Fig. 2) by phenotype very much resemble those described from the southeastern slopes of Mt. Kilimanjaro (cf. Fig. 86 in Hedberg, 1964) which have been described by Klötzli (1958) as *Senecio cottonii-Carex monstachya* Community. At Mt. Elgon the dominant sedge is *Carex runssoroensis*, and *Dendrosenecio elgonensis* was found instead of *D. cottonii* (plot 22 and Fig. 2). In the Ericaceous bush storey *Carex ninagongensis* and two other Cyperaceae, presumably *Scirpus* species (which could not be identified due to the lack of reproductive organs) appear to replace *Carex runssoroensis* (plot 26) at otherwise comparable bogs. The other type of *Carex* bog (type 1 in Table 2) which on the transect was found exclusively inside the caldera (plots 13 and 14) at altitudes around 13,000 ft. appears to be characteristic of more or less permanent flooded areas. It is dominated by the tussocks of *Carex runssoroensis* (Fig. 3) and like the first bog type contains considerable numbers of the attractive giant rosette species *Lobelia elgonensis*. Another similarity results from the occurrence of *Alchemilla johnstonii* in between the hummocks. However, the occurrence of hydrophilic herbs as *Ranunculus volkensii*, *Ericaulon volkensii*, *Crassula granvikii* or *Swertia crassiuscula* and the above mentioned absence of giant groundfels render easy differentiation of the two types of *Carex* bogs which physiognomically may be addressed as mires (plots 23 and 26) and swamps (plots 13 and 14), respectively.

It should be noted that the absence of *Alchemilla elgonensis* from the typical *Carex* bogs and from the tussock grassland clearly distinguishes these vegetation formations from all other plant communities recorded in the alpine zone of Mt. Elgon (Table 2). With a few cuts the same holds true for the absence of *Helichrysum amblyphyllum*, *Lobelia telekii*, *Valeriana kilimandscharica* and *Festuca abyssinica*. Thus, next to the tussock grassland, a scrub vegetation in which in particular *Alchemilla elgonensis* is of great importance characterizes the alpine belt of Mt. Elgon.

c) *Alchemilla* scrub

A pure *Alchemilla* scrub, established by *Alchemilla elgonensis*, *A. johnstonii* and *Valeriana kilimandscharica*, as has been described by Hedberg (1964) from an area near Maji ya Moto, could not be found along the Koitoboss transect. This difference may be rather due to the sizes of plots employed by Hedberg (1964), 1 x 1m) and in the present work (10 x 10m), than to clearcut changes of the vegetation. In spite of a more or less closed and monotonous layer of *Alchemilla* scrubs various plant communities belonging to the vegetation formation *Alchemilla* scrub could be differentiated by the presence of other conspicuous species. Where Everlastings other than *H. amblyphyllum* were as frequent as the *Alchemilla* species (plots 15 and 20) the vegetation was designated as *Helichrysum* scrub which predominantly covers rocky ground. It should be noted that the *Helichrysum* scrub described in this work differs from that mentioned by Hedberg (1964) in that the ubiquitous *H. amblyphyllum* is of minor importance and by the absence of *Alchemilla johnstonii*, *Dendrosenecio elgonensis*, *Peucedanum kerstenii* and *Carduus keniensis*. However, even the pure *Helichrysum* scrub described here for Mt. Elgon is almost identical (allowing for vicarious species such as *Alchemilla argyrophylla* and *elgonensis*) with a mixed vegetation of *Helichrysum* scrub, *Alchemilla* scrub and Ericaceous bush (cf. Table 2 in Beck et al. 1983) on Mt. Kilimanjaro. The *Helichrysum* scrub shown by Hedberg for Mt. Elgon (cf. Fig. 89 in Hedberg 1964) will be described in the present work as *Dendrosenecio elgonensis*-Community. Another plant community abstracted from the *Alchemilla* scrub was designated as *Euryops* bush. It is characterized by the occurrence of the conspicuous bushes of *Euryops elgonensis* together with both *Alchemilla* species, as well as by the absence of a moss layer plots 17, 18, 21) and was usually observed bordering the *Dendrosenecio elgonensis*-Community versus mires or tussock grassland. The *Euryops* bush of Mt. Elgon is completely different from the *Festuca abyssinica-Euryops dacrydiodes* Community (Beck et al. 1983) reported for Mt. Kilimanjaro, as grasses are of minor importance or even lacking. The occurrence of *Peucedanum kerstenii* and *Carduus keniensis* in the *Euryops* bush as well as the localization of this community close to the grassland suggest that its origin may be linked to occasional fires.

d) Dendrosenecio woodlands

The most conspicuous vegetation formations of the alpine belt of Mt. Elgon are those characterized by the trees of giant groundsels. According to Hedberg (1964) they were combined by the term Dendrosenecio woodlands. Like at Mts. Kenya and Kilimanjaro (Rehder et al. 1981, Beck et al. 1983), *Dendrosenecios* occur at Mt. Elgon in a field layer either of *Alchemilla* species or of tussocks. Since in the latter case the scattered occurrence of giant groundsels contradicts the idea of a woodland, such a plant community was described as Carex bog (type 2) which is shown in plots 23 and 26. Thus the Dendrosenecio woodlands of Mt. Elgon, described in this work, consistently exhibit an understorey of *Alchemilla* scrub, and thus closely resemble the *Alchemilla-Dendrosenecio johnstonii*-Community described for the Shira plateau of Mt. Kilimanjaro (Beck et al. 1983). Two types of Dendrosenecio woodlands can easily be differentiated on Mt. Elgon. The lower girdle of that vegetation formation is characterized by the less branched trees of *Dendrosenecio elgonensis* and by the considerable contribution of *Alchemilla johnstonii* to the field layer. The fact that the latter species prefers at least occasionally wet soil, together with the occurrence of *Ranunculus oreophytus*, *Lobelia lindblomii* and *Swertia crassiuscula* indicates that a moist substrate is a prerequisite for the Dendrosenecio elgonensis-Community (plots 16 and 22). This idea is corroborated by the capability of *D. elgonensis* to advance into boggy areas. Completely different from that community is the second type of Dendrosenecio Woodlands which was designated as Dendrosenecio barbatipes-Community (plots 6 - 10) and was recorded on well drained slopes. It is characteristic of the upper alpine zone of Mt. Elgon where the rather dense stands of widely branched *Dendrosenecio barbatipes* trees provide an aspect which is unique for the steep slopes of the caldera (Fig. 4).

Since *Lobelia telekii*, although not specified as a differential species, was consistently found to accompany *Dendrosenecio barbatipes* (Fig. 5). A striking physiognomic similarity of the Dendrosenecio barbatipes-Community with the Dendrosenecio woodlands of Mt. Kenya (Rehder et al. 1981) was established. The latter is characterized by *D. keniodendron*, *L. telekii* and *Alchemilla argyrophylla*.

Vegetation patches composed of species of both types of Dendrosenecio woodlands of Mt. Elgon have also been recorded, predominantly and expectedly at intermediate levels (plot 11) but, interestingly, also on the large summit plateau of Koitoboss (plot 5). The latter, due to poor drainage, is inhabited by hydrophilic species like *Ranunculus oreophytus* and *Lobelia lindblomii*.

CONCLUDING REMARK

The vegetation units described in this work may be typical of the area of the National Park, which apart from fire, appears as widely uninfluenced by man. In contrast to these, heavily grazed areas with different grass communities must be expected to occur on the drier hills inside the crater (Hedberg 1964). Even the Dendrosenecio woodlands appear to be of less importance outside the National Park as it is documented by a photo (Hamilton 1982) showing only scattered groundsel trees in the region between lake Kimilili and Sudek (14,140 ft.). Therefore the altitudinal transect reported herein by no means should be generalized for the whole alpine belt of Mt. Elgon.

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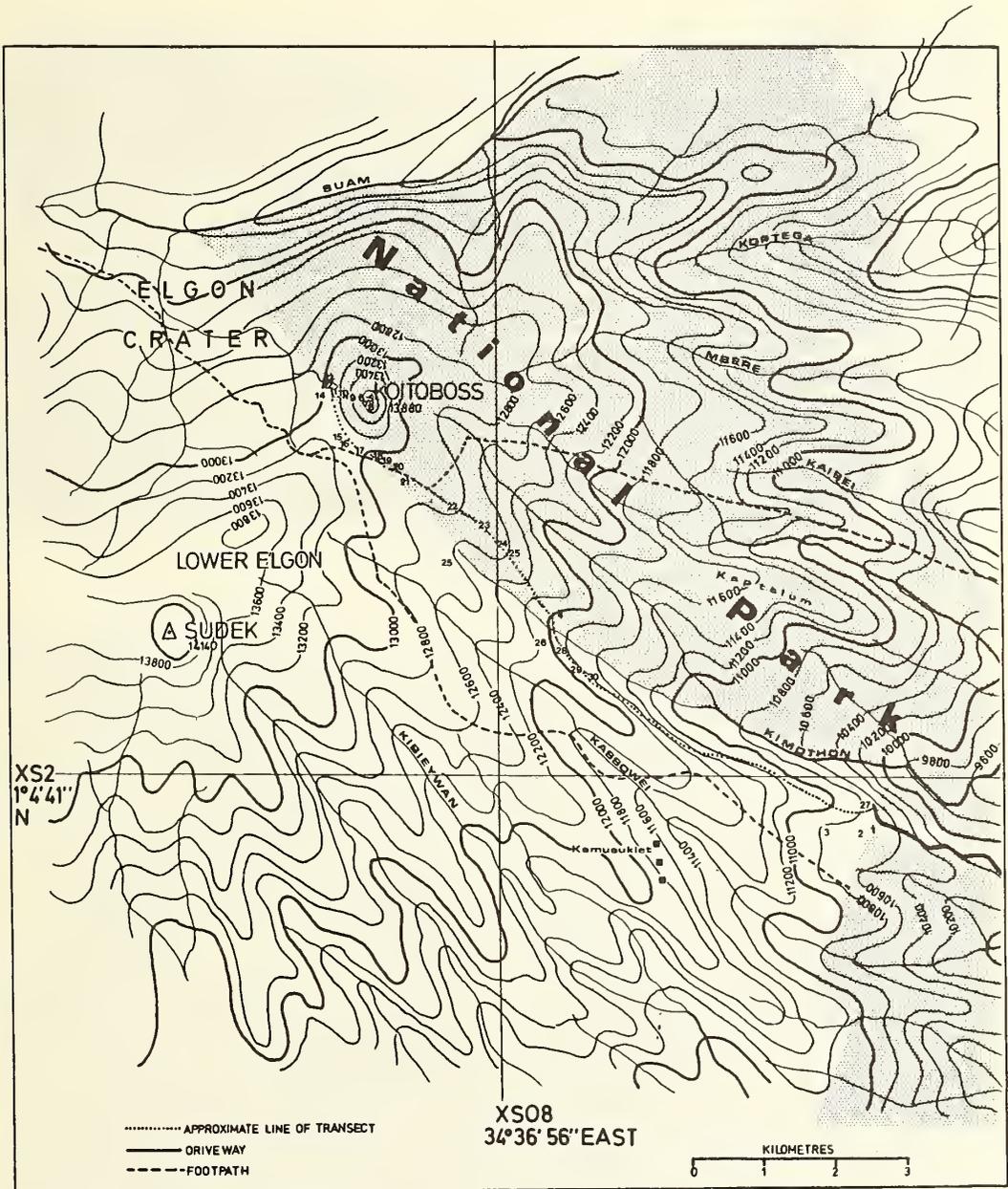


Fig. 1 Map of the Kenyan sector of Mt. Elgon, redrawn and magnified from the Sheet Kapenguria, Series Y 503, Sheet NA-36-12, Edition 2 - 5K, published by Survey of Kenya (Nr. 2400/8/73). The altitudinal transect was made along a faint footpath, the approximate alinement of which is given by the dotted line. The figures represent the numbers of plots of vegetation analysis which are described in detail in Tables 1 and 2.



Fig. 2 *Carex runssorensis* bog (*Carex* bog type 2, cf. Table 2, plot 23) with *Dendrosenecio johnstonii* ssp. *elgonensis*, *Lobelia elgonensis* and scattered specimens of *Helichrysum amblyphyllum*. The slopes in the background are covered by the *Dendrosenecio elgonensis*-community. (Foto: E. Beck, March 15th, 1983).



Fig. 3 *Carex runssorensis* bog (*Carex* bog type 1, cf. Table 2, plot 13) in the caldera of Mt. Elgon (Koitoboss swamp). Patches of *Alchemilla johnstonii* can be detected between the *Carex* tussocks. The slopes in the background are covered by the *Dendrosenecio barbatipes*-Community (Foto: E. Beck, March 15th, 1983).



Fig. 4 Dendrosenecio woodlands: *Dendrosenecio barbatipes*-Community on the southeastern slopes of Lower Elgon at an elevation of 13,000 ft. The field layer consists predominantly of *Alchemilla elgonensis* (Foto: E. Beck, March 15th, 1983).



Fig. 5 Close up the *Dendrosenecio barbatipes*-Community at the western slopes of Koitoboss summit (cf. plot 8 in Table 2). *D. barbatipes*, *Lobelia telekii* and *Alchemilla elgonensis* and *Helichrysum amblyphyllum* can be detected on the photo as important representatives of this community (Foto: E. Beck, March 15th, 1983).

Table 1 Species lists of 7 sample plots of the Ericaceous belt of Mt. Elgon along the Koitoboss Track. Cover abundance numbers after KNAPP (1971):

+ = few individuals with small covers; 1 = numerous or scattered individuals cover up to 5% of the sample area; 2 = cover of 5 - 25%; 3 = cover of 25 - 50%; 4 = cover of 50 - 75%; 5 = cover of 75-100% of the soil surface; T = trees (more than 3 m high). Transitional features in regeneration communities are screened.

- Plot 1 End of the Koitoboss driveway at an altitude of 10,750 ft.; 20 × 20 m; tree layer with 60% cover; 14th March 1983;
 Plot 2 50 m W of Plot 1 at 10,810 ft. altitude; 20 × 20 m; tree layer with 30% cover; 14th March 1983;
 Plot 3 Rocky outcrop near the End of the Koitoboss driveway at an elevation of 10,750 ft.; 20 × 20 m; volcanic rock covered by mosses; 14th March 1983;
 Plot 27 Regeneration stage of Ericaceous bush 50 m N of the end of the driveway at an altitude of 10,800 ft. 10 × 10 m; 16th March 1983;
 Plot 28 Footpath to Koitoboss at an altitude of 11,870 ft.; 50 m S of the valley floor; 10 × 10 m; 15th March 1983;
 Plot 29 Footpath to Koitoboss, upper part of the slope; 11,670 ft.; 10 × 10 m; 15th March 1983;
 Plot 30 Footpath to Koitoboss, close to Plot 29; 11,670 ft.; 10 × 10 m; 15th March 1983;

Table 2 Species list of 23 sample plots of the alpine zone of Mt. Elgon representing an altitudinal transect from the caldera up to the summit of Kotoboss and down to the end of the Koitoboss driveway. Cover abundance numbers as in Table 1; n(n) indicates two layers, usually a tree and a shrub or herb layer. Typical communities are screened; Hatching in the heading indicates mixed vegetation.

All analyses were made on March 15th, 1983.

- Plot 12 W-slope of Koitoboss, 50 ft. above the floor of the crater 13,040 ft., 10 × 10 m;
 Plot 14 Bog in the caldera below Koitoboss summit; 12,970 ft., 10 × 10 m;
 Plot 13 Swamp at the E-rim of the caldera below Koitoboss summit; 13,000 ft.; 10 × 10 m;
 Plot 19 Spring area close to Koitoboss track, 12,970 ft., 10 × 10 m;
 Plot 9 Boulder stream on the W-slope of Koitoboss summit at 13,380 ft.; 15 × 15 m;
 Plot 10 Boulder stream on a flattening of the W-slope of Koitoboss summit; 13,340 ft.; 10 × 10 m;
 Plot 7 NW slope of Koitoboss summit on a plant-covered scree stream; 13,750 ft.; 10 × 10 m;
 Plot 6 As in plot 7 on a shallow ledge; 13,680 ft.; 3 × 12 m;
 Plot 8 W-face of Koitoboss summit with 20% bare rock; 13,800 ft.; 5 × 5 m;
 Plot 11 W-slope of Koitoboss; 110 ft. above caldera; 13,100 ft.; 10 × 10 m;
 Plot 5 Plateau representing the summit of Koitoboss, 13,880 ft.; 15% bare rock; 10 × 10 m;
 Plot 16 Flattening on a rock table E of the saddle W of Koitoboss; 13,130 ft.; 6 × 12 m;
 Plot 22 Along Koitoboss footpath at 12,830 ft.; 10 × 10 m;
 Plot 23 As in plot 22, 12,740 ft.; border of a mire; 10 × 10 m;
 Plot 26 Mire at an altitude of 12,060 ft. in the grassland area; 10 × 10 m;
 Plot 4 100 m N of the footpath (middle of the slope) at 12,230 ft. altitude; 10 × 10 m;
 Plot 17 S-slope of a wide gully on the footpath at 13,070 ft. altitude; 10 × 10 m;
 Plot 18 SE-slope of the same gully as in plot 17; 10 × 10 m;
 Plot 21 50 m SW of Koitoboss footpath at 12,870 ft.; 10 × 10 m;
 Plot 15 Rock outcrop at the saddle W of Koitoboss summit; 13,160 ft.; pure rock 10%; 15 × 15 m;
 Plot 20 Rock outcrop 15 m N of Koitoboss footpath at 12,930 ft.; bare rock 10%; 8 × 8 m;
 Plot 25 Gentle slope on shallow soil 20 m W of Koitoboss footpath at 12,600 ft.; some charred trunks indicate former burning; 10 × 10 m;
 Plot 24 100 m W of plot 25 at 12,670 ft.; no direct evidence of former fire; 10 × 10 m;

TABLE I	Ericaceous Woodland			Ericaceous Bush			
	Transition Zone Forest-Heath		Exo-theca-Agrostis Comm.	Regeneration Types			
	1	2	3	27	28	29	30
Number of plot	1	2	3	27	28	29	30
Altitude x 1,000 (ft.)	10.7	10.7	10.8	10.7	11.8	11.6	11.6
Exposition	NE	NE	NE	NE	NE	N	N
Slope (°)	10	5	10	20	5	5	5
Plant cover (%)	90	95	80	90	85	97	95
Number of species (Mosses = 1)	34	33	26	17	22	25	20
Philippia keniensis S.Moore	3T	1T+1	2T+2	2	3		+
Anthospermum usabarensis K.Schum.	1	1	1	2			+ 2
Helichrysum odoratissimum (L.)Less.	1	2	1		1	2	1
Artemisia afra Willd.	1	2		2	2	2	2
Leucas spec. A Agnew	1	1	1	1			
Stoebe kilimandscharica O.Hoffm.	1T+2	1T+3	1	1			+
Hebenstretia cf. angolensis Rolfe	1	+		1	1		
Satureja biflora (D.Don.)Benth.	+	1	+		+		+
Andropogon lama (Hack.)Stapf	1	+	+		2	1	2
Kniphofia snowdenii C.H.Wright	+	1			+		+
Olea kilimandscharica Knobl.	+	+					
Erlankea fusca S.Moore		1	+				
Hypericum kiboense Oliv.	+	1		+			
Luzula johnstonii Buchen.	1	1					
Caucalis incoqnita Norman	1	+					
Swertia kilimandscharica Engl.	1	+					
Juniperus procera Hochst. ex Endl.		1T					
Rapanea cf rhododendroides (Gilg)Mez		1T+1					
Agauria salicifolia (Comm. ex Lam.)Hook.f.	3T						
Nidorella arborea R.E.Fries	1						
Senecio rhamnatoxyllus Mattf.	+						
Hagenia abyssinica (Bruce)J.F.Gmel.		+					
Helichrysum formosissimum (Sch.Bip.)A.R.	1						
Erica arborea L		1	2T				
Viola eminii (Engl.)R.E.Fries	+						
Cerastium afroontanum T.C.E.Fries&Weim.	+						
Hypericum keniense Schweinf.		1					
Protea kilimandscharica Engl.	+		+	3			
Bartsia kilimandscharica Engl.	1	+	1				
Helichrysum nandense S.Moore	1	+	+				
Lithospermum afroontanum Weim.	+	+	+				
Pilosellcides hirsuta (Forsk.)C.Jeffr.	+	+	1				
Exothea abyssinica (A.Rich.)Anderss.			+				
Agrostis gracilifolia C.E.Hubb.			+		1		
Agrostis kilimandscharica Mez			+				
Dierama pendulum (L.f.)Bak.			+				
Dendrosenecio johnstonii ssp. elgonensis (T.C.E.Fries)B.Nord.						1	2
Helichrysum globosum Sch. Bip.			+			1	1
Anthoxanthum nivale F.Schum.						+	+
Hypericum spec.						2	2
cf Scirpus spec.B						2	1
Anagallis serpens D.C.						2	2
Conyza subscaposa O.Hoffm.						2	1
Carduus keniensis R.E.Fries						+	2
Senecio snowdenii Hutch.						+	+
Swertia crassiuscula Gilg						+	+
Veronica glandulosa Benth.						1	1
cf Dichrocephala alpina R.E.Fries						+	+
Cineraria grandiflora Vatke	+						
Galium ruwenzoriense (Cort.)Chiov.	+		+	+	+		+
Galium glaciale K. Krause		+					
Sonchus bipontini Aschers.	+		+				
Geranium ocellatum Cambess.		+		+		+	+
Geranium elamellatum Kokwaro	+						
Satureja cf kilimandschari (Guerke)Hed.				+			
Satureja uhligii Guerke				+			
Haplocarpha rupepelli (Sch.Bip.)Beauv.		+					+
cf Wahlenbergia arabidifolia (Engl.)Bf.				+			
Mariscus spec.	1						
Agrostis spec.	2						
Conyza welwitschii (S.Moore)Wild							+
Deschampsia caespitosa (L.) PB.	1						
Alchemilla cryptantha A.Rich.							+
Alchemilla elgonensis Mildbr.		2					
Alchemilla johnstonii Oliv.		+			2	2	2
Festuca abyssinica A. Rich.	1		+	2	1	+	
Euryops elgonensis Mattf.			+				
Helichrysum forskahl (Gmel.)Hill.&Burt.			+		+		
Lobelia elgonensis R.E. & T.Fries jr.	1						
Cirsium buchwaldii O. Hoffm.		+					
Geranium kilimandscharicum Engl.					+		
Sedum ruwenzoriense Bak.			1				
Carex ninagongensis (Kuk.)Rebys		+					+
Crassula pentandra (Edgeworth)Schonl.		+					
Mosses			3		2	1	2

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A taxonomic revision of the grasshopper genus

SPATHOSTERNUM (ORTHOPTERA, ACRIDIDAE)

J.P. GRUNSHAW, Overseas Development Natural Resources Institute, London

ABSTRACT

The highly wing-polymorphic, Afro-Oriental grasshopper genus *Spathosternum* Krauss 1977, Hemiacridinae is revised. Keys are provided to the males of the species. Seven species, *prasiniferum*, *abbreviatum*, *curtum*, *malagassum*, *nigrotaeniatum*, *brevipenne* and *pygmaeum* are now recognised. Three species *brevicorne*, *beninense*, *medium* and one subspecies *prasiniferum sinense* are newly synonymised.

INTRODUCTION

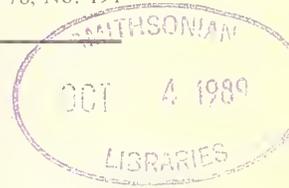
This paper is the second of two revisions of hemiacridine grasshopper genera due to be included in a future handbook and field key to the grasshoppers of Eastern Africa. Reference to current assessments of the systematic problems associated with the sub-family Hemiacridinae Dirsh (1961, 1965 and 1975) were given in the first paper Grunshaw (1986), and are not discussed here. The recently published "Locust and Grasshopper Agricultural Manual" (Centre for Overseas Pest Research, 1982), provides a comprehensively annotated reference guide to much of what has been previously written concerning the biology, distribution and economic importance of the genus. Reference will be made throughout the text to this manual where applicable.

The genus *Spathosternum* was erected by Krauss (1877) to accommodate *Tristria nigro-taeniata* Stål (1876) as its type species, being separated principally from "Oxyae and Tristriae" on the shape of the prosternal process. In 1910 Kirby considered that the genus belonged to a group of the Cyrtacanthacridinae and it had by then grown to include the species *S. nigrotaeniatum*, Stål (1876), *pygmaeum* Karsch (1893), *venulosum* Stål (1878) and *caliginosum* Walker (1871). Four years later Kirby (1914) reassigned it to the sub-family Catantopinae without giving any reason for doing so. Since then the genus has oscillated between the Cyrtacanthacridinae and Catantopinae. Tinkham (1940), for example, allocated it to the group Spathosterni of the Cyrtacanthacridinae. It was returned to the Catantopinae by Johnston (1956) as part of the group "Leptacres", which also contained most of the present Hemiacridinae and Tropidopolinae. In the same year, Dirsh (1956), assigned the genus to the newly erected sub-family Hemiacridinae, on the basis of its divided endophallus and its sound-producing mechanism. In his study, Australian Acrididae, Rehn (1957) subsequently gave the genus tribal status by erecting the tribe Spathosternini, which also included the East Australian genus *Laxabilla*. More recently Dirsh (1975) erected the Spathosterninae as a sub-family of the family Hemiacrididae, but this decision has found little support amongst contemporary workers in the Acridoidea.

The genus is of biogeographical interest since its representatives are Afro-Oriental in distribution. There are four species in Africa, one of which extends into Saudi Arabia. One species is restricted to Madagascar, another to India, and a last widespread and variable species extends from Pakistan through India, Sri Lanka and Burma to South East China. Most species favour marshy habitats in which grasses predominate, typically cohabiting with *Oxya* spp.

Abbreviations used in figures

a, length of a midline drawn between the anterior and posterior edges of the lophal interspace; ad, apical diverticulum; ap, apical penis valves; b, width between the outer extremities of the lophus; cv, cingular valves; lpc, lateral process of cingulum; pd, preapical diverticulum.



Abbreviations for depositories

BMNH, British Museum (Natural History), London; MNHN, Muséum National d'Histoire Naturelle, Paris; MNHU, Museum für Naturkunde der Humboldt-Universität, Berlin; NR, Naturhistoriska Riksmuseet, Stockholm; ODNRI, Overseas Development Natural Resources Institute, London.

PRESENTATION

The preparation and treatment of the male genitalia in this study are the same as those described by Dirsh (1956). Female spermathecae were examined by removal of posterior abdominal segments and maceration in 5% [potassium hydroxide solution]. The nomenclature of the female spermatheca used in this study is that of Dirsh (1957). Separation of taxa is based mainly on male genital morphology. A key is given for the males of all species and subspecies in the genus, based mainly on external characteristics. Females can only be identified reliably by association with sympatric males. Descriptions are given in the form of differential diagnoses. Main diagnostic characters together with the male genitalia, are illustrated. Three views of the aedeagus and two of the epiphallus are given. The former was drawn from dorsal, lateral and posterior aspects, each drawn at right angles to the plane of the aedeagus. The epiphallus was drawn from a dorsal aspect with the plane of the lophi at right angles to the line of sight of the observer and from a posterior view, giving maximum depth to the epiphallal bridge. In the majority of cases the oval sclerite has been omitted. Where types have been examined this is indicated. Measurements (in mm), together with ranges and means are given for the material examined. Total length is measured from the tip of the vertex to the apex of the folded posterior femur.

Key to species of *Spathosternum* (males)

- 1 Fastigium of vertex with median dorsal carinulae present (Figs. 20-23) 2
 — Fastigium of vertex with median dorsal carinulae absent (Figs. 17-19) 5
 2(1) Tegmina fully-winged or brachypterous with (35-50) densely packed stridulatory veinlets (Figs. 42-43). Supra-anal plate comparatively large (Fig. 11), with median transverse groove. (Indo-Oriental) *S. prasiniferum*
 — Tegmina brachypterous or micropterous (Figs. 4-6). Stridulatory file present or absent, if present then vestigial and situated near apex of tegmen, usually with less than 30 stridulatory veinlets. Supra-anal plate comparatively small (Figs. 13-15), with or without median transverse groove. 3
 3(2) Stridulatory veinlets present. Apical penis valves broad with divergent apices (Fig. 53). (India) *S. abbreviatum*
 — Stridulatory veinlets absent. Apical penis valves slender with divergent apices (Fig. 60), or broad with sub-parallel apices (Fig. 112) 4
 4 Small micropterous species (Fig. 6). Supra-anal plate without median transverse groove (Fig. 14). Tegmina touching dorsally. Apical penis valves very slender with divergent tips (Fig. 60). (Angola) *S. curtum*.
 — Small micropterous species (Fig. 4). Supra-anal plate with weakly impressed median transverse groove (Fig. 15). Tegmina not touching dorsally. Tips of apical penis valves not divergent (Fig. 112). (Madagascar) *S. malagassum*
 5(1) Supra-anal plate trilobate with preapical teeth or projections (Fig. 9). (Africa, S. Arabia) *S. nigrotaeniatum*
 — Supra-anal plate not trilobate, preapical teeth or projections absent (Figs. 10-12) 6
 6(5) Supra-anal plate triangular with median transverse groove (Fig. 10). Fully winged or brachypterous species (Fig. 3). (W. Africa) *S. brevipenne*
 — Supra-anal plate parabolic or triangular without median transverse groove (Figs. 12, 16). Fully-winged or with slightly shortened wings (Figs. 66, 83). (Africa south of 15°N latitude) *S. pygmaeum*

Spathosternum Krauss, 1877

Spathosternum Krauss, 1877:45. Type species: *Tristria nigro-taeniata* Stål, 1876:233.

The genus *Spathosternum* forms a natural grouping of closely related taxa assigned to the subfamily Hemiacidinae. Within the confines of this somewhat heterogeneous assemblage of genera, *Spathosternum* can be readily differentiated by a combination of characters. These are the conical, opisthognathous shape of the head, the two distinctive sinuate facial carina, the shape of the prosternal process, the conspicuous longitudinal, lateral stripe markings and by the internal male genitalia. Brachypterous and micropterous species, notably *S. curtum*, *S. malagassum* and *S. abbreviatum*, can be separated from *Paraspathosternum*, which might be considered to be their nearest relative, by the shape of the fastigium verticis (Fig. 1), posterior margin of the pronotum and by the male genitalia (Figs. 51-52, 58-59). The female differs from the male in being larger and more robust.

Note that species in the genus display a widespread incidence of intra- and inter-population wing polymorphism, perhaps implying that many are in a state of active evolution towards flightlessness. This characteristic explains why earlier authors found it difficult to make precise species diagnoses based upon purely external morphology. The genus *Chrotogonus* presented similar problems to Kevan (1957, 1959).

Spathosternum nigrotaeniatum (Stål, 1876)

(Figs. 2, 9, 17, 31-32, 24-26, 27-30, 94, 64)

Tristria nigro-taeniata Stål, 1876:233. Holotype ♂, S.W. Africa, (NR) [examined].

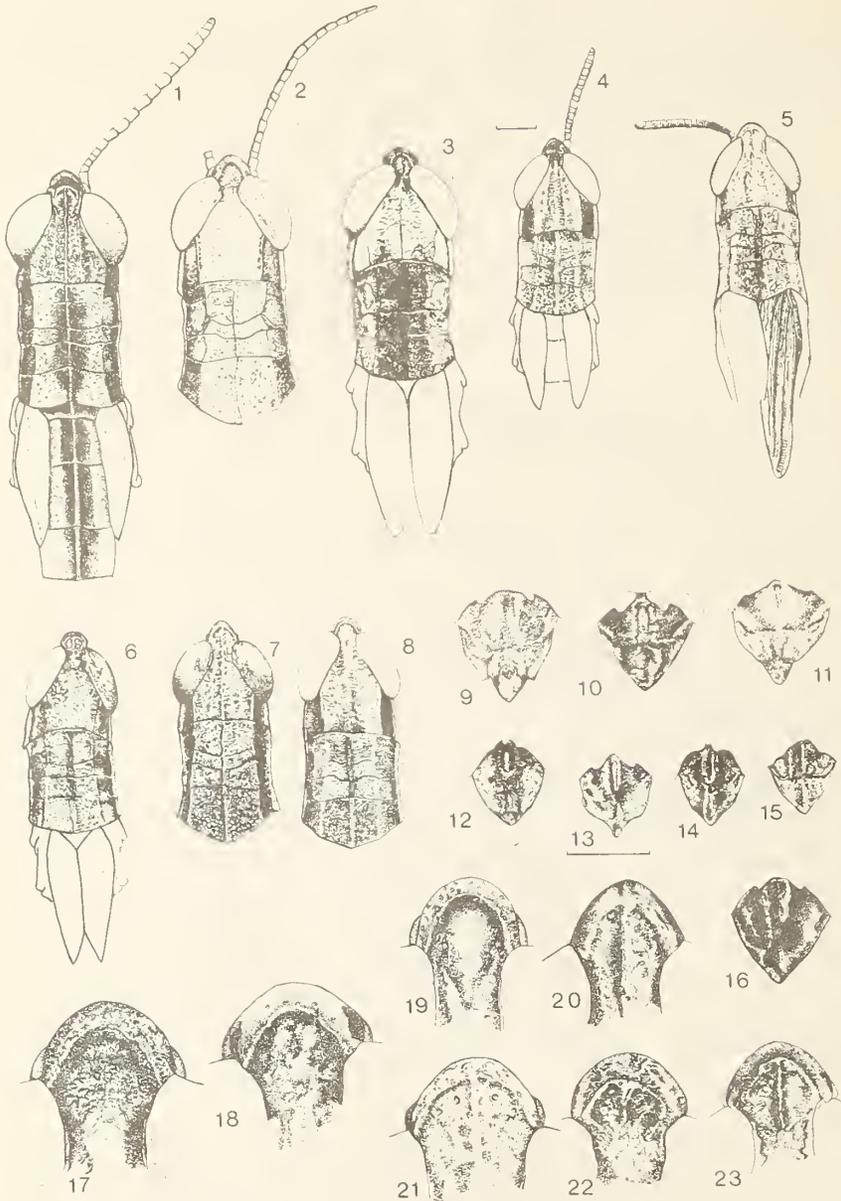
Spathosternum nigrotaeniatum (Stål) Krauss 1877:45

Diagnosis. Male. Small, integument very finely rugose, almost smooth. Head conical; fastigium of vertex (Fig. 17) parabolic, surface concave. Antennae filiform, shorter than head and pronotum together. Frons in profile strongly oblique; frontal ridge (Fig. 31) sulcate, marginal carina well developed, thickened, slightly narrowing below apex of vertex. Face with two distinct sinuate carinae. Eyes large, oval elongate. Dorsum of pronotum flattened; median dorsal pronotal carina well developed, sometimes intersected by second and third sulci, always intersected by principal sulcus; lateral pronotal carina (Fig. 2) becoming sinuate between second and principal sulci, slightly divergent posteriorly. Metazona shorter than prozona; posterior margin of pronotal disc obtuse-angulate. Lateral pronotal lobes more densely pitted in metazona than prozona, with two large smooth areas in upper part of prozona. Prosternal process (Fig. 32) shallowly bilobate, flattened, inclined backwards. Mesosternal interspace strongly constricted, with mesosternal lobes almost confluent, widening posteriorly. Tegmen fully developed, always surpassing apex of folded hind knees. Radian area of tegmen with series of regular parallel veinlets. Posterior femur of normal shape; external apical spine of hind tibia present. Supra-anal plate (Fig. 4) trilobate with pre-apical projections or teeth. Last abdominal tergite with pair of small, widely spaced projections. Subgenital plate obtusely conical. Cercus, unmodified simple, acute straight. Endophallus divided, with slightly elongate aedeagus. Apical penis valves protruding subapically beneath encircling cingular valves. Apices of apical penis valves narrow, divergent. Cingular valves viewed anterodorsally (Figs. 24-26) appearing as a thin membranous, sub-circular structure, forming sub-acute, inwardly curling, slightly thickened apices, flanked by lateral, inflated processes of cingular origin. Epiphallus (Figs. 27-30) bridge-shaped with median area of adjoining lateral plates less sclerotised, almost giving a divided-bridge appearance; oval sclerites present. Ventral edge of bridge forming a small, median, upcurved projection anteriorly. Ancorae small, down-curving with acute apices. Sides of epiphallus incurved. Lophi blunt, triangular, flat, slightly upcurved.

General colouration variable, often expressing green-brown polymorphism. Face light brown, stramineous or green. Dorsal surface of head, pronotum and tegmen same colour as face, or sometimes with darker medial area. A narrow, dark longitudinal stripe extends from below eye to coxae of middle legs, sometimes incomplete; above this a paler stripe extends to abdomen, marginated by a broad dark brown stripe, which continues from behind compound eye, across upper part of lateral pronotal lobes before merging with tegmen. Posterior femur light brown or dull yellow. Knee lunules dark brown. Posterior tibia light brown or grey yellow.

Female. Anterior margin of vertex rounded triangular. Supra-anal plate elongate, triangulate, with raised median ridge; shallowly sulcate along its length and bisected by a median transverse sulcus; pre-apical teeth absent. Spermatheca (Fig. 94) with apical diverticulum becoming bulbous distally, apex bent and obtusely rounded; preapical diverticulum in form of a slender tube expanded proximally.

General colouration green or brown with similar longitudinal lateral markings as male. Posterior femur uniformly green or brown, often showing light green on upper face.



Figs 1-23. *Paraspathosternum* and *Spathosternum* species.
 1, *Paraspathosternum pedestris*, dorsal aspect of male head and pronotum. 2-23, *Spathosternum* spp.
 2-8, 2, *nigrotaeniatum*; 3, *brevipenne*; 4, *malagassum*; 5, *abbreviatum*; 6, *curtum*; 7, *prasiniferum*; 8,
pygmaeum. Scale line represents 1mm. 9-16, *Spathosternum* spp., male supra-anal plates; 9,
nigrotaeniatum; 10, *brevipenne*; 11, *prasiniferum*; 12, *pygmaeum*; 13, *abbreviatum*; 14, *curtum*; 15,
malagassum; 16, *pygmaeum* (Dikwa, N. Nigeria). Scale line represents 1mm. and also applies to
 Figs. 17-23. 17-23, *Spathosternum* spp., dorsal aspect of male fastigium verticis; 17, *nigrotaeniatum*;
 18, *brevipenne*; 19, *pygmaeum*; 20, *abbreviatum*; 21, *prasiniferum*; 22, *curtum*, 23, *malagassum*.

TABLE 1. *Spathosternum nigrotaeniatum*: measurements.

	Males			Females		
	n.	mean	range	n	mean	range
Interocular distance	(29)	0.43	(0.21-0.64)	(24)	0.77	(0.60-0.95)
Head width	(29)	3.06	(2.60-3.35)	(24)	3.71	(3.21-4.58)
Pronotal width	(29)	2.88	(2.46-3.63)	(24)	3.64	(3.08-4.27)
Pronotal length	(29)	3.55	(2.97-4.23)	(24)	4.30	(3.69-4.84)
Posterior femur length	(29)	9.54	(8.40-11.46)	(23)	11.93	(9.73-13.93)
Posterior femur depth	(29)	2.26	(1.91-2.54)	(23)	2.60	(1.85-3.02)
Antennal length	(6)	7.91	(6.65-8.7)	(6)	7.13	(5.52-8.3)
Tegminal length	(23)	16.14	(12.83-20.33)	(24)	17.55	(12.34-21.77)
No. of stridulatory veinlets	(23)	17.08	(15-20)	(13)	17.92	(16-21)
Stridulatory file length	(23)	3.94	(3.18-5.27)	(13)	4.67	(4.01-6.28)
Total length	(29)	19.18	(16.33-22.18)	(18)	23.00	(19.19-26.54)

Discussion. Despite the highly variable nature of this species particularly in relation to tegminal length and epiphallal morphology (see figs. 27-30 for variation in epiphallus shape), it is nevertheless easily differentiated from all other members of the genus by the unique possession of preapical teeth or projections, which arise from the supra-anal plate.

Populations from West Africa, particularly the Sahelian region, are generally larger than their East African equivalents, which approach *pygmaeum* in size.

The available data on the life history, distribution, ecology and economic importance of this species have been reviewed elsewhere (Centre for Overseas Pest Research, 1982).

Type-material examined. Holotype ♂, S.W. AFRICA: Damaraland (NR)

Additional material examined. SAUDI ARABIA: 1♂, Asir, Wadi Jowra, 22-25.xii.1947 (Popov) (BMNH).

YEMEN ARAB REP.: 1♂, Suaid, nr. Beit el Fagih, 23-24.vi.1951 (Tillin) (BMNH). NIGER: 6♂, 5♀, Niamey, (Popov) (ODNRI). MALI: 3♂, 1♀ Diaferabé, i.1957 (Davey) (BMNH), 3♂, 2♀, Tilembeya, 10-12.xii.1956 (Popov) (ODNRI). GHANA: 1♂, 1♀, Elmina, 20.iii.1969 (Richards) (TDRI); 1♂, E. of Shai Hills, 19.xi.1961 (Jago) (BMNH); 1♂, Accra Plain, 23 km. W. of Accra, 18.x.1959 (Jago) (BMNH). NIGERIA: 1♂, Gadau, vi.1923 (Luxton & Lewis) (BMNH); 1♀, 50 km. S. of Bama, 14.xi.1970 (Popov) (ODNRI); 2♂, 2♀, Zaria, Samaru, IAR farm, 11-14.xi.1970 (Jago & Hollis) (ODNRI); 1♂, 1♀, Zaria, 4-14.ix.1970 (Popov) (ODNRI). ZAMBIA: 1♂, 1♀, Mweru-wa-Ntipa, Kangiri Plain, 23.x.1957 (Fitzgerald) (BMNH). REP. S. AFRICA: 1♂, Cape Prov., Queenstown, 16.1-10.ii.1923 (Turner) (BMNH).

Spathosternum abbreviatum Uvarov, 1929

(Figs. 5, 13, 20, 53-55, 56-57, 94, 64)

Spathosternum abbreviatum Uvarov, 1929:556. Holotype ♂, INDIA, (BMNH) [examined].

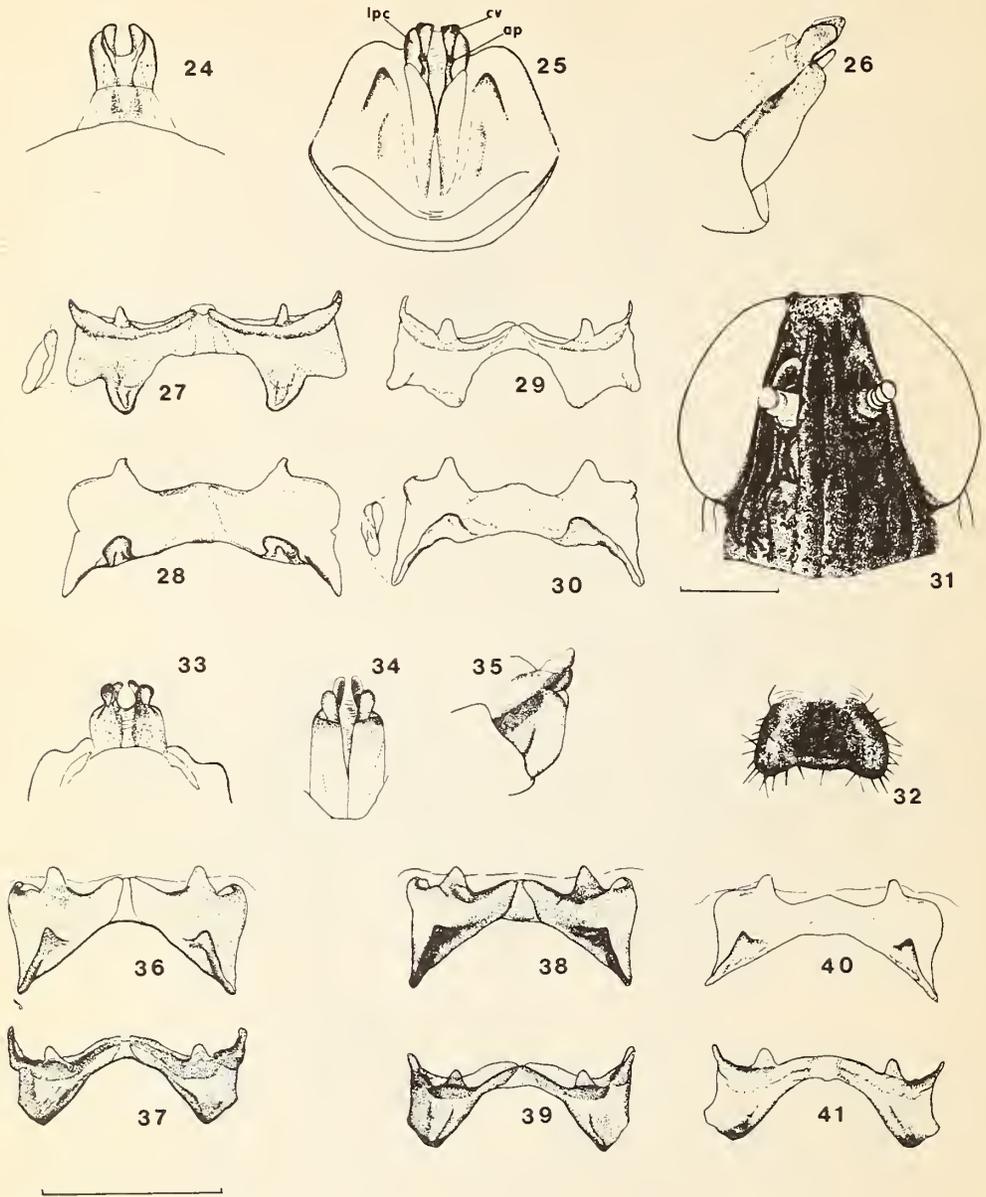
Spathosternum medium Uvarov, 1929:558. Holotype ♂, S. INDIA, Masinigudi, 900-1000m., dry bush, 29.i.1927. **Syn. nov.**

Diagnosis. Male. Antennae (Fig. 5) much shorter than combined length of head and pronotum together, thick, distally flattened and widened. Fastigium of vertex (Fig. 20) with concave surface, divided into two by median carinulae, similar to both *malagassum* and *curtum*. Pronotum relatively short, lateral pronotal carina almost straight; posterior margin of disc rounded, angular.

Tegmen shortened, reaching to middle of posterior femur; stridulatory veinlets vestigial, few in number, located toward apex of tegmen. Posterior femur short, stocky. Supra-anal plate (Fig. 13) with raised, median ridge, variably sulcate along its length; posterior margin forming small elongate apex, cuticular sculpture similar to that in *curtum*. Genitalia (Figs. 53-55) with apices of apical penis valves divergent, like those of *nigrotaeniatum* and *curtum*, but proportionally longer and broader. Inflated lateral processes of cingular valves showing distinctive spicule-like sclerotization. Epiphallus (Figs. 56-57) similar to that of *curtum*, but differing in having diminutive, knob-like lophi.

General colouration brown, with pale buff longitudinal lateral stripe; pattern typical for genus.

Female. Antennae somewhat shorter proportionally than in male. Supra-anal plate elongate, triangular.



Figs. 24-41, *Spathosternum* spp.

24-32, *S. nigrotaeniatum*. 24, male aedeagus, view from above; 25, same, posterior aspect; 26 same, lateral aspect; 27, male epiphallus, dorsal aspect; 28, same, posterior aspect; 29, same, showing variation in epiphallus shape, dorsal aspect; 30, same, posterior aspect; 31, frontal aspect of male head; 32, male prosternal tubercle. 33-41, *S. brevipenne*. 33, male aedeagus, view from above; 34, same, posterior aspect; 35, same, lateral aspect; 36, male epiphallus, shortened-wing form, posterior aspect; 37, same, dorsal aspect; 38, same, long-wing form, posterior aspect; 39, same, dorsal aspect; 40, same, brachypterous form, posterior aspect; 41, same, dorsal aspect. Scale line under Fig. 31 represents 1mm. Scale line under Fig. 37 represents 1mm and applies to all figs except fig. 31.

Spermatheca (Fig. 97) similar to that of *pygmaeum*, but without accessory vesicles of preapical diverticulum; apex of apical diverticulum more bulbous, otherwise like males.

TABLE 2. *Spathosternum abbreviatum*: measurements.

	Males		Females	
	n		n	
Interocular distance	(2)	0.40,0.51	(2)	0.85,0.84
Head width	(2)	2.13,2.27	(2)	2.75,2.83
Pronotal width	(2)	2.09,2.32	(2)	3.03,3.20
Pronotal length	(2)	2.26,2.38	(2)	2.93,3.09
Posterior femur length	(1)	6.44	(2)	7.13,8.61
Posterior femur depth	(1)	1.78	(2)	2.42,2.54
Antennal length	(1)	2.58	(1)	2.44
Tegminal length	(1)	4.10	(2)	5.01,5.44
No. of stridulatory veinlets	(1)	21	(1)	17
Stridulatory file length	(1)	1.38	(1)	1.40
Total length	(1)	12.27	(2)	15.05,16.29

Discussion. The affinity between African and Indian representatives is most clearly illustrated by this species, which is externally very similar to *curtum* and *malagassum* in appearance. Internally the aedeagus shares some characters with that of both *nigrotaeniatum* and *curtum*, such as the divergent apical penis valves (compare Figs. 25, 53 and 60).

In Uvarov (1929) a description of a new species *medium* was also given but unfortunately no mention of the intended depository for the type of this species was cited. As attempts to locate this type for further study have failed, this species has subsequently not been included in the key to species, although the existence of that description is acknowledged here. Curiously Uvarov (1953) made no mention of this species in his list of the species of *Spathosternum*. From Uvarov's description it can be gathered that *medium* appeared to be nearer to *prasiniferum* than to *abbreviatum*. The wings were shorter than *prasiniferum* but longer than *abbreviatum*; the hind femora were short and thick like *abbreviatum* and not thin like *prasiniferum*. It is deduced from the above that *medium* is probably a wing-polymorph of *abbreviatum*, and it is here synonymised.

Type material examined. Holotype ♂, INDIA: Nilgiris, Snowdon Peak (2426m), 6.IX.1917 (Rao) (BMNH), Paratypes, 1♂, 1♀, same data as holotype; 1♀, Nilgiris, Snowdon Peak (2500m), 2.X.1921 (Nathan) (BMNH).

Spathosternum brevipenne Chopard, 1958
(Figs. 3, 10, 18, 33-35, 36-41, 95, 64)

Spathosternum brevipenne Chopard, 1958: 131, Fig. 3. Holotype ♂, GUINEA, (MNH) [examined].
Spathosternum beninense Popov, 1980:45. Holotype ♂, BENIN (BMNH) [examined].

Diagnosis. Male. Antennae, about as long as head and pronotum together. Fastigium verticis (Fig. 18) parabolic, shallowly concave with moderately raised margins. Occiput, relatively convex. Prosternal process very broad, flat, weakly spatulate. Tegmen, shortened with wing tips just surpassing third abdominal tergite (Fig. 3), or fully developed with wing tips just reaching knee of folded hind femur. Last abdominal tergite with diminutive furculi. Supra-anal plate (Fig. 10), broadly triangular in outline with a median transverse sulcus. Genitalia (Figs. 33-35) with apices of penis valves expanded and divergent, showing spicule-like sclerotization, reminiscent to that of *abbreviatum*. Epiphallus (Figs. 36-41) similar in shape to *prasiniferum* but with ancorae more widely spaced and area of lophal interspace curvilinear.

General colouration brown, stramineous, with longitudinal lateral stripes typical of genus. Posterior femur uniformly brown yellow, with outer median area sometimes being more darkly expressed. Upper lobe of hind knee black; lower lobe without black, but sometimes tinged with red.

Female. Antennae, shorter than combined lengths of head and pronotum. Supra-anal plate more

elongate than male; projections of last abdominal tergite absent. Spermatheca (Fig. 95) with apical diverticulum tapering proximally and distally; preapical diverticulum expanded proximally, apex slightly inflated, otherwise like male.

TABLE 3. *Spathosternum: brevipenne* measurements

	Males			Females		
	n	mean	range	n	mean	range
Interocular distance	(8)	0.41	(0.37-0.45)	(3)	0.94	(0.81-1.05)
Head width	(8)	2.92	(2.80-3.05)	(3)	3.81	(3.65-3.89)
Pronotal length	(8)	3.12	(2.85-3.24)	(3)	4.10	(3.95-4.23)
Posterior femur length	(8)	8.92	(8.02-9.42)	(3)	12.12	(11.53-12.37)
Posterior femur depth	(7)	1.99	(1.76-2.09)	(3)	2.57	(2.38-2.39)
Antennal length	(4)	6.71	(5.37-7.7)	(1)	6.2	
Tegminal length	(5)	10.84	(8.92-13.47)	(3)	7.77	(5.59-11.63)
No. of stridulatory veinlets	(5)	21	(17-25)	(2)	18.5	(18-19)
Stridulatory file length	(5)	3.24	(2.62-3.86)	(2)	3	(2.74-3.24)
Total length	(7)	17.23	(15.53-18.18)	(3)	22.65	(22.02-23.03)

Discussion. The species *brevipenne*, originally described from brachypterous specimens, was found to be represented by a complex of wing polymorphic populations. A single long-winged male specimen found within a collection of material, lent by M. Donskoff (MNHN), had been previously identified by Dirsh (on external morphology) as *S. pygmaeum*. Subsequent examination of the genitalia has shown this specimen to be a long-winged variant of *brevipenne* (compare epiphalli Figs. 38-41). It is also of interest to note that this specimen was collected from Nimba, Guinea (Mt. Nimba being the type locality for *brevipenne*). The extreme brachypterous form may be associated with adaptation to montane conditions.

In addition, the recently described species *beninense* (Popov, 1980) was found also to be conspecific with *brevipenne*, this decision being based upon the following criteria; similarity in respective male genital morphology, similarity in shape and cuticular structure of the male supra-anal plates, both being broadly triangular, obtusely pointed with a transverse median sulcus. Other characters common to both include, the possession of two small projections on the last abdominal tergite and a similar red tinge of the posterior knee lunules. A further long-winged variant was collected by Popov and Jago from the Cameroons. The distribution of *brevipenne*, in the light of the above, is now known to be wider than was first thought.

The brachypterous form lacks stridulatory venation. It is not known whether the two forms have similar song or whether song is lacking in this morph. Nor is it known whether the faculty for song recognition has also been lost in brachypterous morphs. It is conceivable that the emission of song from a long-winged individual (still retaining stridulatory venation) could still initiate courtship with brachypterous females.

Type-material examined. *Spathosternum brevipenne* Chopard, holotype ♂, GUINEA: Mt. Nimba, Grand Nimba, 10.xi.1951 (*Lamotte & Roy*) (MNHN).

Spathosternum beninense Popov, holotype ♂, BENIN: Parakou, xii.1977-i.1978 (*Popov*) (BMNH). *Paratypes.* BENIN: 3♂, 2♀, same data as holotype, 1♂, 2, 15.i.1977 (*Popov & Fishpool*); 4♂, 3♀, 20 km. w. of Parakou, 25.xii.1977, (*Popov*). The male holotype, five males and five female paratypes in (BMNH); remaining paratypes in (ODNRI) collection.

Additional material examined. GUINEA: 1♂, 1♀, Nimba, xii.1956-v.1957p (*Lamotte, Amiet & Vanderplaetsen*) (BMNH); 1♂, Nimba 2.vi.1942 (*Lamotte*) (MNHN). CAMEROON: 1♂, 20 km. w. of Tibati, 20.xi.1980 (*Jago & Popov*) (ODNRI).

Spathosternum curtum Uvarov, 1953

(Figs. 6, 1, 22, 60-61, 99, 64)

Spathosternum curtum Uvarov 1953:66. Holotype ♂, ANGOLA (BMNH) ♂ [examined].

Diagnosis. Male. Antennae, shorter than head and pronotum together. Fastigium of vertex (Fig. 22) similar to those of *malagassum* and *abbreviatum*, but with apex more abtusedly rounded. Pronotum (Fig. 6) short with excurved posterior margin. Prosternal process broad, flat, weakly spatulate. Tegmen,

Discussion. In 1931, Uvarov differentiated *sinense* from *prasiniferum* on the basis of the former being larger, more robust and having abbreviated tegmina. Tinkham (1936) gave a vivid account of his encounters with wing-polymorphic populations of *sinense*, and concluded that the two species were in fact "races" (i.e. subspecies) of the same species. Examination of the male genitalia has shown that these wing-polymorphs are conspecific (compare *epiphalli* Figs. 44-47) and subspecies are not involved.

Apart from some slight variation in specimens collected from South East China, in which the lateral lophal margins were slightly indented (Fig. 44), respective aedeagi were the same.

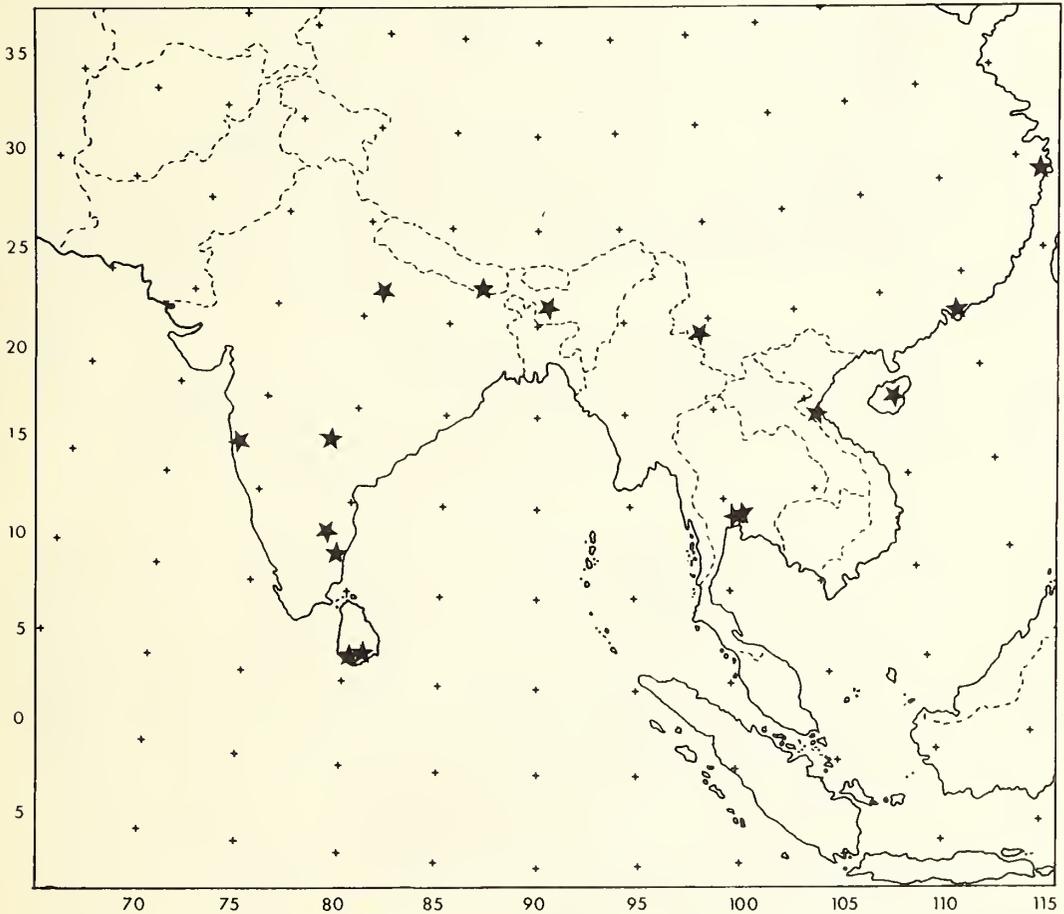


Fig. 65. Distribution of *S. prasiniferum* (stars)

Careful comparisons of the female holotype with all available females and sympatric males, formed the basis of the above diagnoses. The compact array of numerous, closely spaced, stridulatory veinlets, readily distinguishes this species from all other members of the genus.

The available data on the life history, distribution, ecology and economic importance of this species have been reviewed elsewhere (Centre for Overseas Pest Research, 1982).

Type material examined. *Spathosternum prasiniferum* Walker, holotype ♀, India: Bombay, no data (BMNH). *Caloptenus calliginosus* Walker, holotype ♂, no locality data, (BMNH). *Stenobothrus strigulatus* Walker, holotype ♀, India, Bombay, no data, (BMNH) (abdomen missing). *Stenobothrus*

simplex Walker, holotype ♀, India, Bombay, no data (BMNH). *Stenobothrus rectus* Walker, holotype ♀, no label data, (BMNH) (abdomen missing). *Spathosternum sinense* Uvarov, holotype ♀, China, Nainan Dao, S.W. of Dan Xian, 28.vi.1929 (*Hoffmann*) (BMNH).

Additional material examined. INDIA: 1♂, 1♀, Lucknow, 2.xii.1904 (*Brunetti*) (BMNH); 2♂, Assam, Kahao, Lonit Valley, 15-20.x.1926 (*Kingdon-Ward*) (BMNH); 1♂, N.E. Madras, lake Chilka, 4.iii.1910 (*Annandale*) (BMNH); 1♂, 2♀, Assam, Shillong, Khasi Hills, 20.ix.26 (*Sewell*) (BMNH); 2♂, Bihar Prov., Dusi (*Agaruala*) (BMNH); ♂, Madras, Coimbatore, vi.1967 (*Nathan*) (BMNH); 1♀, Pondicherry, St., Karika, xi.1966 (*Nathan*) (ODNRI); 2♂, 2♀, Andhra Pradesh, Patanchem, ICRISAT farm, viii.82 (*Bernays*) (ODNRI). NEPAL: 1♀, Taplejung Distr., forest above Sangu, 17.x-1.xi.1961 (*Coe*) (BMNH); 1♂, 1♀, Phewa Tal, nr. Pokhara, 10.v.1954 (*Quinlan*) (BMNH); 2♂, 2♀, Chitwan Nat. Park, Sauraka, viii-ix.1982 (*Feistner*) (BMNH). SRI LANKA: 1♂, Kalatuwawa, malaise trap, 7-8.viii.1975 (*Huang*) (ODNRI); 1♂, Gal Distr., Kanneliya, black light, 15-17.x.1976 (*Hevel*) (ODNRI); 2♂, 2♀, Maskeliya, S.W. of Hatton 18.iii.62 (*Brinck & Andersson*) (ODNRI); 1♀, China Bay, blacklight, 9-11.x.76 (*Hevel*) (ODNRI); 1♀, Denijaga, Forest, ii.1982 (*Helfert*) (BMNH). BURMA: 1♂, Bangkok, 1928 (*Hillman*) (BMNH); ♂, Wat Salak, Menam Chao, Phya, 21.vi.1926 (*Ladell*) (BMNH); 2♂, Ban Phu Khae, 6.vii.1968 (*Roffey*) (ODNRI). N. VIETNAM: 1♀, Annam, Phuc-Son, 1902 (*Fruhstorfer*) (BMNH). CHINA: 4♂, 4♀, S. Chekiang, Tien Tai Shan, 20.ix.1933 (*Chang*) (BMNH); 1♂, Yunnan, Tengyeh to Nan Tien, 1909-10 (*Brown*) (BMNH); 1♂, Kiangsu Prov., Ibing, 10.vii.33 (*Loubou*) (BMNH); ♀, Hainan Is., S.W. of Nodoo, 28.vi.1929 (*Hoffman*) (BMNH); 1♀, Canton, Honam Is., 27.ix.1931 (*Hoffman*) (BMNH).

Spathosternum pygmaeum Karsch, 1893

(Figs. 8, 12, 16, 69-89, 100-102, 103-107, 108-111, 114-115, 116)

Spathosternum pygmaeum Karsch, 1893:110. Holotype ♂, TOGO (MNHU) [examined].

Spathosternum pygmaeum rammei Roy, 1962: 120. Holotype ♀, BENIN (BNHN) [examined]. Syn. by Dirsh, 1970: 93.

Spathosternum brevicorne Uvarov, 1953: 64. Holotype ♂, UGANDA (BMNH) [examined]. **Syn. nov.**

Diagnosis. Male. Highly variable species, small to very small. Pronotum (Fig. 8), with angulate posterior margin, similar to *prasiniiferum*. Supra-anal plate (Figs. 12, 16) rounded, triangular in shape, bearing median longitudinal ridge, variably sulcate along its length, similar to *malagassum* but lacking median transverse sulcus; preapical teeth absent. Small projections of last abdominal tergite narrowly or widely spaced apart. Length of antennae variable (Figs. 103-107), never longer than combined length of head and pronotum together. Tegmen well developed or shortened (Figs. 71, 83). Genitalia (Figs. 108-111, 114-115) with aedeagus similar to that of *malagassum*, but differing from *nigrotaeniatum* in that apices of apical penis valves are broader and more parallel, and lateral inflated processes of cingular valves are absent. For variation in epiphallic morphology see Figs. 69-89.

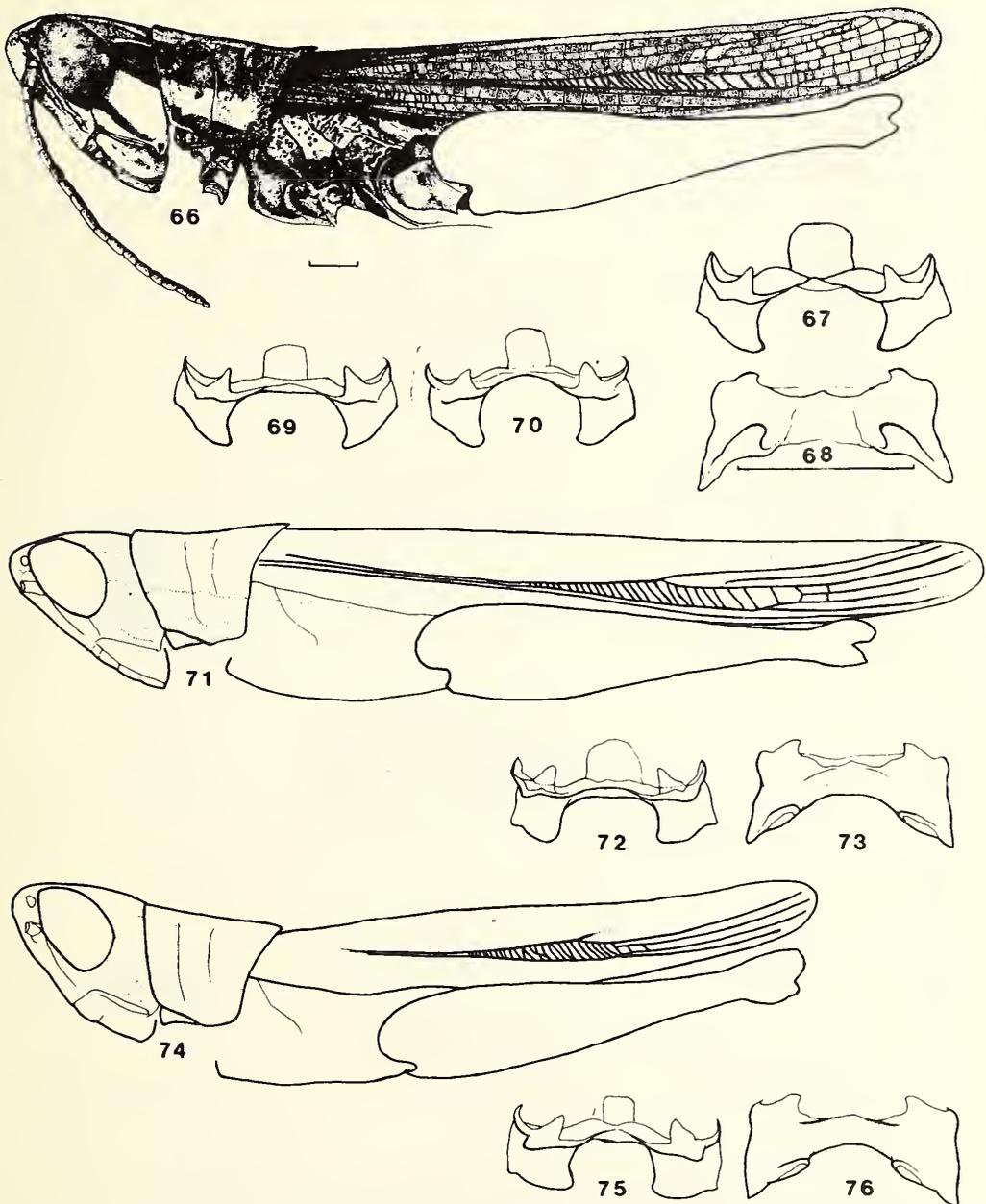
General colouration brown, longitudinal lateral stripe markings typical for genus. Posterior femur yellow or light brown; knee lunules usually dark brown on all surfaces.

Female. Like male but larger and more robust. Spermatheca (Figs. 100-102) with apical diverticulum tapering proximally and distally; preapical diverticulum with accessory vesicles arising proximally. Supra-anal plate similar to that of *nigrotaeniatum*.

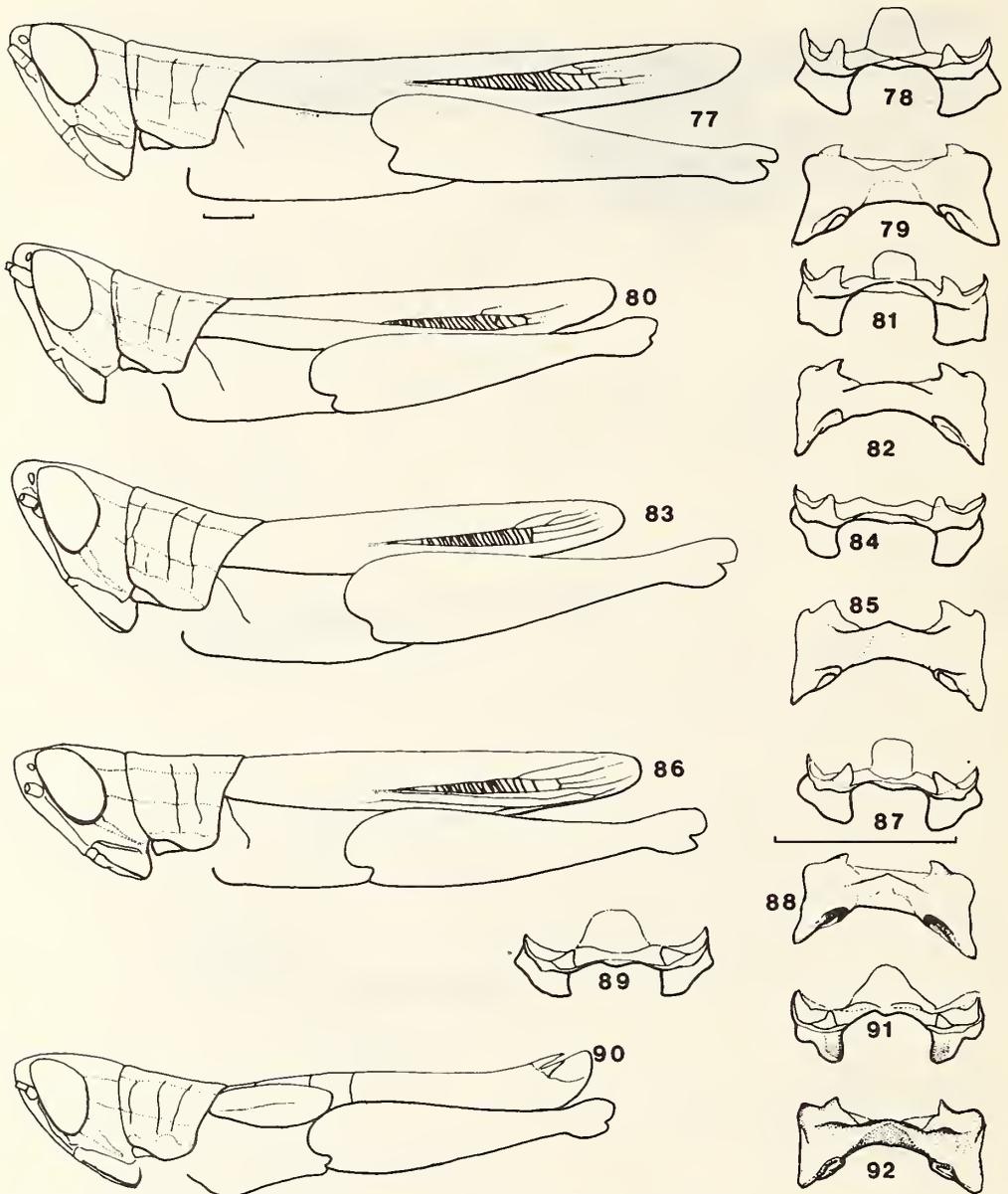
General colouration same as male. Tegmen sometimes with dispersed lighter markings in costal and radial area, similar to *prasiniiferum* but less obtrusive.

Discussion. During examination of material of *S. pygmaeum* and *S. brevicorne*, it became increasingly apparent that wing length was very variable. This suggested, as in the case of *brevipenne*, that *pygmaeum* was represented by a web of heterogeneous populations as collated in Figs. 66-89. By superimposing drawings of the male genitalia on the above figures, it can be seen that the aedeagal apparatus has remained relatively unchanged, while the epiphallus is variable. It is possible that the opposite ends of this range of variation are genetically incompatible and may represent subspecific groupings, but clearly more work with live material is needed.

Because of the highly variable nature of this species no one definitive character or combination of characters, apart from the size and shape of the epiphallus and supra-anal plate (in the case of populations from near Dikwa, N. Nigeria, see Figs. 16, 66-68) could be used successfully to differentiate between

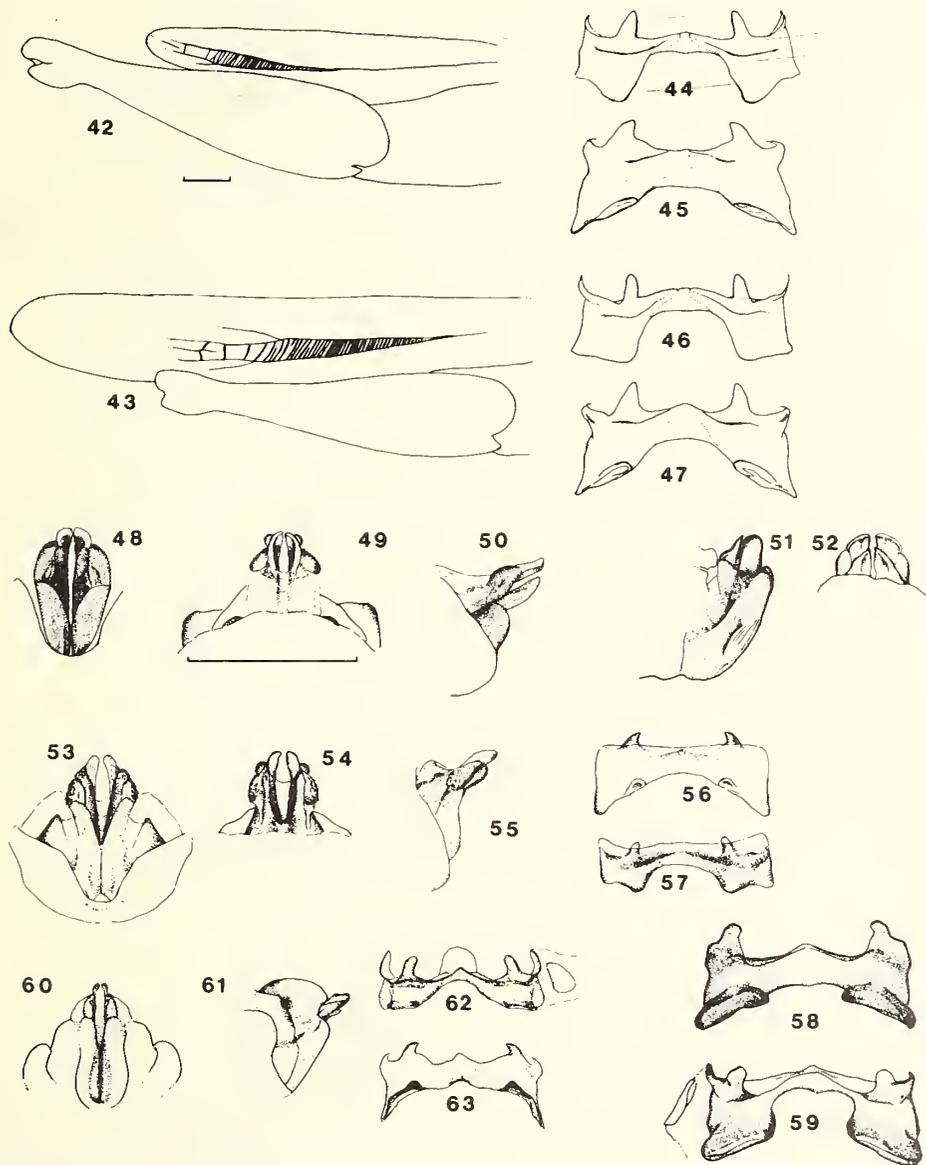


Figs. 66-76. *S. pygmaeum*. Wing polymorphic forms showing variation in epiphallus shape. 66, Dikwa, N. Nigeria, lateral aspect of male; 67, same, male epiphallus, dorsal aspect; 68, same, posterior aspect; 69, Budongo For. Res., Uganda, male epiphallus, dorsal aspect; 70, same, Yei, S. Sudan; 71, long wing form, lateral aspect of male; 72, same, male epiphallus, dorsal aspect; 73, same, posterior aspect; 74, Lateral aspect of male, Kandi, Benin; 75, same, male epiphallus, dorsal aspect; 76, same, posterior aspect. Scale line under Fig. 66 represents 1mm. and applies to Figs. 66, 71, 74. Scale line under Fig. 68 represents 1mm. and applies to Figs. 67-70, 72-73, 75-76.



Figs. 77-89. *S. pygmaeum*. Wing polymorphic forms showing variation in epiphallus shape. 77, Lateral aspect of male, Brazzaville, Congo; 78, same, male epiphallus, dorsal aspect; 79, same, posterior aspect; 80, lateral aspect of male, Maska, Nigeria; 81, same, male epiphallus, dorsal aspect; 82, same, posterior aspect; 83, short-wing form, Bugishu, Uganda, lateral aspect of male; 84, same, male epiphallus, dorsal aspect; 85, same, posterior aspect; 86, *brevicornis* syn.n., lateral aspect of male; 87, same, male epiphallus, dorsal aspect; 88, same, posterior aspect; 89, same, type species.

Figs. 90-92. *S. malagassum*. 90, lateral aspect of male; 91, male epiphallus, dorsal aspect; 92, same, posterior aspect. Scale line under Fig. 77 represents 1mm. and applies to all lateral aspect Figs. Scale line under Fig. 87 represents 1mm. and applies to all epiphallus Figs.



Figs. 42-63. *Spathosternum* spp. and *Paraspastosternum* sp.

42-50, *S. prasiniferum*. 42, lateral aspect of male tegmen, short-wing form; 43, same, long-wing form; 44, male epiphallus, short-wing form, dorsal aspect; 45, same, posterior aspect; 46, same, long-wing form, dorsal aspect; 47, same, posterior aspect; 48, male aedeagus, posterior aspect; 49, same, view from above; 50, same, lateral aspect. 51-52, *Paraspastosternum pedestris*. 51, male aedeagus, lateral aspect; 52, same, view from above; 53-57, *S. abbreviatum*. 53, male aedeagus, posterior aspect; 54, same, view from above; 55, same, lateral aspect; 56, male epiphallus, posterior aspect; 57, same, dorsal aspect. 58-59, *Paraspastosternum pedestris*. 58, male epiphallus, posterior aspect; 59, same, dorsal aspect. 60-63, *S. curtum*. 60, male aedeagus, posterior aspect; 61, same, lateral aspect; 62, male epiphallus, dorsal aspect; 63, same, posterior aspect. Scale line under Fig. 42 represents 1mm and applies to Figs. 42-43. Scale line under Fig. 49 represents 1mm and applies to Figs. 44-63.

shortened, just reaching beyond second abdominal tergite, overlapping dorsally in basal two thirds; stridulatory venation absent. Posterior femora short, stocky. Supra-anal plate (Fig. 14) similar to that of *pygmaeum*, but slightly more angular, elongate. Genitalia (Figs. 60-61) with apices of apical penis valves divergent, like those of *nigrogaeniatum* but considerably more slender. Inflated lateral processes of circular valves absent. Epiphallus as depicted in Figs. 62-63.

General colouration dark brown from above, with longitudinal lateral stripes typical for genus. Outer surface of posterior femur stramineous, with darker brown in median area.

Female. Like male but larger and more robust. Fastigium of vertex somewhat rounded, triangular in shape; median dorsal carinula present as in male. Spermatheca (Fig. 99) small with reduced preapical diverticulum, apex bulbous.

General colouration predominantly green and brown; from above, head, dorsum of pronotum and dorsal area of tegmen light green yellow. Longitudinal lateral stripe markings typical for genus.

TABLE 4. *Spathosternum curtum*: measurements

	Males		Females	
	n		n	
Introcular distance	(2)	0.28,0.4	(1)	0.60
Head width	(2)	2.21,2.31	(1)	2.79
Pronotal width	(2)	2.10,2.33	(1)	2.88
Pronotal length	(1)	2.64	(1)	2.99
Posterior femur length	(2)	6.95,7.39	(1)	8.89
Posterior femur depth	(2)	1.84,1.89	(1)	22.39
Antennal length	—	—	—	—
Tegminal length	(2)	3.14,3.45	(1)	3.20
No. of stridulatory veinlets		ABSENT		ABSENT
Stridulatory file length		—		—
Total length	(2)	13.30,14.21	(1)	16.17

Discussion. This species appears to be restricted in its distribution to the upland Moxico district of Angola. The type locality, River Munhango, was described by Malcolm Burr (1930) as a shallow depression in sandy forest, filled with bogs and uncommonly well watered. Such a scenario may favour the wing reduction seen in this species.

Type material examined. Holotype ♂, ANGOLA: Moxico District, R. Munhango, 10.viii.1927 (Burr) (BMNH). Paratypes, 1 ♀ (nymph), same data as holotype; 1 ♂, District of Bihé, Cohemba, 31.viii.1927 (Burr) (BMNH).

Spathosternum malagassum Dirsh, 1962
(Figs. 4, 15, 23, 64, 90, 91-92, 98, 112-113)

Spathosternum malagassum Dirsh, 1962-6:278. Holotype ♂, MADAGASCAR, (MNHN) [examined].

Diagnosis. **Male.** Antennae short, about as long as head, Fastigium of vertex (Fig. 23) with median dorsal carinulae. Pronotum short (Fig. 90), posterior margin of disc straight. Tegmen reduced to laterally lying scales reaching mid-way between second and third abdominal tergites; not touching dorsally (Fig. 4) stridulatory venation absent. Supra-anal plate (Fig. 15) similar in outline to that of *pygmaeum*; raised median ridge bisected by transverse median sulcus. Genitalia (Figs. 91-92, 112-113) see under discussion *pygmaeum* and *malagassum*.

General colouration brown with longitudinal lateral stripes typical for genus.

Female. Spermatheca (Fig. 98) with apical diverticulum bulbous, tapering distally and proximally; preapical diverticulum, slender, elongate. Otherwise similar to male.

General colouration similar to that of male.

Discussion. This species is found only in Madagascar, and generally resembles *S. curtum* in appearance, microptery and lack of stridula, but is closer to *pygmaeum* in the male genitalia, the only difference being the shape of the lophus and the outer lateral indentation of the lophal plate. The latter attribute is seen to become less distinct when variation is studied.

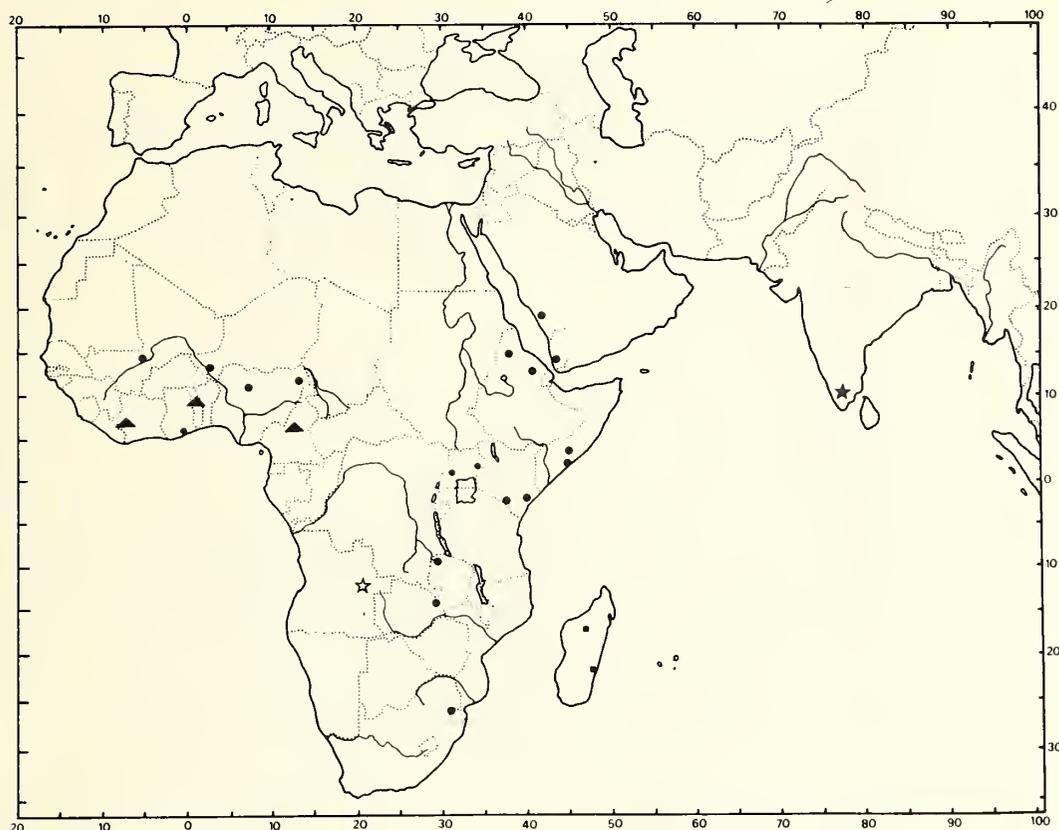


Fig. 64. Distribution of *Spathosternum* spp. circles, *nigrotaeniatum*; squares, *malagassum*; solid star, *abbreviatum*; triangles, *brevipenne*; open star, *curtum*.

TABLE 5. *Spathosternum malagassum*: measurements

	Males			Females	
	n	mean	range	n	
Interocular distance	(3)	0.41	(0.35-0.52)	(1)	0.85
Head width	(3)	2.23	(2.11-2.46)	(1)	3.31
Pronotal width	(3)	2.21	(2.02-2.39)	(1)	3.56
Pronotal length	(3)	2.33	(2.68-2.71)	(1)	3.45
Posterior femur length	(3)	6.68	(6.06-7.66)	(1)	9.43
Posterior femur depth	(3)	1.78	(1.56-2.08)	(1)	2.54
Antennal length	(2)	2.33, 2.78		(1)	2.59
Tegminal length	(3)	2.58	(2.21-3.05)	(1)	3.83
No. of stridulatory veinlets		ABSENT			ABSENT
Stridulatory file length		—			—
Total length	(3)	13.17	(11.99-14.86)	(1)	19.14

These similarities suggest that *malagassum* and *pygmaeum* are derived from a macropterous common ancestor.

Type material examined. Holotype ♂, MADAGASCAR: Ambohitantely For., 28.ii.1948 (*Cachan*) (MNHN). Paratype ♂, MADAGASCAR, Manankaka Inst.Sci.Statn., 6.ii.1948 (*Cachan*) (BMNH). *Additional material examined.* MADAGASCAR: 1♂, 1♀, Ankaratra (2400m), 4.vi.1967 (*Wintrebert*) (MNHN).

Spathosternum prasiniferum Walker, 1871

(Figs. 7, 21, 21, 42-43, 48-50, 65, 96)

Heteracris prasinifera Walker, 1871: 61. Holotype ♀, INDIA (BMNH) [examined].*Caloptenus caliginosus* Walker, 1871: 61. Holotype ♂, INDIA (BMNH) [examined].*Stenobothrus strigulatus* Walker, 1871: 82. Holotype ♀, INDIA (BMNH) [examined]. Synonymised under *caliginosus* by Walker, 1910: 400.*Stenobothrus simplex* Walker, 1871: 82. Holotype ♀, INDIA (BMNH) [examined].*Stenobothrus rectus* Walker, 1871: 83. Holotype ♀, no label data (BMNH) [examined].*Spathosternum venulosum* Stål, 1878: 97. Holotype ♀, INDIA (NR) (not located) Synonymised by Uvarov 1953: 63.*Phlaeoba simplex* (Walker) Kirby, 1910: 138.*Rodunia recta* (Walker) Kirby, 1910: 140.*Spathosternum caliginosum* (Walker) Kirby, 1910: 400.*Spathosternum prasiniferum* (Walker) Kirby, 1914: 208.*Spathosternum sinense* Uvarov, 1931: 220. Holotype ♀, CHINA (BMNH) [examined].*Spathosternum prasiniferum sinense* (Uvarov) Tinkham, 1936: 48. Holotype ♂, S. CHINA (Lingnan Nat. Hist. Mus.) (not located). **Syn.nov.***Spathosternum prasiniferum prasiniferum* (Walker) Tinkham, 1936: 51.

Diagnosis. Male. Fastigium of vertex (Fig. 21) with median carinula continuing faintly along dorsal surface of head. Pronotum (Fig. 7) with roundly arcuate posterior margin. Tegmen well developed or abbreviated, with numerous closely spaced, parallel, stridulatory veinlets in radial area (Figs. 42-43). Supra-anal plate (Fig. 11) broad; lateral margins broadly rounded forming two small lobes from which a small elongate, angular apex arises posteriorly; broadly raised median ridge bisected by transverse sulcus. Genitalia (Figs. 48-51) with broad, slightly excurved apical penis valves, similar to *pygmaeum*. Inflated lateral processes of cingular valves present. Epiphallus as depicted in Figs. 44-47.

General colouration brown with longitudinal lateral stripe markings showing a departure from usual pattern, where lighter stripe of lateral pronotal lobes continues more obliquely onto mesothorax, then sometimes forming a discrete oblique stripe down epimeron and episternum of mesothorax. Tegmen brown with radial area interspersed with lighter blotches. Posterior femur light brown or yellow, sometimes with darker outer median area.

Female. Like male but larger and more robust. Supra-anal plate elongate, triangular, apex obtuse with a transverse median sulcus. Spermatheca (Fig. 96) similar to that of *brevipenne* and *nigrotaeniatum*.

General colouration, variable, predominantly green and brown. Viewed from above, head, dorsum of pronotum and dorsal field of tegmen green or brown, delineated by a thin brown line running from behind eye and continuing to run along lateral pronotal carina, before merging with brown lateral field of tegmen; radial area expressing similar markings to that of male. Postocular area and lateral pronotal lobes green or light brown, interspersed by a longitudinal white or buff stripe which extends from behind eye to coxae of middle legs, marginated below by a darker brown stripe. Pleura light brown, yellow, marginated above by a black stripe confined to leading edge of tegmen, in thoracic region; corresponding oblique markings of males are less obviously portrayed, or sometimes merge with pleural coloration.

TABLE 6. *Spathosternum prasiniferum*: measurements

	Males			Females		
	n	mean	range	n	mean	range
Interocular distance	(18)	0.51	(0.44-0.64)	(12)	0.79	(0.75-1.00)
Head width	(18)	2.65	(2.26-2.97)	(12)	3.33	(2.92-4.12)
Pronotal width	(18)	2.61	(2.31-2.87)	(12)	3.41	(2.94-3.64)
Pronotal length	(17)	3.13	(2.55-3.93)	(12)	3.81	(3.28-4.44)
Posterior femur length	(18)	8.29	(7.22-8.80)	(12)	10.48	(9.23-12.74)
Posterior femur depth	(18)	2.06	(1.81-2.26)	(12)	2.50	(2.31-2.70)
Antennal length	(4)	5.01	(4.3-5.8)	(6)	4.83	(4.6-5.2)
Tegminal length	(12)	10.71	(7.48-13.13)	(9)	12.79	(8.82-14.44)
No. of stridulatory veinlets	(12)	41.58	(35-53)	(9)	44.33	(35-52)
Stridulatory file length	(12)	3.25	(2.10-3.88)	(9)	4.49	(3.07-5.64)
Total length	(18)	16.10	(14.33-17.61)	(12)	20.10	(17.57-25.18)

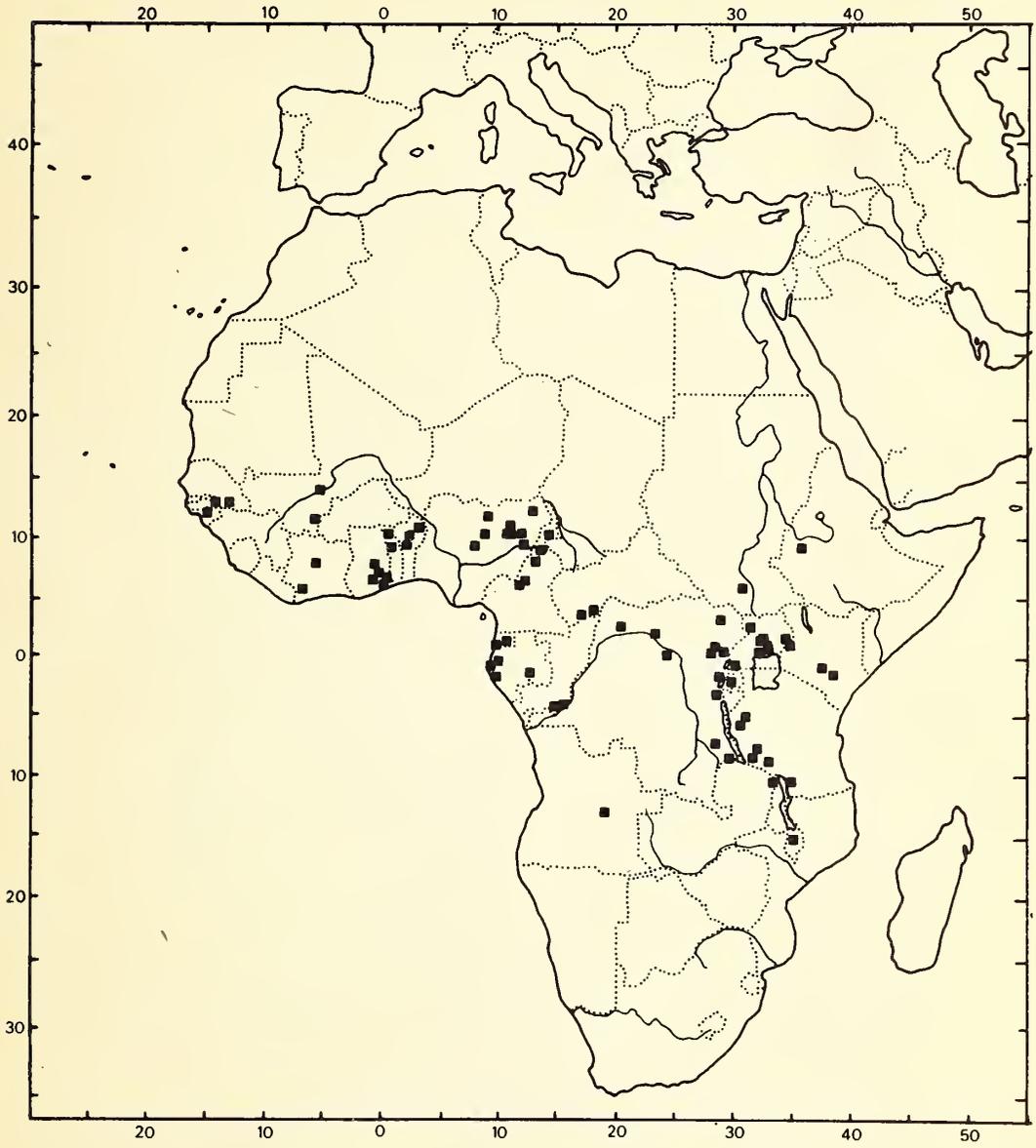
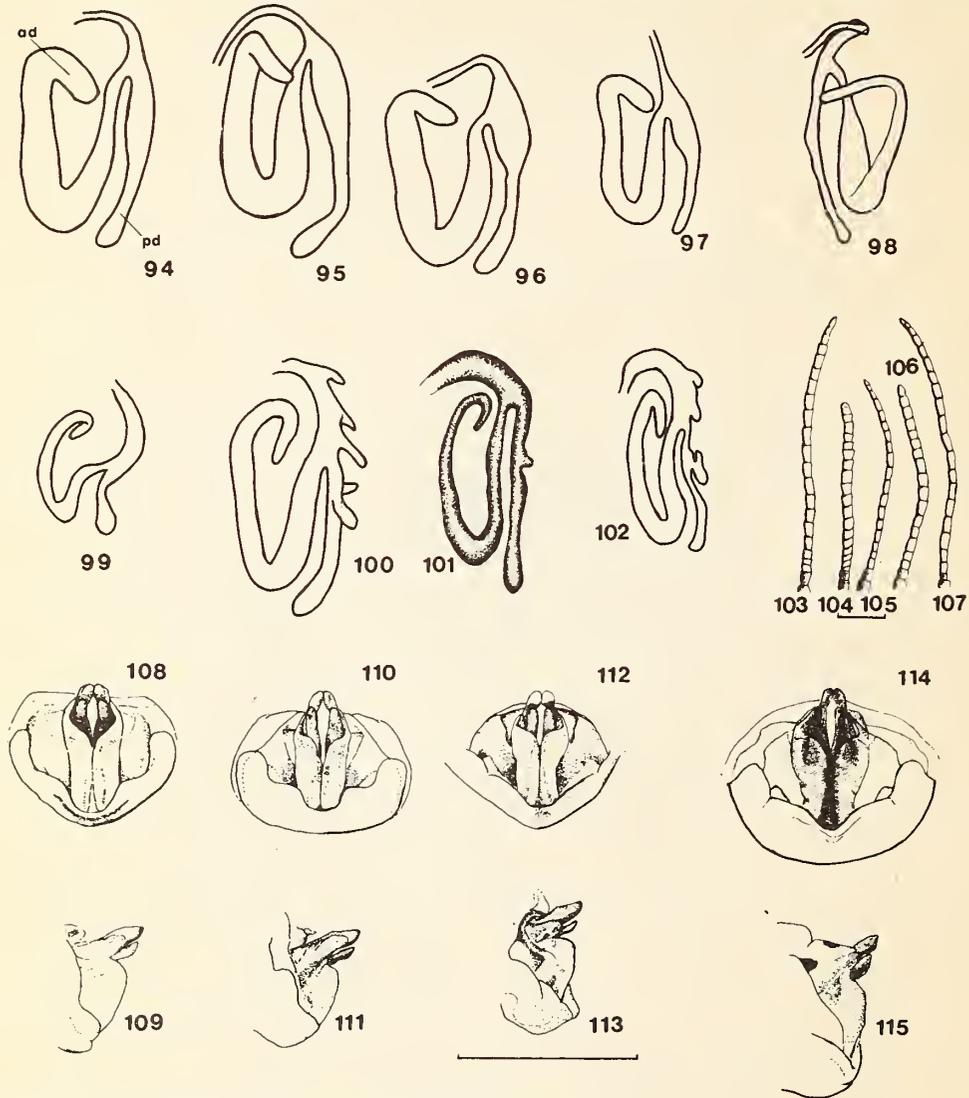


Fig. 93. Distribution of *S. pygmaeum* (squares)

brevicorne and *pygmaeum* on external morphology alone. In overall size *pygmaeum* was generally larger than *brevicorne*, but this alone offered no measure of guarantee, as overlap in size was commonly encountered. For these reasons *brevicorne* is here synonymised under *S. pygmaeum*.



Figs. 94-115. *Spathosternum* spp. 94-102, female spermatheca.

94, *nigrotaeniatum*; 95, *brevipenne*; 96, *prasinferum*; 97, *abbreviatum*; 98, *malagassum*, 99, *curtum*; 100, *pygmaeum*, Dikwa, N. Nigéria; 101, *pygmaeum*, Maska, Nigeria; 102, *brevicorne* syn.n. 103-107, *S. pygmaeum*, male antennae. 103, long-wing form; 104, short-wing form, Bugishu, Uganda; 105, Maska, Nigeria; 106, *brevicorne* syn.n.; 107, Kandi, Benin. 108-115, *Spathosternum* spp., male aedeagus. 108, *pygmaeum*, posterior aspect; 109, same, lateral aspect; 110, *brevicorne* syn.n, posterior aspect; 109, same, lateral aspect; 111, *brevicorne* syn.n, posterior aspect; 109, same, lateral aspect; 112, *S. malagassum*, posterior aspect; 113, same, lateral aspect; 114, *pygmaeum*, Dikwa, N. Nigeria, posterior aspect; 115, same, lateral aspect. All scale lines represent 1mm, that under Figs. 103-107 applies only to those figures.

In 1970, Dirsh synonymised the subspecies *pygmaeum rammei* (Roy, 1962), which differed principally in having longer wings than the nominate subspecies (see Fig. 71), and concluded that the long-winged form represented one of the variants of this species appearing in certain ecological conditions. This view is reaffirmed by the present study. In West Africa, the long-winged form appears to be fairly wide ranging and is commonly found in association with water courses and seasonally flooded grasslands in the South Sudanian zone and interzone between the Sudan and Guinea savanna. It likely that increased flight capacity has been necessary as a response to the climatic fluctuations of this region, enabling dispersion and colonisation of more favourable habitats.

The moist woodland biotype of the Guinea savannah is preferred by the more sedentary shorter-winged form, where it is commonly found around marshes (Golding, 1948), flood plains, and along edges of creeks in *Cynodon—Chloris* associations (Davey et al, 1959). Chapman (1962) also noted the presence of both long- and short-winged populations in Ghana. More recently Popov (1980) reported that *beninense* (here synonymised with *brevipenne*) was sympatric with the longer-winged form in two localities near Parakou, Benin. The former appeared to be restricted to the wettest region of the habitat.

The available data on the life history, distribution, ecology and economic importance of this species have been reviewed elsewhere (Centre for Overseas Pest Research, 1982).

Type material examined. *Spathosternum pygmaeum* Karsch, holotype ♂, TOGO: Bismarckburg (MNHU). *Spathosternum pygmaeum rammei* Roy, holotype ♀, BENIN: Kouand», cercle de Djougou, 1908 (*Brot*) (MNHN). *Spathosternum brevicorne* Uvarov, holotype ♂, UGANDA, Kepeka, 2-5.vii.1933 (*Johnston*) (BMNH). Paratypes. UGANDA: 2♂, same data as holotype (BMNH); 2♀, Bugoma For., vi.1933 (*Johnston*) (BMNH); 1♂, Hoima, 14.vi.1933 (*Johnston*) (BMNH); 3♂, R. Kizibiki, 4.vii.1933 (*Johnston*) (BMNH); 1♂, Bombo, 26.iii.1933 (*Johnston*) (BMNH).

Additional material examined. SENEGAL: 1♂, Diebering, 1-9.ix.62 (*Farrow*) (MNHN); 1♂, 2♀, Tabi, Signona, 12.xi.1961, IFAN (MNHN). MALI: 3♂, 6♀, Sikasso, Klela, 21.x.1963 (*Descamps*) (MNHN); 2♂, 2♀, Diarafab», i.1959 (Davey) (BMNH). IVORY COAST: 2♂, 3♀, Tai, 20.ii.1979 (*Couturier*) (MNHU). GHANA: 1♂, 1♀, Legon, 9-12.iii.1969 (*Richards*) (ODNRI); 3♂, 1♀, Bunru, forest clearing, 24.iii.1969 (Richards) (ODNRI); 1♀, Atewa, 20.ii.1969 (*Richards*) (ODNRI); 1♂, Yeji, 27.iii.69 (*Norris*) (ODNRI); 1♂, 2♀, Ankasa For. Res., 8-9.iv.1969 (*Richards*) (ODNRI); 1♀, Akosombo, 25.i.1969 (*Richards*) (ODNRI). TOGO: 2♂, 5km of S. of Lama-Kara, 13.6.79 (*Cheke*) (ODNRI). REP. BENIN: 1♂, Malanville, 25.ix.1983 (*Popov*) (ODNRI); 10♂, 4♀, Parakou, 13.1.1977 (*Popov*) (ODNRI); 1♂, 1♀, Birni (*Popov*) (ODNRI); 4♂, 2♀, Kandi, 12.i.1977 (*Popov*) (ODNRI). NIGERIA: 1♂, 1♀, L. Alo nr. Maiduguri, ii.xi.1970 (*Popov*) (ODNRI); 1♂, Deba Habe, nr. Gombe, 23-30.x.1970 (*Popov*) (ODNRI); 2♂, 4♀, nr. Yola, 17.x.1970 (*Popov*) (ODNRI); 2♂, 2♀, Gombe 17-25.x.1970 (*Popov*) (ODNRI); 1♂, 1♀, Zaria, Samaru, 20.vii.1970 (*Oyidi*) (ODNRI); 2♂, 1♀, Zaria, Samaru, IAR farm, 11-14.xi.1970 (*Jago & Hollis*) (ODNRI); 10♂, 3♀, Maska fish farm, 15.xi.1970 (*Jago & Hollis*) (ODNRI); 6♂, 6♀, Maska fish farm, 6.xii.1970 (*Popov & Hollis*) (ODNRI); 1♂, Zambuk, 21.ix.1970 (*Popov*) (ODNRI); 1♀, Bauchi, airstrip, 8-19.xi.1970 (*Jago & Hollis*) (ODNRI); 1♀, Shika, IAR farm, 16.xi.1970 (*Jago & Hollis*) (ODNRI); 4♂, 8♀, 4.3 km J.E. of Dikwa, 4.x.71 (*Jago*) (BMNH); 1♂, 2.4 km S.W. of Aliyas market, 17-8 km S.E. of Mongonu, 27.ix.71 (*Jago*) (ODNRI); 3♀, 4.3 km N.E. of Dikwa, 4.x.71 (*Jago*) (TDR); 2♀, 5.5km W. of Gulumba, 9.x.71 (*Jago*) (BMNH); 3♀, 4.3km N.E. of Dikwa, 4.x.71 (*Jago*) (BMNH). CAMEROON: 4♀, 20km W. of Tibati, 20.xi.1980 (*Jago & Popov*) (ODNRI); 3♂, 3♀, 31km N.W. of Bongo, 10.xi.1980 (*Jago & Popov*) (ODNRI); 6♂, 6♀, Mamydu, in forest, 19.ix.65 (*Poole*) (ODNRI); 1♂, 24.2km Bango to Tibati, 19.xi.1980 (*Jago & Popov*) (ODNRI); 1♂, Mayo Taram, 11.29km S. of Bango, 17.xi.1980 (*Jago & Popov*) (ODNRI); 1♀, 27.4km N.W. of Bango, 18.xi.1980 (*Jago & Popov*) (ODNRI); 1♂, Kalfou, Yagoua to Garoua Rd., 11.xi.1980 (*Jago & Popov*); 41♂, 4♀, 32.2km S. of Garoua, Caroua-Yola rd., 27.xi.1980 (*Jago & Popov*) (ODNRI); 2♀, above Wak Plateaux on Garoua-Ngaoundere rd., 14.xi.1980 (*Jago & Popov*) (TDR). REP. CEN. AFRICA: 2♂, 2♀, Bangui, 23km rd. to Damara, 20-28.ix.1963 (*Pajol*) (MNHN); 2♀, la Maboke, xii.1968 (*Teocchi*) (MNHN). GABON: 4♂, 4♀, Komo, 1-15.x.1969 (*Villiers*) (MNHU); 1♀, Franceville, 17.vi.1974 (*Donskoff & Breton*) (MNHN); 2♂, 3♀, Muni, 15-31.x.1969 (*Villiers*) (MNHN). ZAIRE 2♂, 2♀, Yalikanda, 20.ii.1971 (*Isy-Schwartz*) (MNHN); 2♂, 2♀, Ekoli, 22.11.1971 (*Isy-Schwartz*) (MNHN); 2♂, Epulu, 28-29.i.1971 (*Isy-Schwartz*) (MNHN); 2♂, 2♀, Lisala, 25.i.1971 (*Isy-Schwartz*) (MNHU); 2♂, 2♀, Ruzizi, 20km S. of Bukavu, 16.iii.1971 (*Isy-Schwartz*) (MNHN); 2♀, Pweto, 23.iii.1971 (*Isy-Schwartz*) (MNHN);

2♂, 2♀, Kisangani, 19.ii.1971 (*Isy-Schwartz*) (MNHN); 1♂, Kahuzi-Biega Nat. Park, 16.iii.1971 (*Isy-Schwartz*) (MNHN); 1♂, Kinshasa, i.1971 (*Isy-Schwartz*) (MNHN); 2♂, Ngoma, nr. L. Kivu 2-6-ii.63 (*Damas*) (MNHN). RWANDA: 2♂, 2♀, Kigali (1400m), 21-24.ix.1957 (*Heintz*) (MNHN); 4♂, 6♀, Astrida (1700m), ix-x.1957 (*Heintz*) (MNHN); 1♀, Chyanika, 170km N.W. of Astrida (2000m), 10-x.1957 (*Heintz*) (MNHN); 1♂, ♀, Chapelle a la Vierge 30km N. of rd. Kisengi-Kibuge (2000m), 15.x.1957 (*Heintz*) (MNHN). S. SUDAN: 2♂, ♀, Yei, 1.iv.1963 (*Carter*) (ODNRI). ETHIOPIA: 1♂, ♀, 6.4 km of Ghimbi, 1935m., 16.ix.76 (*Jago*) (ODNRI). UGANDA: 1♂, Bunyoro, W. of Masindi, Budongo For. Res., 25-27.viii.1964 (*Jago*) (ODNRI); 1♂, Kigezi, Mafuga For. Res., 3.ix.64 (*Jago*) (ODNRI); 5♂, ♀, Bugisu, Mt. Elgon, 22.viii.1964 (*Jago*) (ODNRI); 2♂, ♀, Kigezi, 25.8km Kabale-Kisoro rd., 4.ix.64 (*Jago*) (ODNRI); 4♂, ♀, W. of Mt. Elgon, abv. Bumafwa For. Res., 22.viii.1964 (*Jago*) (ODNRI); KENYA: 2♂, 5♀, Kitito coffee estate, (1500), 30.v.1975 (*Robertson*) (ODNRI); 15♂, 14♀, Nendugai (1500m), 24.iii.1975 (*Robertson*) (ODNRI); 3♂, Kakamega For. Res., 13.12.1969 (*Brown*) (ODNRI). TANZANIA: 2♂, 3♀, Tabora region, Usinge, 4.viii.1973 (*Tunstall*) (ODNRI); 2♀, 33.6km. S. of Kisulu, 8km E. of main rd., 19.ix.1964 (*Jago*) (ODNRI); 1♂, 4♀, Ufipa plateau 25.6 km NNW of Sumbawanga, 16-27.v.1966 (*Jago*) (ODNRI); 2♀, Tukugu, ix.1923 (*Miller*) (BMNH). ANGOLA: 2♂, ♀, Moxico Distr., Villa Luso, 8.vi.1927 (*Burr*) (BMNH). N ZAMBIA: 4♂, Mbala, L. Chila, 5.i.1952 (*Backlund*) (BMNH), 5♂, Mbala, 16-18.v.1960 (*Jago*) (ODNRI). MALAWI: 2♀, Zomba, 25.xii.74 (ODNRI), 1♂, Nkata Bay, 21.2.61 (*Fitzgerald*) (BMNH).

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THE DISTRIBUTION OF SKATES AND RAYS
ALONG THE KENYAN COAST

By
Peter B.O. Ochumba*

ABSTRACT

The distribution, abundance, reproductive biology and the economic importance of skates and rays along the Kenyan Coast was studied between January 1980 and December 1981. The common species described in this paper are *Raja miraletus*, *Taeniura lymna*, *Myliobatis aquila*, *Dasyatis thetidis*, *D. uarnak* and *D. sephen*. These fish were present throughout the year with increased catches being realised in August, December and March. The size distribution of each fish is described. Linear regression analysis of the length/weight relationship for all the species indicate allometric growth. *Raja miraletus*, *D. thetidis* and *D. uarnak* exhibit sexual dimorphism. All fish, except *Manta birostris*, are carnivorous, feeding on crustaceans, molluscs and fishes. The distribution of skates and rays is discussed with reference to depth, temperature, salinity and the monsoonal phenomena. Temperature changes and low salinity water during the rainy season may act as a trigger mechanism for spawning.

INTRODUCTION

Total landings of elasmobranchs was 46.7 tonnes, about 1% of the total marine fish landings of 4,336 tonnes in 1979 (Kenya Fisheries Department Annual Report 1979). These fishes are caught at numerous points along our coastline (Fig. 1) by fishermen using small and big sized canoes, sail and engine dhows and trawlers. Fishing gear consists of handlines, gillnets, trammel nets and trawlnets. The fish have been exploited for the Vitamin A content of their livers. They yield excellent leather, polishing agents, marketable flesh for human consumption and their fins are used in combs and Chinese cookery. Skates and rays have an evil reputation among fishermen because of their poisonous serrated tail spines and electric shocks that may be received by touching (Ochumba 1984). The meat of the pectoral fins or wings of these fishes is considered a delicacy among the Kenyan coastal people. Demand for such species depends upon a combination of factors, of which the most important are size and ease of skinning or winging the pectoral fins before they are marketed (Grzimek 1973, Holden 1978). Although skates and rays are regularly taken in bottom trawls, they form a small proportion (less than 10%) of the total catch by commercial trawlers. Their landed weight has shown an increment recently (Fig. 2).

*Present Address: Kenya Marine and Fisheries Research Institute
Kisumu Laboratory, P.O. Box 1881,
Kisumu, Kenya.

Skates and Rays belong to the Suborder Batoidei and are flattened dorso-ventrally, with pectoral fins united to the sides of the head. Incomplete fusion of the pectoral fins and abnormality has been observed by Chhapgar (1964). Skates are oviparous (Clark 1922) and the eggs are enclosed in a rectangular horny capsule. Holden (1975) observed that skates are serial spawners. The number of eggs laid by a mature female is over 140 per year. Rays are ovoviviparous, that is, eggs are produced which are hatched internally. Daiber and Booth (1960) found that the left ovaries of some rays were larger than those on the right. Males are considered to be mature when the claspers are fully grown, with the clasper cartilages rigid from calcification. Signs of maturity in females are distinct ova in the ovary, and expansion of the uteri to form loose sacs rather than thin, tight-walled tubes. Copulatory activity can be inferred from the evidence of clasper wounds in the cloaca of females. Sexual dimorphism has been observed by Darracott (1977) in some rays along the East African coast. Skates and dasyatid rays are carnivorous, while the manta ray is adapted to filter feeding on small fishes and planktonic crustaceans taken into the mouth and strained out of the water by means of a specialized branchial apparatus.

The common species during the period of study were: *Raja miraletus* (Blue Eye skate), *Taeniura lymna* (Ribbontail Ray), *Myliobatis aquila* (Duckbill Ray), *Dasyatis thetidis* (Thorntail Ray) and *Dasyatis uarnak* (Feathertail Ray). The major problem in assessing fisheries for skates and rays is that they are often grouped as a mixture of species or just labelled elasmobranchs which are not differentiated in the fishery statistics reports. The objectives of the study were three-fold. First, to identify the skates and rays found along the Kenyan coast. Secondly, to study their reproduction, distribution and abundance, and length/weight relationships. Thirdly, to estimate the biomass and to determine their economic importance.

PHYSICAL ENVIRONMENT OF THE STUDY AREA

The Kenyan coastline (Fig. 1) extends from 1° 30' S to 4° 30' S and is characterized by the presence of fringing coral reefs distributed at depths between 16 - 40 metres. The coastline is very irregular, indented and fronted by several islands of which the larger are in the northern part: Lamu, Manda, Pate and Kiwayu. Mombasa and Funzi Islands are found on the southern coast. The coastline including islands is 880 km long (Coppola 1982) and is broken by the rivers discharging into the Indian Ocean at Vanga, Mombasa, Mtwapa, Mida creek, the Sabaki Rivermouth, the Tana River and the extensive islands of the Lamu Archipelago. The continental shelf in many places along the coast is less than 4 km wide. The Kenyan waters can be divided into 4 parts. The North Kenyan Bank has a rocky bottom with soft corals and sponges. Off Ungama Bay the bottom is mostly sandy and muddy, and the area supports a good fishery (Nzioka 1982). The Malindi Bank area has hard corals and the area between Malindi Bank and Funzi is rocky and muddy.

The dominant feature of the surface currents in the Western Indian Ocean is the seasonal reversal of winds due to the monsoonal atmospheric circulation. The seasonal variation of the monsoonal wind currents (Duing 1970) are the South West Monsoonal (April - October) when the wind velocities exceed 20 ms⁻¹ and the current speeds 200 cm s⁻¹ and the North West Monsoon (November - February) when circulation is generally weaker than the SW monsoon. The intermonsoon period is generally characterized by dry weather. The main current off the Kenya coast is the East African Coastal Current (EACC), which flows northward and parallel to the coast

and is generally poor in nutrients (Birkett 1979). This current, which originates as a branch of the South Equatorial Current (SEC), is 200 km wide and 100 m in depth. During the Southern Monsoon, winds flow northward reinforce the EACC which then flows as a swift current crossing the equator to merge with the Somali Current. During the Northeast monsoon, the wind system blows southward against the EACC.

The water-mass distributions beneath the East African Coastal Current (Williams 1963, Warren et al. 1966, Quadfasel and Schott 1982) are summarised in Fig. 3 for depths where offshore trawls were made. The characteristics of these water masses may determine the depth distribution of rays and skates. Thermocline migration during the onset of the SW monsoon occurs at depths between 40-150m. Water temperatures along the Kenyan coast reach a surface maximum between 29.5 - 30.5° C (range 4.5 - 30.5° C); salinity 34.2 - 35.5‰ and dissolved oxygen 0.01 - 4.0 mL.L⁻¹. The North Kenyan Banks form a topographic barrier that deflects the East African Coastal Current seaward causing localised upwellings. The nutrient rich waters in the upwelling areas have pronounced effects on the food chain dynamics in this area. Records of pH, inorganic and total phosphate, nitrate and silica (Smith and Codispoti 1980) indicate waters dependent on the length and intensity of the monsoon. The long rains occur along the Kenyan Coast between March - May and short rains in October, so that flow from the rivers reaches a maximum from April to June. The brackish outflow from these rivers is kept close inshore by the prevailing northward flow of the East African Coastal Current.

MATERIALS AND METHODS

Specimens of skates and rays were taken from commercial trawlers, line fishing, and landings from the small-scale fishermen along the coast. The fishermen used shark nets set overnight, mostly of 6 and 8 inch stretched mesh size made of heavy ply twisted multifilament nylon. All fishing areas of the small scale fishermen were in water depths of 12 to 24 m and sheltered by a number of coral islands. In a few cases *Taeniura lymna* were taken by skin divers in shallow coralline areas. Study material from the open sea was collected by R. V. 'Ujuzi' during the FAO Project KEN/74/023 between January 1980 to June 1981 covering different fishing grounds and monsoons. Fishing gear consisted of a high opening bottom trawl with cod end mesh size 32 mm and a baloon trawl with cod end mesh size 40 mm. Each fishing operation lasted one hour and the catch rates were determined by weighing the total number of fish caught. The techniques of identifying and measuring skates and rays used in the study were those of Bigelow and Schroeder (1953), Hubbs and Ishiyama (1964), Ishiyama (1955) and Miller and Lea (1972). Identification keys used were Wallace (1967), Hulley (1969, 1972) and Smith (1977). The total length, disc length and width in centimetres of each specimen were taken along a straight line as illustrated in Fig. 4. A measuring board with a metallic ruler was used in measuring skates, while a tape measure was used for rays. Each fish was weighed in freshwet condition in kilograms. To determine the food eaten by skates and rays, the stomach contents of freshly caught specimens were examined and the food items identified as far as possible. The volume and frequency of the various food items for each fish studied were not determined. The presence of milt in males, embryos and clasper wounds in females was recorded.

The length/weight relationships for each species of fish was calculated using the relationship:

$$W = aL^b \text{ (Ricker 1975)}$$

where W = Weight, L = Length (either total length, disc length or disc width), a = a constant, b = the exponent. A logarithmic transformation of the above relationship was used as below:

$$\ln W = \ln a + b \ln L$$

Where the study material consisted of less than ten individuals the range of the measurements taken is given. Bottom substrate and the depth profiles of temperature and salinity were used to determine the fishes' distribution. The total catch of all skates and ray species were grouped together as 'Rays' and their proportion in a trawl catch compared to those of the dominant species. The functional regression value b less than 3 (Ricker 1975) was used to determine allometric growth.

Biomass estimates were calculated according to the formula:

$$B = MD \times A \text{ (Birkett 1979 and Gulland 1979)}$$

Where: B = biomass in metric tonnes (mt).
 MD = mean density in metric tonnes per square nautical mile
 (mt nmi⁻²)
 A = area swept by the trawl net per unit time (nmi²h⁻¹).

The mean density of rays was calculated from the mean catch rates on the basis that effective sweep of the trawlnet was 16.4 m and the average speed of towing was four knots. Under these conditions, the trawl would have swept an area of 0.035 nmi² per hour, so the density of fish is given by the formula:

$$\text{density of fish} = \frac{1}{0.035} \times \text{kg h}^{-1} \times 10^{-3} = 0.028 \text{ kg h}^{-1} \text{ (Birkett 1979)}$$

The fishing areas shown in Fig. 1 within certain depth contours were calculated by planimetry. Maximum sustainable yield (Y) was calculated from the surplus production model (Gulland 1979):

$$Y = 0.5 (C + MB)$$

Where C = present catch, M = natural mortality and B = the biomass at the time of survey.

RESULTS

RHINOBATIDAE (*Shovel Nosed Skates*)

Two genera have been reported to occur in our waters, *Rhynchobatus djeddensis* and *Rhinobatus holcorhynchus* (Barnard 1925, Darracott 1977). During this study one female *R. djeddensis* was caught by a fisherman's gillnet at Vanga. It weighed 3.5kg.

RAJIDAE (*Skates*)

Raja miraletus (Fig. 5a) was the only species collected during the period of study. Skates are characterized by their dorsoventrally flattened rhomboidal disc, moderately slender tail, two dorsal fins, a membranous caudal fin, and lack of serrate tail spines. A large bluish-black ocellus surrounded by narrow rings of black and yellow at the base of each pectoral distinguishes *R. miraletus* from other skates. The dorsal surface of the disc is brownish with numerous small dark spots. The fish formed a significant proportion of the total catch in kg (16%) at depths between 250-800m, and it is not exploited as a source of food. A total of 117 fish were caught in October 1980, and in January and February 1981, of which 48 were male and 69 female. One egg case of *R. miraletus* (Fig. 5b) was collected by a beam trawl in March at a depth of 330 m off Kilifi. It weighed 12g and had a total length of 6.7 cm without horns.

Length and weight histograms for *R. miraletus* are shown in Fig. 6a. There was no difference in modal total length, disc length and disc width between male and female fish. The modal total length of all fish was 22.5 cm, disc length 21.3 cm, disc width 26.3 cm and weight 250 g. Female modal weight was 150 g. These results are comparable to those obtained by Hulley (1970) in his skate study on the west and south coasts of southern Africa. The male mean total length was larger than the female, while mean female disc length, disc width and weight were larger than those for males (Table 1a). Linear regression analysis of the length/weight relationship indicates that the growth in this fish is allometric and there is a significant difference between male and female fish (Table 2a). This supports the finding of Holden (1978) that there is a difference between the growth rates of male and female elasmobranchs. Six *Raja alba*, two *R. springeri* and one *R. stenorynchus* were recorded during the period of study.

TORPEDINIDAE (*Electric Rays*)

Three species representing two genera are known to occur off the Kenyan coast. One female *Torpedo marmorata* ('Taa maji' in Kiswahili, Fig. 5c) was trawled in October. It's total length was 31 cm, disc length 21 cm, disc width 26 cm and weight 345 g. Benbow (1976) reports that the largest fish may grow up to 1.3 metres in length. One female *Torpedo fuscomaculata* (Fig. 5d) was trawled in December off Malindi. It's total length was 47.5 cm, disc length 19.2 cm, disc width 20.6 cm and weight 730 g. Three female *Heteronarce garmani* (Fig. 5e) were trawled in December off Malindi with a disc width range between 90-120 mm.

GYMNURIDAE (*Butterfly Rays*)

One specimen of *Gymnura natalensis* (Fig. 5f) was caught in a gillnet and landed at Mombasa in November. Its total length was 41.4 cm, disc length 38.5 cm, disc width 79.9 cm and weight 4.0 kg. This fish is scarce and considered a delicacy by the local fishermen.

DASYATIDAE (*Stingrays*)

Taeniura lymna (Fig. 5g) is a common stingray found in East Africa (Benbow 1976) and is recognized by its colour, light grey covered with blue spots and the blue band on either side of the tail. The background of the dorsal surface is brownish-yellow and spots are absent on the tail. All specimens were caught in the shallow coral reef areas using gillnets and sometimes harpoons, handguns and spears at low tide. *Taeniura lymna* is exploited as a source of food and was available throughout the year, with more fish in November. A total of 51 fish were caught, of which 28 were identified as female and 23 as male. *Taeniura lymna* is ovoviviparous and two pregnant females were recorded in March. One female had 13 yellowish eggs on the left ovary and none on the right. The other female had a fully developed embryo with a total length including tail of 20.2 cm, a disc length of 8.25 cm, disc width of 9.5 cm and a weight of 100 g. The disc width of the pregnant females were 38 cm and 39 cm and they weighed 3.0 kg and 3.3 kg, respectively.

Length and weight histograms for *T. lymna* are shown in Fig. 6c. The modal total length was 27.5cm, and disc width and length were 26.3 and 24.4 cm., respectively. Thus, the disc is as wide as long. The mean total length of males was greater than that for females, while the mean disc length, disc width and weight of females were greater than those for males (Table 1b). Linear regression analysis of the length and weight relationship (Table 2c) indicates that growth is allometric and there was no significant difference between male and female fish.

Dasyatis thetidis (Fig. 5h) can be distinguished from other stingrays by its markedly thorny tail, a blunt snout and tubercles along the anterior margin of the disc. The tail is armed with 1-2 serrated spines. On each side of the spine are a pair of grooves supplied with a powerful irritant toxin from connected poison glands. The colour of the dorsal surface varies from a uniform dark brown to greyish black and the ventral surface is whitish. Smith (1957) described this fish as *D. lubricus* which Wallace (1967) confirmed was a synonym of *D. thetidis*. The depth distribution of the fish was between 5-400 m. The fish was landed by the local fishermen and formed 25% by weight of the commercially important trawl catches. The trawl catches in August were higher than for any other month during the period of study. Further work is needed to evaluate the possible increase in biomass of this fish in August.

One hundred and eighty-four fish were caught of which 63 were male and 98 females. The mean disc width and length were, respectively, 74 cm and 68.8 cm. This supports Barnard (1925) and Wallace (1967) who reported that disc width is greater than the disc length (see Table 1c). Length and weight frequency histograms are shown in Fig. 5d. The modal total length, disc length, disc width and weight were not significantly different for males and females. The mean were larger than those for males (Table 1c). Linear regression analysis of the disc length, disc width and weight relationship (Table 2d) indicates that growth in this fish is allometric and that disc length and

weight gives a better relationship in females than males. An examination of the stomach contents of *D. thetidis* indicated that its food consisted of oysters, crabs, shrimps, eels and fishes, *Sardinella spp.*, *Leiognathus sp.*, *Nemipterus sp.*, *Stolophorus sp.*, *Upeneus spp.*, *Platycephalus sp.*, *Synagrops sp.*, and a flatfish.

Pregnant female *D. thetidis* were recorded in November (1 specimen), December (2 specimens) and January (1 specimen). Females collected in this survey carried between 7-18 eggs in their ovaries. The ovarian eggs were small and filled with yolk. The eggs were between 2.2 to 5.8 cm in diameter and were encased in a yellowish-white membrane. Males with disc width greater than 50 cm were found to have rigid claspers. They possessed enlarged left testes, and when these were cut a milky fluid was released, indicating that the males were mature. Evidence of clasper wounds on the cloaca of one female was observed in December. This one observation is not enough to confirm that spawning activity starts around December.

Dasyatis uarnak (Fig.5i) can be identified by its variegated dorsal surface. The background colour of the dorsum is brown to black, upon which is superimposed a variable matrix of dark yellowish lines. The ventral surface is white. *D. uarnak* is widespread in the tropical Indo-pacific and is very common on the coasts of Natal, East Africa and the East Indies (Barnard 1925, Smith 1961 and Wallace 1967) A total of 37 fish were caught of which 19 were male and 18 female. The specimens were caught by lines set for 8 hours at a depth of 100m. Length, and weight histograms are shown in Fig.6e. The modal total length, disc length, disc width and weight were 70 cm, 65 cm, 75 cm and 16.3 kg, respectively. The mean total length, disc length, disc width for males were greater than that for females. Female mean weight was greater than the male mean weight (Table 1d). Mean disc width was 76.6 cm and disc length 69.2 cm. This suggests that the disc is wider than long for mature *D. uarnak*. Two juveniles were caught in March at the Mombasa estuary. The minimum total length including the tail was 94 cm, disc length 22 cm, disc width 15 cm and weight 1.0 kg. Linear regression analysis of the length and weight relationship indicates allometric growth (Table 2e).

Dasyatis sephen (Fig 5j) is a widespread dasyatid ray in the Indian Ocean, Red Sea and the Western Tropical Pacific Ocean. It has been recorded from the east coast of Africa, and from Seychelles and Phillipines (Smith 1961, Wallace 1967). This species is readily recognized by its extremely broad lower cutaneous fold which is 2-3 times as deep as the tail and extends more than half way to its tip. The dorsal surface is yellowish brown, becoming darker towards the tail. The caudal fold and the filamentous part of the tail is black. A total of 27 fish were trawled at depths between 50 - 280m, of which 19 were males and 9 females. Length and weight frequency histograms are shown in Fig.6f. The modal disc length of all fish was 65 cm, modal disc width 75 cm and the modal weight 15 kg. Linear regression analysis of the length and weight relationship indicates that growth in this fish is allometric (Table 2f). The results of stomach content analysis of one specimen showed that the food consisted of squid, shrimp, lobster, crabs and the fishes *Saurida sp.*, *Thyrssites spp.*, and *Synagrops sp.* The muscle tissues of this fish appeared oily, and it is not exploited as a source of human food.

MYLIOBATIDAE (*Eagle Rays*)

Myliobatis aquila (Fig. 5k) is widespread in the Indian and Atlantic Oceans and in the Mediterranean Sea (Barnard 1925, Wallace 1967). The species is characterized by a prominent head, short and rounded snout, and a wider conically pointed disc with slightly concave hind margins. A dorsal fin is situated posteriorly to the pelvic fins and just before the tail. Males have a small conical horn above each orbit. This fish was landed by the local fishermen at Msambweni, Vanga and Malindi. It was caught by trawling in January in depths ranging between 25 - 280 m and formed 5% by weight of the commercially important trawl catches. Fifteen specimens were available for examination, of which 9 were female and 6 male. The length and weight histograms are shown in Fig. 6b. The modal total length was 65 cm, modal disc length 55 cm, modal disc width 95 cm and modal weight 12.5 kg. Linear regression analysis of length/weight relationship indicates that growth in this fish is allometric.

Pteromylaeus bovinus (Duckbilled stingray, Fig. 5l) is easily distinguished from *M. aquila* by its long fleshy snout and by the location of the dorsal fin between the pelvics. Nine fish were caught during the period of study, 6 were trawled off the Malindi area and 3 were landed by fishermen at the Mombosa Old Port. Total length range was 85-189 cm, disc length 65-126 cm, disc width 71-190 cm and weight 4.0-20.5 kg. The results of stomach content analysis of two fishes showed that the food of *P. bovinus* consisted of big and small prawns, the fishes *Leoignathus sp.*, *Upeneus sp.*, *Stolephorus sp.*, *Nemipterus sp.*, *Platycephalus sp.*, and *Synagrops sp.*

Aetobatis narinari (Fig. 5m) is a cosmopolitan species that occurs along tropical and subtropical shores in the Atlantic, Indian and Pacific oceans (Barnard 1925, Bigelow and Schroeder 1953, Wallace 1967). The colour pattern on the dorsal surface consists of white spots superimposed upon a blue/black background and the venter is whitish. Five fish were caught during the study, 3 from shark nets set for 14 hours at Vanga and 2 trawled off Malindi. Disc length range was 60-95cm, disc width 82-145cm and weight 7.0 - 60 kg.

MOBULIDAE (*Devil Rays*)

One female *Manta birostris* (Manta ray, Fig. 5N) was entangled in the Kenya Fisheries Department's fishing nets at Waa, Kenya South Coast, in November 1980. Its length excluding tail was 220 cm, disc length 200 cm, disc width 460 cm, mouth width 80 cm and weight 70 kg. Fishermen encountered this fish in shallow areas in March.

FISHERY

The monthly variation in trawl catches (Table 3) and catch rates (Fig. 7) indicates that rays were present throughout the year, with increased catches in August, December and March. *Dasyatis thetidis* dominated the catch in November and December, while *D. uarnak* and *D. sephen* were dominant in July and November. Several eagle-rays (*Myliobatis aquila* and *Aetobatis narinari*) of 30-50 kg. each were also caught throughout the year. Smaller rays were represented by the guitarfishes (*Rhynchobatis djeddensis*). The various dasyatid ray species catches ranged from 30 to 500 kg/hr off Ungama Bay, the North Kenya Banks and Malindi in January, July and November.

More rays were landed at Vanga, South coast, than any of the fish landing stations. Using the present catch (C) in 1981 of 187 tonnes and a natural mortality (M) of 0.29 according to Holden (1974) a total biomass of 7206 tonnes was estimated for the period of study (Table 4). This is higher than the 6000 tonnes that was estimated by Birkett (1979). Using the formula: $Y = 0.5(C+MB)$ a maximum sustainable yield estimate of 1140 tonnes was obtained.

Skates and rays were found to occur on the continental shelf and upper regions of the slope at depths from 5 to over 800 m. Skates were restricted to depths from 250 to over 800 m by temperatures of less than 10°C and a salinity range of 34.9 to 35.1‰. Rays occurred in large numbers at depths less than 200 m with temperatures between 15 to 30.5°C and salinities of less than 34.2‰.

DISCUSSION

The skate and ray species studied show that males are smaller than females. Sexual dimorphism may separate the sexes ecologically and reduce intraspecific competition. The largest species commonly landed, *Dasyatis thetidis*, reaches a maximum total length of 205 cm, disc length 150 cm, disc width 169 cm and weight 130 kg; the smallest, *Taeniura lymna* reaches a maximum total length of 70 cm, a disc length of 45 cm, a disc width of 40 cm and a weight of 3 kg. A wide range of sizes was represented in the fishery. Data like this when collected over a long period of time might yield interesting insights into the changes of size distribution with fishing pressure. Mean body lengths, weight and biomass in terms of catch in kilogrammes under various environmental conditions could be compared over the course of developing a management strategy.

On the basis of my data, *Raja miraletus* and *Taeniura lymna* spawn in March, while *Dasyatis thetidis* spawns in November, December and January. This supports Darracott (1977) who observed that elasmobranchs along the Western Indian Ocean seek shallow waters to give birth to their young during the onset of the long rains in March. The cold waters and increased river flows into the estuarine areas during the rainy seasons may act as a trigger mechanism for spawning. The breeding of other demersal fishes occurs during or just after the rainy seasons and the Northeast Monsoon (Morgans 1962, Williams 1963, Nzioka 1979). The fecundity of skates and rays is low (Holden 1975, 1978), the number of young produced by *T. lymna* during the period of study was 13 and by *D. thetidis* between 7 and 18.

The potential fishery for skates and rays is indicated by a maximum sustainable yield of 1140 tonnes; higher than the recorded landings from small-scale fishermen (Kenya Fisheries Department Annual Report 1979). This is higher than 900 tonnes found in the study by Birkett (1979). For management purposes, it would be wise to set a yearly landing quota of less than 1140 tonnes. The highest catch rates were realised in August during the waning period of the Southwest Monsoon. This is when high primary productivity occurs along the Kenya coast (Smith and Lane 1981) and crustaceans are abundant (Heath 1973, Brusher 1974). The SW monsoon supports a higher fish biomass than the NE Monsoon (Scheffers 1982). In 1981 the average price of skates and rays was Kenyan shillings 3,240.00 per tonne. Not only are the fishes less competitively

priced, but also their landings are localized and therefore the likely returns from trawling investment will be discouraging. In conclusion, this paper has presented data that infer that skates and rays could support a fishery if properly managed.

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Figure 1.

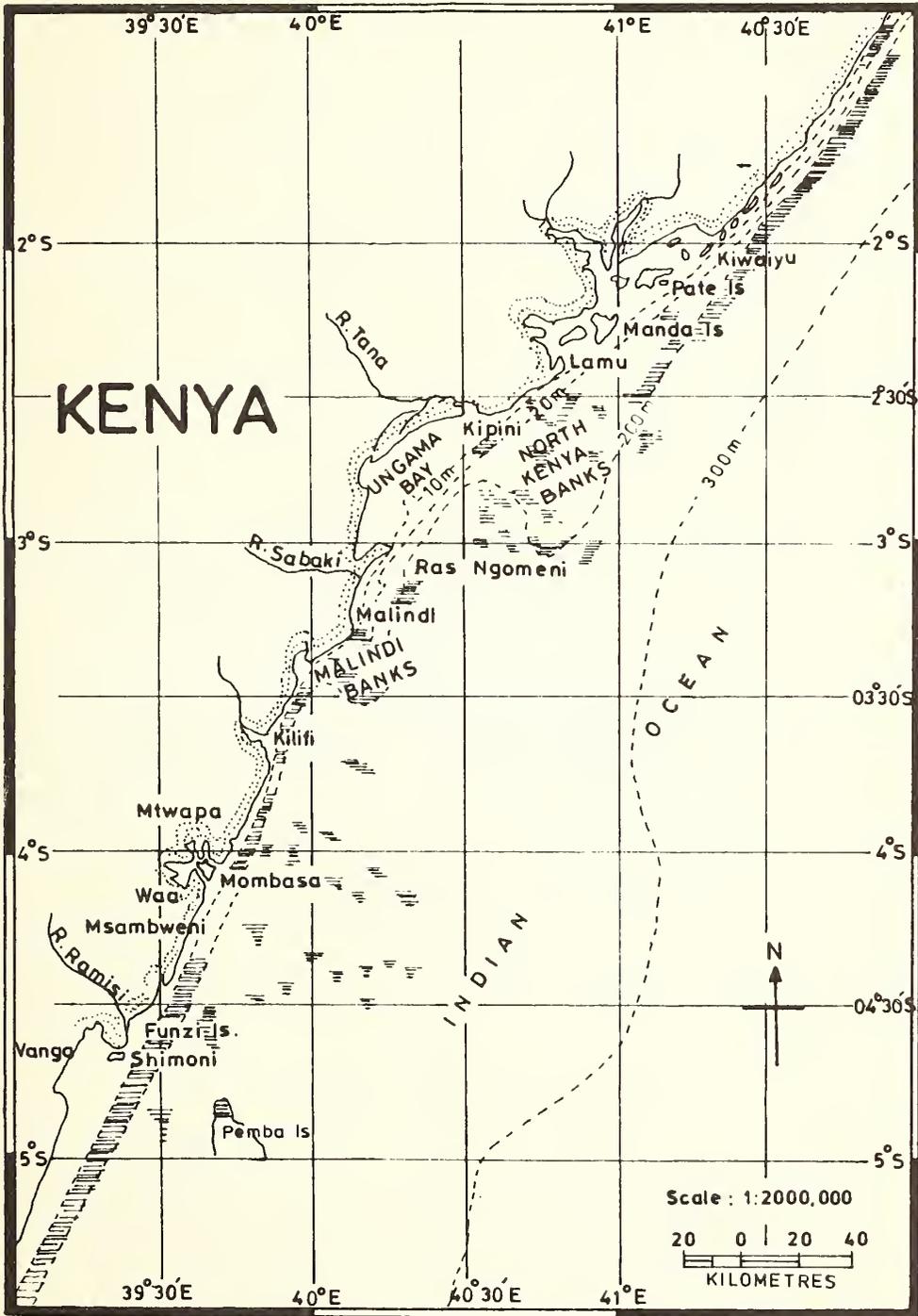


Fig.1. The coast of Kenya showing depth contours fishing areas and fish landing station.  Untrawable areas.

Figure 2

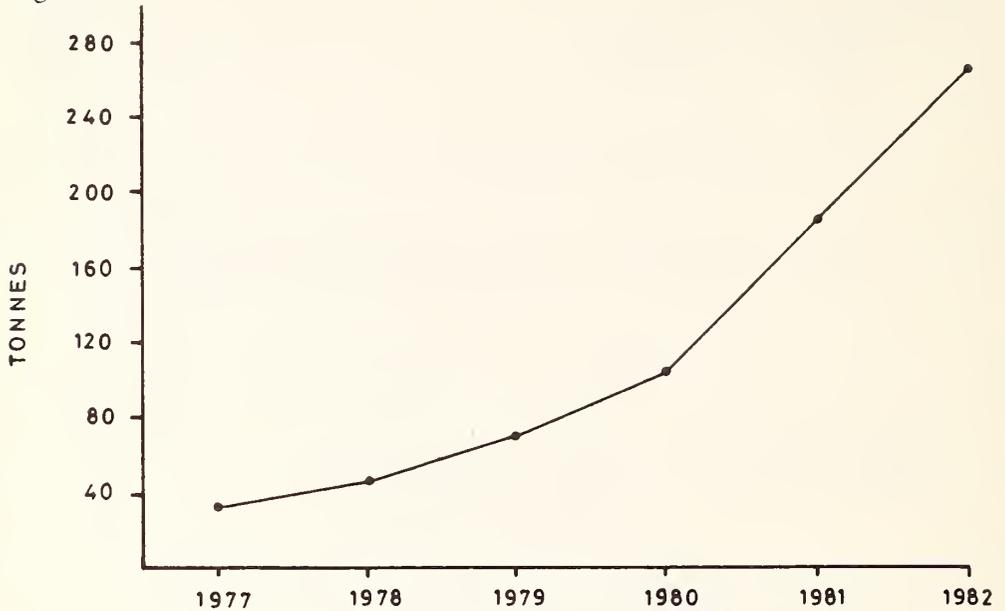


Fig 2. Landings of skates and rays along the Kenyan Coast

Figure 3.

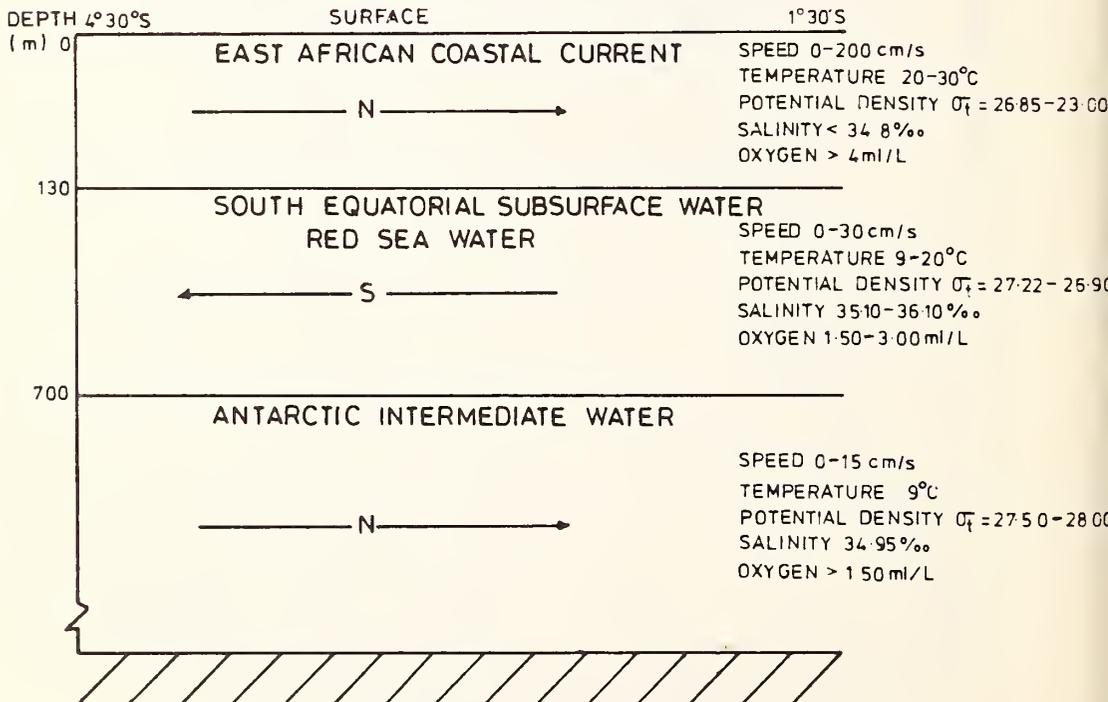


Fig 3. Currents and water mass characteristics off the Kenyan coast
 → shows direction of flow. N= North, S= South.

Figure 4.

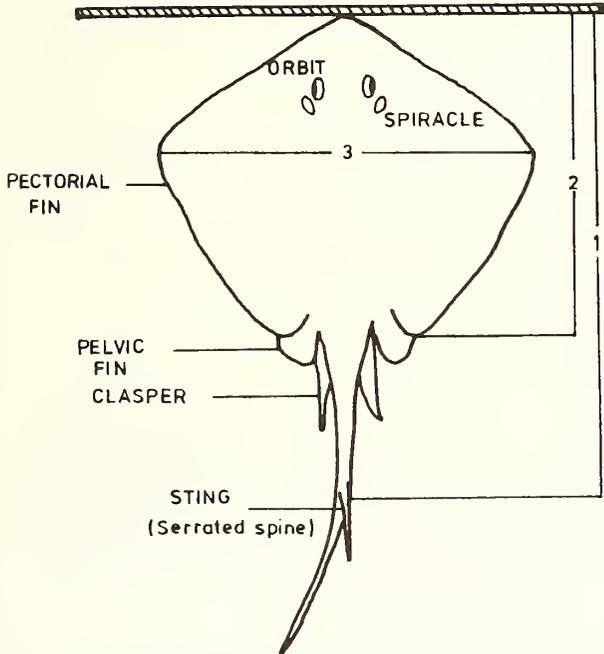


Fig. 4. Morphometric measurements taken on skate and ray specimens .

- 1. Total length TL
- 2. Disc length DL
- 3. Disc width DW

Figure 5.

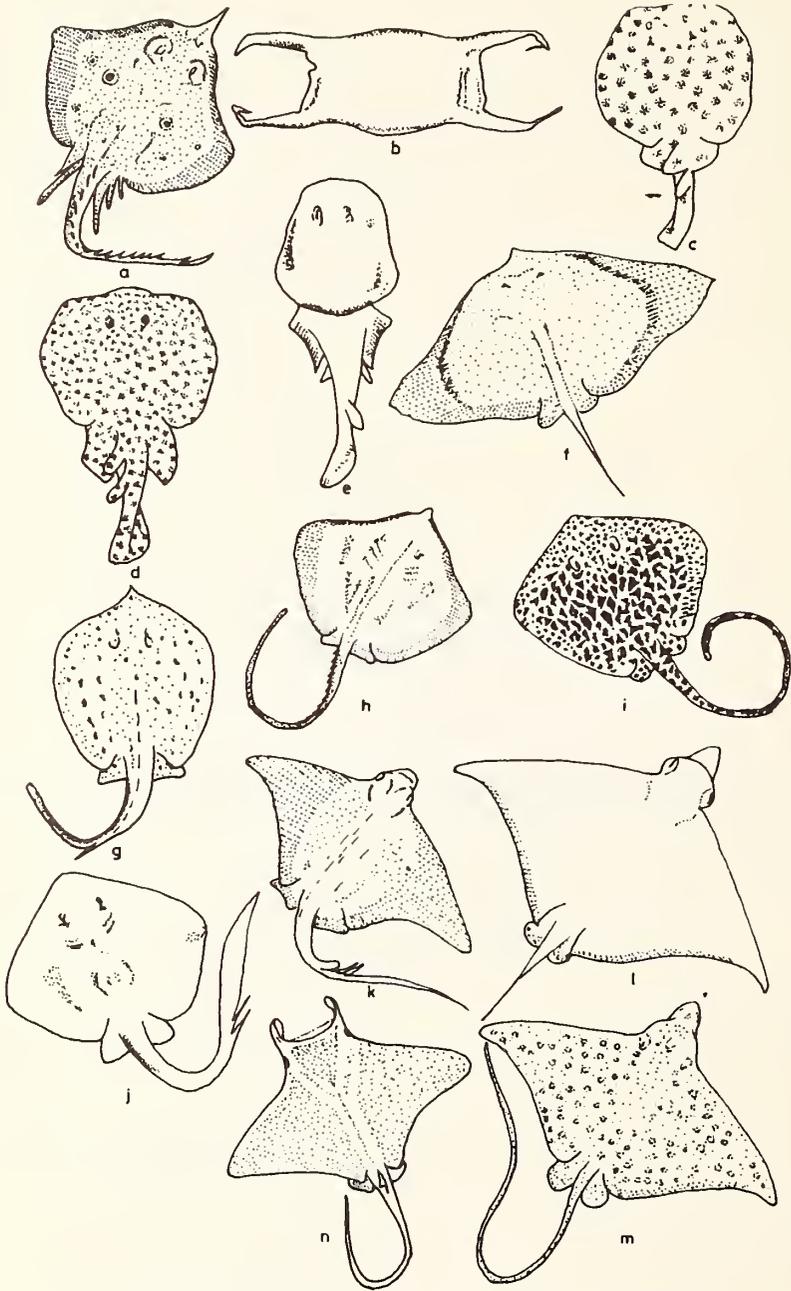


FIG.5. Line drawing of the skates and ray discussed in the papers

KEY: a) Raja miraletus, b) Raja miraletus egg case c) Torpeda marmorata, d) Torpeda fuscamaculata, e) Heteranarce garmani f) Gymnura natalensis g) Taeniura lymna h) Dasyatis thetidis i) Dasyatis uarnak j) Dasyatis sephen k) Myliabatis aquila, l) Pteromylaeus bavinus m) Aetabatis narinari, n) Manta biastris

Figure 6

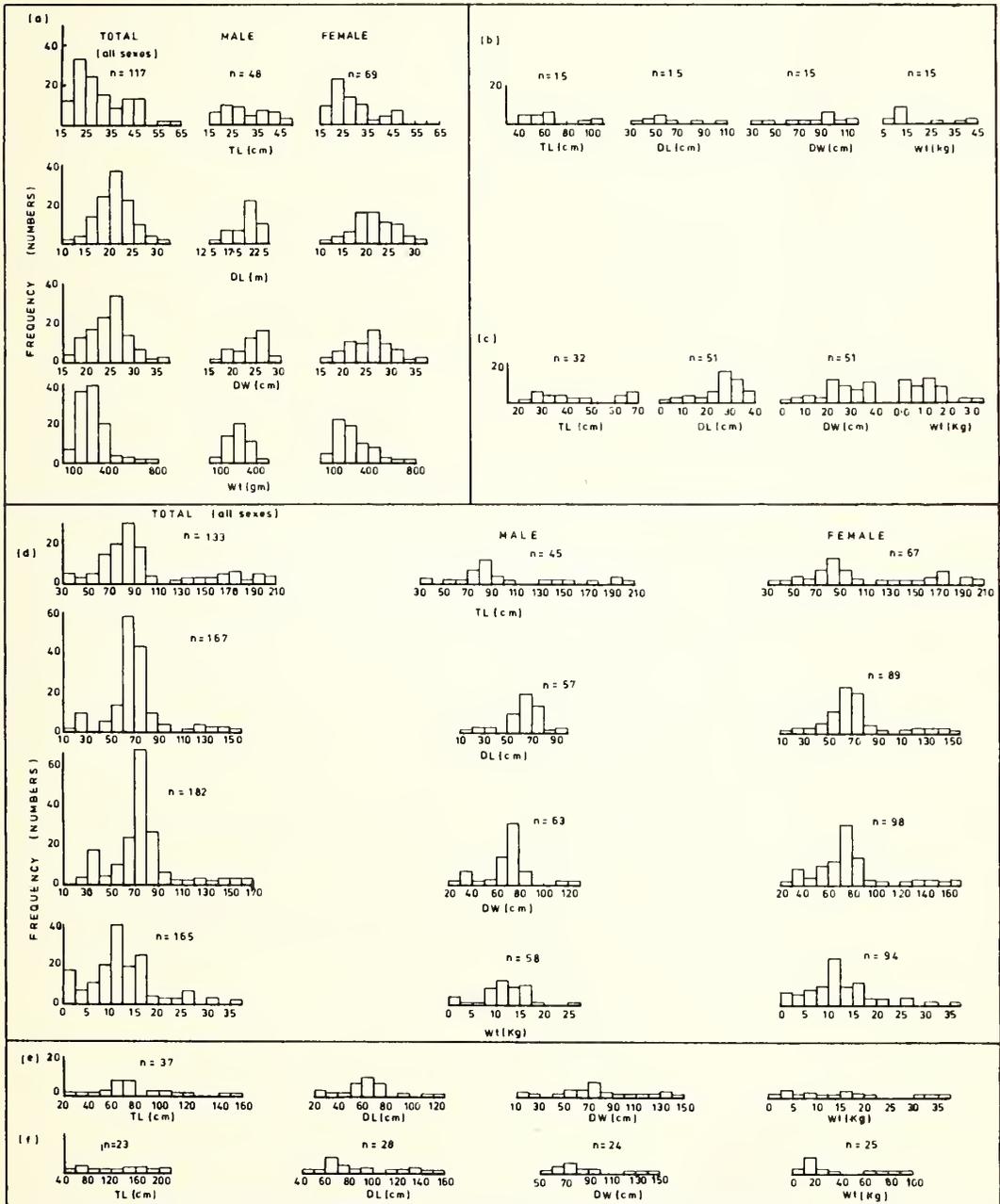


Fig 6 Length and weight histograms of the skates and Rays studied along the Kenyan Coast KEY TL = total length, DL = disc length, DW = disc width, Wt = weight, (a) *Raja miraletus*, (b) *Myliobatis aquila*, (c) *Taeniura lymna*, (d) *Dasyatis thetidis*, (e) *D. uarnak* and (f) *D. sephen*.

Figure 7

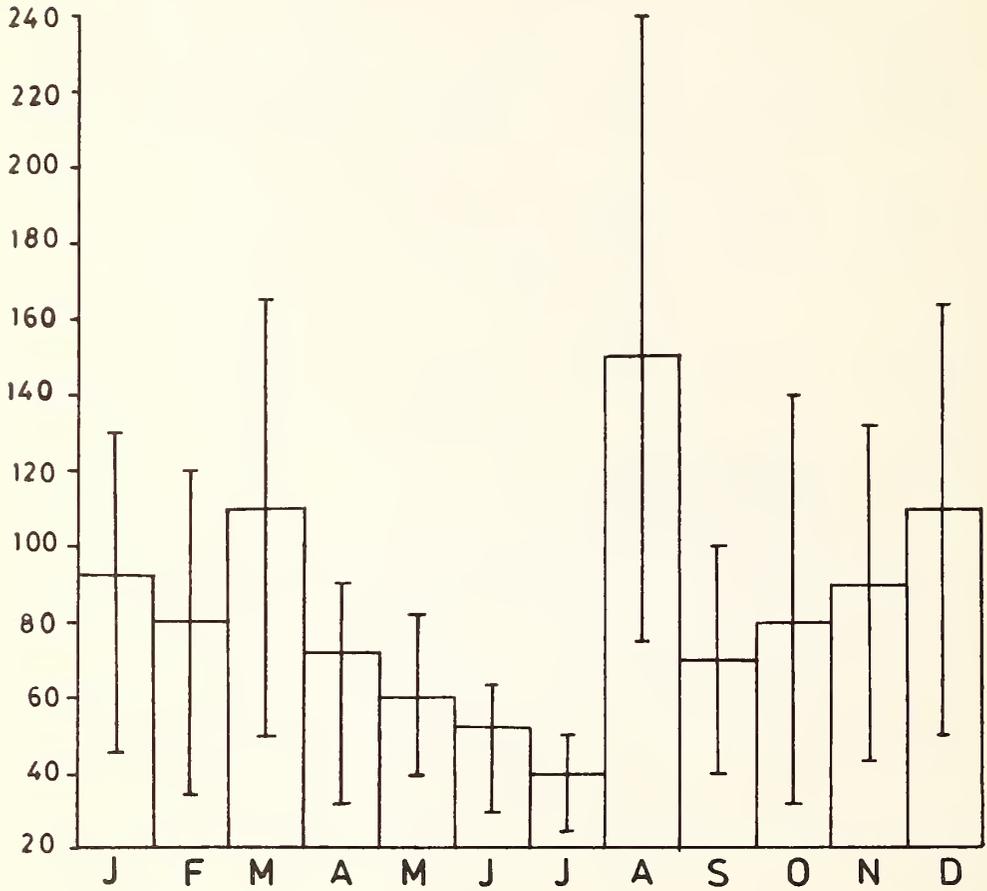


Fig. 7. Mean monthly catch rates of rays caught and landed along the Kenyan coast (vertical bars show the standard error).

Table 1

Table 1. Students t-test for the differences in mean length and weight.

	HYPOTHESIS	DECISION CRITERION	CONCLUSION AT 5% SIGNIFICANCE LEVEL
(a) <u>Raja miraletus</u>	1. Mean female TL > mean male TL	$\bar{x} = 0.352 > t(95,120) = 1.658$	not significant
	2. Mean female DL > mean male DL	$\bar{t} = 1.716 > t(95, \alpha) = 1.645$	significant
	3. Mean female DW > mean male DW	$\bar{x} = 2.177 > t(95, \alpha) = 1.645$	significant
	4. Mean female Wt > mean male Wt	$\bar{x} = 1.322 > t(95,120) = 1.658$	not significant
(b) <u>Taeniura lymna</u>	1. DW = DL (both sexes)	$\bar{x} = 0.1043 < t(95, 120) = 1.645$	not significant
	2. Mean female TL > mean male TL	$\bar{t} = 0.107 < t(95, 25) = 1.708$	not significant
	3. Mean female DL > mean male DL	$\bar{x} = 0.787 < t(95, 40) = 1.684$	not significant
	4. Mean female Wt > mean male Wt	$\bar{x} = 1.398 < t(95, 40) = 1.684$	not significant
(c) <u>Dasyatis thetidis</u>	1. DW = DL	$\bar{x} = 1.868 < t(95, \alpha) = 1.645$	significant
	2. Mean male TL > mean female TL	$\bar{x} = 1.234 > t(95, 120) = 1.658$	not significant
	3. Mean female DL > mean male DL	$\bar{x} = 1.892 < t(95, \alpha) = 1.645$	significant
	4. Mean female DW > mean male DW	$\bar{x} = 1.895 < t(95, \alpha) = 1.645$	significant
	5. Mean female Wt > mean male Wt	$t = 0.772 < t(95, \alpha) = 1.645$	not significant
(d) <u>Dasyatis uarnak</u>	1. DW > DL both sexes	$\bar{x} = 0.824 < t(95, 60) = 1.960$	not significant
	2. Mean male TL > mean female TL	$\bar{x} = 2.26 > t(95, 40) = 1.684$	significant
	3. Mean male DL > mean female DL	$\bar{x} = 0.374 < t(95, 40) = 1.684$	not significant
	4. Mean male DW > mean female DW	$\bar{x} = 0.682 < t(95, 40) = 1.684$	not significant
	5. Mean female Wt > mean male Wt	$\bar{x} = 1.077 < t(95, 40) = 1.684$	not significant
<p>KEY : TL= Total length DL= disc length DW= disc width Wt = weight</p> <p>α = refers to degrees of freedom more than 120 significant = suggests evidence to conclude hypothesis not significant = insufficient evidence</p>			

Table 2

Table 2. Length/weight relationship for skates and rays.

SPECIES	Total length/weight relationship	Number of fish	Correlation coefficient	Male length/weight relationship	Number of fish	Correlation coefficient	Female length/weight relationship	Number of fish	coefficient
(a) Raja mirabilis	$W = 6.98TL^{1.05}$	115	0.654	$W = 13.068TL^{0.836}$	47	W 0.651	$W = 4.509TL^{1.193}$	68	0.679
	$W = 0.090DL^{2.59}$	115	0.910	$W = 0.202DL^{2.324}$	47	0.821	$W = 0.139DL^{2.428}$	58	0.827
	$W = 0.04DW^{2.72}$	115	0.912	$W = 0.207DW^{2.204}$	47	0.807	$W = 0.0166DW^{2.98}$	68	0.956
(b) Myliobatis aquila	$W = 0.007TL^{1.80}$	14	0.725						
	$W = 0.222DL^{1.02}$	15	0.487						
	$W = 0.587DW^{1.22}$	15	0.679						
(c) Toxoptera lyman	$W = 0.003TL^{1.45}$	25	0.716	$W = 0.017TL^{1.073}$	17	0.816			
	$W = 0.006DL^{1.54}$	47	0.739	$W = 0.008DL^{1.456}$	26	0.747	$W = 0.006DL^{1.548}$	20	0.708
	$W = 0.006DW^{1.53}$	47	0.792	$W = 0.005DW^{1.623}$	26	0.812	$W = 0.008DW^{1.472}$	20	0.756
(d) Oesopterus tetricus	$W = 0.006TL^{1.66}$	129	0.664	$W = 0.010TL^{1.510}$	41	0.585			
	$W = 0.0003DL^{2.514}$	154	0.902	$W = 0.0002DL^{2.658}$	52	0.861	$W = 0.0002DL^{2.712}$	83	0.914
	$W = 0.0003DL^{2.419}$	178	0.882	$W = 0.0004DW^{2.438}$	52	0.858	$W = 0.004DW^{1.913}$	91	0.791
(e) D. uarnok	$W = 0.032TL^{1.446}$	26	0.460	$W = 0.001TL^{2.261}$	15	0.907	$W = 0.006TL^{2.357}$	18	0.865
	$W = 0.0002DL^{2.68}$	26	0.897	$W = 0.0003DL^{2.634}$	15	0.929	$W = 0.0001DL^{3.057}$	18	0.339
	$W = 0.003DL^{2.022}$	37	0.883	$W = 0.006DW^{1.868}$	15	0.907	$W = 0.006DW^{1.857}$	18	0.831
(f) D. sephen	$W = 0.002TL^{2.027}$	23	0.891						
	$W = 0.018DL^{2.637}$	28	0.940						
	$W = 0.002DW^{2.588}$	27	0.966						

Table 3

Table 3. Data on trawl operations along the Kenyan coast by 'RV Ujuzi' showing number of hauls, their duration, depth of trawl and monthly variation in catches of 'Rays'

Month	Number of Hauls	Duration (min)	Depth range	Total catch kg
1980 January	4	295	40 - 68	350
February	10	460	35 - 65	607
March	11	795	40 - 328	828
April	8	870	55 - 284	486
May	2	120	280 - 400	300
June	—	—	—	—
July	2	120	235 - 345	80
August	15	1100	5 - 270	2188
September	2	150	14 - 60	48
October	15	1138	14 - 70	1171
November	10	697	40 - 280	838
December	19	985	15 - 270	1406
1981 January	8	475	25 - 280	616
February	8	540	13 - 280	427
March	2	180	35 - 60	48
April	4	270	30 - 280	275
May	1	30	7 - 15	10
June	3	240	9 - 46	175

Table 4.

Table 4. Trawling areas, mean density and biomass for 'Rays' along the Kenya coast.
(Data from RV Ujuzi FAO KEN/74/023 Project Reports 1979-81.)

Area	Trawling Areas nmi	Number of Hauls	Mean density kg/nm	Biomass estimate (tonnes)
1. North Kenya Bank (N.K.B) (01°39's to 02°48' Depth contour < 10 to < 3000m	726	43	1770	1285
	1259	237	34,706	4608
2. Between NKB to Malindi Banks (02°48's) to (03°26's, 40°46'E)	1259	237	34,706	4608
3. Malindi Banks to Shimani Area (03°43s 40°11'E) to (04°42s 39°48'E)	1154	30	1138	1313

A NOTE ON THE FISHES OF LAKE JIPE AND LAKE CHALE ON THE KENYA-TANZANIA BORDER

Stephen Dadzie¹, Rene D. Haller² & Ethelwynn Trewavas³

Lake Jipe is a shallow basin at about 3° 40' S 37° 40' E, east of the North Pare Mountains in Tanzania. Chala is a smaller lake lying in a rocky crater about 19 km north of Lake Jipe. In 1951, when it was visited by Dr. Lowe-McConnell (then Miss R.H. Lowe) Lake Jipe was about 12 miles (19 km) long and 1.5 miles (2 km) wide and only a few feet deep. Its northern end is a swamp into which flows a stream, known in Kenya as the Lumi, from Mount Kilimanjaro. From its northwestern end issues, at least in wetter periods, the River Ruvu⁴ headwater of the long river formerly known by that name, but now called the Pangani, the name of the town at its mouth on the Indian Ocean. Since the formation of the barrage lake Nyumba ya Mungu (NYM) in the upper Pangani the Ruvu flows from Lake Jipe into the swampy north-east corner of this lake. Lake Jipe's swampy edges are surrounded by semi-aquatic grasses and reeds, and patches of water-weeds (*Najas* and *Potamogeton*) spread their leaves and flowers on its surface. Numerous water birds prey on the lake's fauna and these and hippopotamus fertilize the water. The sketch by Sir Harry Johnston, reproduced here from his book of 1886, gives an idea of the lake's appearance as it remains today, (Fig. 1).

At Taveta, NE of Lake Jipe, the well-known pioneer Colonel E.S. Grogan had settled after the Second World War and established a farm including fish-ponds stocked from Lake Jipe. Lake Jipe and Chala and the Taveta ponds were visited in 1951 by Miss Lowe, who was then a member of the East African Fisheries Research Organisation at Jinja, Uganda. She collected fishes from the ponds and both lakes. The two tilapiine species of Lake Jipe proved to have been undescribed. She then travelled on to Korogwe⁵ on the Lower Pangani, where Major R.E. Gould, then fish culturist to the Tanganyikan (Tanzania) Government, had established fish-ponds in which he reared tilapiine species preparatory to using them for stocking dams and ponds. Among his species were the two endemic tilapias from lake Jipe and two from the River Pangani and these were the subject of Lowe's paper of 1955, where they were named *Tilapia jipe* and *T. girigan* (Lake Jipe) and *T. pangani* and *T. mossambica korogwe* (River Pangani). The last named was later given full specific status by Trewavas (1983) and all four were included in the genus *Oreochromis*. The generic name *Oreochromis* had been proposed for *O. hunteri* by Gunther in 1889, a name meaning 'mountain Chromis' in reference to its habitat in Lake Chala on the slopes of the Kilimanjaro volcanic mass. (Chromis is a name that had been used for several cichlids, but really belongs to a marine genus.)

¹ Dept. of Zoology, University of Nairobi, P.O. Box 30197 Nairobi

² Baobab Farm, P.O. Box 90202, Mombasa

³ c/o British Museum (Natural History), London SW7 5BD, England

⁴ The Ruvu of Bailey et al., 1987, not of Bailey, 1969. The latter is also known as the Kingani and enters the Indian Ocean at Bagamoyo.

⁵ Not the Korogwe at the entry of the Ruvu to NYM (Bailey et al., 1978)

The situation in 1951 and until recently was therefore that Lake Chala contained one endemic tilapiine species, *O.hunteri*, and Lake Jipe two, *O.jipe* and *O.g.girigan*. Lowe (1955) recognised that fry of *O.girigan* were difficult to distinguish from *O.pangani* and Trewavas (1983) considered these two forms to be only subspecifically distinct.

One of us (R. Haller), has, since May 1976, been taking *Oreochromis* from Lake Jipe for culture at Baobab Farm, near Mombasa. In January 1983 a third tilapiine species was found in the Lake and a brood of young about 2.5cm long was taken to Baobab Farm and reared to maturity which they reached at an age of 9 months and a total length of 16-18 cm. A sample of these, five of each sex, was sent to the British Museum (Natural History) [BMNH] and identified as *Oreochromis esculentus* (Graham).

Another of us (S. Dadzie) visited the lakes in March-April, 1985, and found in Lake Jipe, as well as the two endemic *Oreochromis* and *O.esculentus* several specimens of *Tilapia rendalli* Boulenger. From Lake Chala he collected *T.rendalli* and a large specimen of *O.p.pangani*, as well as the endemic *O.hunteri*.

We have no doubt that *O.esculentus*, *Tilapia rendalli* and *O.p.pangani* were introduced to these lakes from the Tanzania side, either deliberately or in the case of Lake Jipe by migration up the Ruvu River. The first two are not native to the area and no tilapine except *O.hunteri* was previously known from Lake Chala although this species had been collected there and specimens sent to the BMNH on five occasions, registered in 1889, 1902, 1946, 1952 and 1980.

Non-tilapiine fishes also present in Lake Jipe in 1951 (Lowe, 1951) were *Astatotilapia bloyeti* (Sauvage), *Clarias mossambicus* Peters, *Barbus paludinosus* Peters and *Petersius tangensis* Lonnberg. *Astatotilapia bloyeti* was found also in Lake Chala by W.P. Scott in 1977 and again by Dadzie in 1985.

Specimens of the introduced species and the non-tilapiines were sent to the BMNH and identified by E.T.

The Introduced Species

Gould (1951) published a list of the species that he had imported for culture to Korogwe. Among them were *O.esculentus* and *O.variabilis*, species endemic in the Lake Victoria basin, and *Tilapia rendalli*⁶ and *O.macrochir* from ponds in Katanga (now Shaba).

O.esculentus is a mouth-brooder, now common in several dams and lakes in Tanzania, including Nyumba ya Mungu (see Bailey et al., 1987 and Trewavas, 1983), which probably acquired it from stocked ponds and backwaters in the flooded area. For food it has a strong preference for phytoplankton in open waters. This was shown by observation in its original habitat, the Lake Victoria basin (for references see Trewavas, 1983), in experimental ponds Payne, 1971) and in Nyumba ya Mungu (Bailey et al. 1978). Its weak jaws and minute teeth are unsuited either for

⁶Referred to as *T. melanopleura*, a name no longer in use.

scraping algal growths from stems and leaves or for biting and chewing higher plants. In NYM, although it succeeded in establishing itself as a proportion of the tilapiine fauna, its growth in length was inferior to that of the species of local origin (*O.p.pangani* and *O.jipe*) and also to that in its original habitat. In NYM very few specimens exceeded 22 cm in total length and 350 g in weight, whereas males of *O.jipe* and *O.p.pangani* grew to between 32 and 38 cm with a maximum weight of 1800 g (Bailey et al., 1978, figs 3 & 4). A male *O.esculentus* collected from NYM in 1980 by A.I. Payne was nearly ripe at TL 17 cm; this is about the same as the length of mature fishes reared at Baobab Farm for 9 months (16-18 cm) and that recorded by Lowe (1955) in ponds at Korogwe (16-19 cm at an age of under 7 months). In Lake Victoria the minimum length at first maturity was recorded as 19 or 20-21 cm at different localities, but most do not breed until they are 22 cm or more in total length (Lowe-McConnell; 1956, Garrod, 1959). They go on to reach TL of 30 cm or more.

Tilapia rendalli, a substrate-brooder and guarder of the young, is one of the largest of its genus. It is a voracious feeder on aquatic and semi-aquatic higher plants. Ruwet (1962 and 1963) gives a vivid descriptions of its feeding in the barrage Lake Mwadingusha in the course of River Lufira, Shaba. The lake was shallow, mostly less than 4 metres maximum depth, and in dry seasons or when the rains were deficient the draw-down at the electric power station was so great that the lake shrank to a fraction of its maximum area and semi-aquatic vegetation was able to intrude over vast stretches. When rain again flooded the lake *T.rendalli* immediately attacked flooded grasses. Ruet describes the event as follows (translation from the account of 1963):

“I have often halted in a canoe in the middle of the immense meadows dominated by *Oryza*, the wild rice. I still remember the continuous cracking sound produced by hordes of (*T.rendalli*) tearing, cutting and browsing on the flooded stems, leaves and rhizomes of *Oryza*. From mid-March, under the joint activity of thousands of these fishes, the edge of the meadows from Kinshasha to Shinangwa, that is, over a distance of about 15 Km, retreated by about 8-10 metres”.

Dr G.B. Bernascek, in a letter dated 24.VI.1980 reported that the introduction in 1951 of *T.rendallia* to a densely vegetated lagoon near the mouth of River Lupululu in southern Tanzania had resulted in its clearance to form a lake of open water.

Such are the two species now introduced into Lake Jipe.

The Endemic Tilapiines

What is known of the ecology of the original inhabitants is due to Lowe (1955) and Bailey et al. (1978). They are mouth-brooders, with a characteristic form of nest (mating territory). Stomachs of *O.p.girigan* from Lake Jipe contained fragments of water-lily plants and epiphytic algae from *Najas* stems and leaves. The coarse teeth of this species are well suited to such a diet. Lowe's few specimens of *O.jipe* from Lake Jipe did not provide information about its natural food. In the Korogwe was restricted to ponds both this and *O.p.girigan* fed on detritus, but *O.jipe*, finer particles a difference corresponding to the difference between them in the pharyngeal dentition. In NYM both *O.jipe* and the indigenous *O.p.pangani* fed on periphyton.

The Future of Lake Jipe

One of us (S. Dadzie) has embarked on a study of the reproductive regimes of the two endemic species of Lake Jipe and their ecological relationships. The problem that now faces him is more complex, involving the impact of the introduced species on the endemics.

If *O. esculentus* is shown to feed on phytoplankton in L.Jipe, this will remove it from competition with either *O.jipe* or *O.p.girigan*. In Lake Victoria, before the decline of tilapia fisheries, *O.esculentus* was favoured as food over the sympatric species *O.variabilis*, both for the quality of its flesh and for its ability to grow to a good marketable size, qualities that were no doubt the result of its abundant and rich planktonic diet.

There is evidence however that by 1980 in Nyumba ya Mungu. *O.esculentus* was breeding at a small size and failing to achieve its full growth potential. In 1974 *O.esculentus* comprised 24% of all the tilapiines in the commercial catch (Bailey et al., 1978:122). By 1980 this species constituted the major part of the catch, even in the shallow northern part of the lake; but those measured did not exceed 17.5 cm in total length and many of them were sexually mature (A.I.Payne, personal comm and in press).

Dwarfing of *O.esculentus* in Lake Jipe would endanger the endemic species, because nets of mesh small enough to catch adults of *O.esculentus* would probably catch *O.jipe* and *O.p.girigan* before they had reached sexual maturity.

O.esculentus may also compete with the native species for breeding sites. These are at present unknown and difficult to find in the opaque waters of Lake Jipe. Their presence in a locality may be inferred by the concentration of males in breeding condition. Nursery sites may similarly be located by the predominance of brooding females.

Tilapia rendalli and *O.p.girigan* may occupy the same, rather specialized, trophic niche. A relevant question is, do they sub-divide this niche? For instance, does one species favour floating plants while the other uses grasses in the swamps? Their enemies in Lake Jipe are the birds and the catfish *Clarias gariepinus* with which all species must take their chance together.

Finally, the two introduced species in Lake Jipe may prove to be successful competitors with the local species, *T.rendalli* by competition for food and *O.esculentus* by its strategy of progenesis and dwarfing, and possibly both by competition for breeding sites. There is danger that these may oust the native tilapias, providing instead an abundant but small *O.esculentus* and a *Tilapia rendalli* the quality of which cannot be assumed to exceed or even equal that of *O.p.girigan*.

The Fishery

Lake Jipe supports a considerable fishery. Ninety-six fishermen are registered and 56 of them fish regularly. Dugout canoes are the only crafts used and gillnets of stretched mesh 2" to 3.5" are set, made of nylon thread of 2,3 or 4 ply. The usual catch consists of tilapiines and some *Clarias*. The same species are caught by hook and line, using hooks of sizes 14, 16 and 18. Traditional traps (migono) are set at the shallow edges of the lake and catch all species, including a haplochromine.

Sardine traps, also set at the shallow edges, catch exclusively the small *Petersius* ("sardines") that form schools in the lake (Information from the Kenya Fisheries Department). At the smaller but deeper Lake Chala there are 7 registered fishermen of whom 2 operate regularly.

Fishing in both lakes is for marketing as well as for subsistence. The fields are therefore of legitimate concern, and a factual knowledge about these resources is relevant to the economy of the local people as well as to science.

Pond culture

The experience at Taveta of the Late Colonel Grogan and now at Baobab Farm demonstrates the suitability of the endemic species of Lake Jipe for pond culture. *Tilapia rendalli* has been used in ponds, lagoons and dams both for clearing excess vegetation and as a food fish. Both this and *Oreochromis p.girigan* feed naturally on macrophytes. As Payne (1971) showed with *Tilapia zillii* at Malya (75 miles south of Lake Victoria) plant eaters can efficiently use waste from crops. The problem with *Oreochromis esculentus* in ponds is that it fails to grow as well as in L. Victoria. Payne (1971) found that the growth of *O.esculentus* virtually ceased until he fertilized the pond with ammonium sulphate, to promote a bloom of phytoplankton. This resulted in the resumption of growth. The experiments covered only seven months, however, and the maximum total length of *O.esculentus* at the end of this period was 20 cm, weight 140 g (mean 17 cm and 75 g); and some reproduction was taking place.

In L. Victoria Lowe-McConnell (1956) estimated a growth in length to 14-17 cm for *O.esculentus* in the first year and Garrod's (1959) estimates were in agreement. In ponds and probably in Lake Jipe, growth is brought to a halt by the onset of sexual maturity, which in Lake Victoria is delayed until the age of 2 or 3 years and a length usually of 22 cm or more. Thus the challenge for pond culturists of this species is the familiar one with tilapias - how to delay sexual maturity. This may be done either by design of ponds to discourage territory-establishment by males (Balarin & Haller, 1983) or by hormonal treatment to produce 100% males by sex-reversal of the females. Both methods require specialist skills and capital investment. For a summary see Mires, (1983:600-610).

Acknowledgements

We are grateful to Prof. M. Hyder for encouraging S. Dadzie to pursue this project and to the Director and Trustees of the British Museum (Natural History) for permitting E. Trewavas to use the facilities of the Museum since her retirement in 1961. Baobab Farm is an enterprise of the Bamburi Cement Company. On S. Dadzie's preliminary visit to lakes Jipe and Chala invaluable assistance was given by the Fisheries Department of Kenya, which provided transport from Nairobi to the research site and also the use of fishing nets, outboard engine, fuel and manpower in the field. Mr. David Burnley, a doctorate student from Duke University, Durham, U.S.A., who was carrying out research on the palaeocology of the two Lakes at the time, assisted with logistics and the data collection. The other expenses of the visit and the cost of some apparatus for further laboratory research were funded privately.

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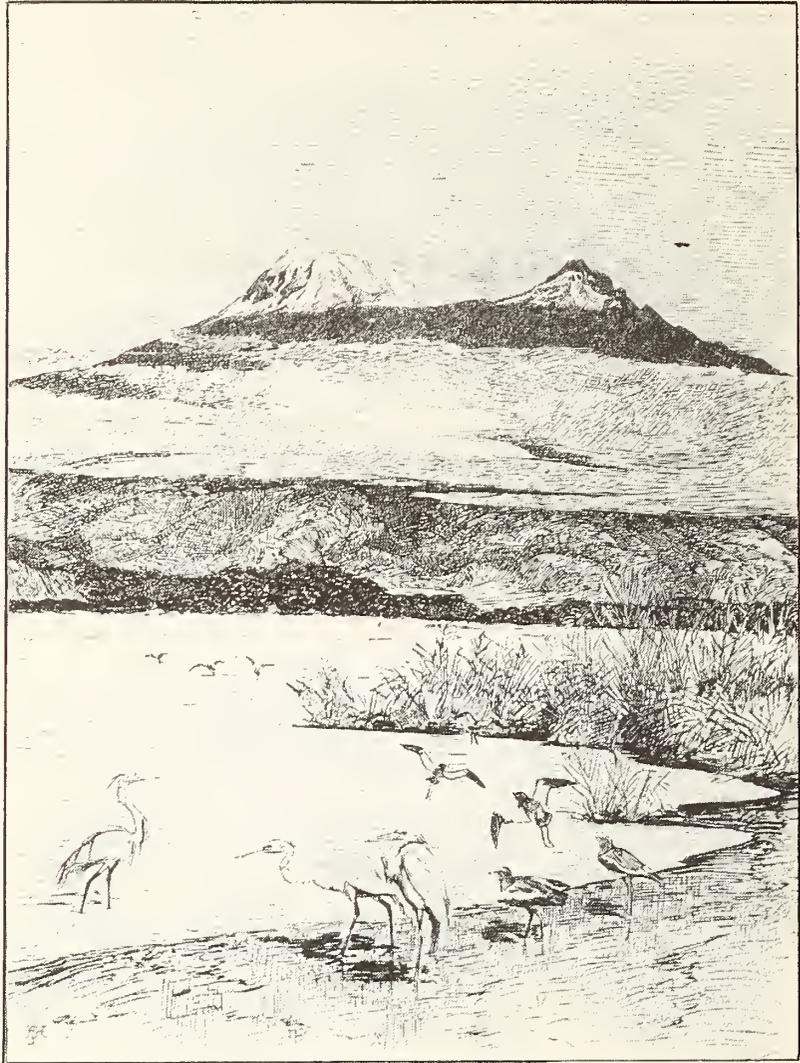


Fig. 1. Lake Jipe. From a sketch by Sir Harry Johnston in his book The Kilima-Njaro Expedition (1886).

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FIG TREES (*Ficus*, Moraceae) OF KENYA

H. J. Beentje
East African Herbarium
National Museums of Kenya



ABSTRACT

An account is given of the wild *Ficus* spp. of Kenya, with a key, descriptions, distribution maps, and line drawings. Preliminary paragraphs deal with the natural history of the genus, particularly with the pollination by Fig wasps (*Agaonidae*, *Hymenoptera*), the biotic community associated with Fig trees and the cultivated species found in Kenya.

Introduction

The Fig trees of Kenya are a relatively poorly known group, as there are no easy keys to identify the many species, and a full treatment of their proper scientific names and synonymy still has to appear (Berg, in press). The account in Dale & Greenway (1961) was for many years the only one treating the Kenyan species, and the keys were unsatisfactory. The present article is a precursor to the new "Kenya Trees, Shrubs and Lianas" which is in preparation at the East African Herbarium. This article is based on the study of the collections of the East African Herbarium, and on some fieldwork by the author. The information on the associated biotic communities was provided by Mr. G.R. Cunningham-van Someren.

Natural History of the Fig tree

Many species of *Ficus* start life as an epiphyte on other trees. Birds and mammals eat ripe figs and excrete the seeds, often in the crooks of branches and trunks of other trees; some of the seeds will germinate in such places, and if there is some moss or plant debris in such a place the young *Ficus* will root, and start its life far from the ground. It sends down roots along the trunk of the 'host' tree, and when these reach the ground (this process may take several years) they take root there, and the root system begins to thicken. Slowly the root system will envelop the trunk of the 'host' tree, the branches of the epiphyte spread through the canopy of the 'host' tree; finally the 'host' tree dies, and the *Ficus* stands on its own. In most of the literature the dying of the 'host' tree is ascribed to strangulation by the roots of the *Ficus*. I think that in many cases the Fig tree will be the victor in the competition for water, food and light, due to its enormous root system in the ground and its much-branched and dense crown. However, Professor Corner (pers. comm.) emphasizes that in the Eastern Tropics many species of *Ficus* do strangle their 'host' as their enveloping root-system expands.

Not all *Ficus* species start life as epiphytes, and many of the so-called epiphytic species may also start life as terrestrials. It is unknown whether this is true for all *Ficus* spp., or if there are really obligatory epiphytes.

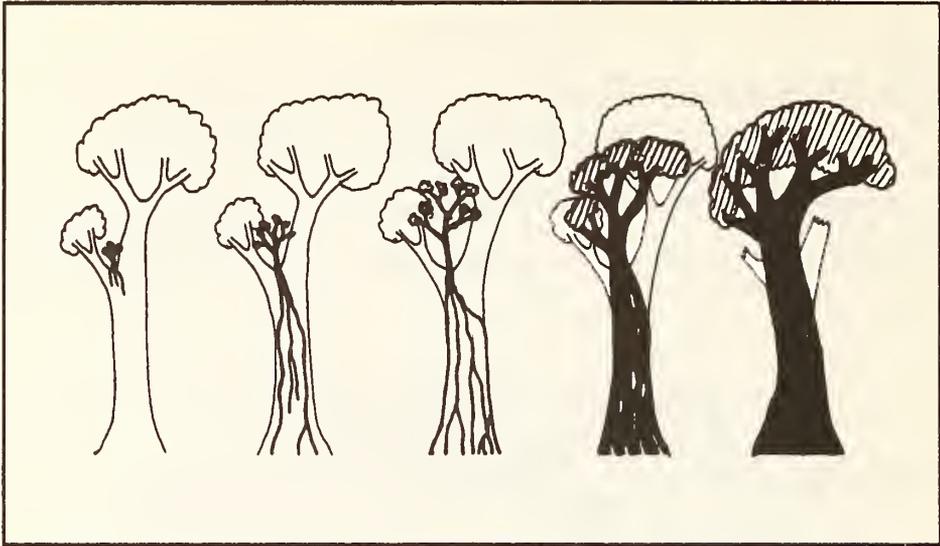


Figure 1.

Most, if not all, species of *Ficus* possess an extensive root system. This allows several species, which seem to be obligatory terrestrials, to grow in localities which are too dry for most other plants: on large rocks and on lava flows (e.g. *Ficus cordata*, *F. glumosa*, *F. ingens*, *F. populifolia*, *F. wakefieldii*). The root system penetrates the smallest of cracks where water might accumulate. There is also a possibility that Fig trees have a capability of picking up moisture from dew, mist, and moisture-saturated air at night. They probably have a large suction-force, enabling the tree to draw moisture from its enormous root system, as well as from the aerial root system which is often present. This large suction force might be the reason why no parasites such as *Loranthaceae* seem to grow on Fig trees.

Pollination

The pollination system of *Ficus* is a beautiful example of a highly evolved symbiosis. The fig, or syconium, regarded by most people as a fruit, is a hollow inflorescence with the flowers, and later the fruits, on the inside. The only opening is at the top, and is called the ostiole; this ostiole is partly blocked by overlapping ostiolar bracts (Figure. 2).

Most species of *Ficus* in Kenya are monoecious, i.e. male and female flowers occur together within a single fig; the following description applies to these species. For the dioecious species, with male and female flowers in separate figs, see page 56.

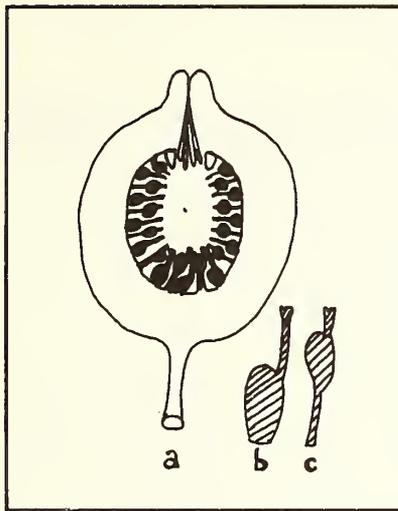
In most monoecious figs, the male flowers are situated near the ostiole, and are few in number. The female flowers are of two kinds: roughly 50% of them have short styles, and the other 50% have long styles; ovules of these two types differ considerably (see Verkerke, 1987). The female flowers are many, up to 2800 in *F. sur* (Verkerke 1988), and the short-styled ones are intermixed with the long-styled ones (Fig. 2). In *F. ottonifolia* Verkerke (1986) found that there is a whole range of style-lengths, and he considers style firmness rather than length the limiting factor for wasp oviposition.

The pollination system consists of several phases:

PHASE 1. The female flowers become receptive; the male flowers are still undeveloped and enclosed (protogyny). The ostiolar bracts open slightly.

PHASE 2. Female fig wasps are attracted by chemical odours (Barker 1985) to their 'own' species of Fig

Figure 2.



- a. longitudinal section of fig (schematic)
 b. long-styled female flower
 c. short-styled female flower

tree, i.e. that species from whose figs they emerged. They enter the fig through the ostiole, a long and difficult labour, even though their bodies are adapted to it. In the process, they lose their wings and the larger part of their antennae; some female wasps even get stuck and die (Galil 1977). In some species the number of female wasps to enter may be controlled by the rapid closing of the ostiolar bracts (Galil et al. 1973a).

PHASE 3. The female fig wasps try to deposit their eggs (oviposit) through the styles of female flowers. In the long-styled flowers the style is longer than the ovipositor of the wasp, and so the attempt fails. In the short-styled flowers it succeeds, as the ovipositor is long enough to deposit an egg between the inner tegument and the nucellus of the fig flower ovary.

As the wasps are very fertile, half of all female flowers (the short-styled half) may receive wasp eggs, while the other (long-styled) half is pollinated when the wasps try to oviposit through the long style. So half the flowers may produce seeds, and half the flowers may produce wasps.

PHASE 4. End of the receptive (female) phase. The fig cavity is sealed by the closing of the ostiolar bracts; the female wasps die inside the fig.

PHASE 5. The interfloral period, seems to be constant for each species of *Ficus* (Ramirez 1974). In the sealed fig the CO_2 level rises, which inhibits the fig from ripening (Galil et al. 1973b). The wasp larvae develop; the ovaries in which the eggs are present develop into galls, grow in size, and produce nutritive tissue for the larvae.

PHASE 6. After a period of between 20 and 100 day the male fig wasps emerge from their galls; they are wingless and look quite different from the female wasps. They seek out the galls with the female wasps, copulate with the females while these are still in the galls, then move to the apical side of the fig and bore and bite their way out of the fig, making one or more holes near the ostiole. The male wasps die soon afterwards.

PHASE 7. Once the fig is holed, the CO_2 level drops, which gives an impulse to the female wasps to emerge from their galls. They move towards the hole made by the male wasps, and on their way encounter the male flowers, which are by now fully ripe. They take pollen from the anthers and deposit it in special pollen pockets or groups of hairs on their thorax. These pollen pockets are closed with a movable lid (Galil & Eisikowitch 1974) so the pollen is not lost when the females crawl through the hole made by the male wasps.

The female wasps then fly away to search for a *Ficus* with figs in phase 1 or 2, to deposit their eggs.

PHASE 8. As the CO₂ level now has dropped, the fig ripens, becoming soft and juicy; mammals and birds eat the fruit and later excrete the seeds, thereby dispersing them.

In dioecious figs (In Kenya *Ficus asperifolia*, *F. capreifolia* and *F. exasperata*) there are two types of figs. "Female" figs contain short-styled as well as long-styled female flowers; "male" figs contain short-styled female flowers as well as male (staminate) flowers. Female wasps emerging from their figs will enter either "female" figs, where they will deposit their eggs in the short-styled flowers or they will enter "male" flowers, where they will do the same. Only young female wasps emerging from "male" figs will carry pollen to the fig they enter, and only if these pollen-carrying wasps enter "female" figs pollination can be achieved. It will be seen that the system with monoecious figs offers four times as many chances of pollination as the system with dioecious figs!

To insure cross-pollination, the pollen-carrying female wasp emerging from a fig must be able to find a fig in phase 1 or 2, and so Fig trees must have staggered flowering seasons. In Nairobi, on 19 February 1986, six trees of *Ficus thonningii* were observed; three of these did not carry figs, one carried young figs, one carried figs from which female wasps were just emerging, and one carried over-mature figs. These trees were within an area of one square kilometre.

Newton & Lomo (1979) observed neatly staggered flowering periods of *Ficus lutea* in Ghana; individual trees showed one or three flowering periods per year.

In most individual Fig trees, all figs seem to be at roughly the same phase at the same time; however, I have observed trees of *Ficus natalensis* and *F. sycomorus* with only a few (not overmature) figs.

The relationship between Fig tree and fig wasp is highly specific; no hybridization between figs is known. Wiebes (1979) thinks that there are 900 species of *Ficus*, each with its own species of fig wasp.

Associated biotic communities

Mammals eating ripe figs include several species of fruitbat (e.g. *Epomops*, *Micropterus*, *Eidolon*, *Rousettus*), monkeys (e.g. Vervet), Baboon, Tree Hyrax, several species of squirrel, Potto, Bushbaby, Nandi Cat, and possibly genet, civet and mongoose. Fallen fruits are eaten by Bushbuck, duiker, Suni, Bush Pig, porcupine, and small rodents.

Birds eating ripe figs include hornbills (Silvery-cheeked, Black and White Casqued, Trumpeter, Crowned, and smaller species), most species of Turaco, pigeons (especially Green, also Speckled), parrots, lovebirds (many species), mousebirds, orioles, starlings (particularly the Violet-backed, which moves around following the fruiting of *Ficus thonningii* and *F. natalensis*), Yellow-vented Bulbul, several species of greenbul and thrush.

Fallen fruits are eaten by francolins and several species of ground dove (Emerald-spotted, Tambourine).

Woodpeckers and barbets excavate nest holes in the soft wood of Fig trees, and these holes are also used by wood hoopoes; many parasitic honeyguides lay their eggs among eggs of these species.

As regards insects, several wood-boring beetles, particularly the long-horned *Cerambycidae* attack the wood of Fig trees. Caterpillars of moths (*Arctiidae*, *Eupterotidae*, *Lymantridae*) feed on the foliage, and are eaten by orioles, cuckoo and cuckoo-shrikes. Caterpillars of the Fig Blues, the butterflies *Myrina silenus* and *M. dermaptera* (Lycenidae) feed on the leaves. Foliage of Fig trees is often infested by scale insects (Coccidae) which are eaten by the smaller honeyguides and by many species of small warblers and sunbirds.

Lichens which grow on the bark of *Ficus thonningii* and *F. natalensis* harbour great numbers of insects, caterpillars and especially spiders, which provide food for tits and the Brown-capped Weaver. Fallen and fermenting figs may attract numbers of butterflies (*Charaxes* spp., *Euphedera* spp., and *Melinis* spp.) as well as many species of flies.

Fig trees often provide support for many kinds of epiphytic plants, such as ferns and orchids.

Mr. Cunningham-van Someren observed a Fig tree in Kakamega with no less than 15 species of orchids. As mentioned on page 54, parasites do not seem to grow on Fig trees.

Uses and cultural significance

Under the descriptions of the species, the specific local uses are given, as recorded on herbarium labels. Some general uses, valid for several or many species, follow.

Because of their soft wood, Fig tree logs are easily hollowed out and can then be used as bee hives, to be hung in trees.

The Fig tree is often used as a shade tree, and for this reason is often left standing when land is cleared for agriculture.

In many cultures, within as well as outside Kenya, Fig trees are considered as being special or even sacred. The Sycomore (*Ficus sycomorus*) is mentioned several times in the Bible (e.g. 1 Ki. x: 27). This species was sacred to several ancient Egyptian gods, especially to Hathor, the goddess of love, and figs of this species have been found in a number of tombs dating back to the first Dynasty (Galil, 1967). *Ficus religiosa* is held sacred by Hindus and Buddhists: The Buddha received his enlightenment under this tree. In Kenya the Mugumo (*Ficus thonningii* and *F. natalensis*) is venerated by the Boran, Maasai, Kiambu, Kikuyu, Kimeru and Kitaita. Meetings of the elders are often held under this tree, and cutting or damaging of such trees is strongly discouraged. The mukuyu (*F. sur*, *F. sycomorus*) is venerated by the Kimeru and Kikuyu as the protector of springs, and several legends are associated with it (Salvadori, pers. comm.). Wood of *Ficus sur* is used for ritual fires during youngsters' circumcision by the Kimeru; Maasai use the latex of this species to protect their cattle from epidemics (Salvadori, pers. comm.)

Cultivated species

In Kenya the following species are cultivated:

F. benjamina L., a tree from India and Malaya.

F. carica L., the edible Fig, originally from the Mediterranean area but now cultivated all over the world. Cultivation in Kenya has not been very successful, but in very hot areas (e.g. Garissa) this species might be a good producer of marketable figs.

F. deltoidea Jack, here a shrub, but normally an epiphyte. Only recorded from City Park, Nairobi; originally from Malaya and Indonesia.

F. elastica Roxb., a tree from South and Southeast Asia, formally widely cultivated for its rubber.

F. macrophylla Desf., a tree from Australia recorded from the Nairobi Arboretum.

F. pumila L., a climber from China and Japan (syn. *F. repens* Rottl.) Leaves on sterile branches are quite different from those on flowering and fruiting branches.

F. religiosa L., the Bo-tree or Peepal. A large tree from India.

F. vogeliana (Miq.) Miq., a tree from West Africa recorded from the Nairobi Arboretum.

These cultivated species may be distinguished as follows:

- | | |
|--|---|
| 1. Climber with dimorphic leaves
Trees or shrubs | <i>F. pumila.</i>
2 |
| 2. Leaves deeply lobed
Leaves entire | <i>F. carica</i>
3 |
| 3. Leaves rounded at apex, small; midrib forked
Leaves acute or acuminate; midrib straight | <i>F. deltoidea</i>
4 |
| 4. Leaf apex acute or subacute
Leaf apex acuminate or caudate | <i>F. vogeliana</i>
5 |
| 5. Leaf apex long-caudate; base rounded or subcordate
Leaf apex acuminate | <i>F. religiosa.</i>
6 |
| 6. Petiole ca. 1 cm long; leaves less than 9 cm long
Petiole more than 2 cm long; leaves more than 10 cm long | <i>F. benamina</i>
7 |
| 7. Leaves white or brown beneath
Leaves greenish beneath | <i>F. macrophylla</i>
<i>F. elastica</i> |

Cultivation of fig trees

Most *Ficus* species will grow from large cuttings planted as the beginning of the rains. Indigenous species such as *F. thonningii*, *F. natalensis* and *F. sycomorus* are widely planted.

One should never plant Fig trees close to houses, as their root systems will crack walls and raise flagstones.

Key to the indigenous species

- | | |
|---|---|
| 1. Leaves sandpapery
Leaves glabrous or hairy, but not sandpapery | 2
7 |
| 2. Leaf apex rounded or obtuse
Leaf apex acute or acuminate | <i>F. sycomorus</i>
3 |
| 3. Leaf base cuneate or narrow and obtuse
Leaf base rounded or (sub)cordate | 4
6 |
| 4. Leaf apex long-acuminate
Leaf apex acute or shortly and bluntly acuminate | <i>F. asperifolia</i>
5 |
| 5. Shrub or small tree or 4.5 m, riverine;
leaves mainly (sub) opposite
Shrub or tree 4-27 m, forest (edge);
leaves always alternate | <i>F. capreifolia</i>
<i>F. exasperata</i> |

- | | |
|---|-------------------------|
| 6. Petiole 3-12 mm, leaves 2-5 cm wide;
shrub or tree to 4.5 m | <i>F. capreifolia</i> |
| Petiole 12-18 mm, leaves 3-13 cm wide;
tree 4.5-25 m | <i>F. sur</i> |
| 7. Leaf base cuneate or narrow and obtuse | 8 |
| Leaf base rounded or (sub) cordate | 16 |
| 8. Leaves hairy | 9 |
| Leaves glabrous | 10 |
| 9. Leaves 13-50 by 3-17 cm; Kakamega | <i>F. saussureana</i> |
| Leaves 3-12.5 by 1.5-6 cm; widely spread | <i>F. thonningii</i> |
| 10. Stipulates persistent, partly connate, 1-2 cm long.
Stipules caducous, or if subsistent, free and less
than 1 cm long | <i>F. cyathistipula</i> |
| | 11 |
| 11. Coastal species, found at altitudes below 50 m;
leaves less than 2 cm wide | <i>F. lingua</i> |
| Inland species, found above 900 m altitude,
or leaves more than 3 cm wide | 12 |
| 12. Ostiole at apex of fig with 3 visible bracts;
swamp species (Kitale) | <i>F. verruculosa</i> |
| Ostiole without visible bracts; only a slit visible | 13 |
| 13. Figs on spurs on old wood, coastal | <i>F. sansibarica</i> |
| Figs in leaf axils | 14 |
| 14. Basal bracts of figs caducous | <i>F. natalensis</i> |
| Basal bracts of fig persistent | 15 |
| 15. Ripe figs yellow or green, 7-14 mm across;
petiole 1-2 mm thick | <i>F. thonningii</i> |
| Ripe figs pale green, 12-30 mm across;
petiole 2-3 mm thick | <i>F. scasselattii</i> |
| 16. Leaf margin repand-dentate or crenulate | 17 |
| Leaf margin entire | 19 |
| 17. Leaf margin crenulate; petiole 0.3-2 cm;
figs sessile | <i>F. nigropunctata</i> |
| Leaf margin repand-dentate; petiole 1.2-11 cm;
figs pedunculate | 18 |

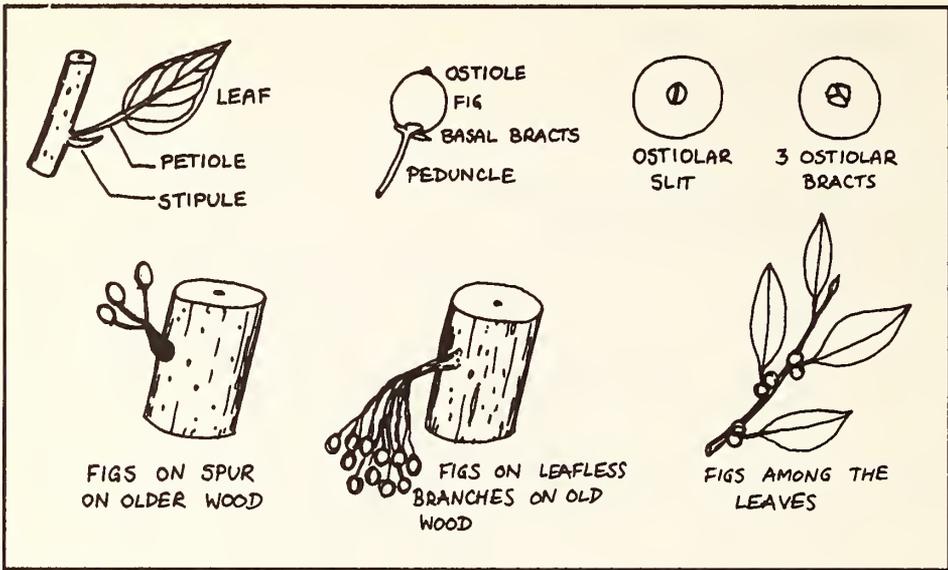


Figure 3.

- | | |
|--|--------------------------------|
| 18. Figs on leafless branches on old wood;
leaves ca. 2 x as long as wide | <i>F. sur</i> |
| Figs among the leaves; leaves less than
1.5 x as long as wide | <i>F. vallis-choudae</i> |
| 19. Stipules persistent, 1-2 cm long; leaves obovate
Stipules caducous, or shorter, or leaves
ovate to elliptic | <i>F. cyathistipula</i>
20 |
| 20. Leaves less than 1.5 x as long as wide | 21 |
| Leaves more than 1.5 x as long as wide | 27 |
| 21. Petiole 0.5-1.5 cm; tertiary venation parallel
to secondary; Shimba Hills
Petiole longer (except in <i>F. glumosa</i>); tertiary
venation partly at right angles to secondary | <i>F. faulkneriana</i>
22 |
| 22. Figs on spurs on old wood | 23 |
| Figs in leaf axils or just below the leaves | 24 |
| 23. Leaves 12-30 cm long, leafy twigs 6-12 mm thick | <i>F. bubu</i> |
| Leaves 5-10 cm long, leafy twigs 2-5 mm thick | <i>F. polita</i> |
| 24. Figs (mature and dried) 20-45 mm across;
riverine tree; leaf base often rounded
Figs when mature 5-16 mm across; tree of
rocky habitats, occasionally also riverine;
leaf base cordate | <i>F. vallis-choudae</i>
25 |

- | | |
|---|------------------------|
| 25. Figs on 8-20 mm long peduncles;
leaf apex acuminate | <i>F. populifolia</i> |
| Figs subsessile or on an up to 5 mm long peduncle;
leaf apex rounded, obtuse, or shortly acuminate | 26 |
| 26. Leafy twig 2-6 mm thick; petiole 0.3-3.5 cm,
not flaking | <i>F. glumosa</i> |
| Leafy twigs 5-12 mm thick; petiole 2-9 cm,
when dry with flaking epiderm | <i>F. vasta</i> |
| 27. Figs on older wood | 28 |
| Figs in leaf axils or just below the leaves | 33 |
| 28. Figs on branched leafless "branches" | <i>F. sur</i> |
| Figs on short unbranched spurs or in clusters
on thicker wood | 29 |
| 29. Petiole thin (less than 1 mm thick) | <i>F. tremula</i> |
| Petiole more than 1 mm thick | 30 |
| 30. Figs with persistent, 2-5 mm long basal bracts; figs glabrous | 31 |
| Figs with caducous basal bracts, figs (minutely) puberulous | 32 |
| 31. Figs 12-18 across, without stipe, on spurs to 15 mm long | <i>F. ottoniifolia</i> |
| Figs 15-22 mm across, with a stipe, on spurs to 30 mm long | <i>F. polita</i> |
| 32. Leaf base cordate; basal veins branched (Thika) | <i>F. chirindensis</i> |
| Leaf base rounded; basal veins unbranched (coast) | <i>F. sansibarica</i> |
| 33. Figs on peduncles more than 10 mm long;
coastal species, at altitudes below 450 m | 34 |
| Figs on peduncles less than 10 mm long, or, if
10 mm long, only found at altitudes above 900 m | 35 |
| 34. Leafy twigs more than 4 mm thick;
leaves 9-22 by 4-11 cm | <i>F. bussei</i> |
| Leafy twigs less than 3 mm thick;
leaves 4-7.5 by 2-4.5 cm | <i>F. faulkneriana</i> |
| 35. Tertiary venation of leaves partly at right angles
to secondary veins | 36 |
| Tertiary venation reticulate | 39 |
| 36. Ostiole of fig with 3 visible bracts | <i>F. ingens</i> |
| Ostiole of fig without visible bracts; only a slit visible | 37 |
| 37. Leaf base cordate; figs 5-12 mm across;
leaves 2-14 cm long | <i>F. glumosa</i> |
| Leaf base rounded or subcordate; figs 12-25 mm across;
leaves 9- 30 cm long | 38 |

- | | |
|--|-----------------------|
| 38. Petiole, when dry, with flaking epiderm | <i>F. lutea</i> |
| Petiole, when dry, not flaking | <i>F. ovata</i> |
| 39. Ostiole of fig with 3 visible bracts | <i>F. cordata</i> |
| Ostiole of fig with only a slit visible | 39 |
| 40. Leaf with the basal veins faintly branched | <i>F. stuhlmannii</i> |
| Leaf with unbranched basal veins | 40 |
| 41. Basal bracts of fig 15-20 mm long | <i>F. amadiensis</i> |
| Basal bracts of fig 2-4 mm long | <i>F. thonningii</i> |

Descriptions of the species

After the current scientific name the synonyms are given which were used in Dale & Greenway (1961) or Gillett & McDonald (1970). In the descriptions, it should be noted that the measurements of figs refer to their dried state. Fresh figs may be up to 20% larger.

After the description, the habitat(s) in which the species is commonly found is given, as well as the altitude range (in meters) as far as known. The roman numerals after the altitude ranger refer to the months in which the species has been found to carry figs in Kenya. A star behind these numerals indicates that there are less than 12 observations of the species with figs.

After this, the known local names are given. These have been taken from herbarium labels and have not been checked. After the name the language of that name is indicated by three or four letters. Finally, the local uses are given.

The illustrations have been prepared by the author from dried material; the leaves are reduced to 30-50% of life size; the figs are life or slightly less. The maps show where the species has been found to occur; each black square covers an area of ca. 38 by 38 km (23 by 23 miles) and may represent either a single collection or several collections.

Ficus amadiensis De Wild. (Syn. *F. kitubalu* Hutch.)

Spreading tree 4-15 m high. Leafy twigs 5-10 mm thick. Stipules subsistent, 5-15 mm long. Leaves glossy, elliptic or ovate, base rounded or subcordate, apex rounded or obtuse, 7-14 by 3-7 cm, glabrous; petiole 1.5-7.5 cm. Figs sessile in leaf axils; basal bracts persistent, 15-20 mm long; figs red, globose, 12-22 mm across and wrinkled when dry.

Wooded grassland, clump bush grassland; 1500-1950 m; III, VIII-IX, XII*. Occurs in Central & East Africa.

Bonyo (Luo). Ripe fruits are edible.

Ficus asperifolia Miq. (Syn. *F. stortophylla* Warb., *F. urceolaris* Hiern)

Shrub 1.5-6 m, often with subscandent branches. Leaves elliptic or slightly (ob)ovate, base cuneate, apex long-acuminate, margin lobed or dentate, 4-20 by 2-9 cm, sandpapery; petiole 0.5-2 cm. Figs sessile or on peduncles to 2 mm long, in the leaf axils; figs yellow or red, globose, 5-14 mm across, sandpapery.

Forest edges and thickets; 1500-1850 m; I, IV, VII, IX-XII*. Also in West and Central Africa.

Luseno (Kav.). The latex is used by the Luhya against skin swellings in humans and livestock.

Ficus bubu Warb.

Tree to 20m, often epiphytic; bark pale green or white; leafy twigs 6-12 mm thick. Leaves elliptic to subcircular, base rounded or cordate, apex shortly acuminate to almost rounded, 12- 30 by 6-23 cm,

glabrous; petiole 4-11 cm long. Figs on short spurs on older wood, with 7-10 mm long peduncles and persistent 4-5 mm long basal bracts; figs brownish, globose, ca. 25 mm across, glabrous or nearly so and wrinkled when dry.

Forest or riverine forest; 1-1200 m; I, IX*. Occurs in East and Central Africa.

Ficus bussei Mildbr. & Burret

Tree 4.5-25 m; trunk fluted at base; bark grey; aerial roots often present. Leafy twigs 4-12 mm thick. Leaves ovate or elliptic, base cordate, apex obtuse, 9-22 by 4-11 cm, glabrous or nearly so; petiole 2-8 cm. Figs in the leaf axils on 10-25 mm long curved peduncles; basal bracts persistent, ca. 3 mm long; figs green with whitish warts, globose, 10-18 mm across, puberulous.

Riverine or in coastal bushland; 1-450 m; II-III, X, XII*. Occurs in large parts of Africa.

Mugandi (Digo, Gir.). String is made from the bark by the Giriama.

Ficus capreifolia Del. (formerly *F. capreaefolia*)

Shrub or small tree, 3-4.5 m. Leaves alternate or subopposite, elliptic, base rounded or cuneate, apex acute, margin sometimes slightly crenate, 6-15 by 2-5 cm, sandpapery; petiole 3-1 mm. Figs in the leaf axils on 5-20 mm long peduncles (including stipe); figs green or pale yellow, globose, 10-25 mm across, scabrid.

Riverine; 200-1200 m; I, VII, IX-XII*. Occurs in most of Africa.

Get (Luo), Arabi sofarra (Som.), Edung/Epwatakela (Turk). The ripe fruit is edible, the leaves are used as sandpaper.

Ficus chirindensis CC Berg

Tree to 35 m. Leaves elliptic, base cordate, apex shortly acuminate, 6-12 by 3-7.5 cm, glabrous or nearly so; petiole 2-4 cm. Figs on up to 3 cm long spurs on older wood; peduncle 15-20 mm; figs green to pale yellow, globose, 15-30 mm across, minutely puberulous.

Riverine forest; ca. 1500 m; V*. Also in Central Africa.

Found only once (Faden 67/149) near Thika. I have not seen the figs.

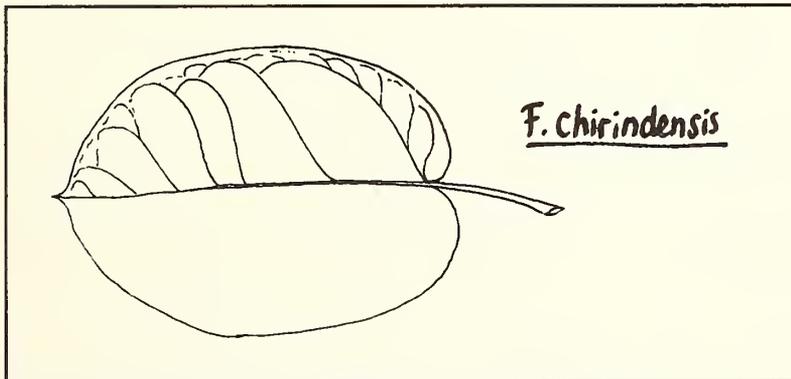


Figure 4.

Ficus cordata Thunb. ssp. *salicifolia* (Vahl) CC Berg (Synonym *F. salicifolia* Vahl)

Tree to 15 m; bark grey, smooth or wrinkled. Leaves narrowly ovate or elliptic, base rounded or subcordate, apex obtuse, acute or shortly acuminate, 7.5-16 by 3-7 cm, glabrous; petiole 1.2-3.6 cm. Figs in the leaf axils, sessile or on up to 3 mm long peduncles; figs green to red, globose, 6-9 mm across, glabrous.

On rocks and cliffs, often near water; 950-1900 m; I-II, IV, IX-XII. Occurs in Eastern & Southern Africa.

Siricho (Boran), Osogunuo (Maa), Simotuet (Kips.), Tipoiwa (Pokot); ripe fruits are edible; Pokot use the latex to fasten feathers to arrows.

***Ficus cyathistipula* Warb. (Synonym *F. rhynchocarpa* Mildbr. & Burret)**

Tree 12-15 m, occasionally epiphytic; aerial roots sometimes present. Leaves shiny, obovate, base cuneate (occ. rounded), apex acuminate, 6-22 by 3-7 cm, glabrous; petiole 1.5-4 cm; stipules persistent, partly connate, 1-2 cm long. Figs in the leaf axils, on 5-25 mm long peduncles; basal bracts persistent, 4 mm long; figs pale green or pale yellow, globose or (ob)ovoid, 2-3 cm across, glabrous, sandpapery or warted.

Forest (edges), occasionally riparian, 1450-1650 m; I, III, X*. Occurs in West and Central Africa.

***Ficus exasperata* Vahl**

Tree 4-27 m; bark whitish. Leaves elliptic or slightly (ob)ovate, base cuneate or obtuse, apex shortly acuminate (rarely rounded), margin dentate or subentire, 2.5-12 by 1-6 cm, scabrid; coppice shoots may be 3-lobed near the apex and up to 21 by 12 cm; petiole 5-25 mm. Figs in leaf axils or on older wood, on peduncles 5-25 mm long; figs yellow or red, 8-17 mm across, scabrid.

Wet forest (edges) or on limestone outcrops; 1-1850 m; II-III, VI-VIII, XI*. Occurs from West Africa to South India and Southern Africa.

Jamisyat (Kips.), Museno (Luhya). Leaves are used as sandpaper.

***Ficus faulkneriana* CC Berg**

Tree 9-30 m (occ. epiphytic?). Leaves elliptic or obovate, base rounded or subcordate, apex rounded, 4-7.5 by 2-4.5 cm, glabrous; petiole 0.5-1.5 cm. Figs in leaf axils on 10-12 mm long peduncles; basal bracts persistent, 1.5-2 mm long; figs yellow or red, 7-8 mm across, glabrous.

Found once (Magogo & Glover 51) in the Shimba Hills, at a forest edge; 420 m; II* Endemic to Kenya and Northeast Tanzania.

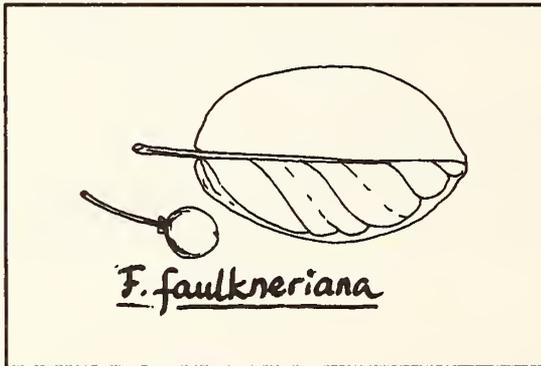


Figure 5.

***Ficus glumosa* Del. (Syn. *F. sonderi* Miq.)**

Shrub or tree 2-15 m, spreading, with smooth grey bark; occasionally with aerial roots. Leaves ovate or elliptic, base cordate, apex rounded, obtuse, or shortly acuminate, 2.5-14 by 2-9 cm, glabrous or (densely) pubescent; petiole 0.3-3.5 cm. Figs in the leaf axils or somewhat below the leaves, sessile or on peduncles to 3 mm; basal bracts persistent, 3 mm long; figs orange or red, globose, 5-12 mm across, glabrous to tomentose.

On rocky outcrops and hillsides, mainly in dry country; 450-2050 m; I-XI. Occurs over most of Africa, and in Yemen.

Kilta (Boran), Kionywe (Kamba), Chilgotwet (Kips.), Olngaboli (Maa), Berde (Som.), Kishoe (Taita). Ripe fruits are edible.

***Ficus ingens* (Miq.) Miq.**

Shrub or tree, 1-17 m, spreading; sometimes epiphytic. Leaves ovate or elliptic, base cordate or rounded, apex obtuse, acute or shortly acuminate, 5-17 by 2-8 cm, glabrous; petiole 0.5-4 cm. Figs in the leaf axils or just below the leaves, sessile or on peduncles to 5 mm long; figs pink, red or purple, globose, 6-12 mm across, glabrous or pubescent, wrinkled when dry.

On rocky sites, on lava (where it is often the only tree), in rocky gorges, always in dry country; 150-2600 m; I-II, IV-XII. Occurs in most of Africa and in Yemen.

Onogoret (Maa), Chemul-Mogoyuet (Kips.), Kionywe/Kiumo (Kamba); the wood is used for doors and stools (Kips.), and branches are used for firesticks (Maa.)

***Ficus lingua* De Wild. & Th. Dur. ssp. *depauperata* (Sim) CC Berg (Syn. *F. depauperata* Sim)**

Tree to 25 m, often starting as an epiphyte, much branched and spreading; bark smooth and grey. Leaves obovate, base cuneate or obtuse, apex obtuse or rounded, 2-6 by 0.8-2 cm, glabrous; petiole 0.2-0.8 cm. Figs in the leaf axils or just below the leaves, on 1.5 mm long peduncles; figs yellow or red, globose, 4-6 mm across, minutely puberulous.

In semi-deciduous coastal forest; 1-25 m; VII-VIII, X*. The variety only occurs in East Africa.

***Ficus lutea* Vahl (Syn. *F. quibeba* Ficalho, *F. subcalcarata* Warb. & Schweinf., *F. vogelii* (Miq.) Miq.)**

Tree to 16 (36?) m, occasionally epiphytic, spreading; occasionally with aerial roots; bark greybrown. Leafy twigs 5-12 mm thick. Leaves elliptic, base rounded or subcordate, apex rounded or shortly acuminate, 9-25 (40) by 4-15 cm, glabrous or pubescent; petiole 1.5-12 cm. Figs in the leaf axils or just below the leaves, sessile; basal bracts persistent, 3-6 mm long; figs yellow or orange, globose, 12-17 mm across, puberulous or pubescent.

Wetter forest (edges), riverine forest or woodland, occasionally on rocks; 350-2000 m; III, V, IX-XII*. Occurs over most of Africa and in Madagascar.

***Ficus natalensis* Hochst.**

Tree 5-30 m, occasionally epiphytic. Leaves elliptic or obovate, base cuneate or obtuse, apex obtuse, rounded or shortly acuminate, 3-8 by 1.5-4.5 cm, glabrous; petiole 0.5-2.5 cm. Figs in leaf axils or just below the leaves, on 2-10 mm long peduncles; basal bracts caducous; figs yellow or red, globose, 8-18 mm across, glabrous, usually wrinkled when dry.

In riverine and groundwater forest, and presumably also in forest away from water; 900-1800 m; I-IV, VII-X, XII. Occurs over most of Africa.

Kiumo (Kamba), Mugumo (Kik.); often confused with *F. thonningii*; *F. natalensis* is much less common in Kenya.

***Ficus nigropunctata* Mildbr. & Burret**

Shrub or tree 3-7 m, sometimes epiphytic. Leaves elliptic or (ob)ovate, base rounded or subcordate, apex acute or shortly acuminate, margin crenulate, 1-9.5 by 0.5-5.5 cm, puberulous, when dry sometimes black-punctate; petiole 0.3-2 cm. Figs in leaf axils or on older wood, sessile; basal bracts persistent, 2-2.5 mm; figs green to reddish, globose, 5-10 mm across, puberulous.

Found once (Gatheri, Mungai & Kanuri 79/124) near Mutomo on rocky ground; ca. 900 m; XI*. Occurs in East and Central Africa.

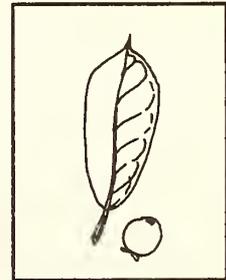


Figure 6.

Ficus ottoniifolia (Miq.) Miq. ssp. *ulugurensis* (Mildbr. & Burret) CC Berg

Shrub or tree to 15 m, occasionally epiphytic. Leaves elliptic or (ob) ovate, base rounded or subcordate, apex acuminate, 6-15 by 3-6 cm, glabrous; petiole 1.5-5 cm. Figs on spurs to 15 mm long on older wood, peduncle 8-18 mm; basal bracts persistent, 2-3 mm; figs green to pale orange, ellipsoid, 12-18 mm across, glabrous.

In riverine forest, near the coast on coral or limestone outcrops; 1-1450 m; I, XI*. The variety is rare and only occurs in East Africa.

Ficus ovata Vahl (Syn. *F. brachypoda* Hutch.)

Tree, 3-15 m, occasionally epiphytic; bark pale grey or red-brown. Leaves ovate or elliptic, base rounded or subcordate, apex acuminate, 10-30 by 6-20 cm, glabrous (rarely puberulous) beneath; petiole 3-10 cm. Figs in the leaf axils or occasionally on older wood, on a 0-5 mm long peduncle; basal bracts persistent, 3-4 mm; figs green, ellipsoid or ovoid, 15-25 mm across, puberulous or pubescent.

Acacia-Terminalia wooded grassland, also riparian; 1100-1950 m; V-VI, XI*. Occurs over most of Africa.

Chemul-Mogoywet (Kips.), Kutoto, Omododo (Luhya), Siritiot (Nandi); used to make doors and stools (Kips.).

Ficus polita Vahl ssp. *polita*

Tree 4.5-15 m, occasionally epiphytic; bark grey. Leaves ovate, base rounded or (sub)cordate, apex acuminate, 5-16 by 4-10 cm, glabrous; petiole 2-12 cm. Figs on up to 3 cm long spurs on older wood, on 8-18 mm long peduncles; basal bracts persistent, 3-5 mm; figs green with yellow specks to purplish, 15-22 (40) mm across, wrinkled when dry.

Found twice, near Kibwezi (Verdcourt & Polhill 2689) and Kilifi (Moggridge 392), probably in bushland; 50-1150 m; IV*. Occurs in most parts of Africa, also in Madagascar.

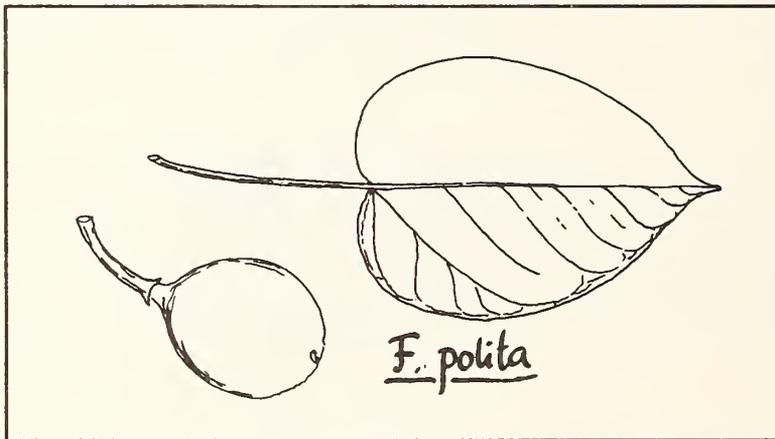


Figure 7.

Ficus populifolia Vahl (incl. *F. abutilifolia*)

Shrub or tree, 1-15 m; bark grey or off-white; leafy twigs 3-10 mm thick. Leaves broadly ovate, base deeply cordate, apex acuminate, 3-18 by 3-15 cm, glabrous or nearly so; petiole 2.5-10 cm. Figs in the leaf axils, on 8-20 mm long peduncles; figs green with red spots or yellowish, slightly obovoid, 6-12 mm across, glabrous or nearly so.

On rocks and lava; 450-1500 m; I, III, V-VII, IX-X, XII. Occurs in most parts of Africa and in Yemen. Ololii (Maa), Sosotwo (Pokot), Nidir/Hamash (Som.), Ekuyen/Ekii (Turk.), Simatwa/Chirilotwa (Tugen). The ripe fruit is edible; Tugen use the latex as a remedy for sore eyes.

Ficus sansibarica Warb. ssp. *sansibarica* (Syn. *F. brachylepis* Hiem)

Tree 9-20 m, occasionally epiphytic. Leaves elliptic or ovate, base rounded, apex obtuse or obtusely acuminate, 5-13 by 2-6 cm, glabrous; petiole 1-5.5 cm. Figs on up to 3.5 cm long spurs on the main branches, on a peduncle 10-25 mm long; figs green or purplish, globose, 15-30 mm across, puberulous, wrinkled when dry.

Evergreen forest (edges); 1-150 m; X*. Occurs in East and Southern Africa. Musangasanga (Gir.)

Ficus saussureana DC. (Syn. *F. eriobotryoides* Kunth & Bouche)

Tree to 20 m (or more?), occasionally epiphytic; crown spreading. Leafy twigs 5-15 mm thick. Leaves slightly obovate, base obtuse or cuneate, apex acuminate, 13-50 by 3-17 cm, puberulous beneath; petiole 1-8 cm. Figs in the leaf axils or just below the leaves, subsessile; basal bracts persistent, 7-15 mm; figs yellow or orange, globose or obovoid, 15-30 mm across, densely long-hairy.

Collected once (Gilbert 6363) in Kakamega Forest; ca. 1600 m; I*. Occurs in East, Central and West Africa.

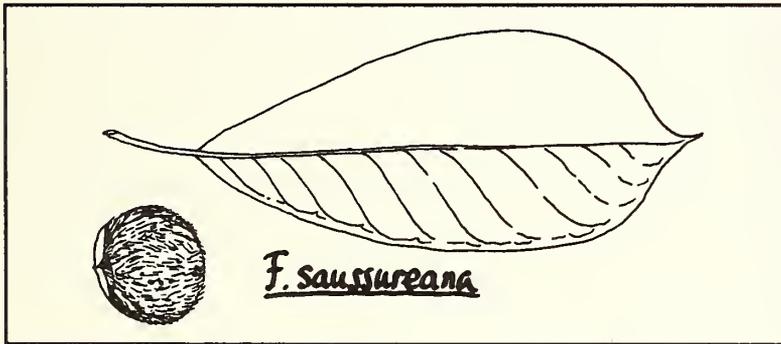


Figure 8.

Ficus scassellatii Pamp. (Syn. *F. kirkii* Hutch.)

Tree to 25 m (or more), occasionally epiphytic; aerial roots may be present; bark grey or whitish. Leaves elliptic or obovate, base cuneate, apex obtuse or shortly acuminate, 6-28 by 3-8 cm, glabrous; petiole 0.5-3 cm. Figs in the leaf axils, sessile (in ssp. *thikaensis*) or on a peduncle 5-15 mm long (ssp. *scassellatii*); basal bracts persistent, 3-5 mm; figs pale green, globose or ellipsoid, 12-20 (ssp. *scassellatii*) or 20-30 (ssp. *thikaensis*) mm across, almost glabrous.

In riverine or groundwater forest, on the coast also in evergreen forest; 1-1800 m; I-III, IX-XII*. Ssp. *scassellatii* occurs in East and Central Africa; ssp. *thikaensis* CC Berg is only recorded from the area around Thika.

Ficus stuhlmannii Warb.

Tree to 10 m, occasionally epiphytic. Leafy twigs 4-8 mm thick. Leaves elliptic or (ob)ovate, base rounded or subcordate, apex rounded or obtuse (rarely shortly and bluntly acuminate), 3-8 cm, densely puberulous; petiole 0.5-4 cm. Figs in the leaf axils, (sub)sessile; figs pink or purplish, globose or ellipsoid, 7-18 mm across, puberulous or pubescent.

Open forest or bushland, but information from Kenya is scarce. In other countries often riverine or on rocks; 1-1500 m; I-II, V, X*. Occurs in Central, East and Southern Africa.

Ficus sur Forssk. (Syn. *F. capensis* Thunb.)

Tree 4.5-25 m, occasionally epiphytic; sometimes buttresses are present; bark grey or whitish. Leaves ovate or elliptic, base rounded or subcordate, apex acute or acuminate, margin repand-dentate or occasionally entire, 5-20 by 3-13 cm, glabrous, pubescent or sandpapery; petiole 1.2-8 cm. Figs on up to 50 cm long leafless branches on old wood, on 3-15 mm long peduncles; figs orange or red, globose or obovoid, 5-33 mm across, puberulous or densely tomentose.

Riverine, groundwater forest, or less often in forest away from water; 1-2100 m; I-XI. Occurs in most of Africa and also in Yemen.

Odaa (Boran), Mukuyu (Digo, Kik.), Mogoyuet (Kip.), Omoraa (Kisii), Musingu (Luhya), Ngowo matundo (Luo), Olngaboli (Maa), Iingaboli (Sam.). The ripe fruit is edible; the Digo use a root decoction as a cough remedy; Maasai use a bark infusion against stomachache and baby's diarrhoea; Kipsigis use the wood to make stools and grain mortars.

Ficus sycomorus L. (Syn. *F. gnaphalocarpa* (Miq.) A. Rich., *F. mucoso* sensu KTS, non Ficalho)

Tree to 21 m, occasionally buttressed; bark yellowish. Leaves broadly (ob)ovate or elliptic, base (sub)cordate, apex rounded or obtuse, margin entire or slightly repand-dentate, 2.5-13 (21) by 2-10 (16) cm, sandpapery at least on the upper surface; petiole 0.9-50 cm. Figs in the leaf axils or on up to 10 cm long leafless branches on old wood; peduncle 3-25 mm; figs yellow or reddish, globose or (ob)ovoid, 14-37 mm across, pubescent or almost glabrous.

Riverine, or in places with a high groundwater table, possibly also in forest or bushland; 1-1850 m; I-XII. Occurs over most of Africa and in Arabia.

Mukuyu (Swa., Kamba, Kik., Meru, Taita), Od (Boran), Mogoiwet (Kips.), Orangaboli (Maa), Sebetwet (Nandi), Mokongwa (Pokot), Santau/Guuden (Rend.), Lngaboli (Sam.), Lokoiwo (Tugen), Echoke (Turk.). The ripe fruit is edible. The wood is used for small implements, e.g. mortar and pestle (Pokot, Turkana) or for doors and house building (Kipsigis); the Taita use the inner part of the root bark for fibre for weaving.

Ficus thonningii Bl. (Syn. *F. dekdekana* (Miq.) A. Rich., *F. eriocarpa* Warb., *F. mammigera* RE Fr.)

Tree 6-21 m, occasionally epiphytic; bark grey; aerial roots often present. Leaves elliptic or obovate, base cuneate or narrow and obtuse (rarely subcordate), apex rounded or obtuse (rarely shortly and bluntly acuminate), 3-12.5 by 1.5-6 cm, glabrous, puberulous or pubescent; petiole 0.8-3 (6) cm. Figs in the leaf axils or occasionally below the leaves, sessile or on peduncles to 10 mm long; basal bracts persistent, 2-4 mm; figs yellow or red, globose or ellipsoid, 7-14 mm across, smooth or warted, glabrous or pubescent.

In wet or dry upland forest, often left standing after clearing; also riverine, on rocky sites, in bushed or wooded grassland (as a forest relict?); 1050-2400 m; I-VI, VIII-XII. Occurs over most of Africa.

Mugumo (Embu, Kik., Meru), Dambi (Boran), Kiumo/Muumo (Kamba), Simotwet (Kips.), Pocho (Luo), Oreteti (Maa), Sapoitit (Okiek). The ripe fruit is edible. A ceremonial tree in several cultures. The bark fibre is used for string (Okiek); branches are used as firesticks by the Maasai.

Ficus tremula Warb.

Tree or liana, 2.4-10 m (or more), occasionally epiphytic. Leaves elliptic or obovate, base rounded or subcordate, apex subacute to shortly acuminate, 3-11 by 2-5 cm, glabrous or with the midrib puberulous; petiole 1-4.5 cm. Figs on up to 2 cm long curved spurs on old wood, on 5-22 mm long peduncles; figs green, globose or ellipsoid, 10-20 mm across, glabrous or puberulous. Two subspecies are found in Kenya:

- ssp. *tremula* - twigs drying yellowish or grey, leaves drying dark brown above.

Dry evergreen forest or coastal woodland; a common epiphyte in *Hyphaene*; also found very close to the beach; 1-50 m; I, VII, X, XII*. Occurs in East and Southern Africa.

Uzi (Swa.). The bark is used to make very strong string.

- ssp. *acuta* (De Wild.) CC Berg - twigs drying brown or blackish, leaves drying brownish on both sides. Wet upland forest; 1650-2200 m; III, XII*. Occurs in Central Africa.

Motirtiruet (Kips.), Shikuyense (Luhya).

Ficus vallis-choudae Del.

Tree 6-20 m; bark greybrown; buttresses occasionally present. Leafy twigs 2-10 mm thick. Leaves broadly ovate, base rounded or cordate, apex obtuse, acute, or shortly acuminate, margin repand-dentate or subentire, 10-26 by 6-24 cm, glabrous or puberulous, rarely sandpapery; petiole 2-11 cm. Figs in the leaf axils or just below the leaves, on 3-7 mm long peduncles; figs yellow or reddish, globose or obovoid, 20-45 mm across, glabrous, puberulous or tomentose.

Riverine; 600-1800 m; I-IV, VI-VIII, X, XII. Occurs over most of Africa.

Ongaboli/El ponyi (Maa).

Ficus vasta Forssk. (Syn. *F. wakefieldii* Hutch., but Berg disagrees with this.)

Tree to 25 m, occasionally epiphytic. Leafy twigs 5-12 mm thick. Leaves broadly elliptic or broadly (ob)ovate, base cordate, apex rounded or obtuse, 6-25 cm, puberulous or hirtellous; leaves (faintly) aromatic, at least when dry; petiole 2-9 cm. Figs in the leaf axils, (sub)sessile; basal bracts persistent, 3-5 mm; figs green with white spots, globose, 10-16 mm across, densely pubescent, sometimes warted.

On rock, lava, and limestone; sometimes riverine; 200-2000 m; I-IV, VI, IX-XII. Occurs in East and Northeast Africa and in Arabia.

Kilta (Boran), Mukuyu (Kamba), Chiptokelat (Pokot), Reteti (Sam.), Berd (Som.), Echoge (Turk.). The ripe fruit is edible.

Ficus verruculosa Warb.

Shrub or small tree 1-7 m. Leaves elliptic, base obtuse or cuneate, apex obtuse or subacute, 3.5-10 by 1.5-3.5 cm, glabrous; petiole 0.3-1 cm. Figs in the leaf axils or just below the leaves, on 3-5 mm long peduncles; figs red or purple, (sub)globose, 5-10 mm across, glabrous or nearly so.

Found once (Bogdan 3733) in a swamp near Kitale; 1860 m; V*. Occurs over large parts of Africa, most often in water.

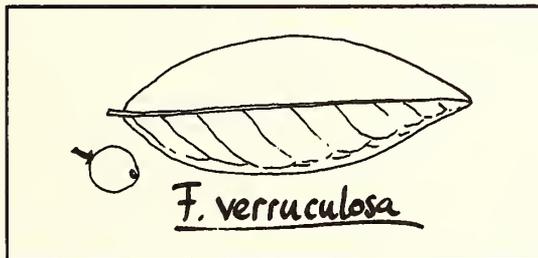


Figure 9.

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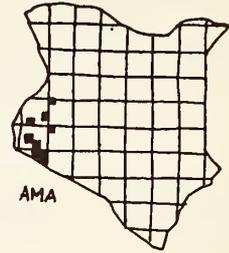
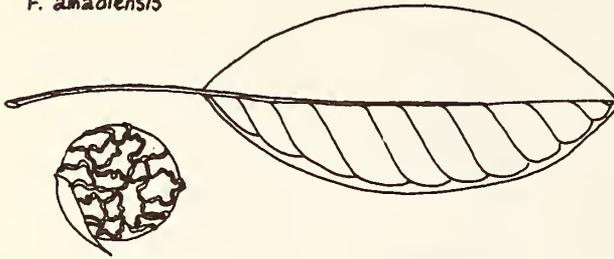
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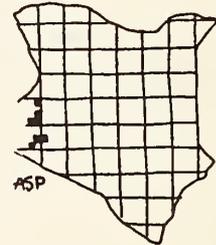
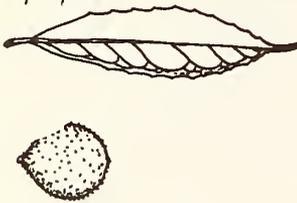
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Chilgotwet	glu	Olngaboli	glu, sur, val
Chirilotwa	pop	Ololil	pop
Dambi	tho	Omododo	ova
Echoge, Echoke	syc, vas	Omoraa	sur
Edung	cap	Onogoret	ing
Ekii	pop	Orangaboli	syc
Ekuyen	pop	Oreteti	tho
Epwatakele	cap	Osogunuo	cor
Get	cap	Pocho	tho
Guuden	syc	Reteti	vas
Hamash	pop	Santau	syc
Ilingboli	sur	Sapoitit	tho
Jamisyat	exa	Sebetwet	syn
Kilta	glu, vas	Shikuyense	tre
Kionywe	glu, ing	Simtwa	pop
Kishoe	glu	Simotuet	cor
Kiumo	ing, nat, tho	Simotwet	tho
Lngaboli	syc	Siricho	cor
Lokoiwo	syc	Siritiot	ova
Luseno	asp	Sosotwo	pop
Mogoiwet	sur, syc	Tipoiwa	cor
Mogoyuet	sur, syc		
Mokongwa	syc		
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Museno	exa		

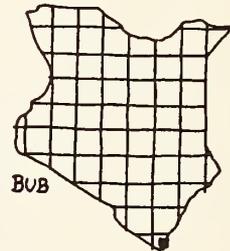
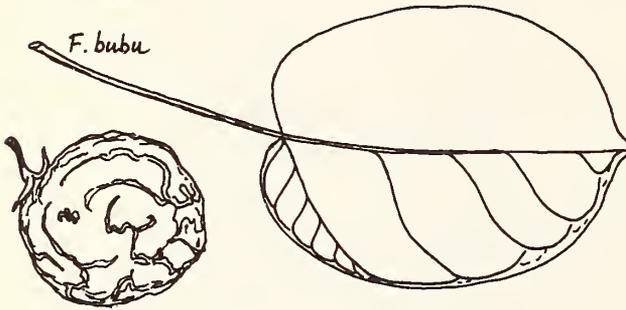
F. anadiensis



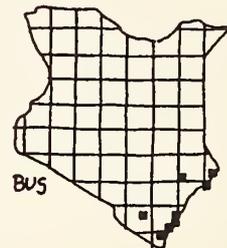
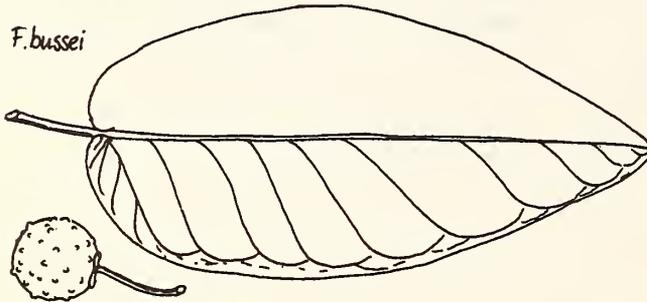
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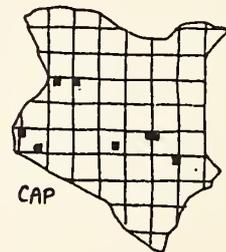
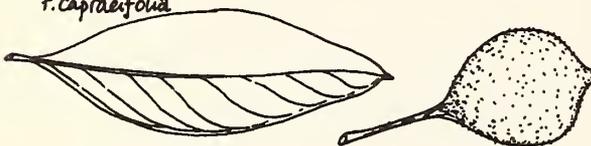
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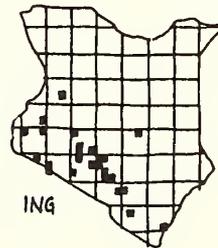
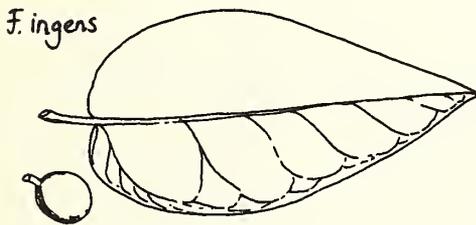
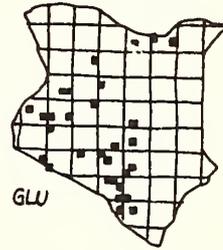
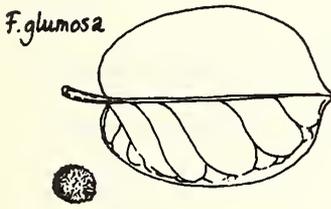
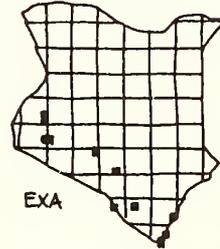
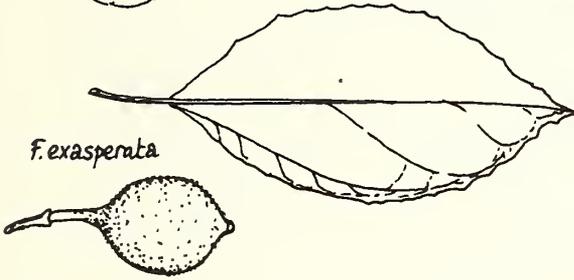
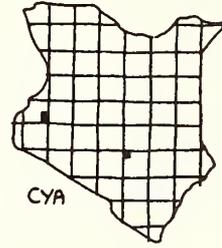
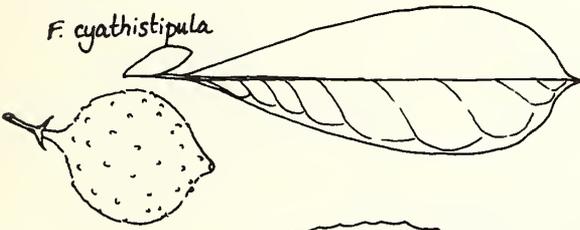
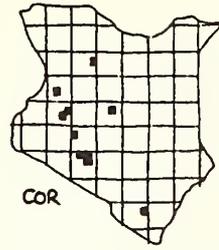
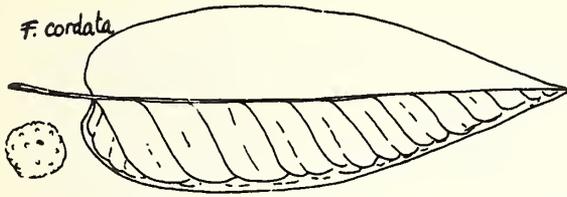


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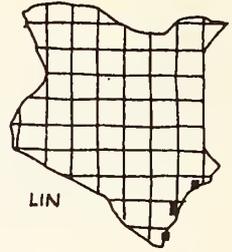
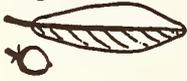


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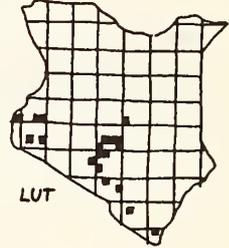
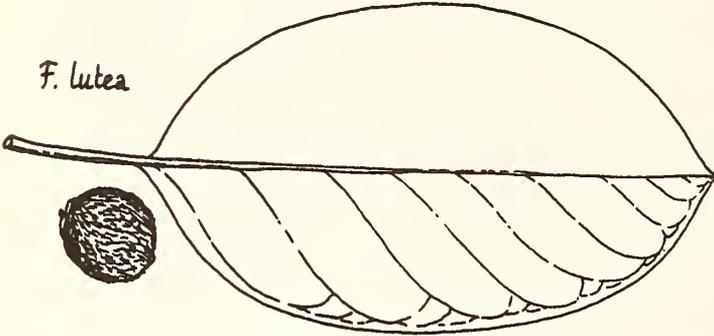


F. lingua



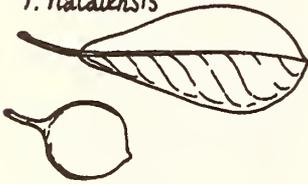
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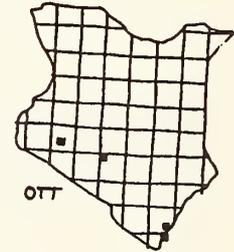
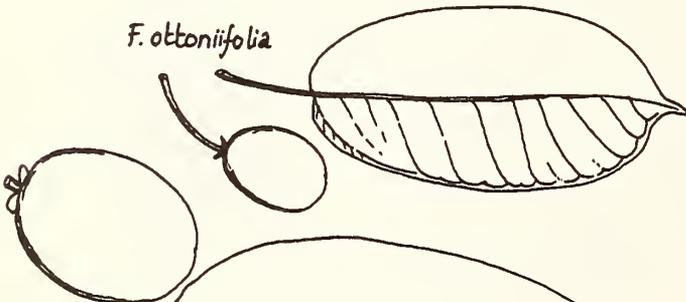
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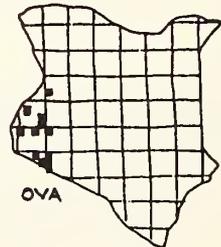
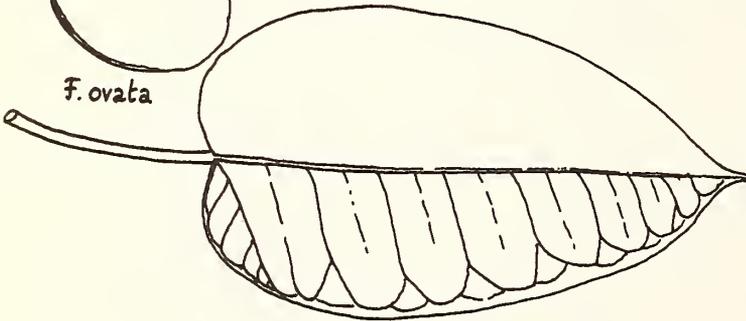
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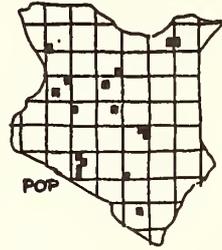
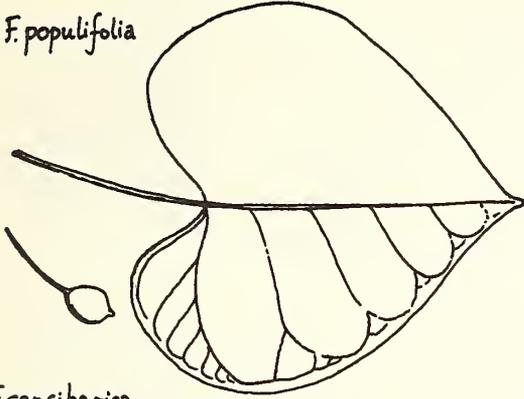
OTT

F. ovata

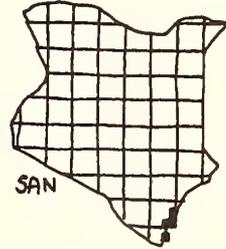
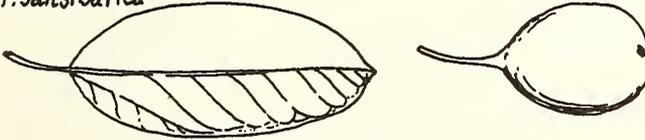


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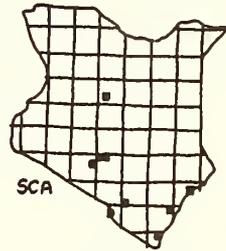
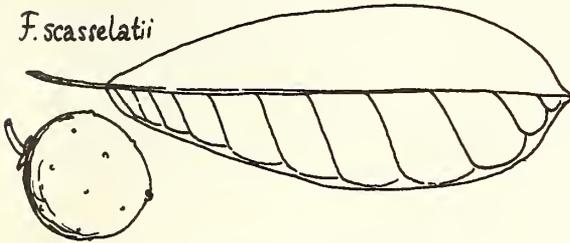
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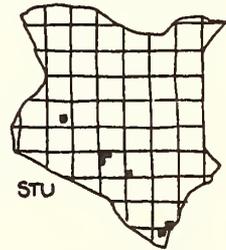
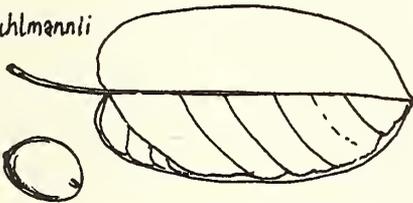
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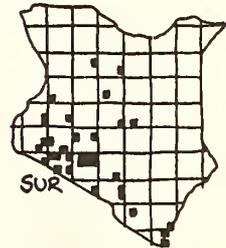
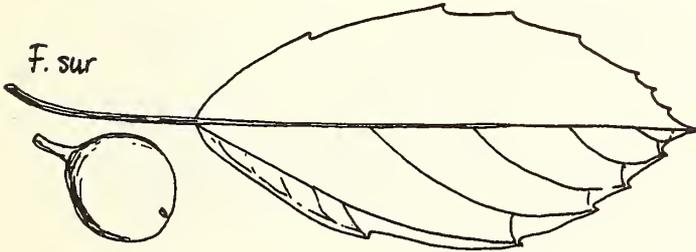
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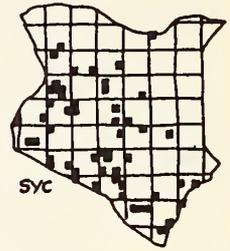
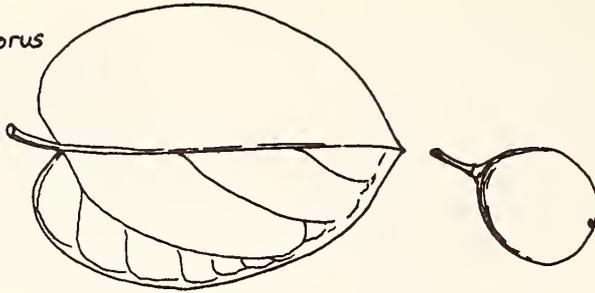
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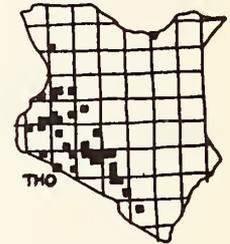
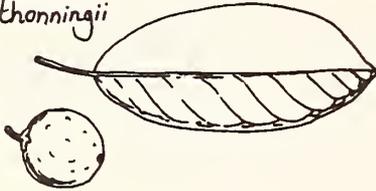
F. sur



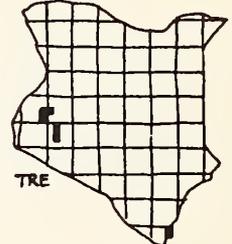
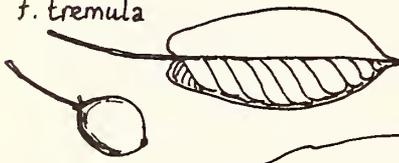
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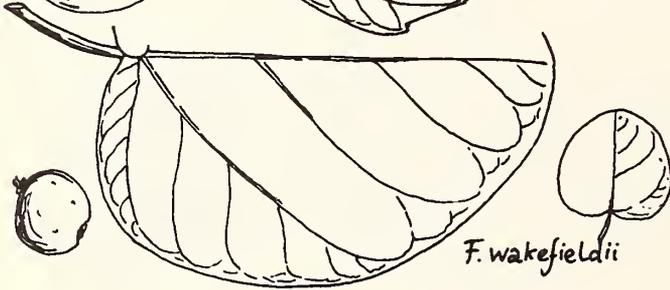
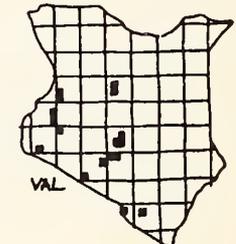
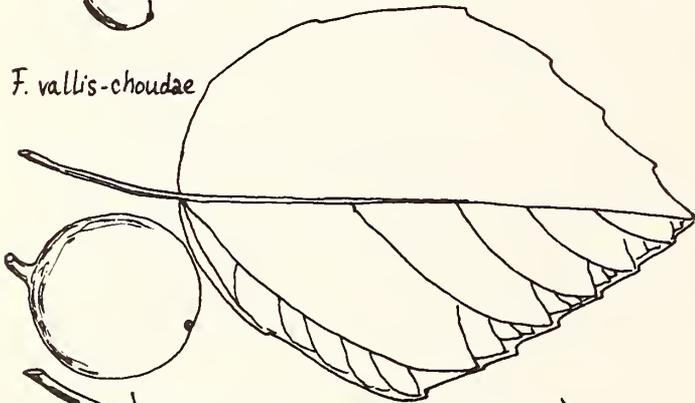
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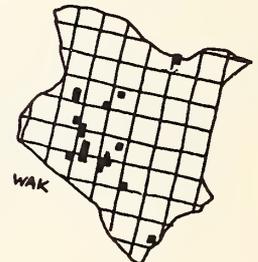
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F. vallis-choudae



F. wakefieldii



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REPORT ON ACTIVITY IN THE NORTHERN CRATER OF
OL DOINYO LENGAI,
JULY 1988 TO AUGUST 1989.

Celia Nyamweru

*Department of Geography, Kenyatta University,
P.O. Box 43844, Nairobi, Kenya.*

ABSTRACT

Ol Doiyo Lengai volcano, Tanzania, has shown almost continuous minor activity since early 1983. During July 1988 several small cones and lava flows formed, and further changes took place between the end of July and late October of the same year. The most striking change during that period was the flow of lava southwards from the floor of the active crater, across the 'saddle', a ridge that had been in existence since the end of the 1966-67 explosive eruption. During 4 days in late November 1988, several flows were observed to originate from a vent north of the saddle and flow across it to spread out over the previously inactive southern segment of the north crater. Eruptive activity between January and June 1989 appears to have been rather less than it was in the second half of 1988, though as of August 1989 it could not be said to have ceased entirely.

INTRODUCTION

An earlier paper (Nyamweru 1989) provided an account of eruptive activity in the northern crater of Ol Doiyo Lengai volcano, Tanzania, between 24 June and 1 July 1988. Here I describe the evolution of the crater since then, using reports and photographs by people who have climbed the mountain or flown over it during the last months. Particular attention is given to events during the period 22-25 November 1988, when a group of geologists camped on the inner slopes of the north crater and a continuous record of eruptive activity was made.

METHODS

The lettering and numbering system in the illustrations follows the scheme used in my earlier report on Ol Doiyo Lengai (Nyamweru 1989 Fig. 1 to 5); the major eruptive centres are designated T1, T2 etc., lava flows are F1, F2, etc., while hornitos are designated H1, H2, etc. Figure 5 of that report shows the state of the crater floor on the morning of 1 July 1988, with the two most recently formed features being the cone T8 and the lava flow F6.

RESULTS

Diary of Eruptive Activity

Changes between 1 and 26 July 1988

Figure 1 is traced from a slide taken by Bert Grootenhuys on 26 July 1988 and shows changes since 1 July. The cone T8 had reached a height of between 6 to 8 m but was not active on 26 July; however about 5 narrow flows had recently spread in all directions from a point slightly to the west

of T8. A new cone (designated T9) had formed slightly to the north-east of T5. During a period of a few hours on 26 July, lava was observed bubbling near T9 and flowing from the vent to the west of T8. One of the flows had gone round T1 and had almost reached the saddle (M), but at this stage lava had not overflowed the saddle.

Changes between 26 July and 20-22 October 1988

Figures 2 and 3 were traced from slides taken by Martin Smith during a visit of a few hours sometime between 20 and 22 October 1988. No liquid lava was observed at the surface, although lava could be heard bubbling at depth. Significant changes in crater morphology had taken place since late July; most notable of these was the overflow of lava across the saddle, to cover the floor of the 'southern depression'. This area had been free of newly formed lava since it came into existence following the end of the 1966 eruption. The cone T1 visible just to the north of the saddle in Fig. 1 was completely buried by fresh lava between 26 July and 20-22 October 1988. Figure 2 gives an overall view of the crater from the south, showing the spillage of lava across the saddle between M1 and M2. On the original colour slide the formerly green vegetation on the saddle west (left) of M1 was brown, killed by sulphurous fumes. Figure 3 shows a cluster of cones (T9B, T10 and T10B) near the eastern wall of the crater, which formed after July 26.

Changes between 20-22 October and 22 November 1988

On arrival at the crater rim early on 22 November 1988 the following changes were observed since late October: (i) A new cone, T11, had formed slightly north of the former alignment of the saddle, and several new flows (e.g. F7 and F9) had spread from its base (ii) more lava had spilled across the saddle and the area of lava (F8) in the floor of the southern depression had increased. No major changes were observed in the areas of T4T7 and T5T9T10. The appearance of the crater on 23 November 1988 is shown in Fig. 4, based on a field sketch by the author. The direction of view is towards the east. Figure 5, also based on a field sketch by the author, provides a more detailed view of the area of T5T9T10, taken from the northwest.

Diary of eruptive activity from 22 to 25 November 1988

- 22 November 1988, 0800h: first sight of the crater floor from the eastern crater rim. Liquid lava was bubbling and splashing in the new vent (T11) from which very recent flows had spilled on to the north crater floor (Flows F7 and F9) and into the depression south of the saddle (F8). During the morning of 22 November, lava began to flow southwards into the southern depression, moving in a narrow (less than 1 m wide) channel that had vertical walls, sometimes undercut and up to 3 m deep. Below the saddle, sections of the channel were roofed over, forming a lava tunnel. The flow of lava continued virtually all day on 22 November 1988, with short pauses. Maximum effusion rate (by visual estimate based on the width, depth and speed of the flow) was about 30 cu-m per min with temperatures (measured with a thermocouple) from 568° to 579 °C (Pinkerton, personal communication). The lava frequently splashed down the channel as a 'waterfall' and spread out in various directions on the floor of the southern depression. No liquid lava was visible at other centres on 22 November 1988, although there was a shimmer of heat from one of the vents on the eastern side of T4T7 and irregular blasts of escaping gas from that centre.
- 22 November 1988, 1230h: small flows of very liquid lava escaped low down on the east side of T11, reaching the crater floor north of the saddle.
- 22 November 1988, 2000h: the flow from T11 continued after dark, when dull red incandescence could be seen at the eastern and southeastern slopes of the southern depression and which set fire to vegetation there.
- 23 November 1988, 0800h: more flows from T11 had formed during the night, covering a large area in the southern depression. By 0800h the southwards flow from T11 had ceased, and the overflow channel appeared blocked. Parts of the lower overhanging rim on both east and

west sides of vent T11 had collapsed so that it was possible to see a bubbling lake of black lava. A long flow (F10 in Fig. 4) had extruded from a hornito (H4) west of T5, and had reached the northwestern crater wall. Beginning at 0812h, and continuing during the morning, a series of thuds and bangs, followed by rapid bubbling noises, occurred near the western wall of the crater, towards the lower end of F10. These were caused by lava flowing over an uneven older lava surface, and trapping pockets of gas which then expanded explosively.

- 23 November 1988, 1200h: the lava lake in T11 continued bubbling, but there was no overflow. At infrequent intervals gas blasts continued from T4T7, but there was no other discernable activity in the crater.
- 23 November 1988, ca. 1700h: there was a short but heavy rainstorm, during which clouds of steam rose from the still warm lava surface south of the saddle (F8 in Fig. 4) and from F10. When the rain stopped and the steam cleared it could be seen that T11 and the flows around it (e.g. F9) which had been rather pale grey, had turned almost black, while F10, which had been dark brown, turned almost white.
- 23 November 1988, ca. 2000h: bubbling and splashing of lava continued in T11, with red incandescence and yellow flares of gas seen after dark, but there was no overflow. The 'snorts' of gas from T4T7 became more frequent in the evening than they had been earlier; one count gave 17 'snorts' over 30 s. These 'snorts' were being emitted from three different holes at the top of pinnacles around the northern and southern sides of T4T7; deep within one of these, a reddish glow could be seen, and much hot gas (maximum temperature 482°C) (Pinkerton, personal communication) was emitted. Some noise of liquid magma at depth could be heard below the eastern part of T4T7.
- 24 November 1988, 0510h: an eruption began to the west of T5, forming hornito H5. Gas emission from T4T7 was now continuous.
- 24 November 1988, 0540h: another vent opened on the southwestern slope of T5, with spattering and outflow of very fluid lava, extending a few tens of metres from the vent. This vent was named T5B, and the lava is F12 (Fig. 5).
- 24 November 1988, 0800h: activity at both H5 and T5B continued, with frothy lava bubbling within H5 and new streams of lava flowing from T5B. Other changes during the night included the spattering of fresh lava from one of the gas-emitting pinnacles on the north side of T4T7, and the building of a new little cone within T4T7. Bubbling of lava within T11 continued, but the eruption became restricted to the central part of the lava lake, resulting in the building up of a new, inner cone. By 0800h only the base of its slopes had been formed.
- 24 November 1988, throughout the day: lava levels fluctuated in H5, higher levels correlating positively with outflow from T5B. At T11 exploding bubbles in the centre of the lava lake continued to build up the lower slopes of an inner cone, and ejecta reached 10 m high. During the day emission rates from T5B averaged approximately 0.1 cu m per min and temperatures ranged from 565° to 579 ° C (Pinkerton, personal communication).
- 24 November 1988, 1700h: at T8 hot, shimmering gases were seen rising from a new opening on the lower west slope of the cone, with the sound of liquid magma moving about at depth.
- 24 November 1988, 1930 to 1950h: at T11 active bubbling and spattering built up the rim of the inner cone to about 1m above the general level of the lava lake. Glowing lava was still visible in H5. From the base of T5B small incandescent flows continued. The small vent on the western side of T8 showed a red glow at depth and some very localized fresh spatter had been ejected.
- 25 November 1988, 0700h: T11 had built up a wide inner cone reaching about 2 m high. At T8 liquid magma could be heard at depth, but there was no sign of any new spatter. The base of H5 had collapsed on its northeastern side, revealing liquid lava bubbling gently. H5 was a few cm higher, due to near-overflow of lava during the night before the collapse had occurred. Several new, small pahoehoe flows had formed below T5B during the night, and

flow in this area continued in the morning of 25 November 1988.

25 November 1988, ca. 1100h: flow from T5B continued, and had encircled a fumarole near the base of the east wall of the crater; loud bangs (like a firecracker) occurred when the liquid lava flowed into the fumarole. At T11 bubbling and spattering continued to build up the inner cone, and another part of the eastern outer wall had collapsed.

Dimensions of crater in November 1988

The horizontal dimensions were obtained by rangefinder and the vertical dimensions by rangefinder and Abney Level; measurements were made by the author with J.B. Dawson and H. Pinkerton. Error factors estimated as of the order of 1 to 2 degrees for bearings, 4 to 4 m for lengths.

Diameter of main (northern) part of north crater across bearing 124°: 236 m

Diameter of main (northern) part of north crater across bearing 018°: 229 m

Diameter of southern part of north crater across the surface of the newly formed lava: 90, 101, 121 m. (different bearings).

Heights above central part of crater floor:

East rim of north crater (low point):	35	m
Top of rim cone C1 on north rim:	45	m
Southwest rim of north crater:	45	m
Top of cone A3 on northwest crater wall:	25	m
Summit of Ol Doinyo Lengai:	96.4	m
Top of cone T9B:	11	m
Top of cone T8:	20	m
Top of cone at west end of T4T7:	7.5	m
Top of cone T10:	13.2	m
Height of south slope of central part of saddle:	4.5	m

List of features visible in the north crater in late November 1988

(See Fig. 4 and 5)

1. Lava Flows

Flow 9: not observed forming; still relatively fresh during the period of observation but older than F7. Darker grey than F7, with a rough, 'blocky' surface; turned almost black in the rain on the afternoon of 23 November 1988.

Flow 7: this flow was relatively fresh during the period of observation but was not observed forming and did not have surface heat when we saw it. On the morning of 23 November 1988 it was pale grey, a clinkery surface with big lobes. It had spread to the west from the southern corner of T11, but was a relatively thick and not highly mobile flow. It was younger than F9.

Flow 8: this includes several different flows that originated from T11, flowed over the saddle and filled in the floor of the southern depression. During the period of observation several flows reached the base of the crater wall and pushed against the soft ash of the older slopes, setting fire to the surrounding vegetation and creating small 'push moraines' of the older ash. Most of the area south of the saddle was covered by fresh mainly 'clinkery' lava during the period from early 22 November 1988 to the following night.

Flow 10: This flow was brown when it formed during the night of 22 November 1988; minor movement at its western end was still continuing on the morning of 23 November 1988. It was largely composed of smooth pahoehoe. Its source was an inconspicuous vent close to hornito H4. The major part of F10 extended to the west wall of the crater but there was also an area of very similar smooth pahoehoe lava to the east of T11, close to the north side of the saddle. F10 turned almost white in the rainstorm on the afternoon of 23 November 1988, and most of it stayed very pale for the rest of the period of observation.

Flow 11: This small pahoehoe flow originated from the vent close to hornito H4 and flowed towards the northwest for a few tens of metres. It formed slightly earlier than Flow 10.

Flow 12: This refers to the thin pahoehoe flows that originated from T5B, starting at 0540h on 24 November 1988.. Flow was continuing at 1100h on 25 November 1988.

2. Eruptive Centres

D : a deeply weathered lava flow on the west wall; not active during 1988 or 1989.

A3: four deeply weathered but well-defined cones on the north wall, of which the largest lies highest and furthest to the west. Not active (except for possible minor emission of steam) during 1988 or 1989.

C1: the 'rim-cone' not active during 1988 or 1989, except for fairly continuous gentle emission of steam. Possible collapse on west side has made the western edge (the highest part) particularly steep.

H5: a hornito that began to form at 0510h on 24 November 1988, to the west of T5, close to and slightly above H4. It reached a maximum height of about 1.5 m and had a flat top (diameter of open vent about 1.1 m).

T2: this cone may have come into existence as early as October 1984; by late 1988 it was virtually buried by younger lava flows from the east; only the upper parts of the northern and southern slopes and the central mound were visible. There was active emission of steam and sulphur fumes and considerable deposition of sulphur crystals around the remaining visible sections of T2. Estimated thickness of lava cover between June and November 1988: at least 1.5 m.

T4T7: the overall appearance of this centre did not change between June and November 1988, but some local changes occurred, most noticeably the building of a rather large, rounded cone on its south side. Collapse occurred within the centre of T4T7, though at least two central pinnacles remained and there was some overhang on its east side. Some centres emitted blasts of gas at varying intervals throughout the period of observation. Occasionally, liquid magma was heard moving around at depth below the eastern side of T4T7. The only signs of fresh lava were some spatters on one of the pinnacles on the north side, formed during the night of 23 November 1988. A large (over 1.5 m high) open but inactive hornito (H3) stood between the east end of T4T7 and T8.

T5: this centre became more complex between June and November 1988; the cone T9 continued to grow and largely merged with the north side of the original T5. A new cone (T9B; see Fig. 5) formed on the east side of T5 and a separate cone (T10) formed close to the east crater wall, with a smaller mound (T10B) to the north of it. West of T5 a number of hornitos were still very fresh on 22 November 1988, including a spectacular vertical hornito about 1.5 m high (H4). At 0540h on 24 November 1988, a small vent (T5B) opened low on the southwest slope of T5, and over the next 24h several small hornitos were built up below it, while small flows of highly liquid pahoehoe lava (F12) were extruded throughout the remaining period of observation.

- T9: this steep, flat topped cone with an open crater at the top, joined by a high level saddle to T5 formed between 1 and 26 July 1988; in the same vicinity, T9B came into existence by 20-22 October. There was no sign of activity from the top of T9 or T9B in late November 1988.
- T10: a steep, sharp pointed pinnacle, with an asymmetrical opening at its top and an inner ('nested') cone within the outer crater. Joined to the east crater wall by a high saddle. A smaller cone (T10B) with a collapsed top lies south of T10, also close to the crater wall. Both these features formed between 26 July and 20-22 October 1988 and were not active in late November 1988.
- T8: the lower slopes of this cone were formed between 1 and 26 July 1988 and the steep pinnacle approximately 20 m high formed between 26 July and 20-22 October 1988. By late November this cone showed some signs of slight collapse at its top and near its base. The lower (gentler) slopes were blackened; the upper (steeper) slopes were pale grey and cream with white patches.
- T11: this came into existence after 20-22 October 1988; a large asymmetrical cone, with long axis approximately NNE-SSW and its highest point (overhanging in late November) to the NNE, rising about 13 m above the surrounding crater floor. Lava from the south side of this cone flowed across the lowest point of the saddle and filled in the floor of the southern, formerly inactive segment of the north crater. Activity continued within or from this centre throughout the period of 22-25 November 1988. The overhanging slopes of the outer cone began to develop cracks and collapse occurred several times.

3. Fumaroles

East rim: deep cracks, steam, sulphur fumes and sulphur crystals; similar to or slightly increased since late June 1988.

East wall: much fumarolic activity on lower slopes between T10B and the saddle.

Southern slope of T4T7: a wide (ca. 5 to 10 cm) crack approximately parallel to the south slope, emitting steam virtually throughout the period of observation. Blackening of lava surface around the lower slopes of T4T7.

Saddle: vegetation on its western slopes and to the southwest had been killed, presumably by sulphur fumes. The original large crack on the west side of the saddle, observed in June 1988, had widened to over 10 cm in parts and showed yellow (sulphur), black and white staining, with constant emission of sulphurous fumes. Above (west of) it ran several transverse (almost SE-NW) cracks of white staining which also emitted steam and crossed the saddle from its lower southern slope to its lower northern slope. The eastern side of the saddle showed much staining by sulphur and emission of sulphurous fumes.

West wall: steam emitted from at least 3 vertical cracks running almost the whole height of the wall, to the south of D.

North wall: steam emitted to the west of A3 and also near the top of the wall above A3 and towards C1.

West rim: still active emission of steam from the cracks observed in June 1988, killing some of the vegetation around these cracks.

Changes during December 1988 and January 1989

Figure 6 is traced from a slide taken from the air on 14 December 1988; the view southwards shows the major features as in late November, with some small recent lava flows from the western slopes of the T5T9 cluster. Figure 7 is traced from a panorama provided by Peggy Forrest and

taken on 12 January 1989. Little change seems to have occurred in cones T10, T11, T8 and T4T7, and no fresh lava is visible on the sections of the crater floor included in the panorama. During that visit there was no liquid lava at the surface but it could be heard bubbling at depth. It would seem that conditions in December 1988 and January 1989 were considerably less active than they had been in October and November 1988.

Changes between January and June 1989

In late May 1989 a pilot (Steve Cunningham) reported bubbling lava in the vicinity of T10, that is at the south-eastern side of the crater. A video film of the crater on 28 June 1989, taken by Alex van Leerdam, gave a clear aerial view of the crater from the north. The overall colour of the crater floor was very pale grey, with a large patch of slightly darker grey lava on the west side of the floor. The general pale colour of the crater floor implies that no fresh lava had flowed out during the two to three weeks before the date of observation. The main cones (i.e. T4T7, T5T9, T8 and T11) were all visible and essentially unchanged since November-December 1988.

Changes between June and July 1989

Figures 8 and 9 were traced from slides taken by Alan Fowler, who climbed the volcano on 26 July 1989 (exactly a year after the Grootenhuis' ascent!) No lava was observed at the surface, although it could be heard bubbling in several vents. Figure 8, taken from a similar viewpoint on the west rim to figure 4, shows T11 now inactive; the inner cone which was observed forming on 25 November 1988 did not develop to any size and was now not visible. The extent of lava overflow across the saddle has not increased significantly; the large boulder (B1) visible on the edge of the lava in Fig. 4 is still visible in Fig. 8. The general appearance of the crater floor (both north and south of the saddle) is very pale, indicating no fresh lava flows for several weeks previous to 26 July 1989. The most recent flow may have been in existence on 28 June 1989. It is identified as F13 in Fig. 8 and 9 and is mid-grey in colour, rather 'blocky' in surface texture, and covers the south-western quadrant of the north crater floor. Dark staining to the north-west of T11 (x in Fig. 8) may indicate a very persistent line of fumaroles that was clearly visible in June 1988 but had been covered up by young lava in late November 1988. Figure 9 is taken from the east rim, looking broadly southwards and shows T8, T10 and T11 all basically unchanged since November 1988. However a rather indeterminate feature (T12) can be observed close to the east wall north of T10 and this may be the vent at which lava was observed bubbling in late May 1989. A higher pinnacle seems to have developed on the west side of the T5T9 cluster and is labelled T13 in Fig. 9. Another medium grey flow at the base of the southeast wall is labelled F14.

Changes between July and August 1989

Figure 10 was traced from a slide taken by Dr. Lester Eshelman on 23 August 1989 and shows an aerial view of the crater from the northeast. All the cones and flows visible in Fig. 9 are clearly recognizable. The darkest feature is the pinnacle of T13, although this may be due to shadow rather than fresh lava. No new flows are visible, but both F13 and F14 show a clear contrast of colour, darker than the rest of the crater floor. The overflow across the saddle between M1 and M2 has not increased since June - July 1989.

GENERAL OBSERVATIONS AND CONCLUSIONS

Liquid lava has continued to be present at or near the surface of the crater throughout the period July 1988 to August 1989. Lava was flowing out on the surface on 26 July 1988, between 22-25 November 1988 and in late May 1989. Significant changes in crater morphology occurred between 26 July and 20-22 October 1988, and between 20-22 October and 22 November 1988. Most important of these was the overflow of lava across the saddle and the beginning of infilling of the southern depression. Apart from this (associated with the formation of the cone T11), activity

has generally been concentrated towards the north-eastern and eastern sides of the north crater floor. Changes between July and December 1988 were more striking than those between January and August 1989, but activity has not ceased yet.

ACKNOWLEDGEMENTS

I am extremely grateful to Professor J.B. Dawson, Department of Geology, University of Sheffield, U.K., for making it possible for me to join his expedition to Ol Doiyo Lengai, and to David, Thad and Michael Peterson of Arusha, Tanzania, who handled all the arrangements for our visit. The account of the activity between 22 and 25 November 1988 owes much to the contributions of Professor Dawson, H. Pinkerton, D. Pyle and G. Norton. I also acknowledge those who have made their slides and information on their climbs of Ol Doiyo Lengai available to me, namely Bert Grootenhuis, Martin Smith, Alex van Leerdam, Alan Fowler and Lester Eshelman. Dr. Eshelman's photographs would not have been available to me without the help of Joe Moran (Chief Pilot of AMREF), to whom I am also very grateful. My thanks are also due to the Vice-Chancellor, Kenyatta University, for permission to be away from the university during our expedition.

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GLOSSARY OF TERMS

CLINKERY: describes a lava surface that is rough, jagged and very porous, resembling the clinker or slag of a furnace.

FUMAROLE: a vent, usually volcanic, from which gases and vapours are emitted.

HORNITO: a small mound built up on top of a lava flow by clots of very fluid rock escaping from openings in the roof of an underlying lava tube.

PAHOEHOE: a lava flow with a smooth, 'billowy' or 'ropy' surface.

PUSH MORaine: this term is properly applied to an arc-shaped ridge consisting of unconsolidated sediments mechanically pushed or shoved along by an advancing glacier. Applied in this case to small ridges of debris pushed along by the advancing lava on the margins of the 'southern depression'.

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Instructions for authors may be obtained from:

The Hon Secretary, E.A.N.H.S., P.O. Box 44486, Nairobi, Kenya

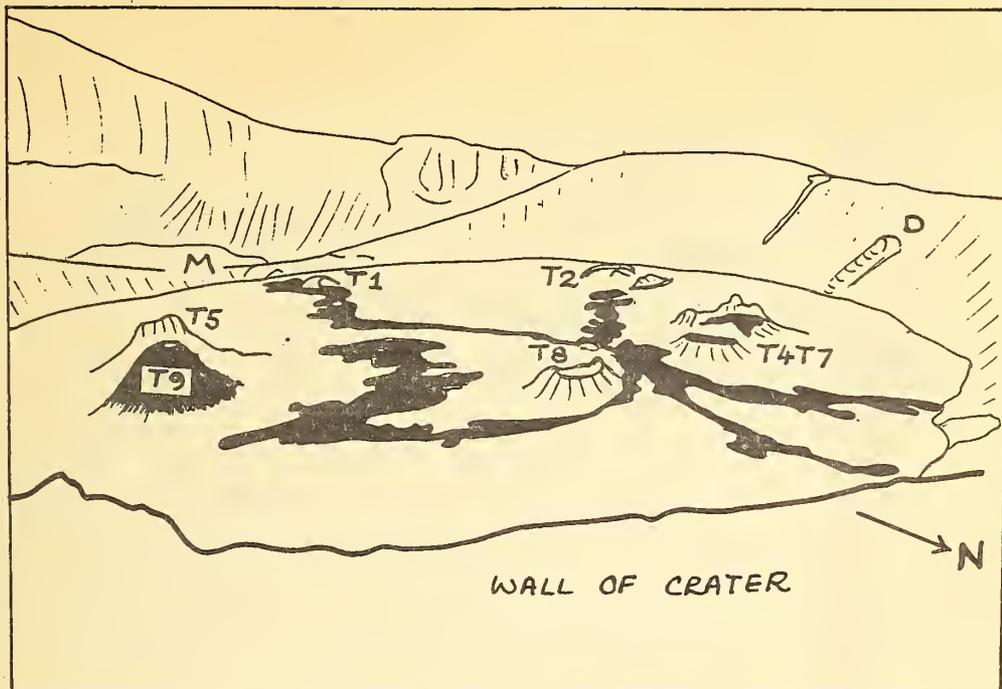


Figure 1: view towards the south across the crater from the north-east rim, traced from a slide taken by Bert Grootenhuys on 26 July 1988. Cone T9 is the most recently formed cone. Diameter of crater floor is ca. 230 m; crater rim at T2 is ca. 45 m above crater floor.

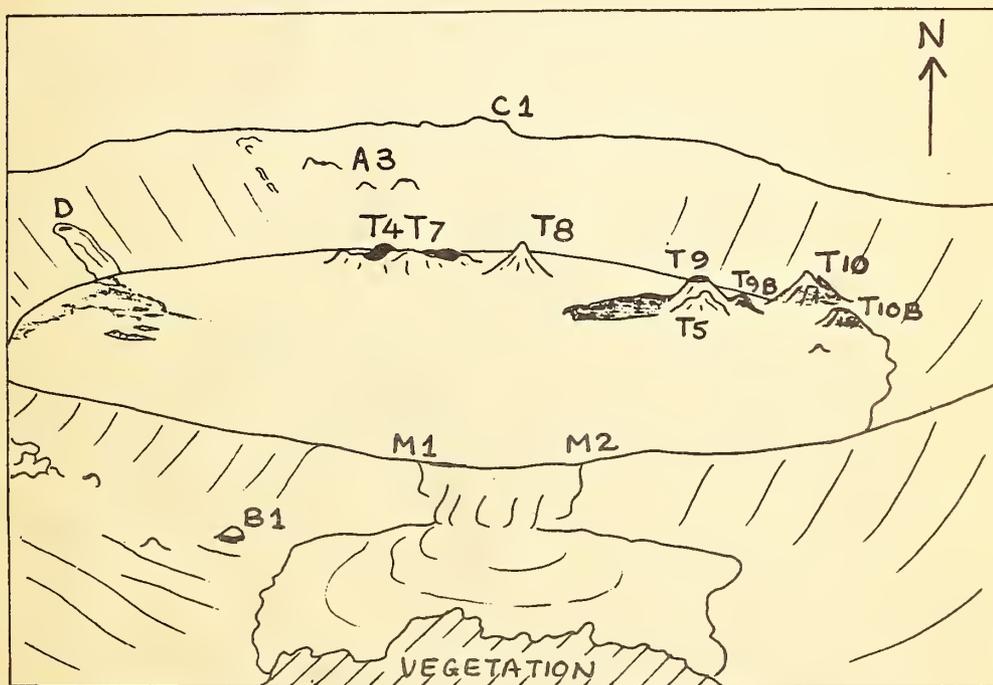


Figure 2: view northwards from the summit, traced from a slide taken by Martin Smith between 20-22 October 1988. Lava has overflowed the saddle between M1 and M2 but has not reached the boulder B1 on the floor of the southern depression. Diameter of crater floor is ca. 230 m; crater rim at C1 is ca. 45 m above crater floor. Diameter of lava patch in front of M1M2 is ca. 90 m.

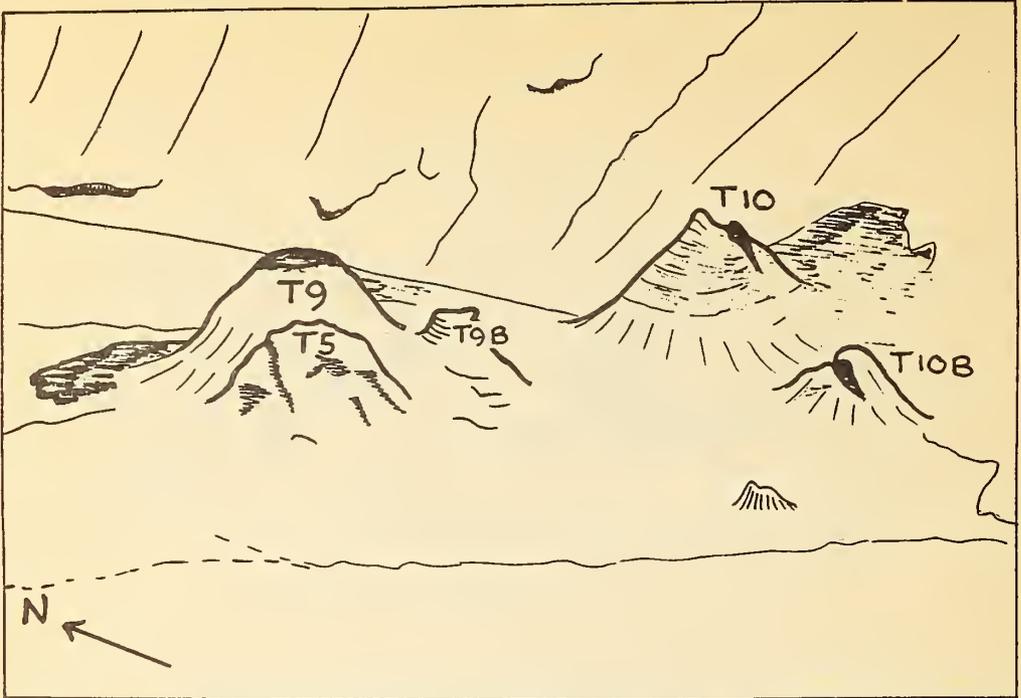


Figure 3: cluster of cones at the base of the east wall (looking approximately north-eastwards); traced from a slide taken by Martin Smith between 20-22 October 1988. T10 and T10B at base of the east wall are rather dark grey and (together with T9B) formed since 26 July 1988. Top of T9 is ca. 12 m above crater floor, top of T10 is ca. 13 m above crater floor. Distance between T9 and T10 is ca. 42 m.

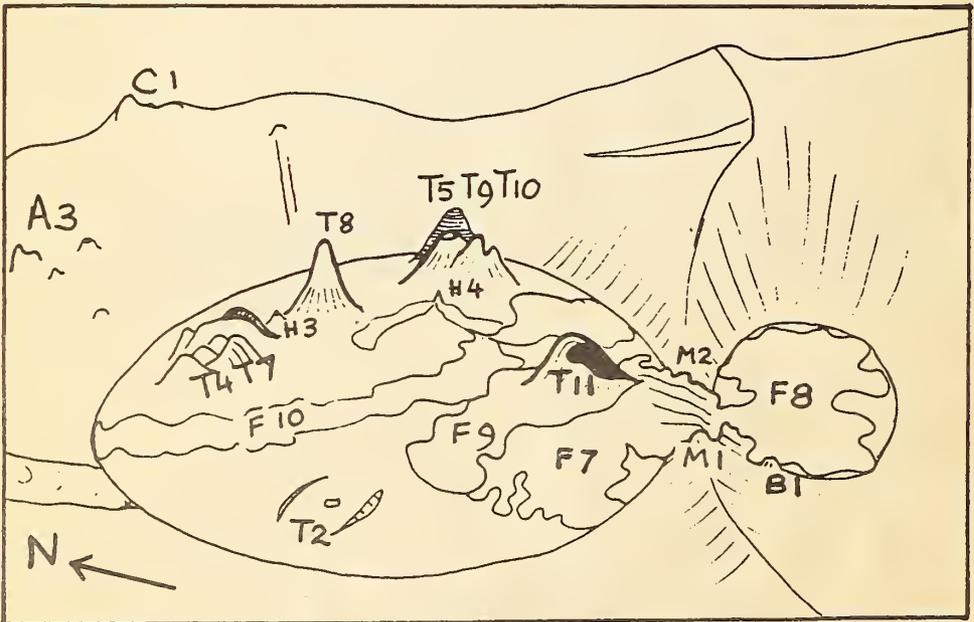


Figure 4: the crater from the west, sketched by C. Nyamweru on 23 November 1988. The cone T11 is new and several new lava flows cover the crater floor both north and south of the saddle. The lava south of the saddle (F8) has just reached the large boulder B1. Diameter of crater floor is ca. 230 m; C1 is about 45 m above the crater floor.

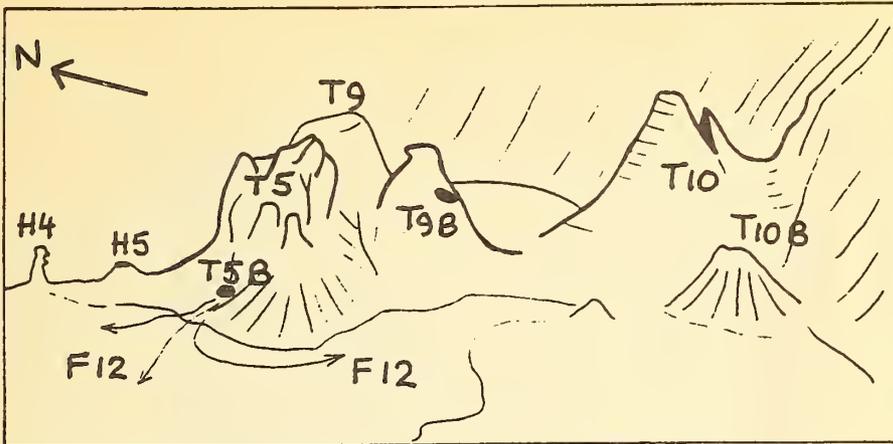


Figure 5: cluster of cones at the base of the east wall; direction of view very similar to that of Fig. 3. Sketched by C. Nyamweru on 23 November 1988. No change in cones T9, T9B, T10 or T10B; formation of hornitos to the west of T5 and effusion of small lava flows (F12). Dimensions as for Fig. 3.

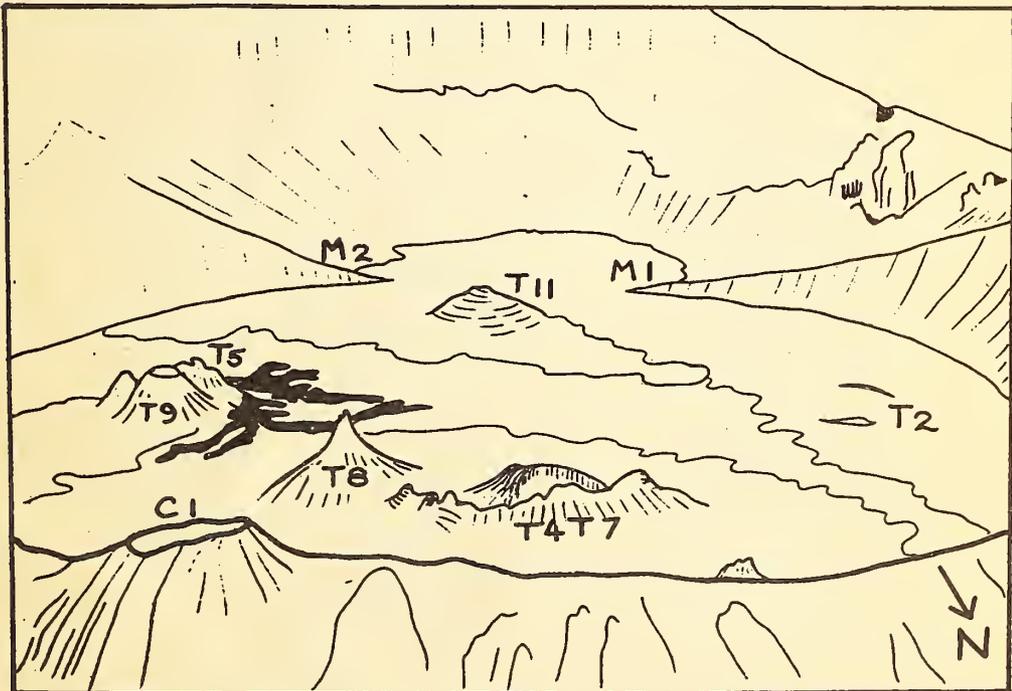


Figure 6: aerial view of the crater from the north, traced from a slide taken by C. Nyamweru on 14 December 1989. Small recent flows from the western side of the T5T9 cluster. Diameter of crater floor is ca. 230 m.

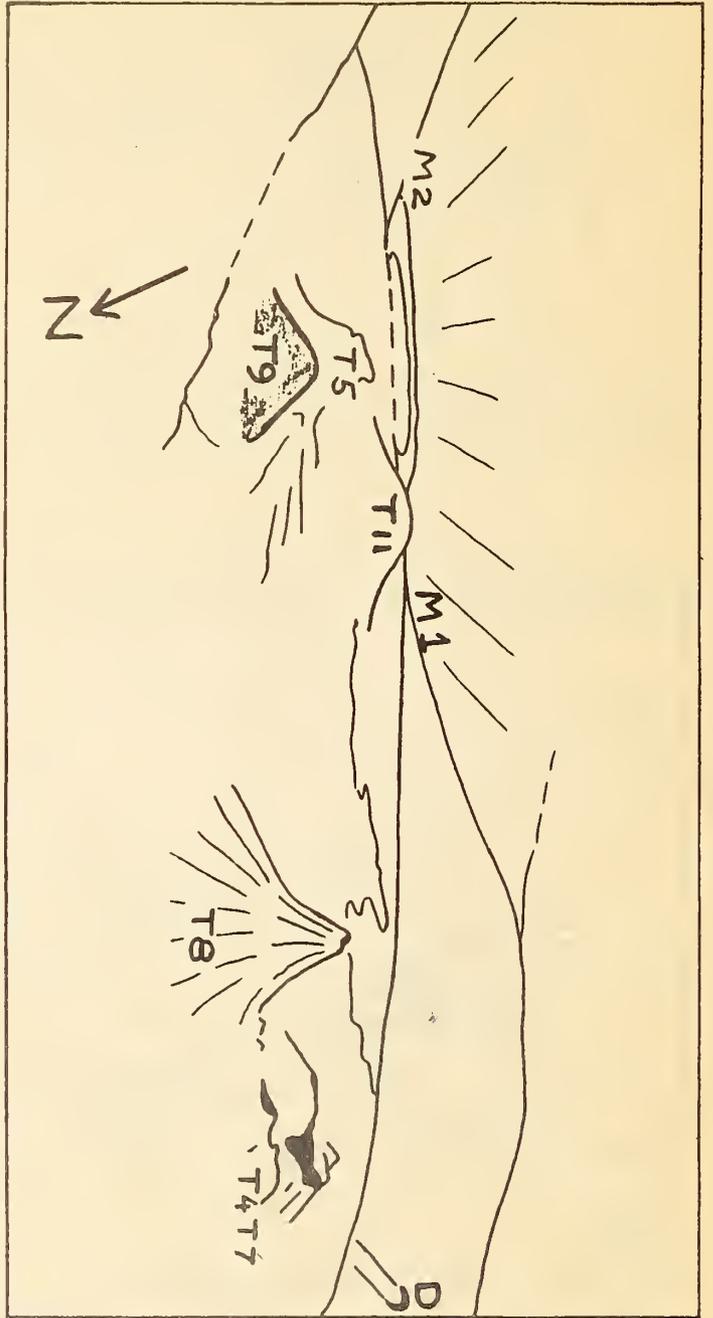


Figure 7: view across the crater to the south-west, traced from a panorama supplied by Peggy Forrest and taken on 12 January 1989. Little change in the overall appearance of the crater though T9 is rather dark in colour and may have had recent spatter of fresh material on its outer slopes. Diameter of crater floor is ca. 230 m.

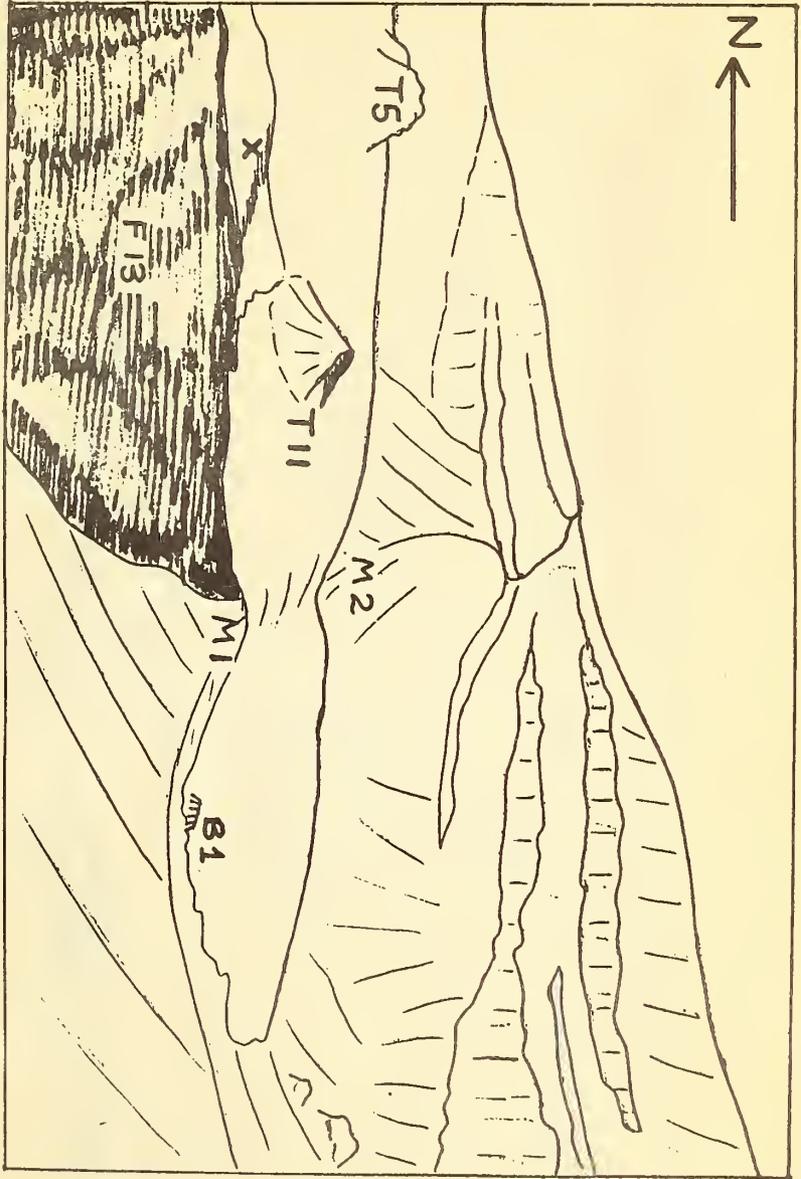


Figure 8: view from the west rim of the crater looking eastwards across the saddle; traced from a slide taken by Alan Fowler on 26 July 1989. The width of overflow (M1 to M2) has not increased significantly and the boulder B1 is still visible. Youngest flow would seem to be F13. Dark line at x may mark persistent fumaroles. Diameter of lava patch to south (right) of saddle M1M2 is ca. 120 m.

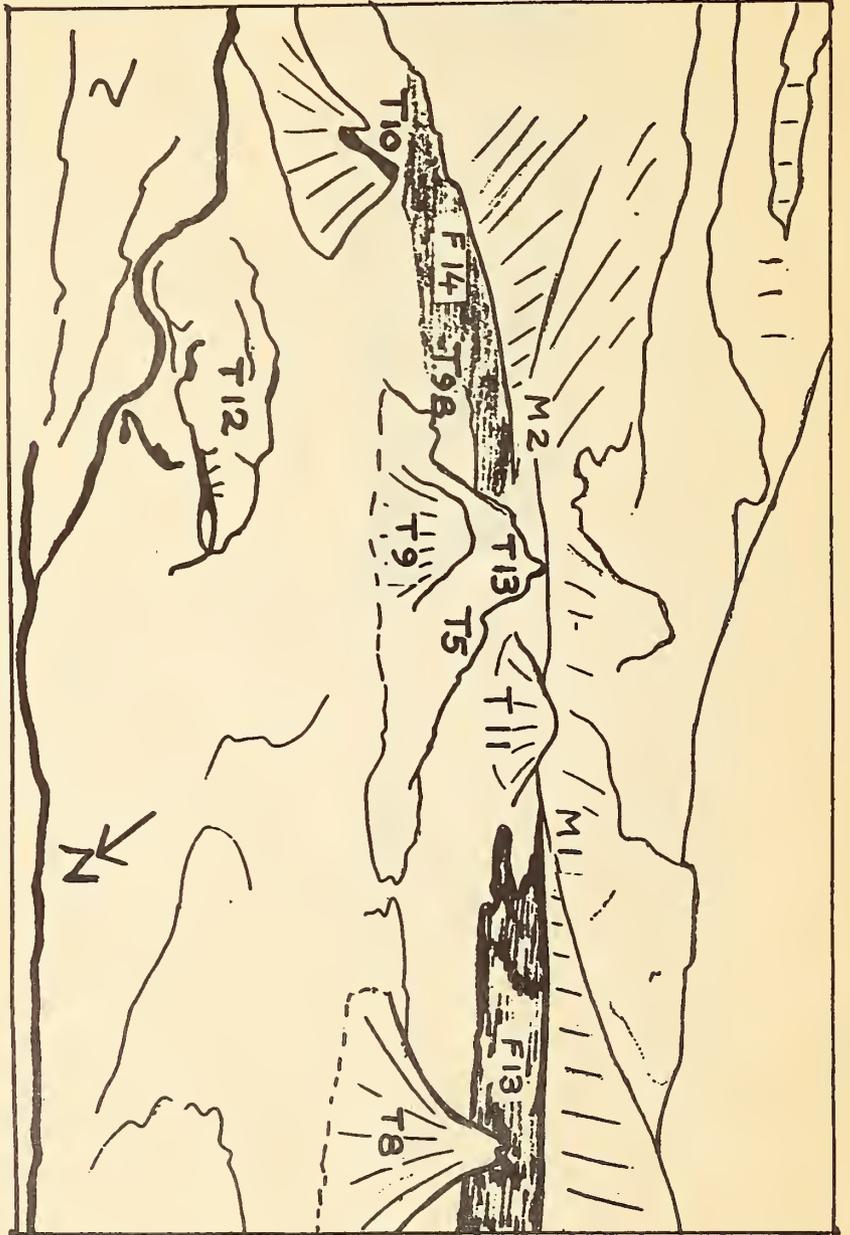


Figure 9: view from the east rim of the crater looking approximately southwards; traced from a slide taken by Alan Fowler on 26 July 1989. There is a possible new vent (T12) at the base of the east wall north of T10. Diameter of visible part of crater floor is ca. 180 m. Top of cone T8 stands ca. 20 m above crater floor.

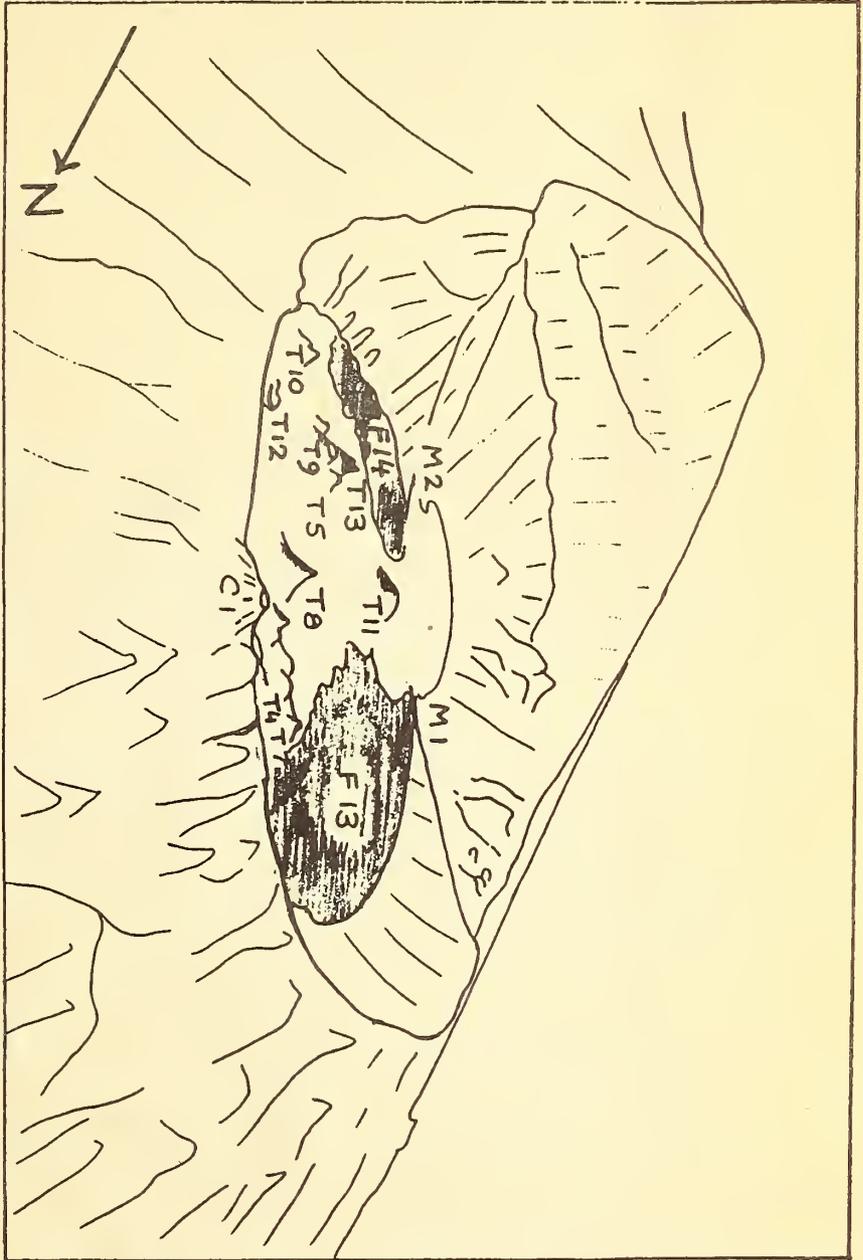


Figure 10: aerial view from the northeast, taken by Lester Eshelman on 23 August 1989. The features visible in Fig. 9 can all be seen with little or no change. The darkest feature is the pinnacle of T13; this may be partly due to shadow as well as to fresh spatter of lava. Diameter of crater floor is ca. 230 m. Summit rises ca. 96 m above level of crater floor.

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AN ECOLOGICAL CHECKLIST OF THE PLANTS OF KIBOKO NATIONAL RANGE RESEARCH STATION, KENYA

NDEGWA WA NDIANG'UI*
Kiboko National Range Research Station

* presently

*Research Fellow, East African Herbarium
National Museums of Kenya
P O Box 45166 NAIROBI - Kenya*

ABSTRACT

The flora of the Kiboko National Range Research Station was systematically sampled and collections made in each major ecological site. Belt transects were laid through the sites to serve as reference points for the collection of species during all seasons of the year.

Representative specimens were collected and identified. The relative abundance, habit and longevity of each species was recorded in the field and this has been compiled to form a checklist.

The most widespread families on the research station in order of prominence were Gramineae (*Eragrostis*, *Digitaria*, *Chloris*, *Brachiaria*, *Setaria*), Leguminosae (*Acacia*), Compositae, Burseraceae (*Commiphora*), Combretaceae (*Combretum*), Capparaceae, Euphorbiaceae, and Acanthaceae.

INTRODUCTION

Knowledge of the flora is fundamental to understanding the ecology of any region. In East Africa, several isolated studies on the plants have been conducted with various objectives. Dale & Greenway (1961), presented a pertinent account of the woody plant species in Kenya, while Lind & Morrison (1974) showed the extent to which the physiognomy of bushland is dependent upon the species comprising the woody vegetation component and the presence or absence of perennial grasses. More recently Coe & Collins (1986) gave an ecological inventory of the Kora National Reserve containing an annotated checklist of plants of the area, while Blundell (1982, 1987) dwelt on selected wild flowers of Kenya and East Africa.

Since about 80% of Kenya is rangeland, there is a need to have a well documented account of the rangeland plants therein, as they are important resources for development. Range management, for instance depends primarily on a knowledge of the plants, their ecophysiology, forage value, poisonous properties, distribution and associated habitat. A floristic study of the potentially productive and unproductive range areas of the country with the objective of documenting the occurrence of forage species as well as poisonous species is necessary. Such an undertaking would benefit from an ecological checklist of the species in ecoclimatic zones four and five, as delineated by Pratt, *et al.* (1966). It was the purpose of this study to contribute to this data base for the Kiboko Range Research Station whose research objective in range management is to increase and sustain livestock production. The results will benefit both basic and applied research in range management in these zones.

DESCRIPTION OF THE STUDY AREA

The study was conducted near Kiboko on the Kenya Government National Range Research Station which is located approximately 160 km from Nairobi, on the Nairobi/Mombasa road (Fig. 1). The station land area is approximately 30,000 h (74,000 acres). The station altitude is approximately 1000 m (3,280 ft) above sea level, and lies between latitude 2° 10' S and 2° 25' S, and longitudes 37° 40' E and 37° 55' E.

Climate

The climate of Kiboko falls under the influence of the Intertropical Convergence Zone (Whyte, 1968), characterised by a bimodal distribution of wet and dry seasons. The months of January and February characterise the short dry season, followed by a long rainy season from March to May. June to October is usually the harsh, long dry season which is followed by a rather short wet season from November to December. It is important to mention the rather off-season rains that tend to fall

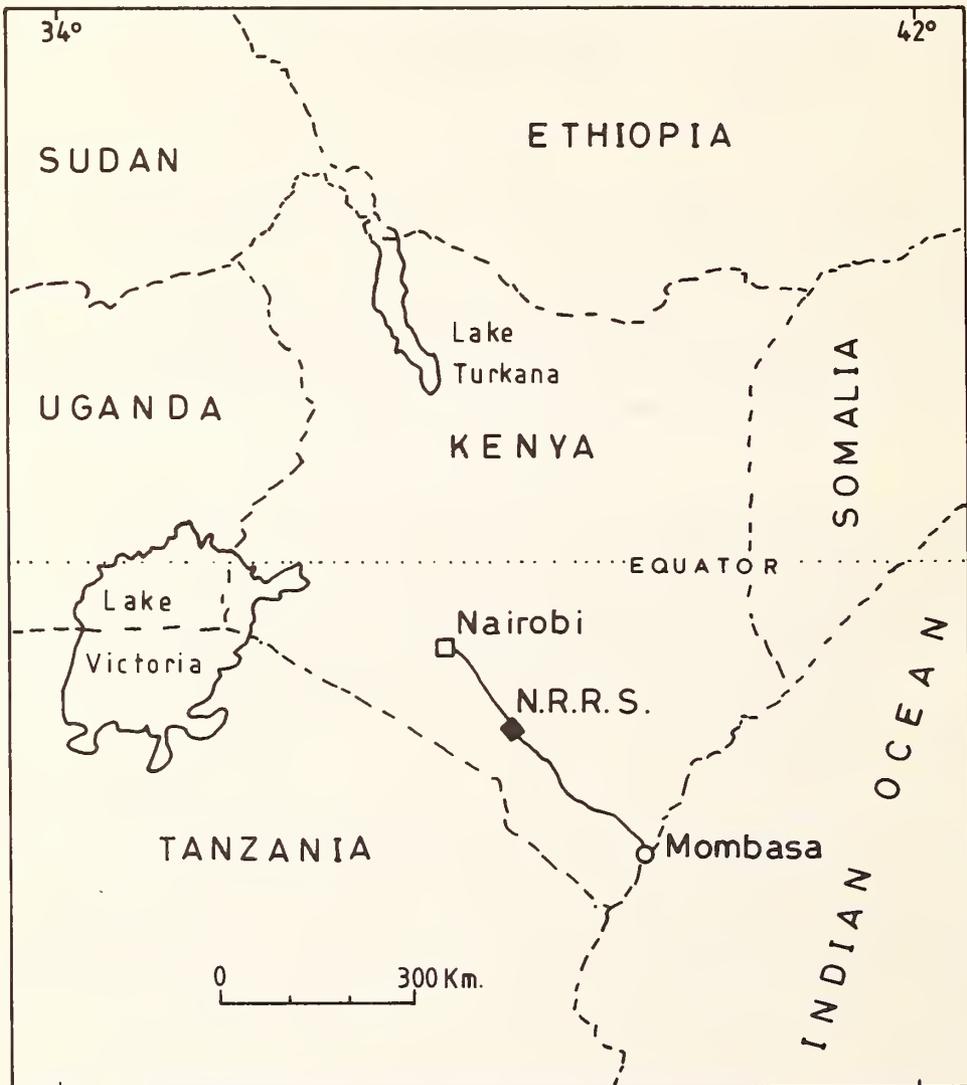


Figure 1: Map of Kenya showing the location of Kiboko Range Research Station (N.R.R.S.).

a few weeks before the expected rainy periods. These trigger early flowering and leaf formation in some woody species, as well as seed germination for the early emerging ephemerals (C. G. Gakahu, personal communication).

Rainfall data for the study area over the past 43 years conform to the long-term annual average of around 600 mm (Michieka & von der Poun, 1977). Most of these data accrue from the well-established Makindu Meteorological Station.

The mean maximum annual temperature for the Makindu Meteorological Station is 28.6°C and the mean minimum temperature is 16.5°C. The long-term annual average temperature is around 23°C. The long-term annual average evaporation is 2000 mm, the mean dew point is around 15.7°C and mean relative humidity is 62.5% (Michieka and von der Poun, 1977).

Geological summary

A large portion of this area is classified as the Basement System gneisses, and approximately one-third is covered by young lava flows of recent deposition (Michieka and von der Poun, 1977). The latter are still in the process of degradation and the soil tends to be shallow and undeveloped, rather rocky and very permeable.

Michieka & von der Poun (1977), defined three major regions which can be identified in the study area with regard to the general geomorphology:

- (i) the area underlain by Basement System rocks of the semi-calcareous group,
- (ii) the area underlain by Basement System rocks of the middle, semi-pelitic group,
- (iii) the area consisting of recent lava flows, associated volcanic vents, cones and recent limestones.

Soils of the study area

The soils of the Kiboko Research Station may be broadly categorized on the basis of the geomorphological and geological history of the area, where influence of the landscape and geology are clearly indicated as follows (Michieka & von der Poun, 1977):

(1) *Soils of hills and footslopes*

These are on the volcanic cones of Mwaitu, Duani, Dojini and Wikiamba among others (Fig. 2). These soils are predominantly shallow, well drained, black to very dark greyish brown, friable and include soils developed over pyroclastic materials. These soils may also be moderately to strongly calcareous. They are generally referred to as regosols.

(2) *Soils of lava flows*

These include both lithosols and rock-outcrops. They tend to be well drained, very shallow, black to very dark greyish brown, stony to very rocky. Some areas also have silty clay derived from "pumice" deposits, with extremes of rocky, irregular mesorelief of many sink holes, piles of olivine basalt rocks and collapsed tunnels.

(3) *Soils of floodplains and bottomlands*

These soils generally developed on olivine basalt and include the chromic vertisols that are imperfectly drained, very deep, dark grey, firm, cracking, and moderately calcareous silty clay to clay. These form the floodplain along the Kiboko river basin, which is the northern border of the station, in Association 15 (Fig.2).

Those soils in this category that have developed on recent alluvial deposits include calcic chernozem, which tend to be moderately well drained, deep, dark brown to greyish brown and strongly calcareous clay. These are found in the area bordering the private land along the Makindu river course, which is in Association 17 (Fig. 2). The imperfectly drained calcic cambisol tend to be very deep, dark grey, firm and extremely calcareous clay with pockets of soft lime. These are the soils near Makindu township (Fig. 2).

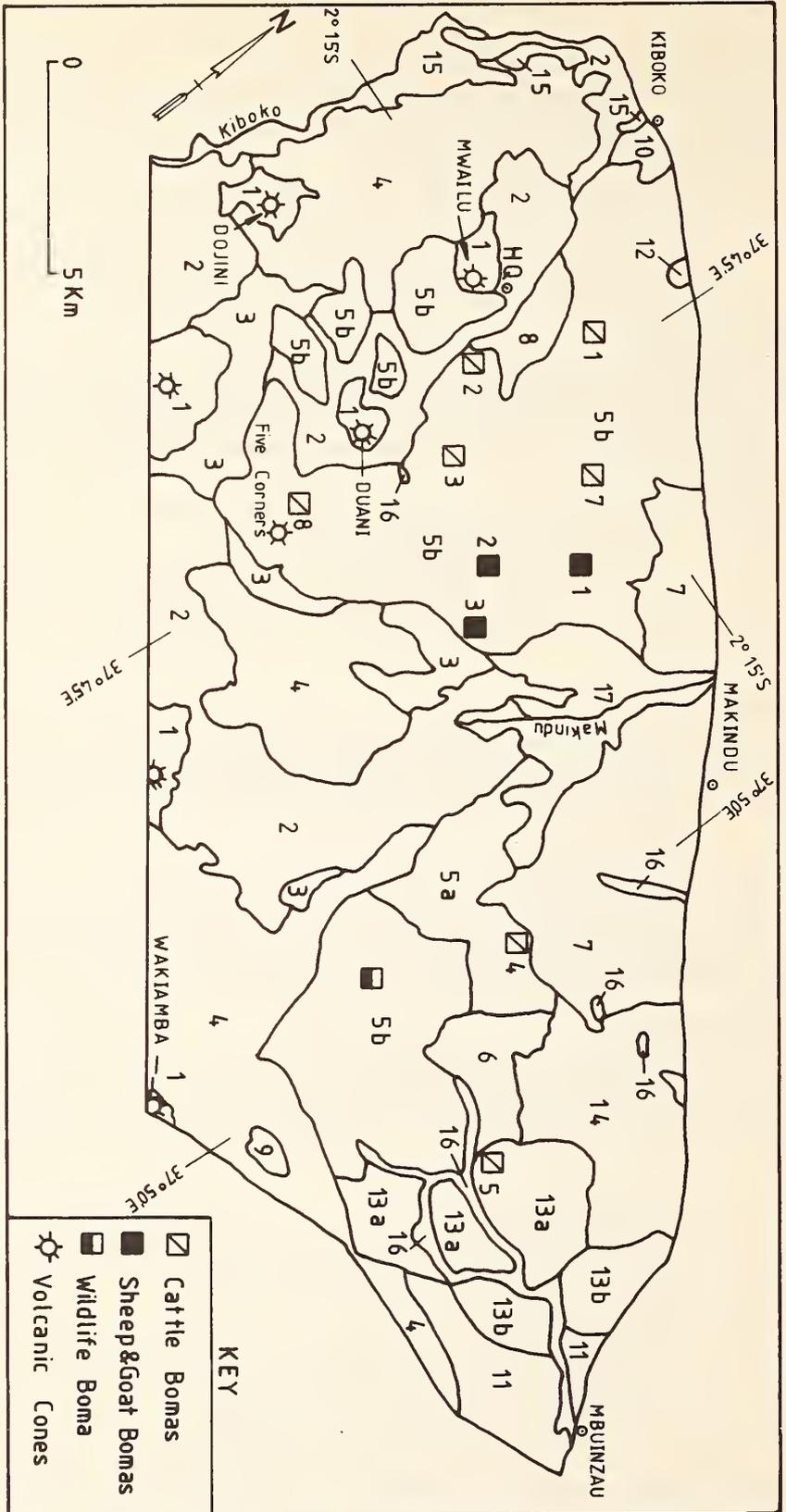


Figure: 2 Plant associations of Kiboko National Range Research Station
 1-4 Vegetation of Volcanic hills, foot slopes and lava flows
 5-14 Vegetation of basement system plains
 15-17 Vegetation of floodplains and bottomlands

The vertisols in this category are imperfectly drained, deep dark grey to black, firm cracking strongly and calcareous. These tend to occur in various pockets in the southern ranch, and also have various narrow arms stretching over this part of the study area down to Mbuinzau (Fig. 2), supporting a characteristic vegetation of *Acacia drepanolobium* Sjostedt and *Pennisetum mezianum* Leeke also *Echinochloa haploclada* (Stapf) Stapf.

Other types of soils in this category include those vertic and calcaric fluvisol types that tend to be imperfectly drained, very deep, strongly to moderately calcareous, firm sandy clay to silty clay sometimes cracking. These occur along the course of the Kiboko river.

(4) *Soils of basement system plains*

These soils cover the largest portion of the Research station. They form the bulk of the grazing blocks on both the northern and southern ranches. Within this rather broad classification occur those soils developed on relatively undifferentiated basement system rocks; predominantly banded gneisses. The ferrosol type, well drained, deep, with colours ranging from dark reddish brown to dark brown and yellowish red, friable to firm clay and sandy clay, come under this category.

Around Shoats* boma 1 stretching down to the south east near Shoats boma 3, occurs a luvisol with characteristic red to dark reddish brown firm sandy clay to clay with topsoil of loamy sand. Bordering this soil type is a stretch of nitosol characterized by well-drained deep dark red friable sandy clay to clay which stretches to the Mombasa road, and along the bottomland soils of the Makindu river course. The soils are said to have developed on basement system rocks rich in ferromagnesian minerals (Michieka & von der Poun, 1977).

The Five-Corners area (Fig. 2) has a type of luvisol which also covers the flat expansive area to the south of Mwailu hill and patches are found to the west and southwest of Duani volcanic cone. These tend to be well-drained, deep reddish brown to dark red. They support predominantly *Acacia tortilis* (Forssk.) Hayne and *Digitaria macroblephara* (Hack.) Stapf, the dominant grass of the understory.

(5) *Soils under swamps*

These constitute a very small portion of the station, they support predominantly *Pennisetum massaicum* stapf as well as other grass species around the edges of the water.

Plant associations

The vegetation of the study area was divided into three broad categories by Michieka & von der Poun (1977), encompassing 13 plant associations as delineated by Langat, *et al.* (1975). These had to be further sub-divided into the now recognized 17 plant associations (Fig. 2), due to evidence of further vegetation changes, mostly arising from overgrazing and accidental fires. These factors have tended to change the rate of succession by affecting species composition, as compared to conditions in 1973-1974 when the last vegetation mapping of the study area was completed by Langat, *et al.* (1975).

The categories have been assigned according to physiographic features and each plant association has been designated with a number as follows:

A. THE VEGETATION OF VOLCANIC HILLS, FOOTSLOPES AND LAVA FLOWS

The hills (volcanic cinder cones) include Mwailu, Duani, Dojini, Wikiamba (Fig. 2).

Association No. 1: *Chrysopogon plumosus* -*Sehima nervosum* association on the hills and lower slopes. The association is relatively open grassland not greatly invaded by shrubs.

Association No. 2: *Sehima nervosum*-*Digitaria macroblephara* - *Grewia bicolor* association

* sheep & goats

on lava flows. This type of lava flow shows some weathering of the rocks, which tend to be small and scattered, enabling some soil formation to take place.

Association No. 3: *Acacia brevispica* - *Commiphora baluensis* association is on shallow, highly permeable volcanic depositions. This type of vegetation occurs on very rocky rough terrain with large volcanic boulders. The trees and shrubs tend to be well-rooted between the rocks. Grass cover, if any, is very low, usually less than 10%.

Association No. 4: Bushland thicket, which is relatively undifferentiated into specific associations. This tends to be a rather complex bushland which is composed of various shrub species that are well-rooted in the rock crevices. Dominants are *Acacia brevispica*, Harms various species of *Maerua*, and *Asparagus falcatus* L. The terrain has little or no grass cover due to a lack of soil that would support the grass root system.

B. THE VEGETATION OF BASEMENT SYSTEM PLAINS

This type of vegetation covers broader categories of associations and is the most widespread and diverse on the Kiboko Station. It covers over half of the grazing blocks in the northern ranch and also over half of the total area of southern ranch. The dominant associations are as follows:

Association No. 5a: *Digitaria macroblephara* - *Acacia tortilis* - *Dousperma kilimandscharicum* - *Commiphora africana* - *Commiphora mildbreadii*. This type of association is predominant around cattle boma 4 on the southern ranch as well as the region between the Makindu river and the wildlife unit. This tends to be densely bushed grassland where burning would reduce the shrub species and upgrade the grazing value of these blocks.

Association No. 5b: *Digitaria macroblephara* - *Acacia senegal* - *Grewia bicolor* - *Acacia tortilis* - *Acacia mellifera* - *Commiphora africana*. In this type of vegetation, *D. macroblephara* and *Bothriochloa insculpta* (A.Rich.) A. Camus are the dominant grasses, whereas the overstory species include *C. africana* (A.Rich.) Engl., *A. senegal* (L) and *A. tortilis*. The remaining are understory species. This association forms the bulk of grazing blocks both in the northern and southern ranches. There has been a change in dominance in the northern ranch close to Shoats boma 1 where *D. macroblephara* has been replaced by *Eragrostis caespitosa* Chiov. on the more closely grazed areas extending eastward toward the Makindu river.

Association No. 6: *Sehima nervosum* - *Commiphora mildbreadii* - *Acacia tortilis*. This association intergrades with No. 5a, but *S. nervosum* (Rottler) Stapf has taken over the understory dominance leaving *Digitaria milanjiana* (Rendle) Stapf in small patches. The higher canopy also includes some *A. senegal*. This association is evident in the grazing block between cattle boma 4 and boma 5 in the southern ranch. In the latter, close grazing tends to cause *Eragrostis caespitosa* to replace *D. milanjiana* and *Themeda triandra* Forssk. which were dominants on the vegetation map of 1975 Langat, et al (1975).

Association No. 7: *Chloris roxburghiana* - *Acacia senegal* - *Commiphora mildbraedii*. In this association *C. roxburghiana* Schult. dominates the understory whereas, the overstory is shared by the woody species. This association occurs to the east of the road from boma 7, on the northern ranch, extending towards and near the Mombasa road; and on both sides of the road to boma 4 from the Mombasa road on the southern ranch, where it tends to be more wooded with taller *C. mildbraedii* Engl.

Association No. 8: *Cymbopogon pospischilii* - *Digitaria macroblephara* - *Commiphora mildbraedii*. This forms sparsely bushed grassland over part of the northern ranch near the location of cattle boma 3. This is the only area where *C. pospischilii* (K. Schum.) C.E. Hubbard occurs in substantial amounts. The association extends towards the lava flow in its western portion where *Sehima nervosum* association forms a very abrupt ecotone.

Association No. 9: This is a rather isolated island of *Cynodon dactylon* - *Eragrostis superba* - *Adansonia digitata* - *Acacia tortilis*. This vegetation island is about 60 h, and surrounded by lava thicket on all sides, and has a deep red clay to sandy clay soil. The herbaceous species include various legumes, notably *Indigofera malindiensis* Gillett and *Crotalaria polysperma* Kotschy.

Association No. 10: Bushland dominated by *Cenchrus ciliaris* L. in the understory layer, *Acacia mellifera* (Vahl) Benth. at the shrub layer and *A. tortilis* in the overstory. It is located in the northern ranch, near Kiboko. A large portion of this area has been disturbed by clearing for a new nursery site, and *Cynodon dactylon* has tended to take over. The undisturbed areas still retain *Cenchrus ciliaris* in the understory.

Association No. 11: An association of *Aristida kenyensis* - *Cynodon dactylon* - *Commiphora africana* - *Combretum apiculatum* forms part of the bushland next to Mbuinzau Market. *C. dactylon* (L) Pers. occurs in patches and overgrazing has tended to favour *A. kenyensis*, an annual grass that sheds seeds quickly after maturity leaving the area bare for the dry season. Bushland in these areas is relatively thick and in some cases impenetrable. Grass cover has greatly diminished here.

Association No. 12: On the northern ranch an almost pure grassland association of *Sporobolus fimbriatus* Nees. - *Cenchrus ciliaris* surrounds the seasonal salt lake which forms next to the Mombasa road (between Kiboko and Makindu). *Acacia tortilis* occurs in patches close to the edges of the pond, where grass cover is very high. *Pennisetum massaicum* Stapf is also a prominent species. *Cynodon dactylon* tends to occur as one moves further away from the pond, where as *Chloris roxburghiana* forms part of the ecotone with other associations.

Association No. 13a: A larger portion of the southern ranch is covered with *Themeda triandra*, and *Chloris roxburghiana*, *Combretum apiculatum* Sond. *T. triandra* and *C. roxburghiana* dominate the understory and *C. apiculatum* dominates the overstory. Illegal grazing on the area close to the Mombasa road has been severe and the species composition has changed to become predominantly annuals, and *A. mellifera* with other shrubs of low grazing value. *A. kenyensis* tends to be the main grass cover, but only during the wet season.

Association No. 13b: *Aristida kenyensis* is the understory dominant with a complex array of shrubs. *Commiphora mildbraedii* is present in this association due to uncontrolled grazing. *T. triandra* and *C. roxburghiana* have been grazed out and replaced by *A. kenyensis* and various other annual weed species, most of which sprout at the onset of the rains and persist only during the wet periods of the year. This association tends to be confined closer to the area near Mbuinzani.

Association No. 14: A complex bushland dominated by *Chloris roxburghiana* and *Digitaria macroblephara* in the understory and *Acacia tortilis* and *Grewia similis*, in the shrub layer. *Commiphora africana* and *A. senegal* dominate the overstory. This association covers a larger portion of the southern ranch and is relatively inaccessible. It has some of the longest transects laid through it and part of the bushland thicket is relatively undifferentiated.

C. VEGETATION OF FLOODPLAINS and BOTTOMLANDS

Association No. 15: This is classified as bottomland silty clay site which occurs along the course of the Kiboko river near Kiboko. *Pennisetum mezianum* dominates the vegetation with occasional annuals especially during the rainy season.

Association No. 16: This vegetation type appears in isolated pockets in both the northern and southern ranches where black-cotton soil supports predominantly *Echinochloa haploclada*. Waterlogging is common during the rainy season due to poor drainage of this soil. *Acacia drepanolobium* is frequent especially where the soil is shallow.

Association No. 17: This association occurs only along the Makindu river where *Acacia xanthophloea* Benth., and *Phoenix reclinata* Jacq. are the dominants. *Cyperus alternifolius* L. is common on the rather swampy habitat in this association.

METHODS

Plant associations in the field were sampled systematically, such that choice of the location and number of transects depended upon the amount of variation evident on a given site. Each plant association sampled had at least two transects across it, whereas the maximum number of transects through a single plant association with great diversity was eight. The length of each transect depended on the relative distance from the centre of each association to the edges. The shortest transect of all was about 80 m long whereas some transects were up to 3.5 km in length.

A total of 110 transects were laid in the 17 plant associations, throughout the study area. About 50 transects were spread over the southern ranch while the rest were in the northern ranch. The Five-Corners area (Fig. 2), where grazing management studies are being conducted, had various transects that were employed but not considered as part of the total number of transects. Compass bearings were used to mark the orientation of each transect. White painted wooden stakes (made of cedar to prevent destruction by termites) were placed along the length of each transect marking its alignment. In addition to the stakes, red ribbons (flags) were tied on trees that occurred along the course of each transect for easy orientation of the direction of the transect.

A wooden stake was placed at the center point of each plant association. Plants occurring along each transect were collected starting from the centre point to the end of the transect. A note was made regarding the longevity (annual or perennial), growth habit (herb, shrub, tree, epiphyte, climber) and relative abundance (rare, common, abundant) of each species encountered. A species was regarded as *rare* if it occurred very infrequently along the transect, for instance if when walking along the transect a species was seen only once or twice, with little evidence of its prominence within the association. A *common* species was one that was encountered frequently along all the transects within the association. The category of *abundant* was accorded those species that were very prominent within the association. Frequently, those species regarded as *abundant* had contributed to the delineation of the vegetation into the different associations. The sites were revisited at two weekly intervals during the growing season to ensure the collection of any newly emergent species.

Voucher specimens were deposited in the S.M. Tracy Herbarium (TAES), Missouri Botanical Garden (MO), Nairobi University Herbarium (NAI) and the East African Herbarium (EA).

An ecological checklist was compiled in the following format. Families are listed in alphabetical order. Within each family the genera are arranged in alphabetical order as are species within each genus.

RESULTS

The vegetation that develops on the Basement System plains generally is characterized by presence of species of *Acacia*, *Commiphora*, *Combretum* and grasses. The grasses may include species of *Eragrostis*, *Digitaria*, *Chloris*, *Themeda* and *Panicum*. These genera may succumb to disturbance and *Aristida* may become prominent with a host of other annuals as a result.

Pratt & Gwynne (1977) point out that *Combretum* is a dominant tree genus of ecoclimatic zones III and IV. Its prominence over a large portion of the southern ranch of the station in association with *Panicum maximum* Vacq. indicates a region of slightly higher rainfall than the rest of the station. This part of the station has been regarded as falling in ecoclimatic zone IV.

The location of the research station offers unique combinations of vegetation types. The lava flows, covering about 30% of the station land area, have pockets of soil that support such species as *Hyparrhenia hirta* (L.) Stapf, *Pennisetum setaceum* (Forsk.) Chiov. and *P. stramineum* Peter, which are expected in higher rainfall areas in ecoclimatic zone III. *Commelina africana* L. var. *boehmiana* (K. Schum.) Brenan, which was found in association with *Cenchrus ciliaris*, *Acacia mellifera* and *A. tortilis* (Association 10), is a new record from this part of Kenya as indicated by records at the East African Herbarium, Nairobi.

A summary of the number of species within each family on the station (Table 1) showed *Gramineae* with the highest number (90 species) followed by *Leguminosae* (47 species) *Euphorbiaceae* and *Compositae* with 20 species each, and the other families represented by fewer species. 27 families were represented by one genus and one species only on the station.

The shrub component of the vegetation represented 18.7% of the total number of species (Table 2) whereas the non-grass herbs constituted 35.4%. The number of tree species was 12.2%, which was half that of the grasses. Only one epiphytic species was recorded on the research station *Plicosepalus sagittifolius* (Sprague) Danser. These results indicate a high species diversity reflected on a small area, as shown also by Ndiang'ui (1984), which is characteristic of the vegetation in the tropics under this type of climate.

Table 1. Summary of the number of genera and species within each family found on the Kiboko National Range Research Station.

Family	No. of genera	No. of species	% of Total species
Acanthaceae	11	14	3.7
Aizoaceae	2	2	0.5
Amaranthaceae	6	8	2.1
Anacardiaceae	3	5	1.3
Araceae	1	1	0.3
Asclepiadaceae	4	4	1.1
Balanitaceae	1	1	0.3
Bignoniaceae	1	1	0.3
Boraginaceae	3	5	1.3
Burseraceae	1	4	1.0
Campanulaceae	2	2	0.5
Capparaceae	5	9	2.4
Caricaceae	1	1	0.3
Celastraceae	1	2	0.5
Chenopodiaceae	1	1	0.3
Combretaceae	2	5	1.3
Commelinaceae	2	4	1.0
Compositae	15	20	5.3
Convolvulaceae	2	6	1.6
Crassulaceae	1	1	0.3
Cruciferae	1	1	0.3
Cucurbitaceae	4	6	1.6
Cyperaceae	3	11	2.9
Ebenaceae	1	1	0.3
Euphorbiaceae	12	20	5.3
Geraniaceae	1	1	0.3
Gramineae	49	90	24.0
Icacinaceae	1	1	0.3
Labiatae	5	9	2.4
Leguminosae	22	47	12.5
Liliaceae	6	9	2.4
Lobeliaceae	1	1	0.3
Loranthaceae	1	1	0.3
Malpighiaceae	1	1	0.3
Malvaceae	4	12	3.2
Meliaceae	2	3	0.8

Family	No. of genera	No. of species	% of Total species
Menispermaceae	1	1	0.3
Moraceae	1	1	0.3
Nyctaginaceae	1	2	0.5
Ochnaceae	1	1	0.3
Olacaceae	1	1	0.3
Palmae	1	1	0.3
Passifloraceae	1	1	0.3
Polygalaceae	1	1	0.3
Polygonaceae	1	1	0.3
Portulacaceae	1	1	0.3
Resedaceae	1	1	0.3
Rhamnaceae	1	2	0.5
Rubiaceae	4	4	1.0
Rutaceae	1	1	0.3
Salvadoraceae	2	2	0.5
Sapindaceae	2	3	0.8
Scrophulariaceae	1	1	0.3
Solanaceae	3	6	1.6
Sterculiaceae	4	6	1.6
Tiliaceae	3	8	2.1
Turneraceae	1	1	0.3
Umbelliferae	1	1	0.3
Verbenaceae	7	11	2.9
Vitaceae	2	6	1.6
Zygophyllaceae	1	1	0.3
TOTAL	223	375	100.0

Table 2. Summary of the growth habits of species found on the Kiboko National Range Research Station.

Growth habit	No. of species	% of Total species
Grasses	90	24.1
Trees	46	12.2
Shrubs	70	18.7
Non-grass herbs	133	35.4
Climbers	35	9.3
Epiphytes	1	0.3

THE CHECKLIST

ACANTHACEAE

<i>Anisotes ukambensis</i> Lindau	S	RARE	3* 4
<i>Asystasia charmian</i> S. Moore	AH	COMMON	1
<i>Barleria eranthemoides</i> C.B.Cl.	AH	RARE	10 11 13 16 17
<i>B. grandicalyx</i> Lindau	AH	RARE	1 2 5b
<i>B. micrantha</i> C.B.Cl.	AH	COMMON	3 13 14
<i>Blepharis linariifolia</i> Pers.	AH	RARE	2 5a 9
<i>B. maderaspatensis</i> (L.) Roth	AH	RARE	5a 9
<i>Crossandra mucronata</i> Lindau	PH	RARE	13b
<i>Dousperma kilimandscharicum</i> (Lindau) Dayton	S	ABUNDANT	5a 11 13
		RARE	6 7 17
<i>Isoglossa laxa</i> Oliv.	PH	RARE	15
<i>Justicia flava</i> Vahl	AH	RARE	5a 14b 15
<i>J. matammensis</i> Oliv.	AH	RARE	16
<i>Monechma debile</i> (Forssk.) Nees	AH	RARE	2 8 9
<i>Ruttya fruticosa</i> Lindau	S	RARE	4
<i>Thunbergia erecta</i> (Benth.) Hook.	A/PH	COMMON	13
		RARE	2

AIZOACEAE

<i>Corbichonia decumbens</i> (Forssk.) Exell	A/PH	RARE	2
<i>Mollugo nudicaulis</i> Lam.	AH	RARE	2

AMARANTHACEAE

<i>Aerva lanata</i> (L.) Schultes	PH	COMMON	1 2 9 12 14 15
<i>Achyranthes aspera</i> L.	A/PH	ABUNDANT	8 15 17
		RARE	3 12
<i>Alternanthera pungens</i> Kunth	AH	ABUNDANT	2
<i>Amaranthus caudatus</i> L.	AH	RARE	2
<i>A. spinosus</i> L.	AH	RARE	2 15
<i>Digera muricata</i> (L.) Mart.	AH	RARE	2 15
<i>Pupalia grandiflora</i> Peter	AH	RARE	3 14
<i>P. lappacea</i> (L.) Juss.	AH	COMMON	5 8 14
		RARE	3 9 13b 15

ANACARDIACEAE

<i>Lannea rivae</i> (Chiov.) Sacle	T	COMMON	5 11 14
		RARE	2 3 6 7 8 13b
<i>L. schweinfurthii</i> (Engl.) Engl.	T	RARE	1 2 3 6 8 9 10
<i>Sclerocarya birrea</i> (A.Rich.) Hochst.	T	RARE	8 9
<i>S. birrea</i> (A.Rich.) Hochst. ssp. <i>caffra</i> (Sond.) Kokwaro	T	RARE	2
<i>Ozoroa insignis</i> Del. ssp. <i>reticulata</i> (Bak. f.) Gillett	T	RARE	2 5 14

* Numbers 3,4,1, etc. denote associations in which the plants were found (See Fig. 2).

AH = Annual herb
AC = Annual climber

S = Shrub
T = Tree PH = Perennial herb

PC = Perennial climber
A/P - Annual or Perennial

	ARACEAE		
<i>Stylochiton puberulus</i> N.E. Br.	AH	COMMON	14
		RARE	5 13
	ASCLEPIADACEAE		
<i>Calotropis procera</i> (Ait.) Ait.f.	S	RARE	5b 9 12
<i>Diplostigma canescens</i> K.Schum.	AH	RARE	2
<i>Gomphocarpus kaessneri</i> N. E. Br.	AH	RARE	2 17
<i>Pentarrhinum insipidum</i> E. Mey	PC	RARE	5b 13b
	BALANITACEAE		
<i>Balanites aegyptiaca</i> (L.) Del.	T	COMMON	5b 8
		RARE	12 13b 15 16 17
	BIGNONIACEAE		
<i>Spathodea campanulata</i> P. Beauv.	T	RARE	2 (ornamental)
	BORAGINACEAE		
<i>Cordia sinensis</i> Lam.	T	RARE	4 8 15
<i>C. ovalis</i> R. Br.	S	RARE	5b 7 8 10 12 16
<i>Heliotropium steudneri</i> Vatke	AH	RARE	5b 10 15
<i>H. subulatum</i> (DC.) Martelli	AH	COMMON	5b 8 14
		RARE	5 7 11 16 17
<i>Trichodesma zeylanicum</i> (L.) R. Br.	AH	RARE	9
	BURSERACEAE		
<i>Commiphora africana</i> (A.Rich.) Engl.	T	ABUNDANT	5 6 7 8 11 14
		COMMON	13
<i>C. baluensis</i> Engl.	T	COMMON	4 14
		RARE	7 10 11
<i>C. boiviniana</i> Engl.	T	COMMON	4 5 14
<i>C. mildbraedii</i> Engl.	T	ABUNDANT	5a 6 7 8 11 14 13
	CAMPANULACEAE		
<i>Wahlenbergia abyssinica</i> (A.Rich.) Thulin	AH	RARE	2
	CAPPARACEAE		
<i>Cadaba farinosa</i> Forssk.	S	COMMON	4
<i>Capparis tomentosa</i> Lam.	S	RARE	4 15
<i>Cleome hirta</i> (Klotzsch) Oliv.	AH	COMMON	2 5 8 10 15
<i>C. monophylla</i> L.	AH	COMMON	2 5 8 13
		RARE	3
<i>Gynandropsis gynandra</i> (L.) Briq.	AH	RARE	2
<i>Maerua angolensis</i> DC.	T	RARE	4
<i>M. decumbens</i> (Brongn.) De Wolf	S	COMMON	4
		RARE	9
<i>M. kirkii</i> (Oliv.) F. White	S	COMMON	4
		RARE	9
<i>M. triphylla</i> A.Rich.	S	COMMON	4
		RARE	9 14

	CARICACEAE		
<i>Carica papaya</i> L.	T	COMMON	2 (cultivated)
	CELASTRACEAE		
<i>Maytenus heterophylla</i> (Eckl. & Zeyh.) N. Robson	S	RARE	14
<i>M. senegalensis</i> (Lam.) Exell	S	RARE	17
	CHENOPODIACEAE		
<i>Chenopodium album</i> L.	AH	RARE	2 15
	COMBRETACEAE		
<i>Combretum aculeatum</i> Vent.	S	COMMON	10
		RARE	5b 8
<i>C. apiculatum</i> Sond.	T	ABUNDANT	11 13a
		RARE	1 2
<i>C. molle</i> G. Don.	T	COMMON	11 13a
<i>Terminalia parvula</i> Pampan	T	RARE	5a 9 11 14
<i>T. kilimandscharica</i> Engl.	T	RARE	5a 13a 14
	COMMELINACEAE		
<i>Aneilema johnstonii</i> K. Schum.	AH	RARE	5a 10
<i>Commelina africana</i> L. var. <i>boehmiana</i> (K. Schum.) Brenan	AH	RARE	10
<i>C. albescens</i> Hassk.	AH	RARE	5a 6 10 11 13a
<i>C. benghalensis</i> L.	AH	RARE	5b 9 10 13a 14
	COMPOSITAE		
<i>Acanthospermum hispidum</i> DC.	AH	RARE	2 5b 6 10 11 13b 16
<i>Aspilia mossambicensis</i> (Oliv.) Wild	PH	COMMON	3
		RARE	4 9 1 14 15 16
<i>A. pluriseta</i> Schweinf.	PH	COMMON	3 15 17
		RARE	4 14
<i>Athroisma psyllioides</i> (Oliv.) Matf.	AH	RARE	8
<i>Bidens pilosa</i> L.	AH	RARE	2 5b
<i>B. schimperi</i> Sch. Bip.	AH	ABUNDANT	15
<i>Blepharispermum pubescens</i> S. Moore	S	RARE	9 14
<i>Conyza aegyptiaca</i> (L.) Ait.	AH	RARE	2 5a
<i>Galinsoga parviflora</i> Cav.	AH	RARE	2
<i>Gynura miniata</i> Welw.	PH	RARE	13b
<i>Launaea cornuta</i> (Oliv. & Hiern) C. Jeffrey	AH	COMMON	2 5b 8 9
<i>Schkuhria pinnata</i> (Lam.) O. Ktze.	AH	COMMON	15
		RARE	2
<i>Sonchus asper</i> (L.) Hill	AH	RARE	2 9
<i>Sphaeranthus cyathuloides</i> O. Hoffm.	AH	COMMON	12 16
		RARE	2
<i>Tagetes minuta</i> L.	AH	RARE	2
<i>Tridax procumbens</i> L.	AH	COMMON	2
<i>Vernonia</i> sp. C of U.K.W.F. (Agnew)	AH	RARE	8
<i>V. galamensis</i> (Cass.) Less. ssp. <i>petitiana</i> (A. Rich.) M.G. Gilbert	AH	RARE	2 5b
<i>V. pteropoda</i> Oliv. & Hiern	S	ABUNDANT	17
<i>V. wakefieldii</i> O. Hoffm.	AH	RARE	3 5b 6 7 8 9 11 16

CONVOLVULACEAE

<i>Astripomoea hyoscyamoides</i>	AH	COMMON	5b
(Vatke) Verdc.		RARE	1 2 3 9 10 12
<i>A. malvaceae</i> (Klotzsch) Meeuse			
var. <i>floccosa</i> (Vatke) Verdc.	PH	RARE	1 2
<i>Ipomoea eriocarpa</i> R. Br.	AC	RARE	2
<i>I. kituiensis</i> Vatke var. <i>kituiensis</i>	PC	RARE	5a 11 13a
<i>I. mombassana</i> Vatke	PC	ABUNDANT	9
<i>I. obscura</i> (L.) Ker-Gawl.	AC	RARE	2 13b

CRASSULACEAE

<i>Kalanchoe lanceolata</i> (Forssk.) Pers.	AH	RARE	2
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CRUCIFERAE

<i>Farsetia stenoptera</i> Hochst.	AH	RARE	2 15
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CUCURBITACEAE

<i>Cucumis dipsaceus</i> Spach	AC	RARE	2 5a 9 15
<i>C. hirsutus</i> Sond.	PC	RARE	9
<i>C. prophetarum</i> L. ssp. <i>dissectus</i>			
(Naud.) C. Jeffrey	PC	RARE	2
<i>Kedrostis gijef</i> (J.F. Gmel.) C. Jeffrey	PC	RARE	5a
<i>Lagenaria abyssinica</i> (Hook.f.) C. Jeffrey	AC	RARE	8
<i>Momordica boivinii</i> Baill.	PH	RARE	2

CYPERACEAE

<i>Cyperus alternifolius</i> L.	PH	ABUNDANT	15 17
<i>C. articulatus</i> L.	PH	ABUNDANT	15
<i>C. bulbosus</i> Vahl var. <i>melanolepis</i> Kukenth.	AH	RARE	
<i>C. giolii</i> Chiov.	AH	RARE	4 10
<i>C. laevigatus</i> L.	PH	ABUNDANT	15
<i>C. longibracteatus</i> Cherm.	PH	ABUNDANT	15
<i>C. obtusiflorus</i> Vahl	AH	RARE	1 2 3 7 8 9 14 15
<i>C. rotundus</i> L.	AH	RARE	1 2 3 7 10 15 16
<i>Fimbristylis dichotoma</i> (L.) Vahl.	PH	COMMON	15
<i>F. hispidula</i> (Vahl) Kunth	PH	ABUNDANT	15
<i>Mariscus obsoletinervosus</i>			
(Peter & Kuk.) Greenway	AH	RARE	5a

EBENACEAE

<i>Euclea racemosa</i> Murr.			
ssp. <i>schimperii</i> (A. DC.) F. White	T	RARE	17

EUPHORBIACEAE

<i>Acalypha fruticosa</i> Forssk.	S	COMMON	14
		RARE	9 10 15
<i>A. indica</i> L.	AH	RARE	2
<i>Bridelia cathartica</i> Bertol.f.	S	RARE	15
<i>Croton dichogamus</i> Pax	S	RARE	3 14
		COMMON	5
<i>C. scheffleri</i> Pax	T	COMMON	4
<i>Dalechampia ipomoeifolia</i> Benth.	PC	COMMON	15
<i>Erythrococca bongensis</i> Pax	S	RARE	15
<i>Euphorbia cotinifolia</i> Pax	S	RARE	15

<i>E. heterochroma</i> Pax	T	COMMON	4
<i>E. heterophylla</i> L.	AH	RARE	2
<i>E. inaequilatera</i> Sond.	AH	COMMON	2
<i>Flueggea virosa</i> (Willd.) Voigt	S	RARE	2 15
<i>Jatropha spicata</i> Pax	S	RARE	10
<i>Phyllanthus amarus</i> Schumach. & Thonn.	AH	RARE	8
<i>P. maderaspatensis</i> L.	PH	RARE	2
<i>Ricinus communis</i> L.	S	RARE	15
<i>Synadenium molle</i> Pax	S	RARE	3 4 5b
<i>Tragia hildebrandtii</i> Muell. Arg.	PH	RARE	12
<i>T. subsessilis</i> Pax	PC	RARE	2 12

GERANIACEAE

<i>Monsonia longipes</i> R. Kunth.	AH	COMMON	15 12 16
		RARE	2

GRAMINEAE

<i>Andropogon chinensis</i> (Nees) Merr.	P	COMMON	2
		RARE	5 6 11
<i>Aristida adscensionis</i> L.	P	ABUNDANT	2
		COMMON	11 13 8
		RARE	3 5 6 10 12
<i>A. barbicollis</i> Trin. & Rupr.	A	RARE	2
<i>A. kenyensis</i> Henn.	A	COMMON	2 1 13
		RARE	7 16
<i>A. mutabilis</i> Trin. & Rupr.	A	RARE	2
<i>Bothriochloa bladhii</i> (Retz.) S.T. Blake	P	COMMON	5
<i>B. insculpta</i> (A.Rich.) A. Camus	P	ABUNDANT	16
		COMMON	12
		RARE	2 8 9 10 15
<i>B. radicans</i> (Lehm.) A. Camus	P	COMMON	12 15 16
		RARE	5 6 7 9 11 13 16 17
<i>Brachiaria deflexa</i> (Schumach.) Robyns	A	COMMON	15
		RARE	2 5 9 13 17
<i>B. eruciformis</i> (J. E. Smith) Griseb.	A	COMMON	15
		RARE	2 5
<i>B. lachnantha</i> (Hochst.) Stapf	A	COMMON	12 16
		RARE	15
<i>B. leersioides</i> (Hochst.) Stapf	A	COMMON	2 5 (roadsides & fire breaks)
		RARE	6 7 10 15 16
<i>B. leucacrantha</i> (K.Schum.) Stapf	A	COMMON	8 (roadsides & fire breaks)
		RARE	2 3 5 6 7 8 9 11 15
<i>B. reptans</i> (L.) Gardner & Hubbard	A	RARE	2 9 15
<i>Cenchrus ciliaris</i> L.	P	ABUNDANT	3 (near Hunters Lodge)
		COMMON	10 15 17
		RARE	1 2 5 6 7 8 9 11 12 13
			14 17
<i>Chloris gayana</i> Kunth.	P	RARE	2 17
<i>C. pycnothrix</i> Trin.	A	RARE	2 15 12
<i>C. roxburghiana</i> Schult.	P	ABUNDANT	5 7 8 9
		COMMON	13 14
		RARE	2 3 6 10 11 12
<i>C. virgata</i> Sw.	A	COMMON	1 2 3 4 5
		RARE	6 10 11 13 16
<i>Chrysopogon plumulosus</i> Hochst.	P	ABUNDANT	1 2
		RARE	5

<i>Cymbopogon caesioides</i> (Hook. & Arn) Stapf	P	ABUNDANT	8
		RARE	5
<i>C. pospichilii</i> (K.Schum.) C.E. Hubbard	P	ABUNDANT	8
		COMMON	12
		RARE	5 16
<i>Cynodon dactylon</i> (L.) Pers.	P	ABUNDANT	1 9
		COMMON	5 10
		RARE	2 6 7 11 12 13 15 16 16
<i>C. plectostachyus</i> (K. Schum.) Pilg.	P	COMMON	3 (near Hunters Lodge) 10
		RARE	6 9
<i>Cypholepis yemenica</i> (Schweinf.) Chiov.	A	RARE	1 2 3 4
<i>Dactyloctenium aegyptium</i> (L.) Willd.	A	COMMON	2 3 (roadsides & fire breaks)
		RARE	5 6 7 8 10 11 13 14 17
<i>Dichanthium annulatum</i> (Forssk.) Stapf var.			
<i>papillosum</i> (A. Rich.) de Wet & Harlan	P	COMMON	12 15 16
<i>Digitaria abyssinica</i> (A. Rich.) Stapf	P	RARE	2
<i>D. gazensis</i> Rendle	P	RARE	5 6 14
<i>D. macroblephara</i> (Hack) Stapf	P	ABUNDANT	5 6 7 13 14
		COMMON	11 8
		RARE	2 16 17
<i>D. milaniana</i> (Rendle) Stapf	P	COMMON	6 11
		RARE	7 14
<i>D. velutina</i> (Forssk.) P. Beauv.	A	COMMON	2 3 15 (roadsides & fire breaks)
		RARE	5 6 7 9 10 13
<i>Diheteropogon amplexens</i> (Nees)			
W.D. Clayton	P	RARE	2
<i>Dinebra polycarpa</i> S.M. Phillips		COMMON	2 12 15
<i>D. retroflexa</i> (Vahl) Panzer	A	COMMON	15
<i>Echinochloa haploclada</i> (Stapf) Stapf	P	ABUNDANT	12 16
		COMMON	17
<i>Eleusine coracana</i> (L.) Gaertn.	A	RARE	2 (cultivated)
<i>E. indica</i> (L.) Gaertn.	A	RARE	2
<i>Enneapogon cenchroides</i> (Roem. & Schult.) C. E. Hubbard	A	COMMON	1 2 3
		RARE	12
<i>Enteropogon macrostachyus</i>	P	ABUNDANT	5b
(A. Rich.) Benth.		COMMON	5a 6 7 8
		RARE	3 10 11 13 14
<i>Eragrostiella bifaria</i> (Vahl) Bor	A	RARE	1 2
<i>Eragrostis aethiopica</i> Chiov.	A	RARE	2 5 10 12 16
<i>E. caespitosa</i> Chiov.	P	ABUNDANT	5a 14 10
		COMMON	5a 14 10
		RARE	6 7 8 11 16
<i>E. cilianensis</i> (All.) Lut.	A	COMMON	2 3 4
		RARE	5 7 10 11 13 17
<i>E. cylindriflora</i> Hochst.	A	RARE	2
<i>E. rigidior</i> Pilg.	P	RARE	2
<i>E. superba</i> Peyr.	P	ABUNDANT	9
		COMMON	5 7 8 11 13 14
		RARE	2 3 6 10
<i>Eriochloa fatmensis</i> (Hochst. & Steud.)			
W.D. Clayton	A	COMMON	12 15 16
<i>Eustachys paspaloides</i> (Vahl) Lanza & Mattei	P	RARE	1 2 5a 6 11 13b
<i>Harpachne schimperii</i> A. Rich.	A	RARE	2

<i>Heteropogon contortus</i> (L.) Rhoem. & Schult.	P	COMMON	(alongside Mombasa road)
		RARE	2 5 6 8 11 17
<i>Hyparrhenia hirta</i> (L.) Stapf	P	RARE	2
<i>Ischaemum afrum</i> (J.F. Gmel.) Dandy	P	COMMON	16 (North Ranch Five-Corners)
		RARE	6
<i>Leptocarydion vulpiastrum</i> (De Not.) Stapf	A	COMMON	2 3 4 17
<i>Leptochloa obtusiflora</i> Hochst.	P	RARE	2 3 4 9 10 15 17
<i>Leptothrium senegalense</i> (Kunth)	A	COMMON	5b
W.D. Clayton		RARE	6 7 8 10 11
<i>Lintonia nutans</i> Stapf	P	RARE	15
<i>Microchloa kunthii</i> Desv.	P	RARE	2
<i>Oropetium thomaemum</i> (L.f.) Trin.	A	COMMON	4
		RARE	2 5 8 10 11 15
<i>Panicum atrosanguineum</i> A. Rich.	A	RARE	5 12 16 17
<i>P. coloratum</i> L.	P	RARE	8
<i>P. deustum</i> Thunb.	P	COMMON	9
		RARE	5 6 10 11 13 14 15
<i>P. maximum</i> Jacq.	P	COMMON	5 7 9 14
		RARE	6 8 10 11 13
<i>Paspalidium desertorum</i> (A. Rich) Stapf	A	RARE	2
<i>Pennisetum massaicum</i> Stapf	P	ABUNDANT	12 15 16
		COMMON	5
		RARE	2 17
<i>P. mezianum</i> Leeke	P	ABUNDANT	12 15 16
		RARE	3 8
<i>P. setaceum</i> (Forssk.) Chiov.	P	RARE	2
<i>P. stramineum</i> Peter	P	RARE	2
<i>Rhynchelytrum repens</i> (Willd.) C. E. Hubbard	P	RARE	2 11
<i>Rottboellia cochinchinensis</i> (Lour.)			
W.D. Clayton	A	RARE	2 3 9 15
<i>Sehima nervosum</i> (Rottler) Stapf	P	ABUNDANT	2 3 6
		RARE	7
<i>Setaria incrasata</i> (Hochst.) Hack.	A	COMMON	2 3
		RARE	12 15 16
<i>S. plicatilis</i> (Hochst.) Engl.	P	COMMON	15
<i>S. pumila</i> (Pior.) Roem. & Schult.	A	RARE	2 15
<i>S. sphacelata</i> (Schumach.) Moss	P	RARE	2
<i>S. verticillata</i> (L.) P. Beauv.	A	COMMON	4
		RARE	2 9 10 12 15
<i>Sorghum arundinaceum</i> (Desv.) Stapf	A	RARE	2
<i>S. purpureo-sericeum</i> (A. Rich.)			
Ascher & Schweinf.	A	RARE	15
<i>Sporobolus fimbriatus</i> (Trin.) Nees	P	ABUNDANT	12
		COMMON	5 8 14
		RARE	2 6 7 10 11 17
<i>S. helvolus</i> (Trin.) Th. Dur. & Schinz	P	RARE	15
<i>S. pellucidus</i> Hochst.	P	RARE	2 17
<i>S. spicatus</i> (Vahl) Kunth	P	RARE	2 15 17
<i>Tetrapogon cenchriformis</i> (A. Rich.)			
W.D. Clayton	P	RARE	6 12 16
<i>T. tenellus</i> (Roxb.) Chiov.	A	COMMON	2 3 4
		RARE	5 10 11 13

<i>Themeda triandra</i> Forssk.	P	ABUNDANT	5a
		COMMON	7 11
		RARE	5b 6 8 13 14
<i>Trachypogon spicatus</i> (L. f.) Kuntze	P	RARE	5a 6 11
<i>Tragus berteronianus</i> Schult.	P	COMMON	2 3 4
		RARE	6 13 16 17
<i>Tricholaena teneriffae</i> (L. f.) Link.	P	ABUNDANT	1 2
		RARE	3
<i>Tripogon minimus</i> (A. Rich.) Steud.	P	RARE	2
<i>Urochloa panicoides</i> P. Beauv.	A	RARE	2 15

ICACINACEAE

<i>Pyrenacantha kaurabassana</i> Baill.	PC	RARE	5
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LABIATAE

<i>Hoslundia opposita</i> Vahl	S	RARE	5 7 9 10 13 14 16
<i>Leucas mollis</i> Baker	AH	COMMON	17
		RARE	12 15 16
<i>Ocimum basilicum</i> L.	AH	COMMON	2 8
		RARE	3 5b 11 13
<i>O. hadiense</i> Forssk.	S	RARE	1 2 3
<i>Orthosiphon parvifolius</i> Vatke	AH	RARE	5
<i>O. rubicundus</i> Benth.	AH	COMMON	2
		RARE	1 3 5 11 13
<i>Plectranthus barbatus</i> Andr.	S	RARE	5a 11 14
<i>P. caninus</i> Roth	AH	RARE	2
<i>P. sylvestris</i> Guerke	AH	RARE	5a 14

LEGUMINOSAE

<i>Acacia brevispica</i> Harms	S	ABUNDANT	3
		COMMON	4 14
		RARE	5 6 9 10 11 13
<i>A. drepanolobium</i> Sjostedt	T	ABUNDANT	12 16
		RARE	15 17
<i>A. hockii</i> De Wild.	S	COMMON	2
		RARE	1
<i>A. mellifera</i> (Vahl) Benth.	S	ABUNDANT	5b 10
		RARE	3 5 6 7 8 9 11 12 15
			16 17
<i>A. nilotica</i> (L.) Del.	T	COMMON	11
		RARE	7 13b 16
<i>A. senegal</i> (L.) Willd.	T	COMMON	5 6 7 14
		RARE	2 3 8 10 11 12 16
<i>A. tortilis</i> (Forssk.) Hayne	T	ABUNDANT	5 6 14
		COMMON	7 9 10
		RARE	3 11 12 13 17
<i>A. xanthophloea</i> Benth.		ABUNDANT	17
	T	RARE	15
<i>Albizia amara</i> (Roxb.) Boiv.			
<i>ssp. sericocephala</i> (Benth.) Brenan	T	RARE	3 5 6 7 8 10 11 13 15
<i>A. anthelmintica</i> Brongn.	S	COMMON	5 6 13

<i>Alysicarpus glumaceus</i> (Vahl) DC.	PH	RARE	5 6 8 9
<i>A. rugosus</i> (Willd.) DC.	PH	COMMON	
		RARE	5 6 8 11 16
<i>Cassia abbreviata</i> Oliv.	T	RARE	7 14
<i>C. absus</i> L.	AH	RARE	5 15
<i>C. mimosoides</i> L.	AH	RARE	9 16
<i>C. occidentalis</i> L.	S	RARE	2 3 9 17
<i>Clitoria ternatea</i> L.	PC	RARE	12 16
<i>Crotalaria goodiiiformis</i> Vatke	S	RARE	11
<i>C. incana</i> L.	AH	RARE	2 9
<i>C. laburnifolia</i> L.	AH	RARE	2 6
<i>C. polysperma</i> Kotschy	AH	RARE	2 5 9 10
<i>Dalbergia melanoxylon</i> Guill. & Perr.	T	COMMON	2
		RARE	3 4 5 11 14
<i>D. vacciniifolia</i> Vatke	S	RARE	2 3
<i>Dichrostachys cinerea</i> (L.) Wight & Arn.	T	COMMON	2
		RARE	1 5 8 11 16
<i>Dolichos sericeus</i> E. Mey.	PC	RARE	12
<i>Entada leptostachya</i> Harms	PC	RARE	2 3 4 5 14
<i>Indigofera colutea</i> (Burm.f.) Merrill	AH	COMMON	9
		RARE	5b 10 14
<i>I. lupatana</i> Bak.f.	AH	RARE	9
<i>I. malindiensis</i> Gillett	AH	RARE	9
<i>Leucaena latisiliqua</i> (L.) Gillis	S	RARE	2 8
<i>Macrotyloma axillare</i> (E. Mey.) Verdc.	PC	RARE	5 11 14
<i>Milletia leucantha</i> Vatke	T	RARE	5 8
<i>Neonotonia wightii</i> (Wight & Arn.) Lackey	PC	RARE	2 5b 13 14
<i>Neorautanenia mitis</i> (A.Rich.) Verdc.	PC	RARE	4 5
<i>Ormocarpum kirkii</i> S. Moore	S	COMMON	2 3 14
<i>O. trachycarpum</i> (Taub.) Harms	S	COMMON	2 3
		RARE	11
<i>Rhynchosia elegans</i> A. Rich.	PC	RARE	17
<i>R. minima</i> (L.) DC.	PC	RARE	2 5 10
<i>Sena bicapsularis</i> (L.) Roxb.	S	RARE	15 17
<i>S. longiracemosa</i> (Vatke) Lock	S	RARE	5b
<i>S. singueana</i> (Del.) Lock	T	RARE	7 10 11 13b
<i>Sesbania keniensis</i> Gillett	S	RARE	17
<i>Tephrosia nana</i> Schweinf.	H A/P	COMMON	1 2 3 8 9
	H A/P	RARE	5 6 10 12
<i>T. pumila</i> (Lam.) Pers.	AH	RARE	9
<i>T. subtiflora</i> Bak.	H A/P	RARE	5 6 7 14
<i>Vigna membranacea</i> A.Rich.	C A/P	RARE	5 14
<i>V. unguiculata</i> (L.) Walp.	AH	RARE	2

LILIACEAE

<i>Anthericum subpetiolatum</i> Bak.	H A/P	RARE	5a 14
<i>A. venulosum</i> Bak.	H A/P	RARE	5a
<i>Asparagus africanus</i> Lam.	PC	RARE	5a 14
<i>A. falcatus</i> L.	PC	RARE	3 4
<i>A. flagellaris</i> (Kunth) Bak.	PC	RARE	2 5a 15
<i>Bulbine abyssinica</i> A. Rich.	AH	RARE	15
<i>Chlorophytum gallabatense</i> Bak.	AH	RARE	5 9 11 13b 14
<i>Gloriosa superba</i> L.	AH	RARE	5a
<i>Wurmbea tenuis</i> Bak.	AH	RARE	1

	LOBELIACEAE		
<i>Cyphia glandulifera</i> A. Rich.	PH	RARE	1
	LORANTHACEAE		
<i>Plicosepalus sagittifolius</i> (Sprague) Danser		RARE	(epiphyte on <i>Acacia senegal</i>)
	MALPIGHIACEAE		
<i>Caucanthus auriculatus</i> (Radlk.) Niedenzu	PC	RARE	9 11 13b 14
	MALVACEAE		
<i>Abutilon figarianum</i> Webb.	AH	RARE	2
<i>A. fruticosum</i> Guill. & Perr.	S	RARE	17
<i>A. mauritianum</i> (Jacq.) Medic.	S	RARE	2 15
<i>Hibiscus aponeurus</i> Sprague & Hutch.	PH	COMMON	2 3
		RARE	5 8 11 13 14
<i>H. calyphyllus</i> Cav.	PH	RARE	5 10 15
<i>H. cannabinus</i> L.	AH	RARE	12 15 16
<i>H. palmatus</i> Forssk.	AH	RARE	2 3
<i>H. vitifolius</i> L.	AH	RARE	2 3 13
<i>Pavonia patens</i> (Andr.) Chiov.	S	COMMON	2 3 5
		RARE	4 11 14
<i>Sida ovata</i> Forssk.	A/PH	RARE	8
	MELIACEAE		
<i>Melia azedarach</i> L.	T	RARE	5 9 (cultivated)
<i>M. volkensii</i> Gurke	T	RARE	5
<i>Trichilia emetica</i> Vahl	T	RARE	15 17
	MENISPERMACEAE		
<i>Cissampelos mucronata</i> A. Rich.	PC	COMMON	15 17
		RARE	3 9 11
	MORACEAE		
<i>Ficus glumosa</i> Del.	T	COMMON	15
		RARE	2
	NYCTAGINACEAE		
<i>Commicarpus pedunculatus</i> (A. Rich.) Cuf.	PH	COMMON	9 17
		RARE	5b 11 14
<i>C. plumbagineus</i> (Cav.) Standl.	PH	COMMON	15 17
		RARE	2 3 5b 6 7 10
	OCHNACEAE		
<i>Ochna ovata</i> F. Hoffm.	S	RARE	5
	OLACACEAE		
<i>Ximenia americana</i> L.	T	RARE	15 17
	PALMAE		
<i>Phoenix reclinata</i> Jacq.	S	COMMON	15
	PASSIFLORACEAE		
<i>Adenia gummiifera</i> (Harvey) Harms	PC	COMMON	15 17
		RARE	4 13

	POLYGALACEAE		
<i>Polygala sphenoptera</i> Fresen.	A/PH	RARE	11
	POLYGONACEAE		
<i>Oxygonum sinuatum</i> (Meisn.) Dammer	AH	RARE	2 6 9 10 13b
	PORTULACACEAE		
<i>Talinum portulacifolium</i> (Forssk.) Schweinf.	PH	RARE	2 3 5 6 7 9 10
	RESEDACEAE		
<i>Caylusea abyssinica</i> (Fresen.) Fisch. & Mey.	AH	RARE	2 9
	RHAMNACEAE		
<i>Helinus integrifolius</i> (Lam.) Kuntze	PC	RARE	2 5 9
<i>H. mystacinus</i> (Ait.) Steud.	PC	RARE	4
	RUBIACEAE		
<i>Oldenlandia corymbosa</i> L. var. <i>caespitosa</i> (Benth.) Verdc.	AH	RARE	16
<i>Pentanisia ouranogyne</i> S. Moore	A/PH	RARE	1 2 3 8 11 (roadsides & firebreaks)
<i>Pentas parvifolia</i> Hiem	S	RARE	11 14
<i>Vangueria madagascariensis</i> Gmel.	S	RARE	15
	RUTACEAE		
<i>Zanthoxylum chalybeum</i> Engl.	T	RARE	14
	SALVADORACEAE		
<i>Azima tetracantha</i> Lam.	S	COMMON	4
<i>Salvadora persica</i> L.	S	COMMON	4
		RARE	12 15
	SAPINDACEAE		
<i>Allophylus rubifolius</i> (A. Rich.) Engl.	S	RARE	2 17
<i>Cardiospermum corindum</i> L.	PC	COMMON	17
	SCROPHULARIACEAE		
<i>Cycnium tubulosum</i> (L. f.) Engl.	AH	RARE	12 16
	SOLANACEAE		
<i>Lycopersicon esculentum</i> Mill.	AH	RARE	2 17 (cultivated)
<i>Solanum incanum</i> L.	S	RARE	2 3 5 7 8 9 10 11 13 16
<i>S. nigrum</i> L.	AH	RARE	2 17
<i>S. renschii</i> Vatke	S	RARE	4
<i>S. sessilistellatum</i> Bitter	S	RARE	15
<i>Withania somnifera</i> (L.) Dunal	AH	RARE	9 17
	STERCULIACEAE		
<i>Dombeya kirkii</i> Mast.	T	RARE	4
<i>D. rotundifolia</i> (Hochst.) Planch.	T	RARE	2 3
<i>Hermannia uhligii</i> Engl.	S	COMMON	5 8
		RARE	2 6 9 10 11 13 16 17
<i>Melhania velutina</i> Forssk.	AH	RARE	2 5
<i>Sterculia africana</i> (Lour.) Fiori	T	COMMON	3 4
		RARE	2 11 14

TILIACEAE

<i>Corchorus trilocularis</i> L.	AH	RARE	8 11 16
<i>Grewia bicolor</i> Juss.	S	COMMON	5 6 7 14
		RARE	3 9 10 11 13
<i>G. densa</i> K. Schum.	S	COMMON	5 6 7 14
		RARE	3 10 11 13
<i>G. fallax</i> K. Schum.	T	COMMON	5 14
		RARE	3 6 7 8
<i>G. similis</i> K. Schum.	T	COMMON	5 15
		RARE	6 7 8
<i>G. tembensis</i> Fres.	T	COMMON	5 14
		RARE	6 7 8 9
<i>G. villosa</i> Willd.	S	COMMON	5 6 8 14
		RARE	2 7 9 10 12 13 16 17
<i>Triumfetta flavescens</i> A. Rich.	S	ABUNDANT	3
		COMMON	2
		RARE	1 8 10 17

TURNERACEAE

<i>Streptopetalum hildebrandtii</i> Urb.	PH	RARE	1
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UMBELLIFERAE

<i>Steganotaenia araliacea</i> Hochst.	T	COMMON	3 4
		RARE	2 5 16

VERBENACEAE

<i>Chascanum hildebrandtii</i> (Vatke) Gillett	PH	RARE	2
<i>Clerodendrum acerbianum</i> (Vis.) Benth. & Hook.f.	S	RARE	2
<i>C. myricoides</i> (Hochst.) Vatke	S	RARE	2 5 11 14
<i>Lantana camara</i> L.	S	RARE	5 15
<i>L. rhodesiensis</i> Moldenke	PH	RARE	5
<i>L. viburnoides</i> (Forssk.) Vahl	PH	RARE	5b
<i>Lippia javanica</i> (Burm.f.) Spreng	S	RARE	2 3 4 8
<i>L. kituiensis</i> Vatke	S	RARE	5 17
<i>Premna oligotricha</i> Bak.	S	COMMON	11 13 14
		RARE	5
<i>Priva curtisiae</i> Kobuski	PH	RARE	2 15

VITACEAE

<i>Cissus aphyllantha</i> Gilg.	PC	COMMON	3 4 5
<i>C. cornifolia</i> (Bak.) Planch.	PH	RARE	2 5 11 13 14
<i>C. quadrangularis</i> L.	PC	COMMON	4
<i>C. rotundifolia</i> (Forssk.) Vahl	PC	RARE	5
<i>Cyphostemma adenocaula</i> (A. Rich.) Wild & Drum.	PC	COMMON	5 14
		RARE	1
<i>C. serpens</i> (A. Rich.) Desc.	PC	COMMON	
		RARE	6 7 11

ZYGOPHYLLACEAE

<i>Tribulus terrestris</i> L.	AH	COMMON	15
		RARE	2

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Instructions for authors may be obtained from:
The Hon. Secretary, E.A.N.H.S., P.O. Box 44486, Nairobi, Kenya

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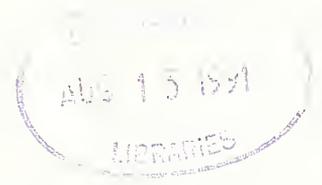
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A PROVISIONAL, ANNOTATED CHECKLIST OF THE
BUTTERFLIES IN LAKE MANYARA NATIONAL PARK,
ARUSHA REGION, TANZANIA.

NORBERT J CORDEIRO
P. O. Box 708, Moshi, Tanzania*



ABSTRACT

Lake Manyara National Park is well known for its diverse habitats and large mammals. While little is understood about most of the smaller vertebrates and invertebrates, this investigation into the butterflies of the park has revealed over 180 species. Several of the following are of particular interest, either because of new extensions to their range or, their taxonomic differences as compared to other East African populations: *Belenois margaritacea plutonica*, *Pieris brassicoides marghanita*, *Charaxes cithaeron kennethi*, *Ch. violetta melloni*, *Ch. hansalii baringana*, a female aberration of *Ch. achaemenes achaemenes* (figured and described in this paper), *Mimacraea marshalli*, *Aloeides conradsi talboti*, *Stugeta bowkeri nyanzana* and *Tuxentius stempfferi*.

INTRODUCTION

Lake Manyara National Park (L.M.N.P.) is one of the areas of highest wildlife biomass in Africa (Coe *et al.*, 1976; Loth & Prins, 1986) and is well known for its diverse fauna and flora. Although Watermeyer & Elliott (1943) initially described the general ecology, probably the most extensive earlier contribution to the ecology of L.M.N.P. is that of Douglas-Hamilton (1972). Greenway & Vesey-FitzGerald (1969), gave a detailed account of the vegetation, emphasizing the diverse habitat types and their corresponding species, whereas Loth & Prins (1986) described the physiography of the park. [see also Prins, 1988; Prins & Loth, 1988].

Most of the scientific research at L.M.N.P. has centred around vegetational changes caused by large herbivores (Vesey-FitzGerald, 1969 1973; Douglas-Hamilton, 1972; Mwalyosi, 1981 1983; Beckman & Prins, 1989; Prins & Beckman, 1989); although numerous ecological and behavioural studies have also been conducted on large mammals (Makacha & Schaller, 1969; Vesey-FitzGerald, 1969; Douglas-Hamilton, 1972; Weyerhauser, 1982; Kalemera, 1987; Beckman & Prins, 1989; Kalemera, 1989; Prins, 1989; Prins & Beckman, 1989; Prins & Iason, 1989). The changes in populations of large mammals have also been monitored over the years (Watson & Turner, 1965; Douglas-Hamilton, 1972; Mwalyosi, 1977; Boshe & Malima, 1986). Morgan-Davies (1964) recorded over 380 species of birds (TANAPA / AWF, 1986). The smaller vertebrates and invertebrate fauna, however, have received scant attention.

* Present address: P. O. Box 0377, Hampshire College, Amherst MA01002 USA

Only a few people have contributed towards butterfly records. Barns (1924) and Cooper collected in the region of L.M.N.P. as early as 1921 and 1935 respectively (according to specimen labels in the collections at the Natural History Museum, London (BMNH), (personal observations). Two-and-a-half decades later, Rydon & Morgan-Davies (1960a, b, and unpublished) collected butterflies in L.M.N.P., compiling two short checklists for the park's authorities; they recorded 56 species. In the early 1970s, S. C. Collins (personal communication) also made a small collection of butterflies in the park.

This paper is an account of the butterflies recorded in L.M.N.P. as a result of a five month study made between late July and early December 1987. The main content has been divided into two sections: (1) a checklist of all the species, and (2) brief notes on over 50 of them.

The checklist is by no means an exhaustive study of the park's butterfly fauna of the park. This is particularly evident in the families *Lycaenidae*, *Acraeidae* and *Hesperiidae*, which are poorly represented. There are also habitats that require exploring in greater depth than I had undertaken, e.g. the groundwater forest, the Marang Forest and the adjoining forest below the Rift Valley wall, as well as the vegetation of the escarpment. (Fig. 1).

Description of the study area

Lake Manyara National Park, is situated in northern Tanzania (centre of the park at 3°30'S, 35°60'E), it encompasses part of the eastern escarpment of the Rift Valley as well as the lake and a portion of the surrounding environment (Fig. 1). The lake lies at an altitude of approximately 960m, while the Rift Valley wall generally rises to about 1000m above it and in some areas is even higher. L.M.N.P. is 330 km² of which about two-thirds comprises the alkaline lake (Mwalyosi, 1981; TANAPA / AWF, 1986). The Marang Forest Reserve and an adjacent strip of land in the south of L.M.N.P. have been proposed for incorporation into the park boundaries in the near future (Loth & Prins, 1986).

Annual rainfall is variable, ranging from 480mm [1969] to 1500mm [1968] (Mwalyosi, 1981) most of which falls between November and May (Prins & Loth, 1988). There is one long dry season from June to October (Prins & Loth, 1988). Within the Lake Manyara ecosystem there are five distinct vegetation zones, namely **groundwater forest**, **marshland** and **reed beds**, **alkaline grassland**, **scrubland** on the escarpment and the **Acacia woodland** (Greenway & Vesey-FitzGerald, 1969).

METHODS

As a result of the reorganization of the park museum, the new L.M.N.P. *Rhopalocera* collection which I re-established entailed the exploration of many vegetation zones of the park. [I replaced the moth-eaten collection made by A. M. Morgan-Davies which had been installed in the early 1960s (Rydon, *in litt.*)]. Collecting was undertaken on an irregular basis for between 1-3 days a week.

To obtain additional records, I briefly studied the African collections in the Natural History Museum, London (BMNH) and the American Museum of Natural History (AMNH) in August 1988 and July 1989 respectively.

I have followed Carcasson's "Simplified Provisional Checklist of the Butterflies of the Afrotropical Region" in his *Collins Handguide to the Butterflies of Africa* (1981) (Hard-back edition) as the basis of this checklist. The list has been organized by families and genera except for the *Lycaenidae* which was placed at the end and the *Hesperiidae* at the beginning, following the arrangement of Kristensen (1976). For simplicity these groups have not been divided into subfamilies and tribes; however, the species have been arranged alphabetically so as to facilitate easy reference by the reader:

Of special interest are *Belenois margaritacea pluonica* Joicey & Talbot, *Pieris brassicoides*

marghanita Hemming, *Charaxes cithaeron kennethi* Poulton, *Ch. violetta melloni* Fox, *Ch. hansalii baringana* Rothschild, and a female aberration of *Ch. achaemenes achaemenes* Felder (which is figured and described in this paper), *Mimacraea marshalli* Trimen, *Aloeides conradi talboti* Tite & Dickson, *Stugeta bowkeri nyanzana* Wichgraf, *Tuxentius stempfferi* Kielland. The significance of the above-named species to L.M.N.P. is discussed later. Other species marked with an asterisk (*) or a question mark (?) after the author(s)' name are also discussed further in the notes section and, where appropriate, I have added additional comments on the taxonomy, behaviour and special geographical ranges. Numbers after generic and specific names refer to species notes in the discussion. Important additional information was provided to me by J. Kielland, S. C. Collins and A. H. B. Rydon.

RESULTS

Lake Manyara checklist

All specimens (except those recorded by other authors / collectors) are in the National Park museum or temporarily in my collection.

Key to the abbreviations and symbols

In the checklist, numbers preceding names refer to species mentioned in the discussion.

Butterfly records other than my own

- * = specimens in the BMNH
- ** = various records from other authors or collectors
- *** = specimens in the AMNH

Butterfly status at L.M.N.P.

- x = rare
- ox = uncommon
- o = common
- oo = very common

Habitat abbreviations, (after Carcasson, 1981)

- | | | | |
|----|------------------|----|--------------------|
| ag | arid grasslands | gf | groundwater forest |
| ah | arid habitats | h | highlands |
| aw | arid woodlands | hf | highland forest |
| c | cultivated areas | oh | open habitats |
| f | forest | rf | riverine forest |
| fm | forest margin | w | woodland |
| g | grasslands | | |

Other abbreviations and symbols

- A (?) after a habitat(s) abbreviation means that the habitat of the species in L.M.N.P. was not known to me as it was recorded by someone else. I have added the known habitat(s) in Africa according to Carcasson (1981).
- A (?) representing the status of the taxon implies that it was recorded by another person, and information on its status in L.M.N.P. is unavailable.
- A (?) after the author(s) name implies that the record is based on my observation and that it was not captured for verification.
- ssp. denotes uncertainty on the sub-specific status of the taxon, or that it is currently being described by another author.

Family, Genus & species	Status	Habitat	Family, Genus & species	Status	Habitat
HESPERIIDAE			<i>N. thalassina sinalata</i> Suffert	ox	rf, f
Coeliades Hübner			Eronia Hübner		
<i>C. anchises anchises</i> Gerstaecker (2)	oo	f	<i>E. cleodora dilatata</i> Butler	o	w
Celaenorrhinus Hübner			<i>E. leda</i> Boisduval	oo	w
<i>C. galenus</i> Fabricius	oo	gf	Colotis Hübner		
Tagiades Hübner			<i>C. antivippe zera</i> Lucas	oo	oh
<i>T. flesus</i> Fabricius	oo	w	<i>C. aurigineus</i> Butler	oo	oh
Eagris Guenée			<i>C. aurora dissociatus</i> Butler	oo	ah
<i>E. sabadius astoria</i> Holland	oo	gf, w	<i>C. auxo incretus</i> Butler (38)	o	w
Sarangesa Moore			<i>C. calais calais</i> Cramer	oo	ah
<i>S. motozi</i> Wallengren	o	w	<i>C. celimene celimene</i> Lucas	o	oh
<i>S. phidyle</i> Walker	oo	ah	<i>C. chrysonome chrysonome</i>	?	a
<i>S. seineri seineri</i> Strand	o	ah	Klug* (41)		
Netrobalene Mabille			<i>C. danae pseudacaste</i> Butler	oo	aw
<i>N. canopus</i> Trimen (8)	oo	oh in f, rf	<i>C. eris eris</i> Klug (43)	oo	ah
Spialia Swinhoe			<i>C. evagore antigone</i> Boisduval	oo	ah
<i>S. spio</i> Linnaeus** (9)	oo	oh	<i>C. evenina xantholeuca</i> Sharpe	oo	w
Gomalia Moore			<i>C. evippe complexivus</i> Butler	oo	oh
<i>G. elma</i> Trimen	o	oh	<i>C. halimede australis</i> Talbot	o	aw
Metisella Hemming			<i>C. hetaera ankolensis</i> Stoneham	oo	oh
<i>M. medea medea</i> Evans (11)	o	gf	<i>C. hildebrandti</i> Staudinger	oo	aw
Ampittia Moore			<i>C. ione</i> Godart	oo	w
<i>A. capenas capenas</i> Hewitson	ox	w	<i>C. pallene pallene</i> Hopffer** (51)	?	oh?
Acleros Mabille			<i>C. regina</i> Trimen	oo	w
<i>A. ploetzi</i> Mabille	oo	gf	<i>C. vesta hanningtoni</i> Butler	oo	oh
Zenonia Evans			<i>C. vestalis castalis</i> Staudinger (54)	o	ah
<i>Z. zeno</i> Trimen	oo	w	Belenois Hübner		
Gegenes Hübner			<i>B. aurota aurota</i> Fabricius	oo	oh
<i>G. hottentota hottentota</i> Latreille (15)	o	oh	<i>B. creona severina</i> Stoll	oo	oh
PAPILIONIDAE			<i>B. gidica</i> Godart	oo	oh
Papilio Linnaeus			<i>B. margaritacea plutonica</i>	x	gf
<i>P. dardanus tibullus</i> Kirby	o	f	Joicey & Talbot (58)		
<i>P. demodocus demodocus</i> Esper	oo	oh	<i>B. thysa thysa</i> Hopffer	o	w, fm
<i>P. echerioides</i> Trimen ssp.	ox	f	<i>B. zochalia agrippinides</i> Holland	o	gf
<i>P. nireus lyaeus</i> Doubleday	o	oh in f, c	Pieris Schrank		
Graphium Scopoli			<i>P. brassicoides marghanita</i>	x	h
<i>G. angolanus angolanus</i> Goeze? (20)	o	oh	Hemming (= <i>meridionalis</i>)		
<i>G. antheus</i> Cramer	o	f, fm	Joicey & Talbot (61)		
<i>G. leonidas leonidas</i> Fabricius (22)	oo	w, f	Dixiea Talbot		
<i>G. policenes</i> Cramer** (23)	?	f?	<i>D. charina liliana</i> Grose-Smith	o	w, fm
PIERIDAE			<i>D. doxo costata</i> Talbot	o	w
Catopsilia Hübner			<i>D. orbona vidua</i> Butler	o	oh
<i>C. florella</i> Fabricius	oo	oh	<i>D. pigea</i> Boisduval	o	w, fm
Eurema Hübner			Appias Hübner		
<i>E. brigitta brigitta</i> Stoll	oo	oh	<i>A. ephia contracta</i> Butler	oo	w, f, rf
<i>E. desjardinsi marshalli</i> Butler (26)	oo	w	<i>A. sabina phoebe</i> Butler	o	rf, f
<i>E. hapale</i> Mabille	o	g	Mylothris Hübner		
<i>E. hecabe solifera</i> Butler	oo	oh, w	<i>M. chloris agathina</i> Cramer	oo	w, fm
Pinacopteryx Wallengren			<i>M. ruppellii tirikensis</i> Neave	o	w, f
<i>P. eriphia melanarge</i> Butler	oo	oh, w	Leptosia Hübner		
Nepheronia Butler			<i>L. alcesta inalcesta</i> Bernardi	oo	f
<i>N. argia mhondana</i> Suffert	oo	rf, f	LIBYTHEIDAE		
<i>N. buqueti buqueti</i> Boisduval	oo	ah	Libythea Fabricius		
			<i>L. labdaca laius</i> Trimen (71)	o	gf, fm

Family, Genus & species	Status	Habitat	Family, Genus & species	Status	Habitat
NYMPHALIDAE			<i>J. limnoria taveta</i> Rogenhöfer	o	ah
Charaxes Ochsenheimer			<i>J. natalica natalica</i> Felder	oo	w, fm
<i>Ch. achaemenes achaemenes</i>			<i>J. octavia sesamus</i> Trimen	o	w
Felder (72)	o	w	<i>J. oenone oenone</i> Linnaeus	oo	oh
<i>Ch. aubyni aubyni</i>			<i>J. orithya madagascariensis</i> Guenée	o	oh
van Someren & Jackson (73)	ox	gf	<i>J. terea elgiva</i> Hewitson	oo	f
<i>Ch. baumanni tenuis</i> van			Catacroptera Karsch		
Someren	o	gf	<i>C. cloanthe cloanthe</i> Stoll	oo	g
<i>Ch. bohemani</i> Felder (75)	oo	w	Vanessa Fabricius		
<i>Ch. brutus alcyone</i> Stoneman	oo	f	<i>V. cardui</i> Linnaeus	oo	oh
<i>Ch. candiope candiope</i> Godart (77)	oo	f, w	Antanartia Rothschild & Jordan		
<i>Ch. cithaeron kennethi</i> Poulton (78)	o	gf	<i>A. abyssinica jacksoni</i> Howarth**(116)?		h?
<i>Ch. etesipe tavetensis</i> Rothschild	o	f	Phalanta Horsfield		
<i>Ch. ethalion littoralis</i> van Someren	oo	f, w	<i>Ph. phalantha aethiopica</i>	oo	w, oh
<i>Ch. hansalii baringana</i> Rothschild (81)x		aw	Rothschild & Jordan		
<i>Ch. jasius saturnus</i> Butler (82)	o	w, c	ACRAEIDAE		
<i>Ch. kirki kirki</i> Butler (83)	oo	w	Bematistes Hemming		
<i>Ch. pollux maua</i> van Someren (84)	ox	gf	<i>B. aganice montana</i> Butler	ox	f
<i>Ch. varanes vologeses</i> Mabille (85)	oo	w, fm	Acraea Fabricius		
<i>Ch. violetta melloni</i> Fox (86)	o	gf	<i>A. acerata</i> Hewitson	o	w
<i>Ch. zoolina zoolina</i> Westwood (87)	oo	w, fm	<i>A. anemosa</i> Hewitson	oo	w, f
Euxanthe Hübner			<i>A. braesia</i> Godman	o	ah
<i>E. wakefieldii</i> Ward (88)	o	gf	<i>A. cabira</i> Hopffer ?	o	fm, rf
Hamanumida Hübner			<i>A. egina areca</i> Mabille	o	f, rf
<i>H. daedalus</i> Fabricius	oo	oh	<i>A. encendon encendon</i> Linnaeus	oo	oh
Pseudacraea Westwood			<i>A. eponina</i> Cramer	oo	oh
<i>Ps. boisduvali trimeni</i> Butler**(90)	?	w, rf, fm?	<i>A. esebria esebria</i> Hewitson	oo	f, rf, w
<i>Ps. lucretia expansa</i> Butler	o	rf, fm	<i>A. johnstoni johnstoni</i> Godman	oo	f
Neptis Fabricius			<i>A. natalica natalica</i> Boisduval	oo	w, fm
<i>N. laeta</i> Overlaet	oo	w	<i>A. neobule neobule</i> Doubleday**(129) ?	?	oh?
<i>N. saclava marpessa</i> Hopffer	oo	w	<i>A. oreas oreas</i> Sharpe	o	gf
Cyrestis Boisduval			<i>A. pudorella pudorella</i>	o	w
<i>C. camillus sublineata</i> Lathy	o	gf, rf	Aurivillius? (131)		
Byblia Hübner			<i>A. sotikensis</i> Sharpe*(132)	?	f
<i>B. anvataara acheloia</i> Wallengren	oo	oh	Pardopsis Trimen		
<i>B. ilithya</i> Drury	oo	oh	<i>P. punctatissima</i> Boisduval? (133)	o	oh
Neptidopsis Aurivillius			SATYRIDAE		
<i>N. ophione velleda</i> Mabille	oo	f, w	Gnophodes Westwood		
Eurytela Boisduval			<i>G. betsimensa diversa</i> Butler	o	f, fm
<i>E. dryope angulata</i> Aurivillius (98)	oo	w	Melantis Fabricius		
<i>E. hiarbas lita</i>	oo	f	<i>M. leda helena</i> West	oo	w
Rothschild & Jordan (99)			Bicyclus Kirby		
Hypolimnas Hübner			<i>B. anynana anynana</i> Butler	oo	w
<i>H. misippus</i> Linnaeus	oo	oh	<i>B. safitza safitza</i> Westwood	oo	w
<i>H. dubius wahlbergi</i> Wallengren	o	f	Henotesia Butler		
Salamis Boisduval			<i>H. perspicua</i> Trimen	oo	w
<i>S. anacardii anacardii</i>			Ypthima Hübner		
Linnaeus (102)	oo	w, rf, oh in f	<i>Y. granulosa</i> Butler (139)	oo	ag
<i>S. parhassus</i> Drury (103)	oo	f	DANAIDAE		
Junonia Hübner			Danaus Kluk		
<i>J. antilope</i> Feisthamel	o	w	<i>D. chrysippus chrysippus</i> Linnaeus	oo	oh
<i>J. archesia</i> Cramer	o	w	Tirumala Moore		
<i>J. cuama</i> Hewitson?	ox	w	<i>T. petiverana</i> Doubleday	oo	w, f
<i>J. hierta cebrene</i> Trimen	oo	oh			

Family, Genus & species	Status	Habitat	Family, Genus & species	Status	Habitat
Amauris Hübner			<i>A. larydas</i> Cramer	oo	aw
<i>A. albimaculata interposita</i> Talbot	o	gf	<i>A. otacilia otacilia</i> Trimen	o	aw
<i>A. echeria meruensis</i> Talbot**	?	hf?	<i>A. princeps princeps</i> Butler	oo	w, aw
<i>A. niavius dominicanus</i> Trimen	o	gf	Petrealea Toxopeus		
LYCAENIDAE			<i>P. sichela sichela</i> Wallengren	o	w
Alaena Boisduval			Lampides Hübner		
<i>A. caissa caissa</i> Rebel*** (145)	?	oh?	<i>L. boeticus</i> Linnaeus	oo	oh
<i>A. ferrulineata</i> Hawker-Smith** (146)	o	ah?	Cacyreus Butler		
Mimacraea Butler			<i>C. lingeus</i> Stoll	oo	w
<i>M. marshalli</i> Trimen ssp.** (147)	o	gf	<i>C. virilis</i> Aurivillius	oo	w
Lachnocnema Trimen			Leptotes Scudder		
<i>L. bibulus</i> Fabricius (148)	oo	u	<i>L. jeanneli</i> Stempffer* (171)	?	w?
Myrina Fabricius			<i>L. pirithous pirithous</i> Linnaeus	oo	w
<i>M. silenus ficedula</i> Trimen	o	rf, w	Tuxentius Larsen		
Aloeides Hübner			<i>T. melaena melaena</i> Trimen	o	aw
<i>A. conradi talboti</i>	?	oh?	<i>T. stempfferi</i> Kielland (174)	x	w
Tite & Dickson** (150)			Taracus Moore		
Epamera Druce			<i>T. grammicus</i>	oo	ag
<i>E. mimoseae rhodosense</i>	?	w?	Grose-Smith & Kirby (175)		
Stempffer & Bennett** (151)			Zizeeria Chapman		
<i>E. tajoraca ertli</i> Aurivillius** (152)	?	aw?	<i>Z. knysna</i> Trimen	o	oh
Stugeta Druce			Acticera Chapman		
<i>S. bowkeri nyanzana</i> Wichgraf (153)	o	w	<i>A. lucida</i> Trimen	o	oh
Hypolycaena Felder			Zizula Chapman		
<i>H. pachalica</i> Butler	o	aw	<i>Z. hylax</i> Fabricius	oo	oh
<i>H. philippus philippus</i> Fabricius	oo	w, f	Azanus Moore		
Virachola Moore			<i>A. jesous</i> Guérin de Ménéville	oo	oh
<i>V. antalus</i> Hopffer	oo	oh	<i>A. mirza</i> Plötz	oo	aw
<i>V. dinochares</i> Grose-Smith	oo	w	<i>A. moriqua</i> Wallengren	o	oh
<i>V. livia</i> Klug	o	ah	<i>A. natalensis</i> Trimen	ox	oh
Anthene Doubleday			Euchrysops Butler		
<i>A. amarah amarah</i>			<i>E. malathana</i> Boisduval	oo	oh
Guérin de Ménéville	oo	ah	<i>E. osiris</i> Hopffer	oo	oh
<i>A. contrastata mashina</i> Stevenson	oo	ah	<i>E. subpallida</i> Bethune-Baker	oo	oh
<i>A. definita definita</i> Butler	oo	w	Freyeria Courvoisier		
<i>A. indefinita</i> Bethune-Baker	oo	f, rf	<i>F. trochilus trochilus</i> Freyer	oo	oh
<i>A. kersteni</i> Gerstaecker	o	w, f			

DISCUSSION

Notes

(2) *Celaenorrhinus galenus*. Understorey trees in the groundwater forest are favoured as territorial perches from which the male of this species swoops down on intruders. I observed that three or more males often occupied territories a few metres apart along road-sides, the edges of forest glades, and other open habitats within the forest. During such times, I saw two males "tumbling" over each other in the air, sometimes joined by a third or fourth party (n=17). Females crossing the paths of these males would be fought for by, usually, two males which would "tumble" over each other in the air and separate, one heading back towards its perch whilst the other pursued the female. Sometimes the female would avoid her pursuer, but on other occasions she would be forced to the ground in order to mate.

(8) *Netrobalene canopus*. Males of *N. canopus* are very territorial, occupying territories in open habitats throughout the groundwater forest. Each male perches on a favoured leaf of a branch that extends far out from the canopy of an understorey tree, often at approximately 2m from the ground. For five consecutive days I observed three males that shared territories on different branches of the same tree, also occupied by a male *Graphium leonidas*. They did not interfere with *G. leonidas* (or *vice versa*) but would fight amongst themselves for hours on end. First one male would fly into the territory of another and then an attack commenced whereupon the intruder was "tussled" with in the air. During such aerial "battles", both would enter the territory of a third male, resulting in all three attacking each other. After several minutes of contest, one male would return to its perch. After further and short aerial combats, the other two would also retreat to their perches.

(9) *Spialia spio*. This species was collected in L.M.N.P. (Rydon & Morgan-Davies, 1960a and unpublished). Three other species of this genus that might occur in L.M.N.P., especially along the escarpment, are *S. colotes transvaaliae*, *S. mafa higginsii* and *S. zebra bifida*. The two former species inhabit hilly and mountainous regions and have been recorded in the "Great Craters" (de Jong, 1978), referring to the Ngorongoro Highlands. The latter species has been recorded in Oldeani (de Jong, 1978), which is a part of these highlands.

(11) *Metisella medea* is common in the groundwater forest and the forest at the southern end of L.M.N.P. However, I rarely found it flying in the woodlands at the Ndala Research Camp, suggesting that it might, occasionally, penetrate densely-wooded areas.

(15) *Gegenes hottentota hottentota*. This species often flies together with *G. nico brevicornis* (Plötz), the latter insect being more common, according to Kielland (*in litt.*) who postulates that *G. nico brevicornis* should also occur in L.M.N.P.

18) *Papilio echerioides* ssp. A new subspecies of *Papilio echerioides* from the southern Kenya highlands and north and eastern Tanzanian mountains is currently being described by Kielland (*in press*). This species was rarely seen in the groundwater forest in the north of the Park. However, in the forest near the Yambi River area, the species flew in slightly greater numbers. Although I did not survey the Marang Forest on the escarpment, *P. echerioides* is much commoner in this higher altitude forest (Kielland, *in litt.*), and it is possible that a few individuals may migrate down into the lower forests.

20) *Graphium angolanus angolanus*. Not a positive identification because I did not manage to secure any specimens. The specimens that were flying at L.M.N.P. superficially resembled *G. angolanus*. As the species is well-spread across East Africa (D'Abrera, 1980; Carcasson, 1981) it is possible that it was *G. angolanus* and not any other *Graphium* of the *pylades* group. Kielland (*in litt.*) tells me that it is most definitely *G. angolanus*.

(22) *Graphium leonidas leonidas*. The male of this species is territorial, perching on understorey trees in the forest and constantly driving off intruders. Its territorial behaviour is similar to the male of *Euxanthe wakefieldii*, which also occupies open habitats in the groundwater forest. Thus the two insects can often be found flying within the same patch of forest. I think that *G. leonidas* and *E. wakefieldii* confuse their predators by resembling each other in colour, pattern and behaviour (as well as their distasteful model *Tirumala petiverana*, which also flies in the same habitat).

(23) *Graphium policenes*. Recorded by S. C. Collins (personal communication) as occurring in L.M.N.P.

(26) *Eurema desjardinsi marshalli*. Typical *E. desjardinsi* occurs in Madagascar and the Comoros (D'Abrera, 1980; Carcasson, 1981). D'Abrera (1980) had recognised the African mainland subspecies as *E. regularis*, however, Berger (1980) subsequently revised the *E. desjardinsi-regularis* complex, raising both to species rank. Thus, the African mainland subspecies of *E. desjardinsi* has been given the next available name *E. marshalli* (Berger, 1981). Kielland (*in litt.*) states that both *E. desjardinsi* and *E. regularis* sometimes fly in the same habitats, though *E. desjardinsi* is the commonest. He also mentioned that it is possible that *E. regularis* also occurs at L.M.N.P.

(38) *Colotis aurora dissociatus*. D'Abrera (1980) had named this insect as *C. eucharis dissociatus*. Berger (1981) recently changed the name to *C. aurora dissociatus*.

Several species of *Colotis* were preyed on by robber flies (*Alcimus* spp., Diptera: Asilidae). Adult robber flies wait for their prey and then attack them in the air, relying primarily on sight (Shelly, 1987). Upon capturing prey species, robber flies then settle down and consume the body fluids of the victim (Shelly, 1987).

At L.M.N.P., individual robber flies utilized open conspicuous sites in which to stake out their territories. For this reason I often observed robber flies along road-sides in the woodlands, and occasionally on forest paths. A robber fly would perch on grass at the road's edge and, when it saw a flying insect it would fly out and attack it in the air. The robber fly would then pin the victim on the ground, secure its hold, and fly off into the grasses where it would begin to consume the body fluids. After feeding on the victim it would then drop it in the grass and fly off to its perch, ready to capture another insect. Slow-flying butterflies, like *Appias* spp., *Belenois* spp., *Eurema* spp., and some Lycaenids (see note 148), were among those fed upon after capture.

(41) *Colotis chrysonome chrysonome*. There is a record of *C. chrysonome* in the BMNH collected by B. Cooper in July 1938 from "Ngaruka, north of L. Manyara" (personal observations) and below Mt. Oldeani in the Ngorongoro Highlands (Kielland, *in litt.*).

(43) *Colotis eris eris*. A very common species, especially in the arid grasslands at the southern end of the lake. At times *C. eris* would frequent the *Acacia* woodlands but in smaller numbers.

(51) *Colotis pallene pallene* has been recorded by T. A. Barns in the "District of Great Craters, [ii.-iii. 1921]" (Talbot, 1939), referring to the Ngorongoro Highlands region.

(54). *Colotis vestalis castalis* is not a very common species at L.M.N.P. It occasionally flies among the *Acacia* woodlands and alkaline grasslands.

(58) *Belenois margaritacea plutonica* is mainly a montane species, and for it to occur at a much lower altitude is an interesting record. I have also recorded this species at 900m in the Rau Forest Reserve in Moshi, about 800m below its normal altitudinal range on Mt. Kilimanjaro (Cordeiro, *in preparation.*). Both low altitude populations are most likely to be ecological variants.

(61) *Pieris brassicoides marghanita* (= *meridionalis*). Only one specimen was observed and identified as belonging to this species, based on the underside pattern. I saw it in the lacustrine woodlands around the Ndala Research Camp (Fig.1). This locality is much hotter and drier than its typical montane grassland (in association with forest) habitat in the Ethiopian highlands, and on Ngorongoro and Mt. Meru in northern Tanzania (Carcasson, 1964), thus it is unlikely that a population exists at L.M.N.P. As *P. brassicoides* occurs higher up in the Ngorongoro Highlands (D'Abrera, 1980; Carcasson, 1981; Kielland, *in litt.*, Rydon, *in litt.*) north-west of L.M.N.P.; it is likely that the specimen drifted downhill with the wind. Wind-assistance of lepidoptera on

mountains has been noted before by some authors (Salt, 1954; Robbins & Small, 1981). For example, in a study on wind-dispersal in Panamanian hairstreaks, Robbins & Small (1981) found that some high-altitude species were observed 5 km downwind from their normal habitats, this being due to the seasonal trade winds.

Kielland (*in litt.*), however, thinks that its occurrence in L.M.N.P. "is very unlikely" and suggests that it should be collected for verification. Rydon and Collins are both of the same opinion.

This taxon is interesting from a zoogeographical perspective as it is the only species of the Palaearctic genus *Pieris* occurring in Africa (Carcasson, 1964; D'Abrera, 1980; Rydon, *in litt.*). It is unusual and a baffling phenomenon that this species is found below the equator and yet that it has strong affiliations with the Palaearctic butterfly fauna.

(71) *Libythea labdacca laius* frequents river banks and the groundwater forest. It flies close to the ground, darting around in a typical Hesperiid fashion, often settling on damp sand to probe with its proboscis for moisture.

(72) *Charaxes achaemenes achaemenes*. An aberrant female of *Ch. achaemenes* was baited in the lacustrine woodlands in the vicinity of the Ndala Research Camp. It was unusual in having an extensive blue-grey hind wing patch. Recently, Henning (1988: 228) figured a similar-looking aberration. Henning (*in litt.*) states that the extensive 'grey' hind wing patch in the figured specimen should actually be more bluish-green. The colouring of that plate is therefore somewhat misleading. Similar aberrations are known to occur in *Ch. jasius saturnus* (Henning, *in litt.*). As Henning has not given this aberration a name, I am taking the opportunity of doing so myself here: *Charaxes a. achaemenes* ab. *glaucomaculata* nov. (female) (Plate 1) (c.f. aberration figured in colour on p. 228 of S. F. Henning *Charaxinae Butterflies of Africa*, 1988).

Description: Fore wing length: 36mm. *Upperside:* Pattern and colouration of *f.w.* typical *Ch. a. achaemenes*. Hind wing with a diffuse bluish-grey area extending inwards from between the anal angle and vein 6 (M1). The bluish-grey obscuring to a certain extent the submarginal series of white spots and reaching almost as far as the middle of the wing; colouring and markings otherwise typical *Ch. a. achaemenes*.

Underside: Typical *Ch. a. achaemenes* pattern.

Holotype (female): Ndala Research Camp, Lake Manyara National Park, Arusha Region, Tanzania, 960m, 9. ix. 1987, N. J. Cordeiro.

Specimen to be deposited in the Natural History Museum, London.



Plate 1. *Charaxes achaemenes achaemenes* (Felder) (female) ab. *glaucomaculata* nov.

(73) *Charaxes aubyni aubyni* inhabits montane / sub-montane forests in East Africa. The population in the groundwater forest at L.M.N.P. is probably an ecological variant as it occurs in a habitat that is somewhat below its normal altitude range.

(75) *Charaxes bohemani*. There was a battered specimen with no label in the park museum, which was probably collected by Morgan-Davies, as he had curated the insect collection during the early 1960s (Rydon, personal communication). This taxon, was not recorded in the Rydon & Morgan-Davies's checklists (1960a, b and unpublished). It was very common in the *Acacia* woodlands at the southern end of the park but less common in the mixed woodlands in the north.

(77) *Charaxes candiope candiope* is a very abundant species in the groundwater forest, but occurs in fewer numbers in the *Acacia* woodlands. It was observed feeding on exudations from *Kigelia africana* Lam. (Bignoniaceae) (n=35) throughout the park together with *Euxanthe wakefieldii* and *Ch. varanes* (see note 85). *Charaxes candiope* is a very aggressive butterfly, often molesting rivals of the same species or other members of the genus. *Euxanthe wakefieldii* was not disturbed by *Ch. candiope*, and both were frequently seen imbibing at the same wound (n=29). For interactions with *Ch. varanes*, see note 85.

(78) *Charaxes cithaeron kennethi*. The L.M.N.P. population of *Ch. cithaeron* has been placed to *kennethi* by van Someren (1964: 232) who, however, qualified his action by saying that "the specimens from Arusha and Lake Manyara are less stable than typical coastal material." L.M.N.P. is possibly the western-most extent of this subspecies range.

(81) *Charaxes hansalii baringana*. van Someren (1971, Map 2) records this species between Lakes Eyasi and Manyara, though he does not state the actual locality. I recorded *Ch. hansalii* in the lacustrine woodlands and on the escarpment where it apparently flies in very small numbers. Lequeux, (*in litt.*) tells me that this species is very local. In Rwanda he found it to be very common in a small area.

(82) *Charaxes jasius saturnus*. This species flew in the woodlands and cultivated areas around the park, often probing the Castor Oil plants *Ricinus communis* Linn. (Euphorbiaceae) with its proboscis.

(83) *Charaxes kirki kirki*. Rydon (1982), in his revision of the *Charaxes viola* group, has reinstated *Ch. kirki* to its original rank of full species removing its sub-specific status. Henning (1988) has accepted this revision.

(84) *Charaxes pollux maua*. Typically a sub-montane / montane species, *pollux* was occasionally seen few in the lower altitude groundwater forest at the north end of the park.

(85) *Charaxes varanes vologeses* was seen feeding on the sap of *Kigelia africana* with *Ch. candiope* and *Euxanthe wakefieldii*, along the forest margin at the north end of the lake (n=27 from September-December). *Charaxes varanes* showed an intolerant behaviour to the latter two species in that it always fed from a smaller sap source, away from *Ch. candiope* and *E. wakefieldii*. On most occasions when *Ch. varanes* came to feed, *Ch. candiope* would arrive to chase it away by a constant beating of wings (n=15). On three other occasions *Ch. candiope* did not exhibit rivalry towards *varanes*. I believe that the inferiority of *Ch. varanes* to *Ch. candiope* often led to the former species arriving at the food source to feed in the early mornings (0700-0900h) and evenings (1730-1830h) if weather permitted (n=21). *Charaxes candiope* was rarely present during these periods (n=2/21). Henning (1988) further provides evidence of the intolerance by competitors of *Ch. varanes* when he mentions that the butterfly establishes territories on the slopes rather than the

tops of hills, thus escaping molestation from hill-top territorial *Charaxes*. According to Rydon, (*in litt.*), however, *Ch. lacteinctus* Karsch (which maintains territories on hill-tops) chases *Ch. varanes* on the Tororo Hills (Uganda) and on the kopjes at Kabras (Kenya), even though *Ch. varanes* keeps lower down and tries to avoid contact with *Ch. acteinctus*. Nevertheless, on one occasion in November, I observed a battered specimen of *Ch. varanes* twice driving off a female of *Ch. zoolina*, suggesting that *Ch. varanes* is not inferior to all members of the genus, at least not to the smaller species, as I have observed elsewhere in eastern Africa.

(86) *Charaxes violetta melloni*. van Someren (1966) mentions that the aggregate from "Tanzania: Newala, Iringa, Morogoro area, the higher zones of the Usambara Mts., and the area west of Kilimanjaro (Arusha-Meru)" represents the form/cline *Ch. melloni* Fox. More recently, this taxon was raised to subspecies rank (Henning, 1988). The population at L.M.N.P. probably represents the western and northern-most extent of range of this subspecies.

(87) *Charaxes zoolina zoolina*, is a very common species of diverse habitats, and was observed feeding on exuding sap from two different tree species in September. In its lacustrine woodland habitat *Ch. zoolina* showed a preference for the juices of *Maerua triphylla* A. Rich. (Capparaceae), whereas in the groundwater forest it imbibed at wounds on *Croton macrostachyus* Del. (Euphorbiaceae) and a number of other unidentified forest trees. For further notes on inter-specific interactions see note 85.

88) *Euxanthe wakefieldii*. The behaviour and possible mimetic associations of this insect at L.M.N.P. has been recorded elsewhere (Cordeiro, 1988). Both sexes are partial to the exudations of *Kigelia africana*. The males are very territorial, driving away intruders from favoured perches at the edges of forests or in open areas in the forest. Females are uncommon, and are usually seen flying in the early mornings and late afternoons. For further information on the ecological relationships of this insect with some *Charaxes*, see notes 77 & 85.

(90) *Pseudacraea boisduvali trimeni*. Although a common species throughout its range, I did not identify *boisduvali* at L.M.N.P., S. C. Collins (personal communication) mentioned that it does occur there.

(98, 99) *Eurytela dryope angulata* and *E. hiarbas lita* fly in the understorey of forests and can often be seen feeding with the smaller species of *Charaxes*. When they do feed on the same tree as the larger *Charaxes* and beetles (Coleoptera), they are often to be found on the more distant wounds because the latter competitors tend to be very aggressive towards the smaller species of Nymphalidae.

(102, 103) *Salamis anacardii anacardii* and *S. parhassus*. Open habitats within the forest are often favoured by these species in order to bask in the sun whilst perched on sun-lit branches. During periods of intense heat they take refuge in shaded spots or hang upside-down underneath large leaves. I came across both species feeding on elephant dung several times (n=7), together with some members of the Pieridae and/or Lycaenidae.

(108) *Junonia limnoria taveta*. D'Abrera, (1980) mentions that this taxon occurs "in the extreme north of Tanzania". I believe that the range of ssp. *taveta* in Tanzania extends from the north-east of the country westwards to the Great Rift Valley, as I have recorded this species from Kilimanjaro to Babati (Arusha region).

(116) *Antanartia abyssinica jacksoni*. This species is common in forests of the Ngorongoro Highlands, north-west of the lake. I did not observe *abyssinica* in the groundwater forest of

L.M.N.P. although Howarth (1966) mentions that it occurs on the western shore, possibly suggesting the Marang Forest where it does occur (Kielland, *in litt.*).

(127) *Acraea johnstoni johnstoni* was very common in the groundwater forest. It was also recorded from the lacustrine woodlands, where it was encountered infrequently together with *A. esebria*. It is typical that this sub-montane/montane butterfly was found in an arid woodland habitat at times, although Kielland (*in litt.*) notes that *A. johnstoni* often penetrates dense woodland when its forest habitat is not far away.

(129) *Acraea neobule neobule*. This taxon was identified as *A. terpsicore* in Rydon & Morgan-Davies's checklist (1960b, and unpublished). Kielland (*in litt.*) notified me that Pierre (1978) recently separated *A. neobule* from *A. terpsicore* on the basis that the *A. terpsicore* has an Oriental distribution and different genitalia.

(131) *Acraea pudorella pudorella*. I observed several specimens that resembled *A. pudorella*, flying in the mixed woodland throughout most areas in L.M.N.P. but did I not capture any specimens for verification.

(132) *Acraea sotikensis* is probably a common species in the Marang Forest on the escarpment, and in the forest at the southern end of the lake. However, I did not manage to fully explore either habitats and thus record the species. Nevertheless, B. Cooper (coll. BMNH), in July 1938, obtained specimens of *A. sotikensis* "along [the] western shore in forest between lake and rift wall, Manyara".

(133) *Pardopsis punctatissima*. I might have seen this species flying in the arid grassland areas. Kielland, (*in litt.*) notes that *P. punctatissima* might inhabit the Maasai plains in northern Tanzania as it is a woodland and open-habitat species that occurs throughout Africa south of the Sahara.

(139) *Ypthima granulosa*. Kielland, (1982) says that *Y. granulosa* inhabits "open, deciduous woodlands". I found that it was more common in grassy-shrubby areas in the southern half of L.M.N.P., although it was also seen in smaller numbers in the *Acacia* woodlands.

(143) *Amauris echeria meruensis*. Talbot, (1940) mentions that this taxon was collected by B. Cooper at "Lake Manyara, 3,000ft, vi-vii. 1937".

(145) *Alaena caissa caissa* occurs in "Manyara" [v. 1944, *leg?*, A. M. N. H.]. Kielland, (*in litt.*) notes that it is a very common species in this area.

(146) *Alaena ferrulineata*. D' Abrera (1980) states that this insect has been recorded at "Ngorongoro Crater and Lake Manyara".

147) *Mimacraea marshalli*. S. C. Collins (personal communication) was apparently the first person to collect this species in L.M.N.P. It is common in the understorey of the groundwater forest, often fluttering gently and settling on lichen-covered tree trunks. The Lake Manyara population is quite distinct in pattern from ssp. *dohertyi* Rothschild which occurs in the Kenya highlands (East of the Rift Valley) and at Mt. Meru in Tanzania. Rydon (*in litt.*) collected many specimens of the form *dohertyi* at Karamu and Lake Duluti in the foothills of Mt. Meru in April 1960. He only caught one specimen of f. *marshalli* which was larger than the specimens of f. *dohertyi*. Kielland (*in litt.*) thinks that the L.M.N.P. population is a cline between ssp. *dohertyi* and ssp. *marshalli* Trimen.

(148) *Lachnocnema bibulus*. This insect was often preyed upon by the *Alcimus* sp. For more information on the predatory behaviour of the robber fly, see note 35.

(150) *Aloeides conradsi talboti*. Tite & Dickson, (1973) state that T. A. Barns and B. Cooper recorded *B. talboti* at the “north end of Lake Manyara” [ii. 1921] and on the “west shore of Lake Manyara” [ii. v. 1935] respectively. This taxon is interesting from a zoogeographical viewpoint, as it is one of three species of the genus *Aloeides* located in Tanzania, the genus itself being mainly represented in southern Africa with over 30 species (D’Abrera, 1980). *Aloeides conradsi* has been recorded in the Ngorongoro Highlands (Tite & Dickson 1973; Kielland, *in litt.*), Singida and areas around Tabora (Kielland, *in litt.*) as ssp. *talboti*. West of Mt. Longido ssp. *jacksoni* occurs whereas [near] ssp. *angoniensis* occurs in western Tanzania at Kigoma and Mpanda (Kielland, *in litt.*). In southern Africa *Aloeides* ssp. generally inhabit grassland areas in a region of distinct seasons, quite unlike that of the equatorial regions. It is therefore of great interest that *A. conradsi* should be found some thousands of kilometres away to the north, in an environment that closely approaches the alpine climate. *Aloeides conradsi* has apparently adapted to moderately high-altitude grassland areas in eastern Africa, thereby living in weather conditions similar to those found in southern Africa.

(151) *Epamera mimoseae rhodosense*. Recorded at L.M.N.P. by S. C. Collins (personal communication). He observed this species breeding on *Loranthus* spp. (Loranthaceae).

(152) *E. tajoraca ertli*. S. C. Collins recorded this taxon feeding on *Loranthus* spp. at L.M.N.P.

(153) *Stugeta bowkeri nyanzana*. D’Abrera (1980) states that the localities of this taxon in Tanzania are in the “southern and eastern shores of L. Victoria and Ukerewe Is.” Kielland (*in litt.*) states that this race also occurs in the region of the Northern Highlands. I found this insect to be very common in the lacustrine woodlands, often settling on bushes for long periods of time, apparently basking in the sun.

(171) *Leptotes jeanneli*. B. Cooper collected this species at “Ngaruka” [2,800 ft, vi-viii, 1937], north of Lake Manyara. Kielland, (*in litt.*) mentions that the *Leptotes* species are very difficult to identify without dissection of the genitalia. However, he postulates that it is probable that *L. pulchra* Murray inhabits the marshy areas in L.M.N.P.

(174) *Tuxentius stempfferi*. Larsen (1982) separated the African ‘*Castalius*’ from the Oriental *Castalius* on the basis that the genitalia of both groups were radically different. He proposed the new generic name *Tuxentius* for the African species. Kielland, (1976) described *T. stempfferi* which is closely related to *T. melaena*. Kielland, (*in litt.*) identified a specimen that closely resembled typical *T. stempfferi*. This taxon has also been collected in nearby Oldeani in the Ngorongoro Highlands and as far away as Mikumi in Morogoro Region, (Kielland, 1976). That it has not been recorded in between the two distant localities is not surprising as Tanzania has been poorly collected and studied with regard to lepidoptera, and hence *T. stempfferi* may easily occur in many more places.

(175) *Tarucus grammicus*. A very common species of the *Acacia* woodlands, has a preference for open, arid grassy habitats, as found in the *Acacia* woodlands which elephants have disturbed. The flight of this insect is weak and low, but due to its dark-brown upperside and zebra-patterned underside, I often lost sight of it in the long grass. When in flight, I think that the overall pattern and colours of *T. grammicus* enable it to escape from predators through this “disruptive colouration” - analogous to the effect created by the stripes of a zebra when seen from a distance.

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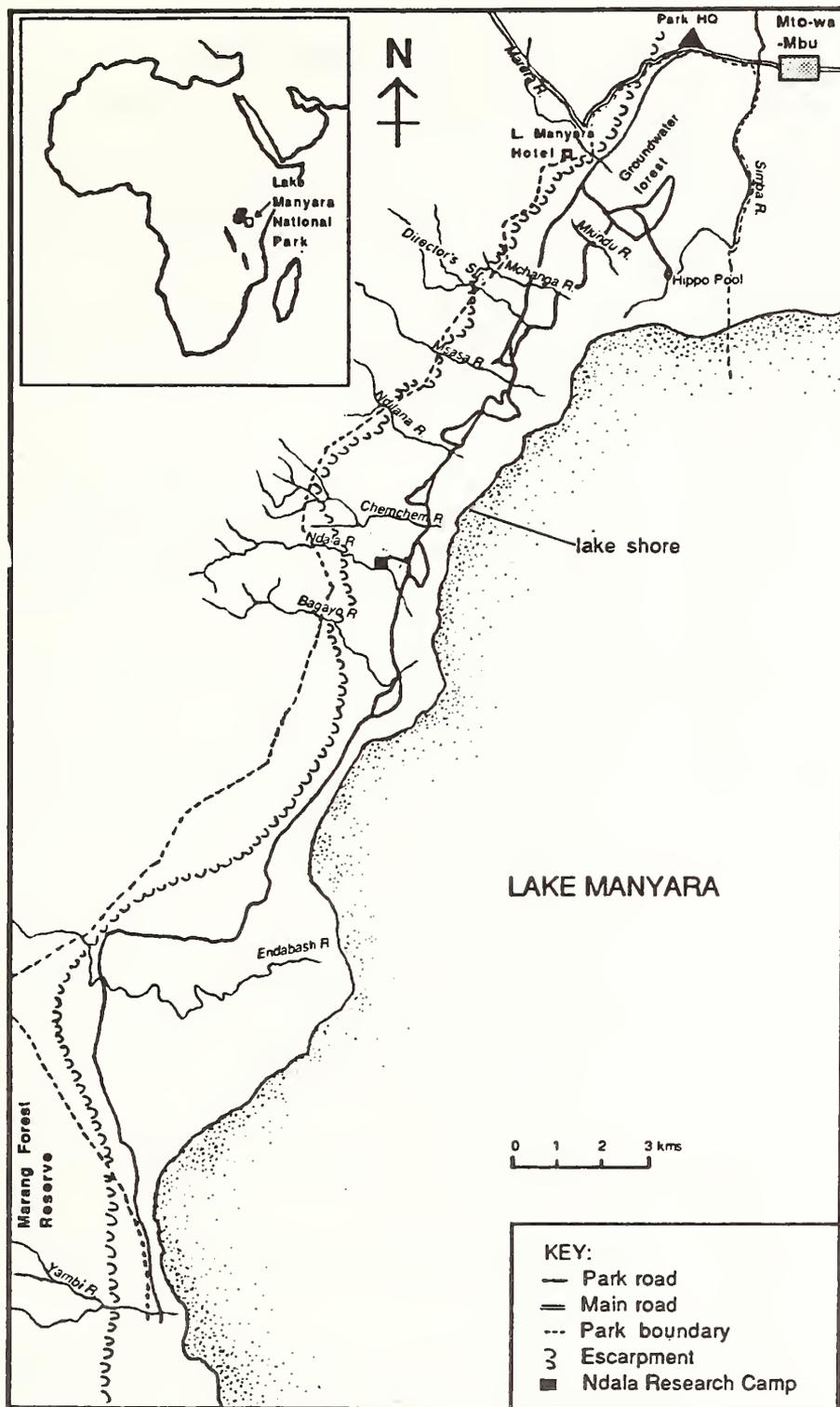


Figure 1. Sketch Map of Lake Manyara National Park. (For more detail, see "Landscape ecological vegetation map of Lake Manyara National Park, Tanzania" [Loth & Prins 1986]).

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NATURAL INDICATORS OF SHALLOW GROUND WATER IN KIBWEZI DIVISION, KENYA

MELVIN WOODHOUSE
Environmental Health Unit
African Medical and Research Foundation, Nairobi, Kenya*



ABSTRACT

Human ability to locate sources of ground water using natural indicators is a skill developed from experience which improves with use. This ability, essential in many environments for survival, has to be nurtured. This paper describes the use of natural indicators to detect ground water in Kibwezi Division, Kenya. These skills have been developed and adapted during the period of recent settlement of the area in the early 1970s. The local people have become self-reliant in siting wells with a success rate of 70% in part of the area. The purpose of this paper is to record these methods before they become redundant, replaced or forgotten. Already the reduction of natural tree cover in Kibwezi has reduced the variety of signs available.

INTRODUCTION

Kibwezi Division, situated some 200 km south east of Nairobi (Fig. 1) has erratic rainfall averaging 644 mm per year. The Division covers an area of 8000 km² and experiences droughts during both rainy seasons in 60% of years (Fenner, 1982a). In the past, the area was covered with tangled scrub such as *Acacia mellifera* (Vahl) Benth. and was home for a wide variety of game. Maasai passed through the area and the Akamba people hunted there, although few made permanent settlements in the area in the last century.

In 1891 the Lovedale Mission was established in Kibwezi near to the present site of the railway station. Due to an earth tremor in 1896 (Younge, 1977) the Kibwezi river, then the main source of water, increased its flow. The Mtiito Andei river and the Masongaleni river were also important sources of water in the area and consequently were stop-over points for Arab and Akamba traders. Mackinnon's road reached Kibwezi in 1895, from where Sclater's road began as the continuation towards Uganda.

With the establishment of a road through the area, enterprising persons ventured into the inhospitable environment and attempted to grow rubber, to harvest *Sansevieria* and, more successfully, to grow sisal. This all required permanent sources of water, both for agriculture and human consumption. The most reliable and readily available sources were the rivers. Undoubtedly wells were dug at prime sites not far from the visible surface water sources.

* Address for correspondence: AMREF, P.O. Box 30125, Nairobi, Kenya.

The railway line was built soon after the road and water sources for the steam engines, initially railed to the stations, were secured. A number of stations to the east of Kibwezi were supplied via a pipeline from Umani spring in the nearby Chyulu Hills. The water from this pipeline still supports a considerable number of inhabitants. In 1918 a second major earth tremor reduced the flow of the Masongaleni river considerably, but it was partially restored in the 1930s. It became obvious that without adequate ground water any development in the area would have to depend totally on the rains or the rivers, of which only the Kibwezi appeared reliable, and of good quality. There was therefore considerable incentive to investigate ground water resources.

The geological knowledge of the area was based on an early speculative, but perceptive, report (Brantwood Muff, 1908). It was not until 1954 that a more thorough investigation was carried out in a study which established the basis for the present-day understanding of the hydrogeology of the area (Temperley, 1955). The colonial administration was active during the 1930s drilling boreholes, as was the Kenya Sisal Company at Dwa farm. A more recent study has served to quantify the system suggested by Temperley (British Geological Survey *et al.*, 1988).

The Chyulu Hills, which form the southern boundary of the Division, rise 900 metres above the surrounding country. Benefiting from an average annual rainfall above 1200 mm, they form the focal point of hydrogeological studies. The Chyulu Hills are of recent volcanic origin and as a result of their high porosity there is no rainwater run off. The rainwater percolates down into the lava and meets an Archaean basement of the Kasigau and Kurase series. Water flows east on top of the basement to emerge at Mzima Springs, the source of Mombasa's water supply. Temperley (1955) estimated that 80% of the rainfall on the Chyulus reappears at Mzima Springs and that the remaining 20% feeds the springs of the local rivers, showing that very little Chyulu water is recharging local aquifers.

The basement system emerges from under the Chyulu lava and gives rise to the flat, red landscape characteristic of the area. Along the edge of the lava there exists a mosaic of gneisses which are poor but useable aquifers. It is these aquifers which are now being tapped by local people. Significant numbers of people began to settle in Kibwezi with the immigration of Akamba in the late 1960s, the previous restrictions on settlement now only applying to the Chyulu Hills. The availability of drinking water became a priority and the Government and non governmental organisations began to develop water resources in the area. With a present population of about 180,000 people a great demand for water exists. In a 1985 survey, the average distance people travelled to a water source was 4.4 km, the average amount of water obtained was eight litres per head per day, and a single journey took an average round-trip time of 90 minutes returning with 20 litres of water of dubious quality (Ferguson *et al.*, 1988).

Efforts are continuing in the Division to improve the water-supply situation via pipeline schemes, rainwater harvesting, boreholes and shallow wells. In the case of shallow wells, this is largely a community-based activity. The local people organize themselves into well groups, select a suitable site to dig and seek assistance with construction from agencies active in the area.

Well-site selection using geophysical equipment has not been particularly successful in the past (Temperley, 1965) largely because no alternatives to resistivity techniques were available in Kenya. Well groups usually have only their own resources to call upon when siting a new well and consequently do not have the option of an elaborate geophysical survey. As a result, they have used natural indicators to help them. As the population of the Division increases and more land is cleared for farming, indicator trees, in particular, are becoming scarce. At the same time, advances have been made in geophysical techniques which are enabling cheaper and more accurate well siting to be done. The use of natural indicators may well become redundant.

METHODS

Over a six-year period the author became familiar with the current state of scientific knowledge of water resources in the Kibwezi area. Local knowledge was gathered informally through discussions with local Well group members and leaders. The African Medical and Research Foundation (AMREF) has held annual training workshops for groups constructing wells. There are now over 80 such groups. The workshops were a valuable forum for the exchange of local knowledge and served to consolidate the information gained through discussion. In particular, the close association between AMREF field staff and the Well groups they have assisted has led to a deeper insight into local methods for well siting.

RESULTS

There is increasing reliance upon machines to assist in locating ground water. In Zimbabwe in 1987, when using integrated geophysical techniques, a success rate of 90% was obtained for boreholes. When sites were allocated "logistically" the success rate was 50% (White, 1987). These interpretations still require human judgement to be made, whether computer assisted or not.

In cases where people do not have access to modern technologies, they can only hope to use their own judgement to interpret their senses to find ground water. In Kibwezi a success rate of 70% has been obtained for siting wells in areas where natural indicators exist. The community is not reliant upon outside technical expertise and is in a position to continue unaided to find well sites.

Where no alternatives exist there is little need to argue the merits of such an approach and the methods should only be judged by their success. Since the exploitation of ground water is essential to sustain human life, it would be expected that our senses do give indications of the location of ground water.

Natural indicators of ground water in Kibwezi

The indicators identified in Kibwezi may not be suitable for use in other areas. In fact in Kibwezi itself the indicators are not ubiquitous. The people of Kibwezi are currently making accurate identifications of the indicators discussed below, and this is reflected in the fact that many of the indicators have specific local names. Good knowledge of the environment has always been important for survival in Kibwezi, a fact still evident as well groups continue to develop their skills in locating ground water. For reasons of clarity the indicators are here put into six groups.

Topography

The flat topography of Kibwezi is punctuated only by resistant inliers and seasonal river channels. The more resistant basement geology has formed the watersheds of the area. The land drains north into the Athi river. As there is no run off from the Chyulu Hills, seasonal rivers rise where the lava ends, which having eroded lines of least resistance have preferentially cut into the softer gneisses, thus indicating their location. The gneisses to the east of the main road are less permeable and therefore poorer aquifers.

The lack of definitive indicators of ground water on the Chyulu lava meant that Well groups applied their efforts away from the lava belt and initially concentrated on the larger seasonal river beds. The edges of lava flows are easily recognizable as they are several metres thick, end abruptly and have very little soil cover. The lava is black, often set against a red soil, and supports green vegetation for much of the year. The most productive wells are located in river basins generally not more than 2 km from the edge of the lava flow. Typical yields from these wells of depths between 6.5 and 7.5 metres are above 3³ m per day.

Without exception, the Well groups chose to dig in low-lying places, locating their wells in areas of softer gneiss rock and away from the basement watersheds. As more wells were dug, the people quickly realized that the closer they were to the watersheds the deeper they would have to dig, and there was the increased likelihood of a low yield. As experience grew, initial siting of wells began with a general survey to recognize the location of watersheds. Generally, the drainage channels are well defined and there was little difficulty in excluding potential basement sites and the watersheds as they bear different soils and vegetation.

Some confusion occurs where seasonal water sources exist at the edge of basement outcrops. These sites have, without exception, failed to provide permanent water. Such sources are probably fed from local rainfall recharge on the outcrops, the water being stored in cracks. The storage volume is low and likely to be subject to evaporation losses.

There are a number of old earth dams in the area which were explored as potential well sites. The dams generally only store water until September and are thus useful but inadequate during the dry season. As the dams dry out people make shallow excavations in the dam floors and along the walls thus gaining accurate information about the location of water. Frequently, groups went on to dig wells downstream of the dam walls. Presumably, the dams leak from the floor thus recharging a small area of local aquifer. Digging at the sides and upstream of the dams has so far proved unsuccessful.

As most of the wells are dug along river channels, flood damage is a risk. Initially this risk was not a consideration in siting a well and certainly previous experience with shallow holes in river beds had resigned their users to the inevitable annual chore of re-excavation. With the location of good wells outside the channels, better practice quickly caught on. Sites could still be improved by a more thorough consideration of flood levels, easily done by checking for past flood debris caught up in riverine trees. Similarly, wells could also be better sited after consideration of the erosion patterns of the river — wells dug on the inside of meanders are less likely to be damaged in the future.

Changing patterns of land use are also increasing the run off carried by seasonal rivers. Land clearance for farming, resulting in less retention of rain water, is extending the drainage systems. It is now quite common to see drainage channels which have encroached upon sites of previously stable vegetation. Well groups should be particularly wary when they choose to dig a well near a river where there are mature trees being undercut in the middle of the channel; this is clear sign of rapidly increasing erosion.

Geology

The Kibwezi area can be divided into two distinct geological regions, the area underlain by basement system gneisses, and the volcanic region to the south of the railway (Saggerson, 1963). (Fig. 2)

There are three main classes of rock of interest to potential well groups: lava, gneiss and undifferentiated basement rocks. These rocks have specific names in the Kamba language of Kibwezi; they are, respectively; *kivuthi*, *ingee* and *nganza*.

Being agriculturalists, the Akamba who moved into Kibwezi were well aware of the potential of the various soil types encountered and had a good knowledge of the rock types in the area. Although this knowledge is more general than specific, it was quickly applied in the search for ground water. Experience gained from successful wells has enhanced common knowledge and soils and geology are now included amongst the natural indicators of ground water in common use.

The siting of wells on lava is a very difficult task for which there is little local expertise. Suitable geophysical techniques have yet to be found, although some very productive wells have been dug in lava flows. Being a haphazard process, few groups are willing to risk wasting their energies and resources digging in lava. It is important, however, to establish where a lava-flow ends when siting a new well. In following the courses of old rivers, which cut preferentially into the softer

gneisses, lava flow boundaries point towards the location of suitable digging sites. The soils found near the edge of a lava flow are a hybrid between black cotton soil and red laterite soil. These soils are rarely deeper than five metres and the gneiss aquifers are found beneath them.

At the edge of the lava flow, where water may seep into gneisses from local recharge, many of the tree species which are indicators of water may be seen.

When river channels arise at the end of a lava flow, exposures of limestone may be seen. These were laid down in places where water collected over a long period of time, presumably showing historic drainage systems which cut into softer rock. They indicate suitable sites for well digging. Goats are quick to identify these outcrops and use them as salt licks.

River channels which expose geology are surveyed by local Well groups. They look for the darker biotite-rich gneisses which are more productive aquifers. It is rare to find a homogeneous gneiss more than four metres thick. The gneiss hardens off and becomes less productive at depth until it is impossible to dig by hand. When banded with schists it can still be productive at depths of up to 26 metres. Due to the very mixed nature of these metamorphic rocks, local knowledge has not yet developed to the point at which accurate determination of possible well depth can be made from surface geological information alone. Once digging has begun, and the gneiss reached, its colour and hardness are interpreted to give a reasonably accurate prediction of the depth at which water may be found.

In some cases, bars of gneiss can be seen cutting across river channels where they form good sites for sand dams. As these bars may have cut through productive gneiss, they help retain water in the buried gneiss. Wells have been successful downstream of these bars where presumably leakage is occurring and the bars are acting as sub-surface dams. Such areas are frequently explored as seasonal water holes by the local people.

Undifferentiated basement outcrops forming inliers are not good sites for well construction. The soils in the vicinity of the outcrops are sandy, reddish and often contain large quartz fragments. Such soils are good negative indicators of water presence even when rock does not outcrop.

On the eastern side of the main Mombasa road, the river channels are considerably larger; some have almost permanent baseflows which are held in the sandy river beds. The sands found in these locations are good for construction work and can be over 12 metres deep. Some productive wells have been sunk into these sands using concrete rings. Caution is needed in such places since not only are flash floods a major hazard but also the performance of the proposed well in the dry season must first be established.

There are good murrums beneath the topsoil on the eastern side of the road. When people have dug pits for latrines here they have found that water has entered. These stony murrum layers are usually not thicker than one metre, thus their storage capacity is small. So far a permanent dry-season source of water has not been found from these murrums.

There are some clays and soils in the area which act as impermeable layers preventing rainwater from percolating downwards. Water is often taken from these clay pan areas, but the pans are heavily influenced by evapotranspiration and rarely remain wet throughout the dry season.

As more experience is gained from wells that have been dug, the richer the understanding of the relationship between geology and ground water becomes. Obviously local knowledge of geology will not develop to a specialist level, nonetheless the present basic understanding is a significant contribution to well siting.

Trees

Table 1 gives the English, Kamba, Swahili and scientific names of trees found in the area.

Longland (1952) refers to "Mkuju", (*Ficus sur* Forsk.) together with *Acacia tortilis* (Forsk.) as indicators of ground water in Tanzania. The use of trees as indicators of ground water is a very old practice, however, the usefulness of some species is probably only applicable to certain areas. For example, Longland's (1952) observation that ground water is found at a depth of three times the height of the crown of *A. tortilis* has not been shown to be the case in Kibwezi. It is important to

realize that trees may be associated with a certain soil type and environment and not directly with the ground water table itself.

A good general description of the woodland of Kibwezi is given in Fenner (1982a).

The Kamba people were new to this area in the 1970s but knew most of the trees they came across. The names used locally for trees are not all of Kamba origin; many are similar to Taita names. Presumably these names were imported by the Akamba settlers. They had never needed to look at these trees in relation to ground water in this area before; rather they had to learn from experience.

As the number of successful wells has increased, it has been possible to compare local tree cover with the degree of success. As a consequence, confidence and reliability have increased and now, once a general site has been selected, the tree species present are used as the principal indicator of the exact site to dig.

The most successful tree indicator of good-quality ground water at shallow depth so far identified is *Acacia robusta*. (Taub.) Brenn (Figs. 3, 4) Where this tree is found and supported by topographical indicators, ground water of salinity below $1500 \mu\text{S}^1$ can be obtained at depths of less than ten metres. The appearance of *A. robusta* can differ greatly depending upon its environment, and the anatomy of its non-reproductive parts is diverse.

Acacia gerrardii (Benth.), *Acacia xanthophloea* (Benth.), and *F. sur* are all useful indicators of ground water at shallow depth and their presence in conjunction with *A. robusta* confirms a good site.

Hyphaene compressa Gaeren is a very good ground water indicator but it is only found in Mangaleta Sub-location of Kibwezi. Where present, water can be obtained at depths of less than seven metres.

Grewia bicolor (Juss.) is frequently used as a forked stick by dowsers³. Even though found near river valleys, its presence has not been associated with ground water.

Table 1. Botanical names

Generic/specific names	English	Kikamba	Kiswahili
<i>Acacia gerrardii</i> (Benth.)	Gerrards acacia	<i>Muthithiu</i>	-
<i>Acacia mellifera</i> (Vahl) Benth	Hook-thorn	<i>Muthia</i>	<i>Kikwata</i>
<i>Acacia robusta</i> (Taub.) Brenan		<i>Munina</i>	-
<i>Acacia tortilis</i> (Forsk.) Hayne	Umbrella thorn	<i>Mulaa, Kilaa</i>	<i>Mgunga</i>
<i>Acacia xanthophloea</i> (Benth.)	Fever tree	<i>Mulela</i>	<i>Mukonge</i>
<i>Cyperus papyrus</i> L.	Papyrus	<i>Ndoi</i>	<i>Ndago mwitu</i>
<i>Ficus sur</i> (Forsk.)	Cape fig	<i>Mukuyu</i>	<i>Mkuyu</i>
<i>Grewia bicolor</i> (Juss.)		<i>Mulawa</i>	<i>Mkone</i>
<i>Hyphaene compressa</i> (Gaeren)	Doum palm	<i>Malala</i>	<i>Mkoma</i>
<i>Newtonia hildebrandtii</i> . (Vatke) Torre		<i>Mukami</i>	
<i>Sansevieria</i> . spp.	Bowstring hemp		<i>Mkonge</i>
<i>Sphaeranthus cyathuloides</i> . O. Hoffm.		<i>Musonzouwa</i>	
<i>Sterculia rhynchocarpa</i> (K. Sch.)		<i>Kyusia</i>	

¹ μS or microsiemen is a unit of the electrical conductivity of water and is proportional to its salinity.

³water diviner

Some tree species have also been found to be useful negative indicators of ground water thus enabling an area to be excluded from a survey. *Acacia mellifera* (Vahl) Benth. and *Sterculia rhynchocarpa* (K. Sch.) generally exist where there is very little chance of finding shallow water. Thus, by elimination, the margins of aquifers can be inferred. Even so, *S. rhynchocarpa* can be seen growing close to seasonal river beds. The change in tree cover above different geological systems is readily observable. *Newtonia hildebrandtii* (Vatke) is a very useful indicator of water, but due to the high value of its timber for carving and charcoal it is now rarely found in the settled areas. Mature specimens of *N. hildebrandtii* can be seen near to the springs and dams protected on Dwa sisal estate.

A rough estimate of the number of wells in Kibwezi with tree indicators in their immediate vicinity is 30%. As more land is cleared for agriculture it can be expected that in the not too distant future the natural tree cover of the area will have been removed.

Herbaceous plants

No herbaceous plants have been recognized in Kibwezi as reliable ground water indicators. Those which were considered were mainly wet-area plants and included marsh grasses, rushes and *Cyperus papyrus* L. and *Sphaeranthus cyathuloides* (O. Hoffm.) which can be found near most of the wells in the rainy season. The latter species appears to enjoy the moist freshwater environment resulting from retained run-off. Presumably it is for the same reasons that it is found growing near to granite inliers. Even so, *S. cyathuloides* does not thrive in areas of stagnant water and thus may indicate good quality local recharge, although this has not been confirmed by the author.

Areas which retain some green cover during the dry season are likely well sites. The obvious exception is on lava flows where moisture can be retained in pockets of black soil and support some green cover for most of the year.

Fauna

In the past, the area supported abundant wildlife and many of the earlier settlers remember places where animals could be seen drinking water. Some people insist that Elephant (*Loxodonta africana*) (Blumenbach), Warthog (*Phacochoerus aethiopicus*) (Pallas) and Zebra (*Equus (Hippotigris) burchelli*) Gray, are all able to detect shallow ground water and dig for it. Even though some people say that their wells were sited where these animals used to drink, there is little consensus of opinion as to whether this is a true relationship or not.

Bees (Hymenoptera: Apidae) are undoubtedly fond of wet areas and are very common around wells. Local bee-keepers say that bees will not occupy a hive if the nearest source of open water is more than 1.5 km away. However, bees are not regarded as a definitive indicator of ground water. It is also well known that termites do not build mounds in places which are wet. This can be seen particularly when trying to determine where spring lines exist when springs are non-emergent. The termite mound margin on the uphill side of a swampy area would normally mark the limit for attempted excavations.

Perception by the local people

There are numerous dowsers in the area and some have a good reputation having sited good wells. Many of them utilize natural indicators together with a forked stick (Fig. 5). Sticks of *G. bicolor* are commonly used. The dowsers use a simple technique. They have not been seen to make multiple passes over a specific site, but sometimes do give clients an indication of depth and yield but not of quality.

There are also a number of very poor dowsers in the area. As considerable amounts of money can be made from dowsing, this is not surprising. At some particularly poor sites a dowser may specify a considerable depth to water, through a rock which cannot be dug by hand, thus maintaining his reputation, since the depth specified can never be reached. The dowsers encountered by the

author have all been men. It would be useful to study the abilities of the local dowzers in detail and to introduce them to the approaches and experiences of established dowsing societies.

At a few wells people have said that a further reason for choosing the site was a sensation of warmth or cold when walking past the site at night. This may be linked to a microclimatic effect resulting from ground water or from the fact that the site was in a low-lying enclosed area. It is not disputed that such sensations exist.

Table 2. Summary of natural indicators for detecting shallow ground water in Kibwezi

Highly likely	Near seasonal/permanent river beds. Within 2 km of the edge of the lava belt. Presence of <i>A. robusta</i> , <i>A. gerrardii</i> , <i>A. xanthophloea</i> Absence of termite mounds, <i>S. rhynchocarpa</i> and <i>A. mellifera</i>
Likely	Absence of basement outcrops. Near to a dam. Green cover in the dry season. In a low-lying area. Surface outcrops of mafic schist. Approved by a reputable dowser. Humid / cool sensation in still weather.
Poor	Presence of murram. On high ground. Near granite outcrops. Sandy/quartz soils.

Water quality

It is important, when promoting the methods mentioned, that as far as possible good-quality water is identified. This is due to the need for drinking water and because digging a well by hand is a major undertaking.

The average salinity of the wells dug so far is 1900 μS . This is high because 17% of the wells had a salinity above 3000 μS . Water is often potable up to 2500 μS , whilst international standards may be set as low as 400 μS . At present an investigation is being carried out to relate salinity to soil type and vegetation and it is apparent that the high-salinity wells are restricted to a small geographical area. It is hoped that, should a relationship be identified, then the vegetation of the "salt aquifer" areas could be used as a negative indicator to prevent people from digging where such an aquifer exists.

It is a major concern that the change in land use, which is resulting in the removal of natural bush cover, will increase evapotranspiration losses from the soil. This in turn may increase the salinity of the well water. The resultant increase in run off also represents the loss of a valuable resource as well as a threat to the stability of river morphology.

There is a considerable wealth of local knowledge and awareness of the environment in Kibwezi. This may change as land pressure increases and new technologies are introduced. In such a fragile ecosystem the inhabitants represent the most powerful force to conserve or destroy the environment. Fortunately, the people of Kibwezi have an intimate awareness of their environment and it is encouraging to see the present trend of community-based conservation strategies emerge. The harnessing of the knowledge and attitudes of people in Kibwezi could tip the balance in favour of successful conservation of the area.

ACKNOWLEDGEMENTS

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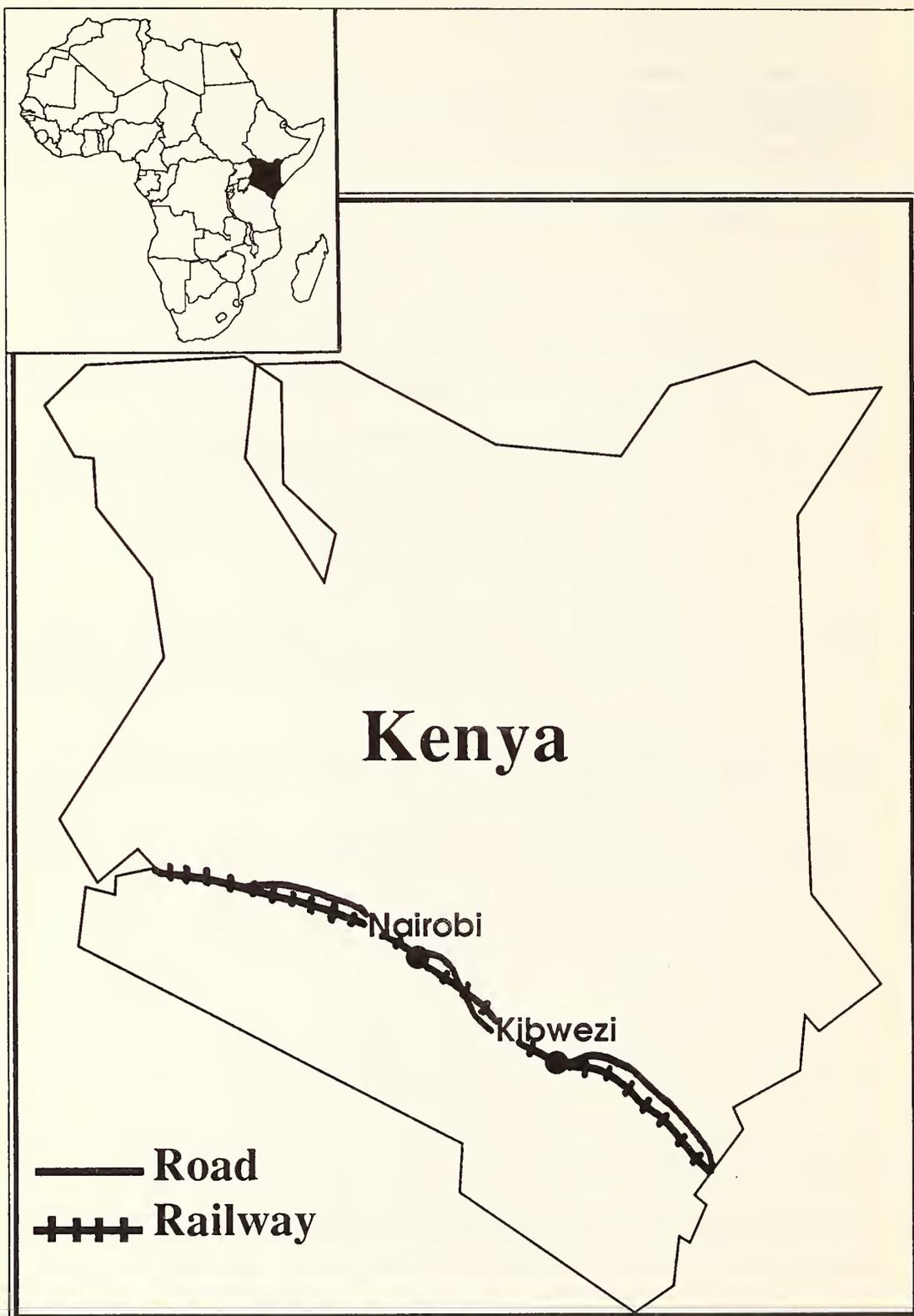


Figure 1. Map of Kenya showing location of Kibwezi

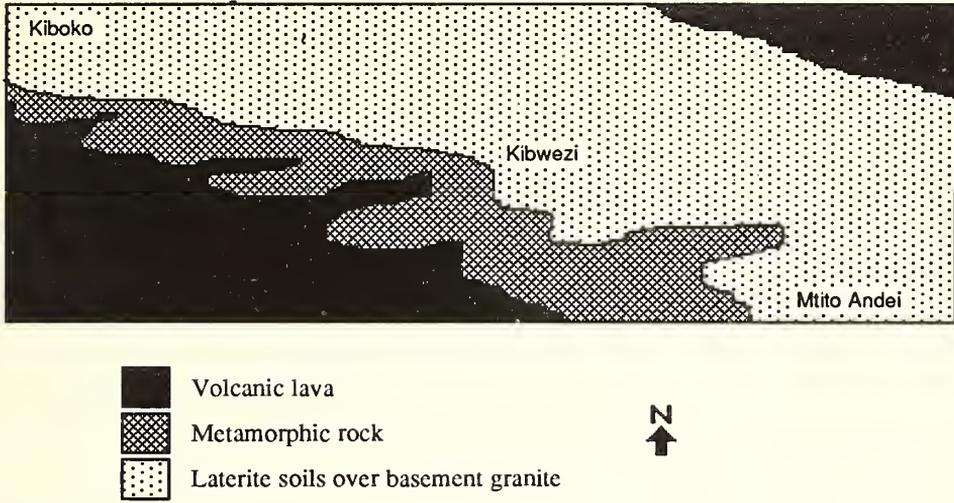


Figure 2. Geology of Kibwezi Division



Figure 3. *Acacia robusta* mature tree

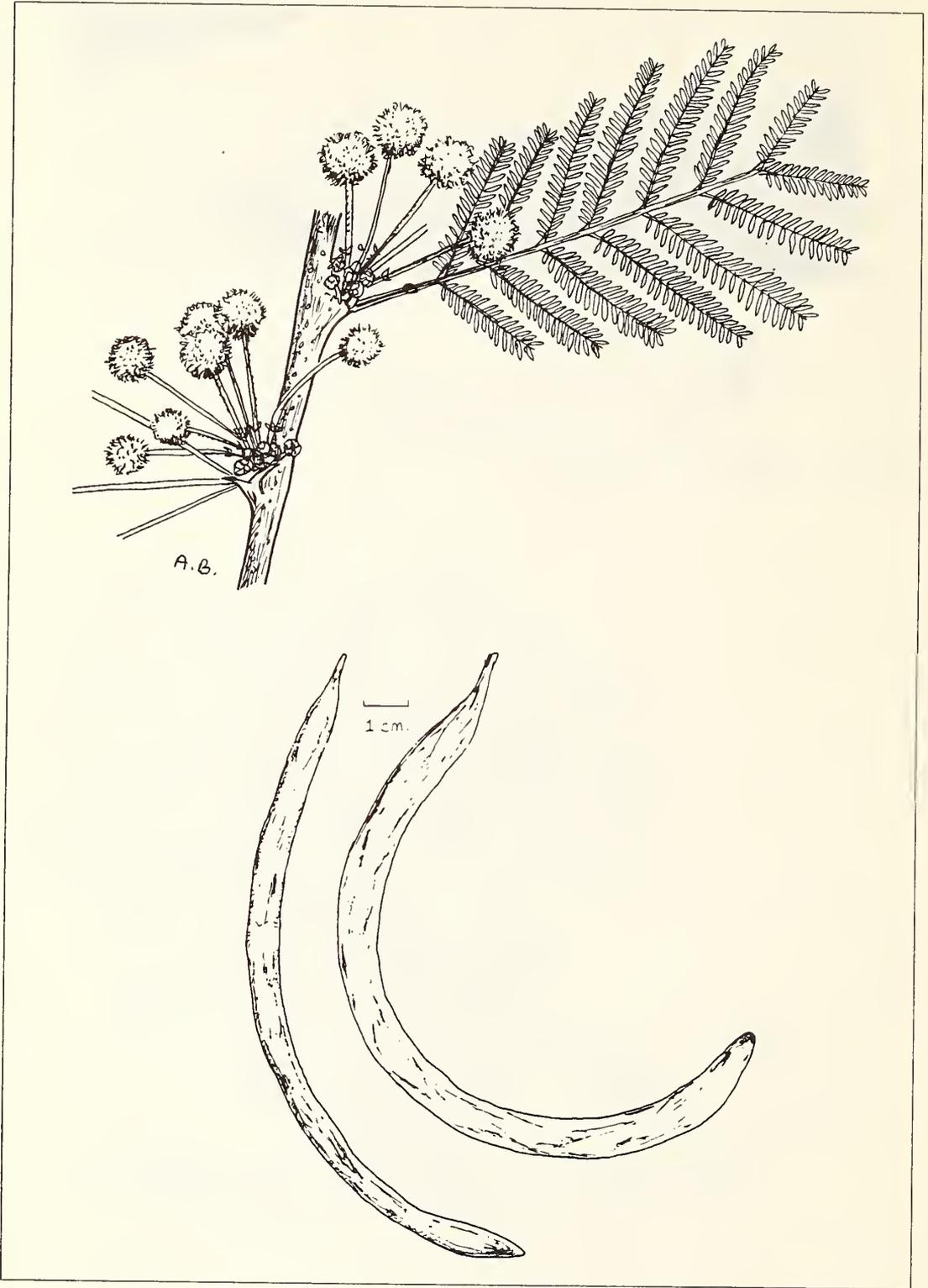
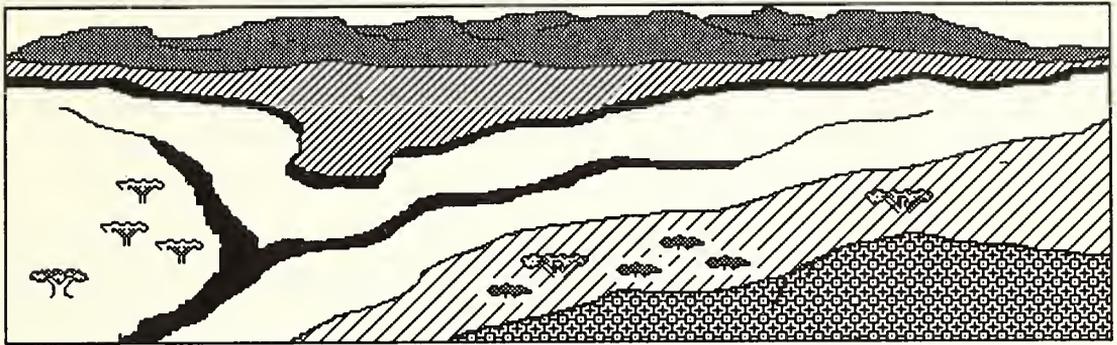


Figure 4. *Acacia robusta*: flower cluster, leaf and pod



Positive signs

- Presence of *A. robusta*
- A. gerrardii*
- A. xanthophloea*
- Near to a river bed
- Within 2 km of lava belt

Likely signs

- Near to a dam
- Green cover in dry season

Negative signs

- Basement outcrops
- On high ground
- Sandy/Quartz rich soils
- Presence of *A. mellifera*

-  Chyulu Hills
-  Lava flow
-  Seasonal river bed
-  Laterite soils
-  Basement outcrop

Figure 5. Summary of natural indicators for detecting shallow ground water in Kibwezi

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The authority should not be given if scientific names are used to describe an "association" or species complex, e.g. *Acacia drepanolobium* – *Themeda triandra*, wooded grassland. Type in capitals the first letter of the English names of species (e.g. Crowned Eagle, Grey-capped Warbler) but not of the higher taxa (e.g. eagles, warblers).

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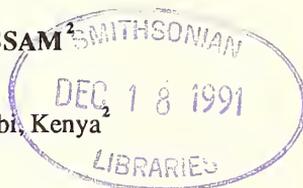
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AN ETHNO-BOTANICAL STUDY OF GABRA PLANT USE IN MARSABIT DISTRICT, KENYA

DANIEL STILES¹ AND ANEESA KASSAM²

P.O. Box 23456 Nairobi, Kenya¹

Department of Literature University of Nairobi, Kenya²



ABSTRACT

This paper reports on the results of several research trips made to the Chalbi Desert area of Marsabit District, northern Kenya, between 1979 and 1983 to study various ecological and social aspects of Gabra life. We report here specifically on the preliminary results of an analysis of Gabra plant use. The research was conducted in collaboration with the UNESCO Integrated Project on Arid Lands and this study provides supplemental data for their Technical Report series of publications.

INTRODUCTION

The Eastern Cushitic Gabra are an Oromo-speaking people closely related to the Booran. One point of ideological differentiation between the two groups focuses on livestock: the Gabra depend mainly on camels and the Booran are cattle people. The approximately 30,000 Gabra occupy a large area about the size of Switzerland (40,000 km²) (Fig. 1) between Lake Turkana in the west and the Bule Dera plain in the east, the Mega escarpment in Ethiopia to the north and an ill-defined southern limit running from the Marsabit highlands northwest across the Chalbi Desert towards the Chari Ashe hills (Fig. 2). Territorial boundaries with neighbouring pastoral groups fluctuate (Stiles, 1981).

The ecology of nomadic pastoralism is extremely complex. In a simplified way one could say that traditional pastoralists are in a never-ending search for pasture and water for their livestock, and that settlement distribution and movement are related to where these necessities can be found. The type, abundance and quality of plant species vary according to soils and rainfall, and also by the season. Different livestock animals have different forage needs in general, and these also vary according to the seasons (mainly defined as either wet or dry).

People too have needs for plants, as medicine, for construction, food, for household utensils and tools, for ritual ceremonies and for firewood. The location of certain plant species is thus also of interest to man himself.

Climate

The climate of the Chalbi Desert region is the driest in East Africa. Rainfall is extremely variable from year to year, averaging roughly 150–200 mm annually at 500 m altitude and rising to around 1000 mm at 2000 m. Potential evaporation in the lowland areas is in the order of 2500 mm a year (Bake, 1983),

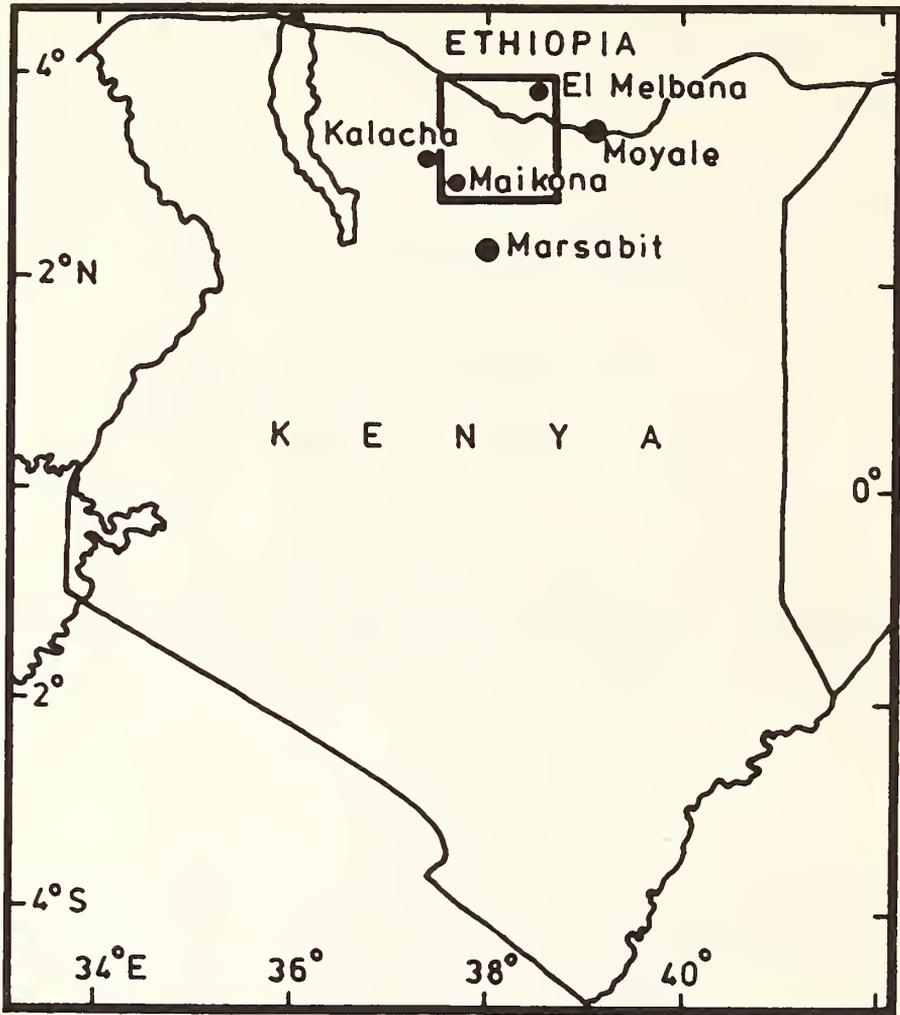


Figure 1. Map of Kenya showing study area (in square)

thus there is a very large water deficit, making rainfed cultivation impossible. Even in areas of over 1200 m altitude, agriculture is an uncertain occupation, as demonstrated by the Konso on the Hurri Hills where only one harvest out of three meets the needs of the people (personal observation).

Northern Kenya experiences the eastern African system of northeast and southeast monsoons. The southeast monsoon, which originates over the Indian Ocean, brings the most moisture and the probability for rain is highest between the end of March and early June, with a peak in April. The northeast monsoon, originating over the Arabian region, brings less moisture with the highest probability of rain in November. July through September and December to March are normally very dry months (Ojany & Ogendero, 1982; Edwards *et al.*, 1979).

In the Chalbi Desert the wind direction is almost always from the east or southeast and it blows very strongly, increasing potential evaporation and aeolian erosion. Temperatures are high, reaching 45°C in the shade during the driest months at 450 m altitude, though the mean daily maximum temperature at Kalacha (500 m) is about 38°C (Herbert Anderson, personal communication).

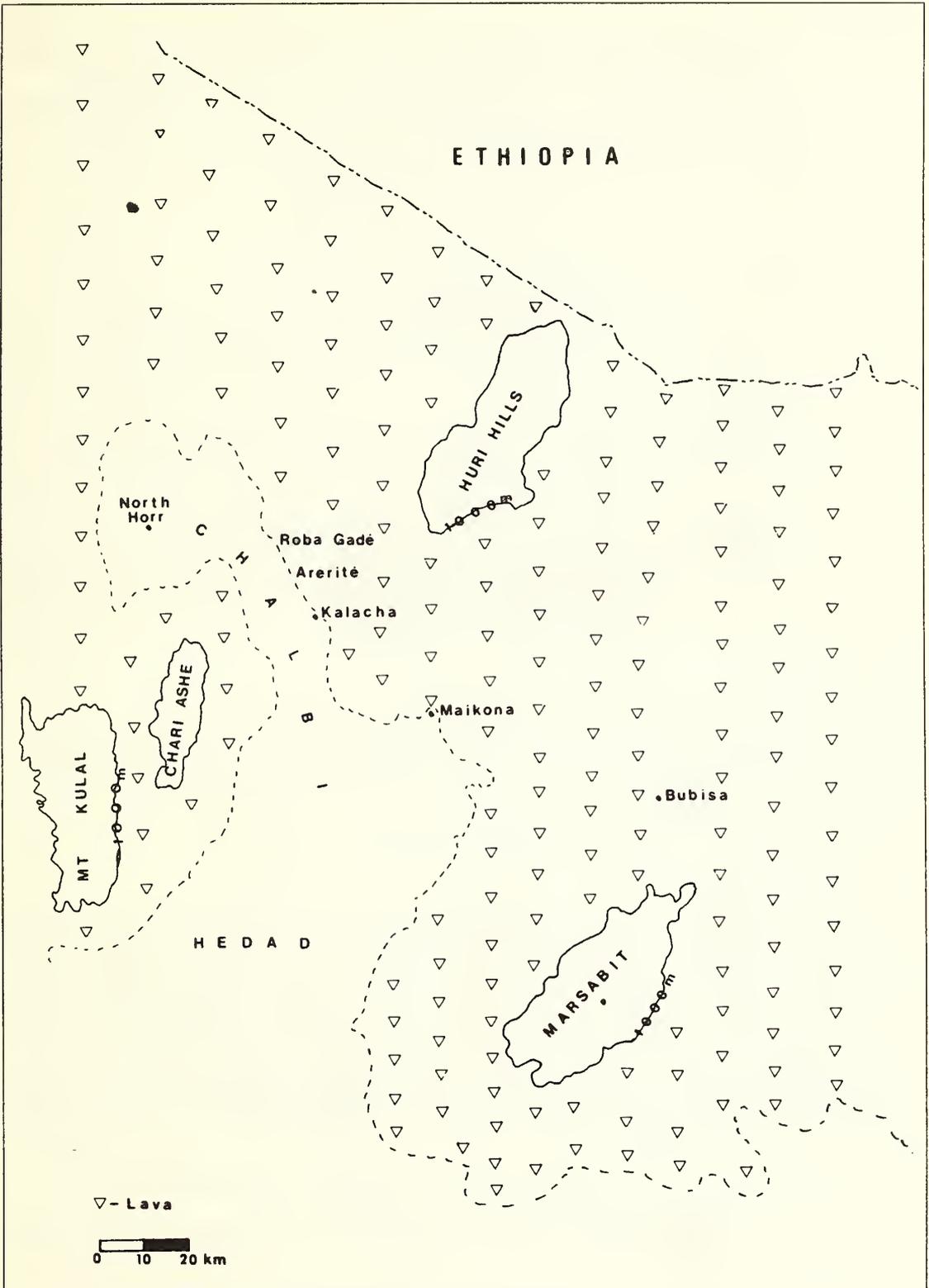


Figure 2. Map of area of northern Kenya occupied by the Gabra

Vegetation

Some of the more detailed descriptions of vegetation in the Gabra area include Edwards (1940, 1945), Pratt *et al.* (1966), Pratt & Gwynne (1977) and FAO (1971). Herlocker (1979) presents the most detailed description and mapping of the plant communities and is the only study based on field work, except for a brief survey conducted by FAO. Following Herlocker (1979), the main primary and tertiary vegetation types sampled in our study were:

- | | |
|---------------------|---|
| Forest | - Lowland groundwater (<i>Hyphaene</i>) (2) ¹ |
| Shrubland | - Evergreen (<i>Suaeda</i>) (20) |
| | - Evergreen with occasional perennial grasses (<i>Salvadora</i> with <i>Sporobolus spicatus</i>) (22) |
| | - Deciduous (<i>Acacia mellifera</i> / <i>A. seyal</i> / <i>Commiphora</i>) (26) |
| Dwarf shrubland | - <i>Duosperma</i> (34) |
| Perennial grassland | - Upland (<i>Chrysopogon</i>) (46) and (<i>Panicum</i> / <i>Chrysopogon</i>) (48) |
| | - Wooded upland (<i>Aristida</i> / <i>Chrysopogon</i> / <i>Pennisetum</i> with <i>Erythrina</i>) (51) |
| Annual grassland | - Bushed dwarf shrub: short (<i>Aristida</i> / <i>Enneapogon</i> with <i>Acacia reficiens</i> - <i>Indigofera</i>) (64) |
| | - Wooded dwarf shrub: short (<i>Aristida</i> with <i>Acacia tortilis</i> - <i>Lagenantha</i>) (70) |
| Barren land | (73) |

The largest area of the study sampling zone was covered by type 64, then type 70, followed by type 34. The Chalbi Desert itself is type 73, with various halophytic plants occurring in some places (Fig. 3).

Most of the study area falls within eco-climatic zone VI (very arid) of Pratt & Gwynne (1977), with a small area in the Hurri Hills in eco-climatic zone V (arid).

Topography and soils

The Chalbi Desert (Fig. 2) a former lake, is a depression of some 950 km² in an area forming the sump of an interior drainage system covering 36,615 km². The relatively flat surface of the Chalbi averages 450-480 m a.s.l. The ground rises to the northeast from lacustrine sediments onto volcanic plain which slopes up to the Hurri Hills (1685 m). This volcanic plain extends to the east and southeast and crosses to the north of the Marsabit highlands (Dida Galgallo plain). The Chari Ashe hills rise to 1165 m on the western side of the Chalbi Desert, and to the southwest lies Mt. Kulal (2335 m), a former volcano. These highlands lie between the central and southern Chalbi Desert and Lake Turkana (410 m). The northern part of the Chalbi desert is separated from the lake by an intervening dissected lava plateau of approximately 700 m in altitude.

The vegetation sampled in this study lies on one of four soil types (Sombroek *et al.*, 1982):

1. M7 - well drained rocky and stony Cambisols, with inclusions of rocky vents (lower part of Hurri Hills).

¹ The numbers in parentheses are those used in the Herlocker (1979) tertiary vegetation types system.

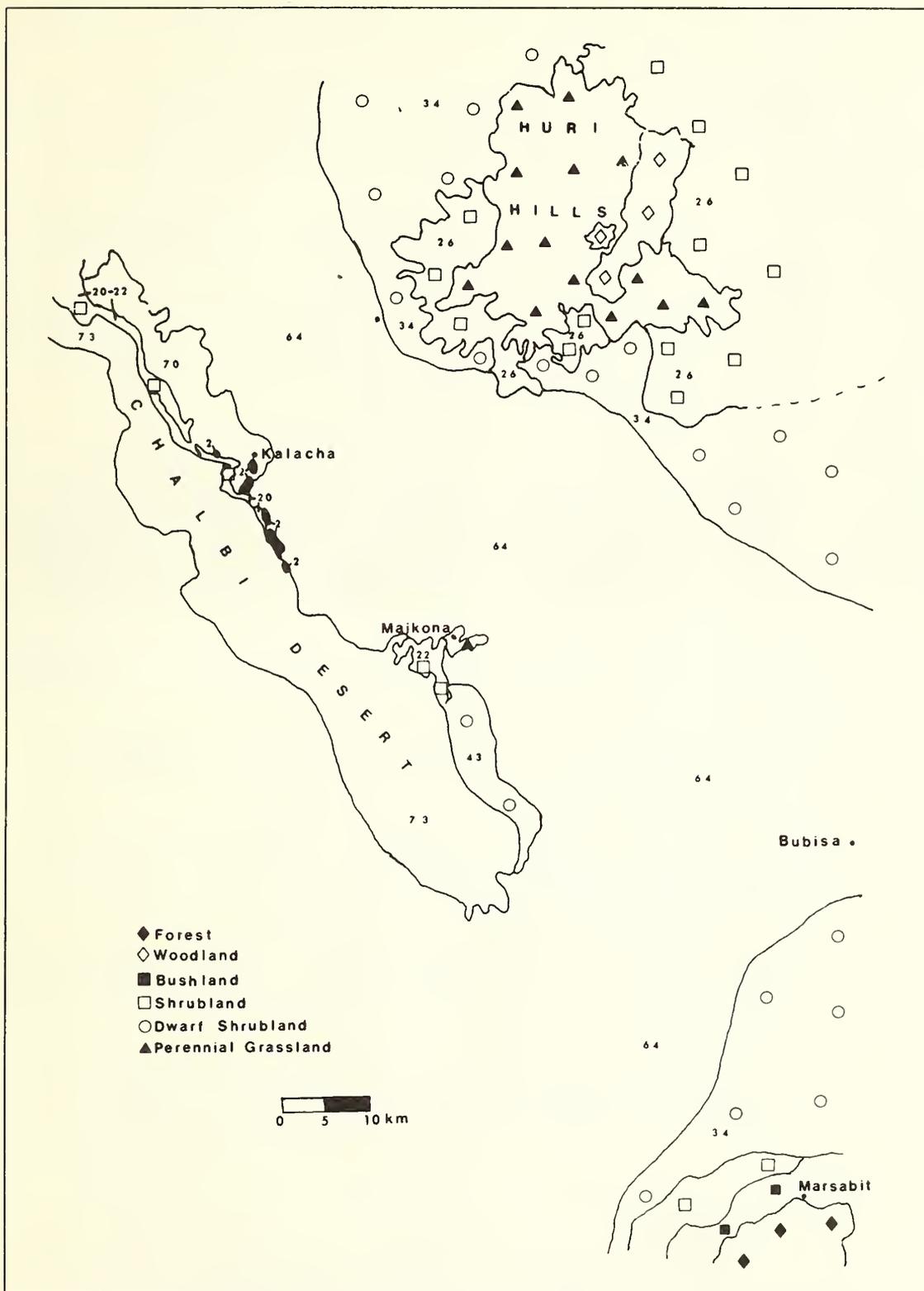


Figure 3. Distribution of tertiary vegetation types in the study area as defined by Herlocker (1979)

2. P12 - light coloured Lithosols and calcic Xerosols developed on limestone lacustrine sediments (eastern edge of Chalbi Desert).
3. F8 - imperfectly drained calcic Xerosols developed on colluvium from various volcanic rocks, in many places with a boulder mantle (in broad fingering zones leading up to the Hurri Hills away from the Chalbi Desert and following drainage lines to the north of Marsabit away from the highlands).
4. R14 - well drained Lithosols and calcic Xerosols with a rocky and bouldery surface, developed on olivine basalts and pyroclastic rocks (completely surrounding the Hurri Hills, the Chari Ashe, Mt. Kulal and Marsabit, descending in places to the Chalbi Desert).

The perennial grasslands are found on M7 soils, the annual grasslands (except for type 70) and the shrub and dwarf shrublands on F8 and R14 soils, and the *Aristida / Acacia tortilis* annual grassland (type 70) is found on the P12 soils. The Chalbi Desert itself is made up of poorly to very poorly drained, brown, saline Solonchak clays (P14 and 5 of Sombroek *et al.*, 1982).

Gabra environmental classification

The Gabra, like other Oromo, have a complex system of classifying environmental and geographic features, which not only serve to describe the physical landscape, but also to express cultural concepts. For the purpose of land-use analysis, however, the system can be greatly simplified and related to the vegetation and soil maps of the area (Herlocker, 1979; Sombroek *et al.*, 1982) to derive four land-use zones:-

- I. *Chalbi** – mostly barrenland (73) with *Hyphaene* (2) oases along the eastern margin at the base of the volcanic plain (R14) and around North Horr; saline Solonchak soils (p14 and 5); 450–480 m average altitude.
- II. *Basa* – evergreen shrubland (20 and 22) and wooded dwarf shrub; short annual grassland (70); calcareous lacustrine Lithosols and calcic Xerosols (P12); 500–600 m.
- III. *Bule* – shrubland (26) on the higher part and lower down there is mainly bushed dwarf shrub annual grassland (64) and dwarf shrubland (34); either well or imperfectly drained Lithosols or calcic Xerosols derived from volcanic rocks, a lava cobble mantle common, sometimes a finer stony surface, punctuated by lava outcrops (F8 and R14); 600–1250 m.
- IV. *Badda* – perennial grasslands (46, 48 and 51) and woodlands and shrublands (woodlands were not sampled in this study); rocky and stony Cambisols (M7) and reddish brown, eutric Nitisols (M3 of Sombroek *et al.*, 1982); 1250–1685 m.

Each of these zones can be defined in relation to a primary opposition recognized by all Oromo, between lowlands (*gammooggi*) and highlands (*badda*), so that zones I, II, and the lower parts of III occur in the former category and the higher levels of III and IV occur in the latter category.

* All Gabra terms used in this paper have been transcribed according to the system of notation used by Gragg (1982) except that for typographical convenience where he writes *s*, *n*, we use *sh*, *ny* to denote the same sound. When there is an existing convention of noting place names like chalbi, charri, etc., this has been retained. Q is transcribed *k*. The vernacular terms have been checked by Oromo speakers, but as there is no fixed system of writing, thus notation varies and it should not be seen as definitive.

Other geographic features distinguished by the Gabra are: *dida*, "plain", *c' albi* (*chalbi*), being a type of plain generally barren and characterized by its salty soil (*muludde*); *lafica*, an open, flat savanna area; *kurkura* an area of dense pebbles opposed to the *bule* which is formed of volcanic cobbles and boulders; *c' arri* (*charri*), a range of low-lying hills which occurs in the lowlands, *tulluu* (*tulu*), hills which occur in the highlands and *k' ubi*, hillocks which can occur anywhere. A mountain is *gaara*, and a crater *gofa*. Foothills are known as *sarba*, literally "calf" (of leg). *Golbo* is a type of trough; large expanses of water, like lakes and rivers are termed *galaana* and river valleys and dry river beds are called *laga*.

The Gabra are intimately aware of what each of these zones has to offer in the way of vegetation, water and soils and use this knowledge when planning their movement patterns. They measure the quality of pasture on the fluctuating scale of *finna* (fertility). This is a complex cultural notion which enters frequently into Gabra decisions on livestock herding strategies and some areas are known to be *koshee* (having *finna*) for certain stock types.

METHODS

Gabra pastoralists were requested to take plant samples in the area surrounding their settlement and return with them. Samples were collected in the vicinity of Kalacha, around four *olla* (nomadic camps) in the Arerite and Roba Gade areas, from various spots on the lava plateau (*bule*) and the lower parts of the Hurri Hills and from around Bubisa (Fig. 2).

Each Gabra informant was asked a series of questions about the human uses, if any, of each plant, which livestock animals fed on the plant and how important it was in the diet according to season, and the areas where the plant could be found. The Gabra name for each plant was also recorded. The questioning was undertaken in English through a Gabra secondary-school student acting as interpreter. Plant-use information was also obtained when conducting studies of material culture and ritual and during periods of participant observation of Gabra daily life.

The plant samples were put into a plant press and subsequently deposited at the East African Herbarium for identification. In analysing the results of four collection lists two major problems arose: (1) some plant samples given the same Gabra name by different informants received more than one species identification by the Herbarium, and (2) some plant samples given different names by the informants were identified as the same species by the Herbarium.

There are several possible explanations for these apparent anomalies: (1) a Gabra informant misidentified the plant, (2) the Herbarium misidentified the sample, (3) the authors made a mistake in record-keeping before depositing the plants at the Herbarium, (4) some plants receive different names by the Gabra during different stages of growth or in different localities, and (5) some plants of similar appearance receive the same Gabra name. These possibilities are not mutually exclusive.

The identifications posing problems, along with all the others, were checked against the vernacular names given in Dale and Greenway (1961) and Synott (1979), and in some cases Legesse's Herbarium list (1981). Where either or all of these authors agreed with one of our matching pairs of Gabra - Herbarium identifications, we chose that one to include in our list (Table 1). Possible alternative identifications are noted in parentheses in the column containing the Gabra names. The Gabra do recognize higher orders of classification which group related plants into families, where most of the problematic identifications were found.*

The principal problem families were (*h*) *ammeesaa* and *buuyyo*; (*h*) *ammeesaa* corresponds to Bursaceae and other Herbarium identifications and those in Dale and Greenway (1961) indicate that

* The reasons for these "confusions" from the botanical point of view may be explained by Gabra / Booran plant taxonomy. Field-work would suggest that when a plant "degenerates" (i.e. when it reproduces itself in a slightly modified form), it is given a different name.

there is some confusion in correctly identifying the various *Commiphora* species. The Gabra also include the trees *Terminalia polycarpa* / *spinosa* (Combretaceae) in (*h*) *ammeesaa*.

Much more confusion was found in the *d'umashoo* family, which corresponds to the Capparaeae. *Boscia*, *Cadaba* and *Maerua* plant samples were identified interchangeably as *deekuku*, *k'ad' u*, *k'alk'acca* and (*h*) *afuursaa* and could belong to almost any of the three genera.

Buuyyo is the term for grass and thus corresponds to the Poaceae (Gramineae). Considering that samples were usually taken during the dry season when grass consists of little more than dry tufts, it was not always possible to get full identifications.

The fact that multiple identifications (c.15%) occurred raises the question of the accuracy in single-collection studies. For this reason we feel that any ethno-botanical study needs to obtain two or more corroborating sample identifications to be considered valid. As not all of our samples meet that criterion, the list presented here should be considered provisional and subject to verification and possible revision.

Plant identification and use

There is always a question as to what is the best method to present a plant list. We have chosen alphabetical order by family because many of the users of this list will not be botanists, and for non-specialists it is the simplest method of reference. Hepper *et al.* (1981) chose to list the plants of Mt. Kulal, near our study area, by order of evolution and degree of relatedness of the families. The families were ordered and numbered. For those wishing information of this sort, the Hepper *et al.* numbers are reproduced here in the first column in Table 1. In general, the lower the number the more primitive the family, and the closer together the numbers the more closely related are the families. An alphabetical list of vernacular names is also appended.

Table 1: A list of Gabra plants and their uses: (abbreviations used).

Plant	Uses
T — Tree	Co — Construction
Sh — Shrub	F — Food
Dsh — Dwarf shrub	Fw — Firewood
L — Liane	M — Medicine
Tw — Twiner	O — Cultural objects
Tc — Tendril climber	R — Ritual
H — Herb	V — Veterinary use
G — Grass	
Food:	Score
C — Camel food	0 — Not eaten or used
Ca — Cattle food	* — No good data collected
G — Goat food	+ — Minor importance
S — Sheep food	++ — Moderate importance
	+++ — Very important

No.	Family, genus and species	Gabra name	Plant type	Animal					Human										
				C	Ca	G	S	V	M	F	Co	O	R	Fw					
259	ACANTHACEAE																		
	<i>Barleria acanthoides</i> Vahl	shiisha	D Sh	+++	0	+	+	0	*	0	0	0	+	0					
	<i>Barleria</i> sp.	maadeeka		+	0	0	0	0	0	0	0	0	0	0					
	<i>Blepharis ciliaris</i> (L.) B.L. Burtt	baarataa	H	++	+	++	+	+	*	0	0	0	0	0	+				
	<i>B. linariifolia</i> Pers.																		
	<i>Duosperma ermophilum</i> (Milne-Redh.) Napper	saariima	D Sh	++	++	++	+	0	0	0	0	0	0	0	0				
	<i>Echolium revolutum</i> (L.) C.B. Cl.	k'atte	D Sh	+	0	+	+	0	0	0	0	0	0	0	0				
	<i>Ruellia patula</i> Jacq.	(<i>Lantana</i> sp.) d'ad'ale		+	+	+	+	0	0	0	0	0	0	0	0				
	Indet.	lakud'e	Sh	+	+	+	+	0	0	0	0	0	0	0	0				
313	AGAVACEAE																		
	<i>Dracaena ellenbeckiana</i> Engl.	butte	T Sh	0	0	0	0	0	0	0	0	0	+	0	0				
	<i>Sansevieria robusta</i> (N.E. Br.) Jake	alge	Sh	0	0	0	0	0	0	0	++	+	+	+	0				
54	AIZOACEAE																		
	<i>Trianthema salsoides</i> Fenzl.	k'ant'ala	H	+	0	+	0	0	0	0	0	0	0	0	0				
	<i>Zaleya pentandra</i> (L.) Jeffrey	laamisho	H	+	+	+	+	0	0	0	0	0	0	0	0				
63	AMARANTHACEAE																		
	<i>Aerva javanica</i> Schultes (<i>A. persica</i> (Burm. f.)) Merrill	muk-illeensa sufki	H H	0 0	0 0	0 0	0 0	0 0	+	0	0	0	0	0	0				
	<i>Digera muricata</i> (L.) Mart.	gelgedaana	H	++	+	++	+	0	0	0	0	0	0	0	0				
	<i>Pupalia lappacea</i> (L.) Juss. var. <i>velutina</i> (Moq.) Hook. f.	matt'anne (<i>Serico-</i> <i>comopsis</i> sp.)	H	+	0	+	0	0	0	0	0	+	0	0	0				
	<i>Sericocomopsis hilde-</i> <i>brandtii</i> Schinz	jiibeete (<i>Dasyphaera</i> <i>prostrata</i> (Gilg & Schinz)	H	++	0	++	+	0	+	0	0	0	0	0	+				
205	ANACARDIACEAE																		
	<i>Rhus natalensis</i> Krauss	dabobbesa	Sh	+	*	+	+	*	*	+	*	*	*	*	+				
230	APOCYNACEAE																		
	<i>Aconanthera schimperi</i> (A.DC.) Schweinf.	k'arraaru	T	0	0	0	0	0	+	0	0	0	0	0	0				
	<i>Adenium obesum</i> (Forsk.) Roem. & Schult.	obbe	Sh	0	0	0	0	0	+	0	0	0	0	0	0				
	<i>Carissa edulis</i> (Forsk.) Vahl	dagamsa	Sh/L	0	0	0	0	0	+	0	0	0	0	0	0				
	ARISTOLOCHIACEAE																		
	<i>Aristolochia bracteolata</i> Lam.	raafu	?	0	0	0	0	0	0	0	0	0	0	0	0				
314	ARECACEAE (PALMAE)																		
	<i>Hyphaene compressa</i> H. Wendle.	meetti	T	0	0	0	0	0	0	+	++	+	0	+					

No.	Family, genus and species	Gabra name	Plant type	Animal					Human									
				C	Ca	G	S	V	M	F	Co	O	R	Fw				
231	ASCLEPIADACEAE																	
	<i>Calotropis procera</i> (Ait.) Ait. f.	k'obboo	Sh	0	0	0	0	0		+	0	0	0	0	0	0		
	<i>Caralluma speciosa</i> (N.E. Br.) N.E. Br.	boorara	H	0	0	0	0	0		+	0	0	0	0	0	0		
195	BALANITACEAE																	
	<i>Balanites aegyptiaca</i> (L.) Del.	baddana (<i>B. orbicularis</i>)	T	+	0	0	0	0		0	+	0	+	+	0			
249	BORAGINACEAE																	
	<i>Cordia sinensis</i> Lam. Aschers (<i>C. gharaf</i> (Forsk.)) <i>Heliotropium albohispidum</i> Bak. <i>H. somalense</i> Vatke <i>H. subulatum</i> (DC.) Martelli	mad'eera	T/Sh	+	0	+	+	0		0	+	++	++++	++				
		kokoomisha	H	++	+	+	+	+		+	0	0	0	0	0	0		
		dubarraara	H	+	0	+	+	0		0	0	0	0	0	0	0		
196	BURSERACEAE																	
	<i>Boswellia hildebrandtii</i> Engl.	dakkara	T	+	0	+	+	0		0	0	0	0	+	+			
	<i>Commiphora cf. africana</i> (A. Rich). Engl.	ammeesaa	T/Sh	+	0	+	+	+		0	0	+	++	0	+			
	<i>C. boiviniana</i> Engl.	dakd'aa	T/Sh	+	*	+	*	0		0	+	0	+	0	+			
	<i>C. myrrha</i> (Nees) Engl.	k'umbi (<i>C. ellenbeckii</i> Engl.)	T	0	0	0	0	+		++	0	0	0	++	+			
	<i>C. habessinica</i> (O. Berg) Engl.	c'allankaa	T	+	*	+	*	*		*	+	*	+	*	*			
	<i>C. erythraea</i> (Ehrenb.) Engl.	agarsu	T	+	0	+	+	0		0	0	0	+	0	+			
	<i>C. incisa</i> Chiov.	waaraa	T/Sh	+	0	+	+	*		+	0	0	+	+	+			
	<i>Commiphora</i> sp.	warab reeba	T/Sh	+	0	+	+	0		0	0	+	0	0	+			
146	CAESALPINIACEAE																	
	<i>Delonix elata</i> (L.) Gamble	sukellaa	T	+	0	0	0	0		0	0	0	++	0	+			
36	CAPPARACEAE																	
	<i>Cadaba farinosa</i> Forsk.	deekuku (<i>Maerua oblongifolia</i> (Forsk.) A. Rich.)	Sh	++	0	++	++	0		0	0	0	0	0	0	0		
	<i>C. mirabilis</i> Gilg <i>C. gillettii</i> R.A. Graham	k'adu (<i>Boscia?</i>)	Sh	++	+	++	+	0		0	0	0	0	0	0	0		
	<i>Maerua angolensis</i> DC.) <i>M. crassifolia</i> Forsk.	k'alk'acca (<i>Boscia coriacea</i> Pax)	T	+	*	*	*	*		*	*	+	*	*	*			
	<i>M. crassifolia</i> Forsk.) <i>M. kaessneri</i> Gilg. Bened.)	d'umashoo	Sh	+	0	+	+	0		0	0	0	0	0	++			

No.	Family, genus and species	Gabra name	Plant type	Animal					Human					
				C	Ca	G	S	V	M	F	Co	O	R	Fw
	<i>Maerua</i> sp.	(h) afuursaa (<i>Cadaba mirabilis</i>)	T/Sh	++	+	++	+	0	0	0	0	0	0	+
	Indet.	k'ork'odda	Sh	+	+	+	+	0	0	0	0	0	0	+
61	CHENOPODIACEAE													
	<i>Fadenia zygophylloides</i> Allen & Townsend	had'um (<i>Gyroptera gilletti</i> Bosch.)	H	++	0	+	+	0	0	0	0	0	0	0
	<i>Suaeda monoica</i> J.F. Gmel.	d'uurtee (<i>Salsola dendroides</i> Pallas)	T/Sh	+++	0	+	+	0	0	0	0	0	0	+
121	COMBRETACEAE													
	<i>Combretum</i> cf. <i>denhardtiorum</i> Engl. & Diels	c'anc'ali	Sh	+	0	+	+	0	0	0	0	+	0	+
	<i>C. molle</i> G. Don	rukeesa	T	+	0	+	+	0	0	0	0	0	0	+
	<i>Terminalia spinosa</i> Engl.	k'orobo	T	+	0	+	+	0	0	0	0	0	0	+
	<i>T. polycarpa</i> Engl. & Diels													
280	COMMELINACEAE													
	<i>Commelina latifolia</i> A. Rich.	k'ayyu	H	+	++	+	++	0	0	0	0	0	0	0
238	COMPOSITAE													
	<i>Aspilia mossambicensis</i> (Oliv.) Wild.	(h) ada (<i>Vernonia wakefieldii</i> Oliv.)	H	+	0	+	0	0	+	0	0	0	0	0
251	CONVOLVULACEAE													
	<i>Seddera hirsuta</i> Hall. f.	gurbi	+	0	+	0	0	0	0	0	0	0	0	0
103	CUCURBITACEAE													
	<i>Cucumis dipsaceus</i> Spach	buratte	Tc	0	0	+	+	0	0	0	0	0	0	0
	<i>C. prophetarum</i> L.	baram-barro	Tc	+	+	++	+	0	0	0	0	0	0	0
	<i>Kedrostis gijef</i> (J.F. Gmel) C. Jeffrey	gaalle (<i>Cucumis</i> sp.)	Tc	++	0	++	+	0	0	+	0	0	++	0
	CUPRESSACEAE													
	<i>Juniperus procera</i> Endl.	arru	T	0	0	0	0	0	0	0	0	0	++	0
221	EBENACEAE													
	<i>Diospyros abyssinica</i> (Hiern) F. White	lookko	T	*	*	*	*	*	+	+	*	+	*	*
136	EUPHORBIACEAE													
	<i>Croton somalensis</i> Vatke & Pax	d'irri	Sh	+	+	+	+	+	*	*	*	*	*	*
	<i>Euphorbia candelabrum</i> Kotschy	addamma	T	0	0	0	0	+	0	0	0	0	0	0
	<i>E. cuneata</i> Vahl	(h) idaa	Sh	+	0	+	+	0	0	0	0	0	0	0
	<i>E. tescorum</i> Carter	harkeena	Sh	0	0	0	0	0	+	0	0	0	0	0

No.	Family, genus and species	Gabra name	Plant type	Animal					Human						
				C	Ca	G	S	V	M	F	Co	O	R	Fw	
264	LAMIACEAE (LABIATAE) <i>Leucas pododiskos</i> Bullock	jilbeete kurooftu	H	0	0	0	0	0	+	0	0	0	0	0	0
293	LILIACEAE <i>Asparagus africanus</i> Lam.	ergamssa	Tc	0	0	0	0	0	0	0	0	++	0	0	
	<i>Asparagus</i> sp.	okolle	Tc	0	0	0	0	0	0	0	0	+	0	0	
132	MALVACEAE <i>Pavonia zeylanica</i> (L.) Cav.	ilk'abata	H	+	0	+	0	0	0	0	0	0	0	0	
23	MENISPERMACEAE <i>Cocculus pendulus</i> (J.R. & G. Forst.) Diels	mamma	Tw	+	0	+	0	0	0	0	0	0	0	0	
147	MIMOSACEAE <i>A. etbaica</i> Schweinf.	(h) allak'abeessa	T	+	0	+	+	0	*	*	*	+	*	+	
	<i>A. goetzei</i> Harms	burraa	T	+	0	+	+	0	+	0	0	0	0	+	
	<i>A. mellifera</i> (Vahl) Benth.	sap'ans gurraaca	T/Sh	+	0	+	+	0	0	0	+	0	0	+	
	<i>A. nilotica</i> var. <i>subalata</i> (L.) Del.	burk'uk'e	T/Sh	+	0	+	+	0	0	0	+	0	0	+	
	<i>A. nubica</i> Benth.	waanga	Sh	+	0	+	+	0	+	0	0	0	0	+	
	<i>Acacia paolii</i> Chiov.	c'aac'anne (<i>A. horrida</i>)	S	+	0	+	+	0	0	0	0	++	0	+	
	<i>Acacia reficiens</i> Wawra ssp. <i>misera</i> (Vatke) Brennan	sigirso	T/Sh	++	0	++	+	0	0	0	+	+	+	++	
	<i>A. senegal</i> (L.) Willd.	iddaad'o	T/Sh	+	0	++	+	0	0	0	+	0	0	+	
	<i>A. seyal</i> Del. var. <i>fistula</i> (Schweinf.) Oliv.	waac'c'u	T	0	0	+	0	0	0	+	+	0	0	+	
	<i>A. tortilis</i> (Forsk.) Hayne	d'addaca	T	++	0	++	+	0	0	+	+++	+++	+++	+++	
167	MORACEAE <i>Ficus glumosa</i> Del.	k'iltaa	T/Sh	0	0	0	0	0	0	*	0	0	0	0	
83	NYCTAGINACEAE <i>Commicarpus helenae</i> (J.A. Schultes) Meikle	araddo, k'oraatti gaala	H	+	0	+	0	+	0	0	0	0	0	0	
182	OLEACEAE <i>Olea europaea</i> L. var. <i>africana</i> (Mill.) P.S. Green	ejersa	T/Sh	0	0	0	0	0	0	0	0	+	++	+	
253	OROBANCHACEAE <i>Cistanche tubulosa</i> (Schenk.) Hook.f.	(h)armaac'a	H	0	0	0	0	0	+	0	0	0	0	0	
148	PAPILIONACEAE <i>Abrus schimperi</i> Bak.	wargidda	H	0	0	0	0	0	0	0	0	+	0	0	
	ssp. <i>africanus</i> (Vatke) Verdc.														
	<i>Crotalaria</i> cf. <i>dumosa</i> Franch.	(h)asura	H	+	+	+	+	0	0	0	0	0	0	0	

No.	Family, genus and species	Gabra name	Plant type	Animal					Human							
				C	Ca	G	S	V	M	F	Co	O	R	Fw		
	<i>Erythrina rotundata-obovata</i> (Harms)	waleena	T	0	0	0	0	0	0	0	0	0	0	+	0	+
	<i>E. burttii</i> Bak. f.)															
	<i>Indigofera coerulea</i> Roxb. var. <i>occidentalis</i> Gillett & Ali	(h)asura harre (Cassia italica)	H	0	0	0	0	0	0	0	0	0	0	+	0	0
	<i>I. coerulea</i> Roxb.)	agaggaro	H	++	+	++	++	0	0	0	0	0	0	0	0	0
	<i>I. colutea</i> (Burm. f.) Merrill															
	<i>I. cliffordiana</i> Gillett															
	<i>I. insularis</i> Chiov.															
	<i>I. spicata</i> Forsk.															
	<i>I. spinosa</i> Forsk.	k'ilt'ip'p'e	Ds	++	+	++	++	0	0	+	0	0	0	0	0	0
	<i>Ormocarpum trichocarpum</i> (Taub). Engl.	buutiyye	Sh	0	0	+	+	0	0	0	0	0	0	0	0	+
	<i>Rhynchosia minima</i> (L.) DC.	uube	H/Tw	+	0	++	++	0	0	0	0	0	0	0	0	0
	<i>Vatovaea psuedolablab</i> (Harms) Gillett	gaabbe	Tw	+	0	+	+	0	0	+	0	+	0	0	0	
	<i>Vigna frutescens</i> A. Rich.	c'iimp'a	H	+	+	+	+	*	0	+	0	0	0	0	0	
101	PASSIFLORACEAE															
	<i>Adenia venenata</i> Forsk.	obbe	Tc	0	0	+	0	0	0	0	0	0	0	0	0	
332	POACEAE (GRAMINEAE)															
	<i>Aristida adscensionis</i> L.	buuyyo biila	G	++	+++	++	++	0	0	0	++	0	0	0	+	
	<i>Aristida mutabilis</i> Trin. & Rupr.															
	<i>Cenchrus ciliaris</i> L.	diilaleesa	G	+	+	+	+	*	*	*	*	*	*	*	*	
	<i>C. pennisetiformis</i> Steud.	k'onc'orro	G	+	+	++	++	0	0	0	0	0	0	0	0	
	<i>C. setigerus</i> Vahl	buuyyo harre	G	+	+	+	+	0	0	0	0	0	0	0	0	
	<i>Chrysopogon plumulosus</i> Hochst.	alala	G	+	++	+	++	0	*	*	*	*	*	*	*	
	<i>Dactyloctenium bogdanii</i> S.M. Phillips	maa	G	+	++	+	++	0	0	0	0	0	0	0	+	
	<i>Digitaria velutina</i> (Forsk.) P. Beauv.	biila	G	+	++	+	++	0	0	0	0	0	0	0	0	
	<i>Echinochloa haploclada</i> (Stapf) Stapf	geedi	G	+	+	+	+	*	*	*	*	*	*	*	*	
	<i>Leptothrium senegalense</i> (Kunth) Clayton	ilmmogora	G	+	+	+	+	0	0	0	0	0	0	0	0	
	<i>Panicum coloratum</i> L.	laabbesa	G	+	++	+	+	*	*	*	*	*	*	*	*	
	<i>Paspalidium desertorum</i> (A. Rich.) Stapf	c'iraa (Cenchrus sp. <i>Sporobolus helvolus</i>).	G	+	++	+	++	0	0	0	+	0	+	0		
	<i>Pennisetum mezianum</i> Leeke	ogoona	G	+	+	+	+	*	*	*	*	*	*	*	*	
	<i>Sehima nervosum</i> (Rottl.) Stapf	sokhorsitu	G	*	*	*	*	*	*	*	*	*	*	*	*	

No.	Family, genus and species	Gabra name	Plant type	Animal					Human					
				C	Ca	G	S	V	M	F	Co	O	R	Fw
	<i>Setaria verticillata</i> (L.) P. Beauv.	hank'arre	G	+	+	+	+	*	*	*	+	*	*	*
	<i>Sporobolus ioclados</i> (Trin.) Nees	buuyyo fiinc'oo	G	+	++	+	++	0	0	0	0	0	0	0
	<i>S. spicatus</i> (Vahl) Kunth	harfuuk'a	G	+	+	+	+	0	0	0	0	0	0	+
	<i>Themeda triandra</i> Forsk. Indet.	buuyyo diimtu saatu	G G	+	+	+	+	*	*	*	*	*	*	*
190	RHAMNACEAE <i>Ziziphus abyssinica</i> A. Rich.	k'urk'uura	T/Sh	+	0	+	*	0	0	+	+	+	0	+
	RUTACEAE <i>Zanthoxylum chalybeum</i> (Engl.) Kokw.	gaddaa	T	*	*	*	*	*	+	+	0	0	0	0
180	SALVADORACEAE <i>Salvadora persica</i> L.	aadde	T/Sh	+++	0	++	+	0	+	0	+	0	0	+
252	SCROPHULARIACEAE <i>Pseudosopubia hildebrandtii</i> (Vatke) Engl.	k'ors nyaata	H	0	0	+	0	+	0	0	0	0	+	0
250	SOLANACEAE <i>Lycium europaeum</i> L. <i>Solanum coagulans</i> Forsk. (<i>S. dubium</i> Fres. (<i>S. coagulans</i> Forsk.))	fursaa (h)iddi, (h)iddi ree, hididi arado (small version)	Sh H H	+	0	+	+	0	0	0	+	+	0	+
130	STERCULIACEAE <i>Sterculia africana</i> (Lour.) Fiori	k'ararri	T	0	0	0	0	0	0	0	0	++	0	+
128	TILIACEAE <i>Corchorus triocularis</i> L. <i>Grewia tenax</i> (Forsk.) Fiori <i>G. trichocarpa</i> A. Rich. <i>G. bicolor</i> Juss. <i>G. villosa</i> Willd. <i>Triumfetta flavescens</i> Hochst.	luuftoole (<i>Farsetia stenoptera</i> Hochst.) d'eeka (h)arorressa ogomdi ic'iinni	H Sh Sh S S	+	+	+	+	0	+	+	0	+	+	0
	VIOLACEAE <i>Rinorea convallariiflora</i> M. Brandt	fit'o	T	*	*	*	*	*	*	*	*	*	+	*
193	VITACEAE <i>Cyphostemma nierense</i> (Th. Fr. jr.) Desc.	rorroddo	Tc	0	0	0	0	0	+	0	0	0	0	0
66	ZYGOPHYLLACEAE <i>Tribulus cistoides</i> L.	mogorree	H	+	+	+	+	0	+	0	0	0	0	0

RESULTS

Livestock

The degree of importance of each plant as livestock forage is a subjective measure in this study based on the combined opinions of approximately a dozen informants. The importance of a plant in the diet of any particular animal is a function of its availability, i.e. its abundance, and of the dietary needs of the animals at any point in time. Due to the ever-changing nature of these variables, and the methodological problems involved in recording timed feeding observations, we feel that this method probably yields results as valid as timed feeding trials, with less chance of a bias due to local species availability in the area of the feeding trials. The data provided here are from samples collected within an area of approximately 2400 km² covering a variety of ecological zones.

The degree of importance of a plant to livestock diet as reported in Table 1 needs some qualification. It is not based entirely on what would be a measure of the weight dry matter ingested by the animal, as quantity is not always of the utmost importance to a pastoralist, particularly concerning the camel. For example, *d'uurtee* (*Suaeda monoica* / *Salsola dendroides*) is considered as a very important plant for camel health due to its high salt content, particularly during the dry season. *Kilt'ip'p'e*, (*Indigofera spinosa*), however, is rated as only moderately important. Measured in dry-matter weight, camels probably eat more *k'ilt'ip'p'e*, since it is more widespread and abundant than *d'uurtee*. This is certainly true during the rainy seasons. *D'uurtee* is more important, however, because of its food value, not quantity, and as such a pastoralist would be much more likely to plan his herding strategy at certain times to take into account the location of *d'uurtee* than he would of *k'ilt'ip'p'e*. This kind of analysis is another reason why we think that a qualitative evaluation of plants as forage has some usefulness. We also tried to make a distinction between "importance" and "liking" in our questioning of informants. For example, camels have a very strong liking for *mad'eera* (*Cordia sinensis*), but because it is not very abundant in the study area it does not form a very important part of the camel diet (Table 1).

Goats display the widest range in diet, eating 91 of the 140-150 plants listed (the number depends on how many alternative identifications might be valid). Camels come next with 88, followed by sheep with 78 and lastly by cattle with only 34. The seven grass species in Table 1, mentioned by informants but about which we had collected no first-hand information, can be added to the total number of plants eaten by each livestock type, as others have listed them (Pratt & Gwynne 1977; Field 1979 a & b; Sato 1980). Nothing can be said about their relative importance in the diet, however. This would bring the total number of species eaten to 98 for goats, 95 for camels, 85 for sheep and 41 for cattle.

Table 2 presents a summary of the plants considered by our informants as being either "very important" or "moderately important" in the diet of each stock species.

Table 2: The Very and Moderately important plants in the livestock diet in the eastern Chalbi Desert area.

Camels	
Very important (+++):	Moderately important (++):
<i>Barleria acanthoides</i>	<i>Blepharis ciliaris</i> / <i>linariifolia</i>
<i>Duosperma eremophilum</i>	<i>Digera muricata</i>
<i>Suaeda monoica</i> (<i>Salsola dendroides</i> ?)	<i>Sericocomopsis hildebrandtii</i>
<i>Salvadora persica</i>	<i>Heliotropium albohispidium</i>
(<i>Indigofera</i> all species)	<i>Cadaba farinosa</i>
	<i>C. gilletti</i>
	<i>Maerua</i> sp.
	<i>Fadenia zygophylloides</i>
	<i>Kedrostis gijef</i>

Aristida adscensionis / *mutabilis*
Indigofera (many species)
Acacia reficiens
A. tortilis

Cattle

Very important (+++):

Aristida adscensionis / *mutabilis*

Moderately important (++):

Commelina latifolia
Cenchrus pennisetiformis
Chrysopogon plumulosus
Dactyloctenium bogdanii
Digitaria velutina
Paspalidium desertorum
Sporobolus ioclados

Goats

Very important (+++):

Indigofera (all species)

Moderately important (++):

Blepharis ciliaris / *linariifolia*
Duosperma eremophilum
Digera muricata
Sericocomopsis hildebrandtii
Cadaba farinosa
C. gillettii
Maerua sp.
Cucumis prophetarum
Kedrostis gijef
Cenchrus pennisetiformis
Indigofera spinosa
Indigofera (many species)
Rhynchosia minima
Salvadora persica
Acacia reficiens
A. paolii
A. senegal
A. tortilis

Sheep

Very important (+++):

Indigofera (all species)

Moderately important (++):

Cadaba farinosa
Commelina sp.
Aristida adscensionis / *mutabilis*
Cenchrus pennisetiformis
Chrysopogon plumulosus
Dactyloctenium bogdanii
Digitaria velutina
Paspalidium desertorum
Sporobolus sp.
Indigofera (many species)
Rhynchosia minima

Camels have the highest number of “very important” species with four: *shiisha* (*Barleria acanthoides*), called “food of the camel” by the Gabra, *saariima* (*Duosperma eremophilum*) *d'uurtee* (*Suaeda monoica* / *Salsola dendroides*), and *aadde* (*Salvadora persica*). The genus *Indigofera* can be added to this class by combining *agaggaro* (several *Indigofera* species) and *k'ilt'ip'e* (*I. spinosa*). Twenty species (14 Gabra taxa) were rated as “moderately important” in the camel diet.

Two species of plants, *Aristida adscensionis* / *mutabilis*, both known as *buuyyo biila* in Gabra, are the only ones rated “very important” for cattle by the informants. This was undoubtedly due to their widespread abundance in the study area. Seven species were identified as being of “moderate importance”, only one of them (*Commelina* sp.) not a grass.

It is interesting to note that no plant was specifically identified as being “very important” in the diet of goats or sheep. However, as in the case with camels, the genus *Indigofera* could be included here by combining the two Gabra taxa of *agaggaro* and *k'ilt'ip'e*, each considered “moderately important.” Goats had 23 (18 Gabra) species names as “moderately important” and sheep had 17 (12 Gabra) in that class.

These results accord well with studies conducted by A.C. Field (1978), C.R. Field (1979a & b) and Sato (1980) on livestock feeding habits in northern Kenya, though these authors did not work in exactly the same study area.

Little research was conducted in the area of traditional veterinary treatments, but eight plants were identified as being employed for this purpose, all of them of minor importance. *Barataa* (*Blepharis*) is burned and the ashes are spread over camel wounds; *kookomisha* (*Heliotropium albohispidum*) leaves are chewed up and applied to a snake bite to reduce swelling; the resin (*aamp'e*) from (*h*) *ammeesaa* (*C. africana*) is mixed with milk and applied to camels to remove ticks when they are in highland areas; *k'umbi* (*Commiphora myrrha jellenbeckii*), the myrrh tree, yields a resin which has many uses. One use is as a ritual cure for anthrax and is practised by a few clans. The resin is chewed and then spat all around the animal enclosure; *aaddaama* (*Euphorbia candelabrum*) is used to cure a camel disease called *gaal malaa*. A traditional doctor (*c'iressa*) must prepare and administer the medicine; *araddo* (*Commicarpus helenae*) is chewed and spat into the nose of a calf as a decongestant; *k'ors nyaata* (*Pseudosopubia hildebrandtii*) leaves are chewed up and the saliva put into the animal's mouth to protect it from a curse by a *budaa* (person with the evil eye); and (*h*) *iddi araddo* (the small or young *Solanum coagulans*) is used to treat a throat swelling disease called *c'ilmale* by burning it and passing the smoke under the animal's throat.

We cannot attest to the efficacy of any of these treatments.

Human uses

The Gabra use more species of plants for firewood than for any other purpose, with over 40 recorded Gabra taxa, though many more are certainly used. The most important, and preferred, wood is that of *Acacia tortilis*, followed by *A. reficiens* and *Maerua crassifolia* / *kaessneri*. Wood from other *Acacia* and *Commiphora* species is also commonly utilized as firewood, the frequency depending on local abundance. *Salvadora persica* (*aadde*) is not supposed to be used as firewood for reasons of *aada* (tradition), but as wood becomes more scarce younger women are sometimes using it.

According to Gabra traditional beliefs, live wood should not be cut for use as firewood. In most cases this rule is adhered to, but in areas where dead wood is rare or absent, particularly on the lava plains (*bule*), branches from living trees and shrubs will be cut. The Gabra are very conservation minded in their use of wood in cooking fires. They use small amounts and usually pull unburned faggots away from the centre of the hearth for re-use later on. The grasses listed under firewood are those most commonly used as tinder.

In construction use, 18 Gabra taxa (21 species) have been recorded. The most important is *A. tortilis* (*d'addac'a*), the preferred thorn branch to make animal enclosures and the only one allowed for building the ritual *naabo* enclosure. Other *Acacia* species are also used in boma construction and *A. reficiens* (*sigirso*) shrub is most often used as the animal enclosure gate, replaced each year in a ceremony (*almado*). Since the Gabra build on average about 10 new animal enclosures a year for

camels and sheep / goats in the main family settlements (*olla*) and several more at the satellite camps (*fora*), the amount of woody vegetation consumed per year for this purpose is substantial. Live wood is almost always used; however, it serves a dual purpose as it is later used as firewood.

The traditional Gabra house (*mana*) is also heavily dependent on plant matter. The house, or tent as it is sometimes called, is made by placing skins, cloth, mats and sometimes grass over a domed frame made of bent poles. The house poles (*dediee*, *uubaa*) are made from *Cordia / sinensis* (*mad'eera*) or *Grewia bicolor / trichocarpa* (*h arorresa*) saplings. Wood for these poles is collected at certain ritually prescribed times of the year. The tops of houses are traditionally covered with thick grass-like mats made from *Sanseveria* (*algge*), the wild sisal, but because of the large amount of time needed to go to the Golbo / Charri Ashe areas to collect it, the difficulty in processing it and its reduced abundance, other materials such as scrap aluminium and plastic sheeting are now being used. Sometimes grass thatch made from *Aristida* or, less commonly, *Paspalidium / Cenchrus / Sporobolus* (*c'iira*) is used to cover open patches on the roof or to plug air holes in the walls. *Algge* and *c'iraa* are also used to make rope and twine which are used to tie intersecting house poles and interior partition sticks together.

Leaves of *Hyphaene compressa* (*meetti*), the doum palm, are important today for roofing of permanent wattle and daub housing, and the straight branches are sometimes employed in making the wattle frame and for bed poles. *Commiphora* wood is not very important in building, being mainly used in the construction of fences of ritual enclosures (*naabo d'eeda* and *gosse*).

In the manufacture of objects of material culture ten Gabra taxa (32 species) were recorded. The most common type of object was a container or vessel, of which the Gabra have a wide variety. No attempt will be made here to present a full description of Gabra material culture as this is still subject to further research. The six most important plants used were: *Cordia* (*mad'eera*), used to make a man's walking stick (*hororo*), sometimes the (*h*) *okkoo* stick (used to shake *Acacia* pods (*arbuu*) from trees and to construct and repair the fence of the animal enclosure) and other ritual sticks; *Commiphora* (*c'allankaa* and (*h*) *ammeesaa*) used to make stools (*kaara* and *barc'uma*), water and fresh milk containers (*soroora*), and as a toothbrush stick (*rigaa*); *Delonix elata* (*sukellaa*) has a soft wood used very often in carving to make camel bells (*kokke*), fat-storage containers (*dibbe*), *soroora* and a large wooden bead (*q'ilinto*) put around camel bulls' necks during the mating season to protect them against the evil eye; *Asparagus africanus* (*ergamsa*) roots are used to weave milk containers (*c'iic'oo*), camel milking containers (*gorfa*), small containers used by children for carrying milk or water when herding, and the base and rim of *soroora*. The roots of another *Asparagus* species (or perhaps the same?) which the Gabra call *okolle* are used to weave the large (c.20 litres) water-transport and storage container (*butte*), which one commonly sees at well sites in Gabra country. *Acacia paolii* (*c'aac'anne*) is used to make various containers, and *Sterculia africana* (*k'arrari*) is used to make cleaning "cloths" (*sosso*) by shredding and then soaking the bark in fat.

The Gabra depend very little on wild plant foods. The 15 Gabra taxa (17 species) recorded were all rated by our informants as of "minimal importance". The outside of the nut of the doum palm (*k'one*) is one of the most common wild plant foods, usually eaten by children as snacks, although in times of famine they may be eaten in great quantities by everyone. Wild berries produced by *Cordia*, *Kedrostis*, *Ziziphus* and *Grewia*, amongst others, are also enjoyed by people. The root of *Vatovaea* is eaten raw, mainly for its moisture, and the seedless pods of *A. tortilis* are eaten as a famine food. The other plants in the list are usually used to make infusions from the leaves or roots. Not marked in the food category were gums and resins, commonly chewed by the Gabra, belonging mainly to various *Acacia* and *Commiphora* species.

Only 19 plants were recorded as being of medicinal use. Perhaps the Gabra do not depend as heavily as most East African peoples on herbal medicines (Kokwaro, 1976), but this list is incomplete. Investigations will have to be made with knowledgeable Gabra *c'iressa* and with *waata* (traditionally low caste hunter-gatherers), who are reputed to be very learned in the use of plant medicines, in order to discuss in detail Gabra medicinal plant use. Gabra medicine in any case seems to be based more on what one could call "faith healing", often performed by people who are known as specialists for a certain part of the body because of their clan membership. Certain clans are associated with certain

parts of the human body. Treatments often consist of ritualistic ceremonies which may or may not make use of plants; even when they do, the treatment may be no more than chewing *k'umbi* and spitting it on the afflicted person.

Plants are very important in Gabra ritual life, which itself permeates all aspects of socio-economic behaviour. Due to the complexity of explaining plant use in this domain, and the large amount of data which we have, this subject will form the basis of a separate article.

We also have the names for about 50 uncollected Gabra plants and their uses, which would add several species to each of the livestock- and human-use categories discussed above.

CONCLUSIONS

The Gabra have an intimate knowledge of plant types and distribution in their territory because their existence depends on it. Grass, herbs, shrubs and trees feed the livestock which supply the Gabra with milk, meal, blood, skins, a medium of exchange, a repository of wealth and the basis of their social organisation. Plants are therefore of most importance in terms of livestock forage, but they are also essential for use as fuel, in construction and in the manufacture of material culture objects, though with the introduction of metal and plastic items this latter use is beginning to diminish. Plants are of less importance in medicine and as human food, but they are deeply involved in Gabra ritual life.

Deforestation and land degradation from overpopulation and overstocking — desertification — is a very great threat to the future of the Gabra as nomadic pastoralists. Unless a lasting solution is found to the problem of desertification the Gabra will eventually not have the plants they need for survival.

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APPENDIX

Alphabetical list of Gabra plant names with their botanical equivalents. (Genus, species & family names)

A

aadde	<i>Salvadora persica</i> L., SALVADORACEAE
addaama	<i>Euphorbia candelabrum</i> Kotschy, EUPHORBIACEAE
agaggaro*	<i>Indigofera coerulea</i> Roxb.; <i>I. colutea</i> (Burm. f.) Merrill; <i>I. cliffordiana</i> Gillett; <i>I. insularis</i> Chiov.; <i>I. spicata</i> Forsk., PAPILIONACEAE
agarsu	<i>Commiphora erythraea</i> (Ehrenb.) Engl., BURSERACEAE
alala (buuyyo)	<i>Chrysopogon plumulosus</i> Hochst., POACEAE (GRAMINEAE)
alala)	
alge	<i>Sansevieria robusta</i> N.E. Br., AGAVACEAE
araddo	<i>Commicarpus helenae</i> (J.A. Schultes) Meikle, NYCTAGINACEAE
arru	<i>Juniperus procera</i> Endl., CUPRESSACEAE

B

baddana	<i>Balanites aegyptiaca</i> (L.) Del.; <i>B. orbicularis</i> Sprague, BALANITACEAE
baram-barro*	<i>Cucumis prophetarum</i> L., CUCURBITACEAE
barataa	<i>Blepharis ciliaris</i> (L.) B.L. Burt.; <i>B. linariifolia</i> Pers., ACANTHACEAE
boorara	<i>Caralluma speciosa</i> (N.E. Br.) N.E. Br ASCLEPIADACEAE
buratte	<i>Cucumis dipsaceus</i> Spach, CUCURBITACEAE
burk'uk'e	<i>Acacia nilotica</i> ssp. <i>subalata</i> (L.) Del., MIMOSACEAE
burraa	<i>Acacia goetzei</i> Harms, MIMOSACEAE
butte	<i>Dracaena ellenbeckiana</i> Engl., AGAVACEAE
buutiyye	<i>Ormocarpum trichocarpum</i> (Taub) Engl., PAPILIONACEAE
buuyyo**	
—biila	<i>Aristida adscensionis</i> L.; <i>A. mutabilis</i> Trin. & Rupr.; <i>Digitaria velutina</i> , POACEAE (GRAMINEAE)
—diimtu	<i>Themeda triandra</i> Forsk., POACEAE (GRAMINEAE)
—fiinc'oo	<i>Sporobolus ioclados</i> (Trin.) Nees, POACEAE (GRAMINEAE)
—harre	<i>Cenchrus setigerus</i> Vahl., POACEAE (GRAMINEAE)

C'

c'aac'anne	<i>Acacia paolii</i> Chiov., <i>A. horrida</i> (L.) Willd., MIMOSACEAE
c'allankaa	<i>Commiphora habessinica</i> (O. Berg) Engl. BURSERACEAE
c'anc'ali	<i>Combretum</i> cf. <i>denhardtiorum</i> Engl. & Diels, COMBRETACEAE
c'imp'a	<i>Vigna frutescens</i> A. Rich, PAPILIONACEAE
c'iraa (buuyyo)	<i>Paspalidium desertorum</i> (A. Rich.) Stapf; <i>Cenchrus</i> sp., <i>Sporobolus helvolus</i> (Trin.) Th. Dur. & Schinz, POACEAE (GRAMINEAE)
c'iraa)	

D

dabobbesa	<i>Rhus natalensis</i> Krauss, ANACARDIACEAE
dagamsa	<i>Carissa edulis</i> (Forsk.) Vahl, APOCYNACEAE
dak(a)d'aa	<i>Commiphora boiviniana</i> Engl., BURSERACEAE
dakkara	<i>Boswellia hildebrandtii</i> Engl., BURSERACEAE
deekuku	<i>Cadaba farinosa</i> Forsk., <i>Maerua oblongifolia</i> (Forsk.) A. Rich., CAPPARACEAE
diilaleesa	<i>Cenchrus ciliaris</i> L., POACEAE (GRAMINEAE)
dubarraara	<i>Heliotropium somalense</i> Vatke, <i>H. subulatum</i> (DC.) Martelli, BORAGINACEAE
d'ad'ale	<i>Ruellia patula</i> Jacq., ACANTHACEAE
d'addaca	<i>Acacia tortilis</i> (Forsk.) Hayne, MIMOSACEAE
d'eekaa	<i>Grewia tenax</i> (Forsk.) Fiori, TILIACEAE

- d'irri* *Croton somalensis* (Vatke) Pax EUPHORBIACEAE
d'umashoo *Maerua crassifolia* Forsk., *M. kaessneri* Gilg & Bened., CAPPARACEAE
d'uurtee *Suaeda monoica* J.F. Gmel., CHENOPODIACEAE
- E
ejerssa *Olea europea* L. ssp. *africana*, (Mill.) P.S. Green, OLEACEAE
ergamassa *Asparagus africanus* Lam., LILIACEAE
- F
fit'o *Rinorea convallariiflora* M. Brandt, VIOLACEAE
fursaa *Lycium europaeum* L., SOLANACEAE
- G
gaabbe *Vatovaea psuedolablab* (Harms) Gillett, PAPILIONACEAE
gaalle *Kedrostis gijef* (J.F. Gmel.) C. Jeffrey, CUCURBITACEAE
gaddaa *Zanthoxylum chalybeum* (Engl.) Engl., RUTACEAE
geeddi *Echinochloa haploclada* (Stapf) Stapf., POACEAE (GRAMINEAE)
gelgedaana *Digera muricata* (L.) Mart, AMARANTHACEAE
gurbi** *Seddera hirsuta* Hall. f., CONVOLVULACEAE
- H
(h)addaa *Aspilia mossambicensis* (Oliv.) Wild, *Vernonia wakefieldii* Oliv., COMPOSITAE
(h)ad'um *Fadenia zygophylloides* Allen & Townsend, *Gyroptera gilletti* Botsch, CHENOPODIACEAE
(h)afuursaa *Maerua* sp., *Cadaba mirabilis* Gilg, CAPPARACEAE
(h)allak'abeesa *Acacia etbaica* Schweinf., MIMOSACEAE
(h)ammeesaa* *Commiphora africana* (A. Rich.) Engl., BURSERACEAE
(h)ank'arre *Setaria verticillata* (L.) P. Beauv., POACEAE (GRAMINEAE)
(h)arkeena *Euphorbia tescorum* Carter, EUPHORBIACEAE
(h)arfuuk'a *Sporobolus spicatus* (Vahl) Kunth, POACEAE (GRAMINEAE)
(h)armaac'a *Cistanche tubulosa* (Schenk.) Hook. f., OROBANCHACEAE
(h)arorressa *Grewia trichocarpa* A. Rich., *G. bicolor* Juss., TILIACEAE
(h)asura*
— *Crotalaria* cf. *dumosa* Franch, PAPILIONACEAE
—harre *Indigofera coerulea* Roxb. var. *occidentalis* Gillett & Ali, PAPILIONACEAE
— *Cassia italica* (Mill.) F.W. Andr., subsp. *micrantha* Brenan, CAESALPINIACEAE
(h)idaa *Euphorbia cuneata* Vahl, EUPHORBIACEAE
(h)iddi*
—loonni *Solanum incanum* L., SOLANACEAE
—ree (aradab) *S. coagulans* Forsk., SOLANACEAE
- I
ic'iinni *Triumfetta flavescens* Hochst., TILIACEAE
id'd'aad'o *Acacia senegal* (L.) Willd., MIMOSACEAE
ilk'abate *Pavonia zeylanica* (L.) Cav., MALVACEAE
ilmmogora *Leptrothrium senegalense* (Kunth), Clayton, POACEAE (GRAMINEAE)
- J
jilbeete *Sericocomopsis hildebrandtii* Schinz, *Dasysphaera prostrata* (Gilg & Schinz) Caraco, AMARANTHACEAE
—kurroftu *Leucas pododiskos* Bullock, LAMIACEAE
- K
kokoomisha *Heliotropium albohispidum* Bak., BORAGINACEAE

- K'
- k'ad'u *Cadaba mirabilis* Gilg, *C. gillettii* R.A. Graham; *Boscia* (?), CAPPARACEAE
- k'alk'acca *Maerua angolensis* DC., *M. crassifolia* Forsk.; *boscia coriacea* Pax, CAPPARACEAE
- k'antallaa *Trianthema salsoides* Fenzl., AIZOACEAE
- k'arrarri *Sterculia africana* (Lour.) Fiori, STERCULIACEAE
- k'arrarru *Acokanthera schimperi* (A.DC.) Schweinf., APOCYNACEAE
- k'atte *Ecbolium revolutum* (L.) C.B. Cl., ACANTHACEAE
- k'ayyu *Commelina latifolia* A. Rich., COMMELINACEAE
- k'iltaa *Ficus glumosa* Del., MORACEAE
- k'iltip'p'e *Indigofera spinosa* Forsk., PAPILIONACEAE
- k'obbo *Calotropis procera* (Ait.) Ait. f., ASCLEPIADACEAE
- k'onc'orro *Cenchrus pennisetiformis* Steud., POACEAE (GRAMINEAE)
- k'oraatti gaala *Commicarpus helenae* (J.A. Schultes) Meikle, NYCTAGINACEAE
- k'ork'odda Indet., CAPPARACEAE
- k'orrobbo *Terminalia spinosa* Engl., *T. polycarpa* Engl. & Diels, COMBRETACEAE
- k'ors nyaata *Pseudosopubia hildebrandtii* (Vatke) Engl., SCROPHULARIACEAE
- k'umbi *Commiphora coriacea* Engl., *C. ellenbeckii* Engl., BURSERACEAE
- k'urk'uura *Ziziphus abyssinica* A. Rich., RHAMNACEAE
- L
- laabbesa *Panicum coloratum* L. POACEAE (GRAMINEAE)
- laamisho *Zaleya pentandra* (L.) Jeffrey, AIZOACEAE
- lakud'e Indet., ACANTHACEAE
- lookko *Diospyros abyssinica* (Hiern) F. White, EBENACEAE
- luuftoole *Corchorus trilocularis* L., TILIACEAE
- Farsetia stenoptera* Hochst. CRUCIFERAE
- M
- maa *Dactyloctenium bogdanii* S.M. Phillips, POACEAE (GRAMINEAE)
- mad'eeka *Barleria* sp., ACANTHACEAE
- mad'eera *Cordia sinensis* Lam., BORAGINACEAE
- marmma *Cocculus pendulus* (J. R. & G. Forst.) Diels, MENISPERMACEAE
- mat't'anne *Pupalia lappacea* (L.) Juss, *Sericocomopsis* sp. (?). AMARANTHACEAE
- meetti *Hyphaene compressa* Wendl., ARECACEAE
- mogorre *Tribulus cistoides* L., ZYGOPHYLLACEAE
- mookofa *Croton dichogamus* Pax, EUPHORBIACEAE
- muk-illeensaa *Aerva javanica* Schultes, AMARANTHACEAE
- N
- nyaap'p'o *Croton megalocarpus* Hutch., EUPHORBIACEAE
- O
- obbe *Adenium obesum* (Forsk.) Roem. & Schult., APOCYNACEAE
- Adenia venenata* Forsk., PASSIFLORACEAE
- ogomdi *Grewia villosa* Willd., TILIACEAE
- ogoono *Pennisetum mezianum* Leke, POACEAE (GRAMINEAE)
- okolle *Asparagus africanus* Lam., LILIACEAE
- R
- raafu*** *Aristolochia bracteolata* Lam., ARISTOLOCHIACEAE
- rorroddo *Cyphostemma nieriense* (Th. Fr. jr.) Desc., VITACEAE
- rukesa *Combretum molle* G. Don, COMBRETACEAE

S

- saariima *Duosperma eremophilum* (Milne-Redh.) Napper, ACANTHACEAE
 saatu Indet., POACEAE (GRAMINEAE)
 sap'ans gurraaca *Acacia mellifera* (Vahl) Benth., MIMOSACEAE
 sigirso *Acacia reficiens*, *Wawra* ssp. *miser* (Vatke) Brenan, MIMOSACEAE
 sokorsitu *Sehima nervosum* (Rottl.) Stapf., POACEAE (GRAMINEAE)
 sukellaa *Delonix elata* (L.) Gamble, *Caesalpinaceae*
 suufki *Aerva javanica* Schultes, AMARANTHACEAE

SH

- shiisha *Barleria acanthoides* Vahl, ACANTHACEAE

U

- uube *Rhynchosia minima* (L.) DC., PAPILIONACEAE

W

- waac'c'u *Acacia seyal* Del. var. *fistula* (Schweinf.) Oliv., MIMOSACEAE
 waaraa *Commiphora incisa* Chiov., BURSERACEAE
 waanga *Acacia nubica* Benth., MIMOSACEAE
 waleena *Erythrina melanacantha* Harms, *E. burtii* Bak. f., *E. rotundata-obovata*
 Bak. f., PAPILIONACEAE
 warab reeba *Commiphora ellenbeckii* Engl., BURSERACEAE
 warjidda *Abrus schimperi* Bak. ssp. *africanus* (Vatke) Verdc., PAPILIONACEAE

* These are generics. The specific forms are labelled according to their use (liked by camel, goat etc.; incense; toothbrush, etc.), eco-zone (*badda*, *gammooji*, *bule*, etc.), sometimes by colour (given by the soil) or reproductive characteristic (male, female).

** *Buuyyo* is the general word for grass and *gurbi* means "bush" or "shrub". Both words sometimes form part of the name, followed by a qualifier.

*** *Raafu* is the general work for plants whose leaves are cooked and eaten like spinach. It applies to more than one species.

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The authority should not be given if scientific names are used to describe an "association" or species complex, e.g. *Acacia drepanolobium* - *Themeda triandra*, wooded grassland. Type in capitals the first letter of the English names of species (e.g. Crowned Eagle, Grey-capped Warbler) but not of the higher taxa (e.g. eagles, warblers).

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STRUCTURE AND FUNCTION OF AFRICAN FLOODPLAINS

JOHN J. GAUDET*

United States Agency for International Development,

ABSTRACT

In Africa, floodplains often cover enormous areas. They represent a formidable dry season refuge for the indigenous flora and fauna, but at the same time they have a large potential for the intensive, highly productive agriculture and hydropower production so desperately needed in Africa. The main topographic features of the larger floodplains are reviewed in this paper, along with a general insight into water relations, nutrient dynamics, productivity, species distribution and changes in vegetation induced by present management practice. The question is raised of whether floodplains will survive in the face of development, and a call is made for alternative management strategies.

INTRODUCTION

The inland water habitats of Africa make up about 450,000 km² of the continent (Table 1). These habitats include seasonally inundated wetlands, such as swamp forest, peatland, mangrove swamp, inland herbaceous swamp and floodplain, as well as permanent water habitats. The habitat of most concern to us here is the floodplain, which is any region along the course of a river where large seasonal variation in rainfall results in overbank flooding into the surrounding plains. Some of these flooded plains are enormous and are equal in size to the world's largest lakes (Tables 1 & 2). In African floodplains the typical complex vegetation mosaic is most obvious from the air, because they often cover enormous areas, stretching out as far as the eye can see.

In this paper I can only touch briefly on the more important aspects of floodplains. In Africa they defy intensive study for a number of reasons, consequently this paper must be regarded only as a review. I hope it will provide some food for thought and a basis for future research.

* Present address: AFR/ARTS/FARA, Room 2941, Dept. of State, Washington DC 20523, U.S.A.

The views and opinions expressed here are strictly those of the author, and in no way should they be interpreted as the views and opinions of the U.S. Government or its official agencies.

Table 1: Large open water habitats in Africa.
Estimated area based on information in Beadle, (1974) and world atlases

Water body	Area (km ²)
Lake Victoria	75,000
Lake Turkana	32,500
Lake Malawi	24,000
Lake Kivu	16,000
Lake Chad	15,000
Lake Tanganyika	8,000
Lake Mobutu	4,700
Lake Edward	2,250
Lake Chilwa	700
Lake George	290
Lake Naivasha	240
Man-made lakes	27,000
<u>Total open water</u>	<u>205,680</u>
Floodplains	245,075
<u>Total water habitats</u>	<u><u>450,755</u></u>

METHODS

General features

The complexity of the vegetation mosaic seen in tropical floodplains is often the result of physical features relating to local substratum or to the effects of topography, which in turn affect the availability of water and nutrients. Thus in order to understand the basic functions of the floodplain systems we must first look at their general features (see Welcomme, 1979).

Topography

The main topographic features within floodplains are either depressions, i.e. water bodies, or areas raised because of deposition, such as sand bars and mud flats. A typical feature is the *levée*, which is a raised berm or crest above the floodplain surface. It contains coarse material deposited as the flood flows over the top of the channel bank (Welcomme, 1979). Sutcliffe (1957) described the process whereby a silt-laden river, such as the White Nile, descending an appreciable gradient builds up its own bed and *levées* until it actually flows at a level above the surrounding floodplain. As the bed slope flattens and flow rates decrease, suspended material is deposited more rapidly, *levées* decrease in size, and the floodplain widens. Deposition is encouraged by vegetation growing on the *levées*. A good example is seen on the Cubango River after it leaves Angola and before it enters the Okavango Delta (Fig. 1), also the upper Zaire River with its associated vegetation (Fig. 2). *Levées* are seen further downstream in the Okavango, and they are also evident where the Nile traverses the Sudan in the Sudd Swamp region. The *levées* along the Nile River in the Sudd region trap the annual floods in depressions adjacent to the river. These are locally known as "toiches" (Fig. 3) and are fertile, seasonally-flooded habitats which support a wide variety of plant and animal species.

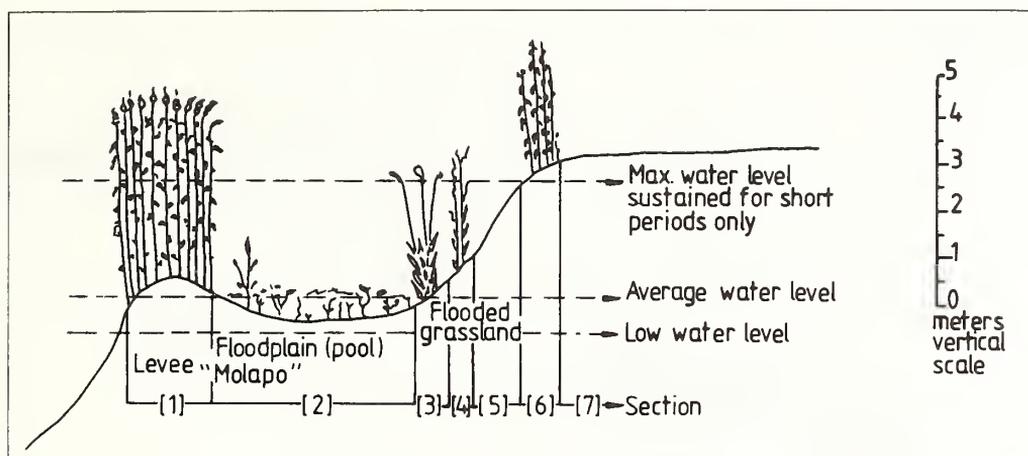


Figure 1. Profile of levée and floodplain (molapo) along the Cubango River, Angola (after Smith, 1976)

Table 2: Major African floodplains (after Welcomme, 1979 & Thompson, 1985). Location numbers refer to figure 6

Location number	River system	Region	Area of high water (km ²)	Area of low water (km ²)	Range of conductance ($\mu\text{s}\cdot\text{cm}^{-1}$)
1	White Nile	Sudd Region, southern Sudan	92,000	10,000	20-500
2	Middle Congo	Zaire and Congo	40,500	-	-
3	Niger	(see text)	25,980	5,980	31-70
4	Chari and Logone	Lake Chad swamps Yaerés floodplain	13,800 <u>5,950</u>	-	41-82
		<i>Sub total</i>	19,750		
5	Okavango	Botswana internal delta	16,000	3,120	-
6	Kenamuke in S. Sudan	Internal delta	13,950	-	-
7	White Volta and Oti	Volta Swamps in Ghana	8,530 <u>4,810</u>	-	41-124
		<i>Sub total</i>	13,340		
8	Senegal	Main river swamps Delta	4,560 <u>7,970</u>	500 -	72 -
		<i>Sub total</i>	12,530		
9	Lualaba	SE Zaire, Kamulando depression in the Upemba Basin	11,800	7,040	141-255
10	Zambezi	Barotse Plains in Zambia	9,000	700	57-126
11	Luapula	Bangweula swamp, Zambia	8,800	-	-
12	Rufiji	Kilombero area in Tanzania	6,650	-	-
13	Kafue	Kafue flats in Zambia	6,000	-	130-320
14	Niger	Niger River floodplain	4,800	1,800	-
15	Luena	Liuiwa plains in Zambia	3,500	-	-
16	Benue	Benue floodplain in Nigeria	3,100	1,290	-
17	Kafue	Lukanga swamps N. of Kafue flats, Zambia	2,500	-	-
		<i>Sub total</i>	<u>56,150</u>		
		Total area	290,200	30,430	

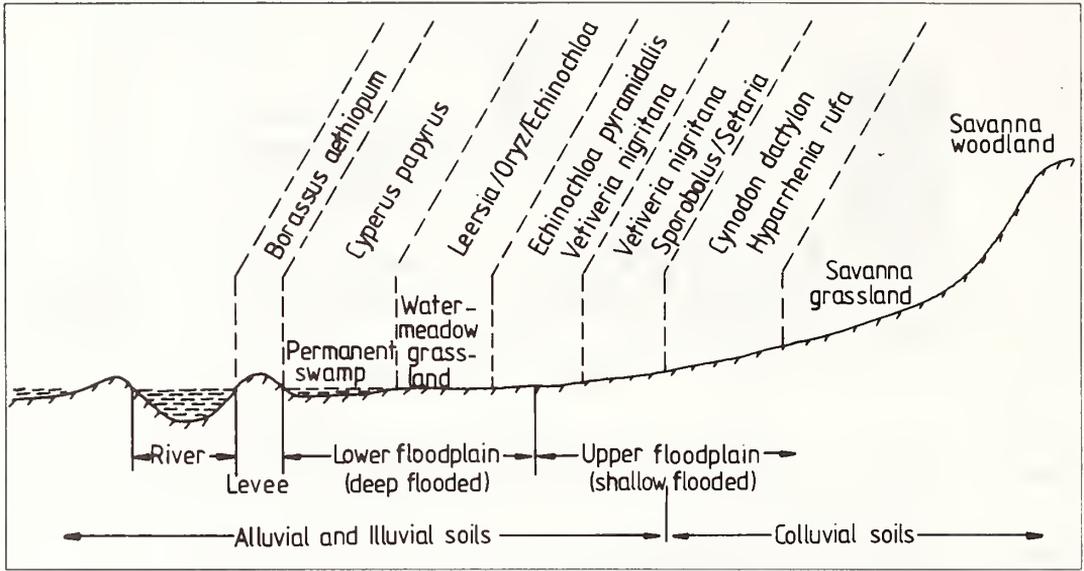


Figure 2. Sectional diagram of the upper Zaire River Basin (Shaba Province, Zaire) showing typical vegetation zonation associated with levées (after Thompson, 1985)

As the level of the floodplain rises through deposition, the river eventually permanently breaches through some overspill notch in a levée, usually upstream. Flow is then diverted in a new direction across the floodplain. This leads to a complex system containing numerous water bodies. Welcomme (1979) distinguished the following:

- Lakes: large features which persist relatively unchanged over a number of years;
- Lagoons: water bodies which remain connected to the river throughout the year;
- Pools: smaller, more ephemeral bodies of water becoming isolated, drying out in some seasons; and
- Swamps: depressions where the soil remains saturated, more or less permanently covered with water

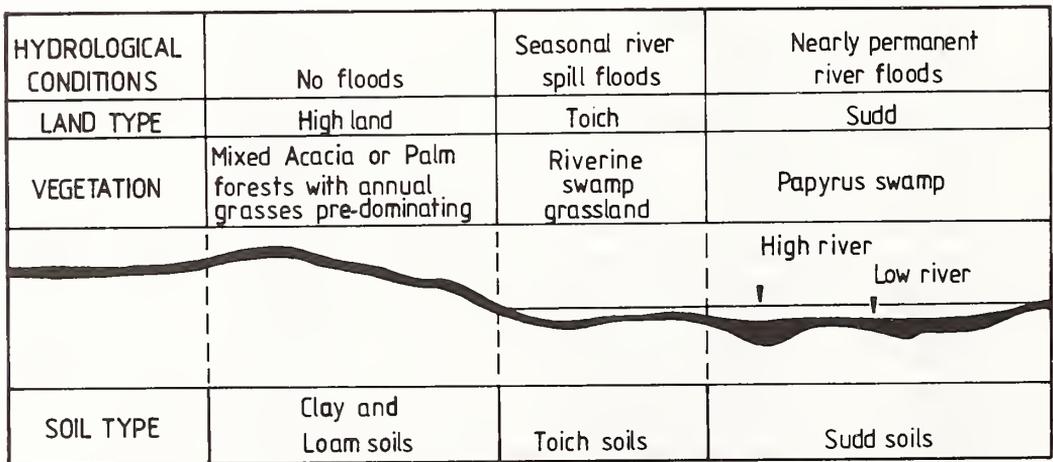
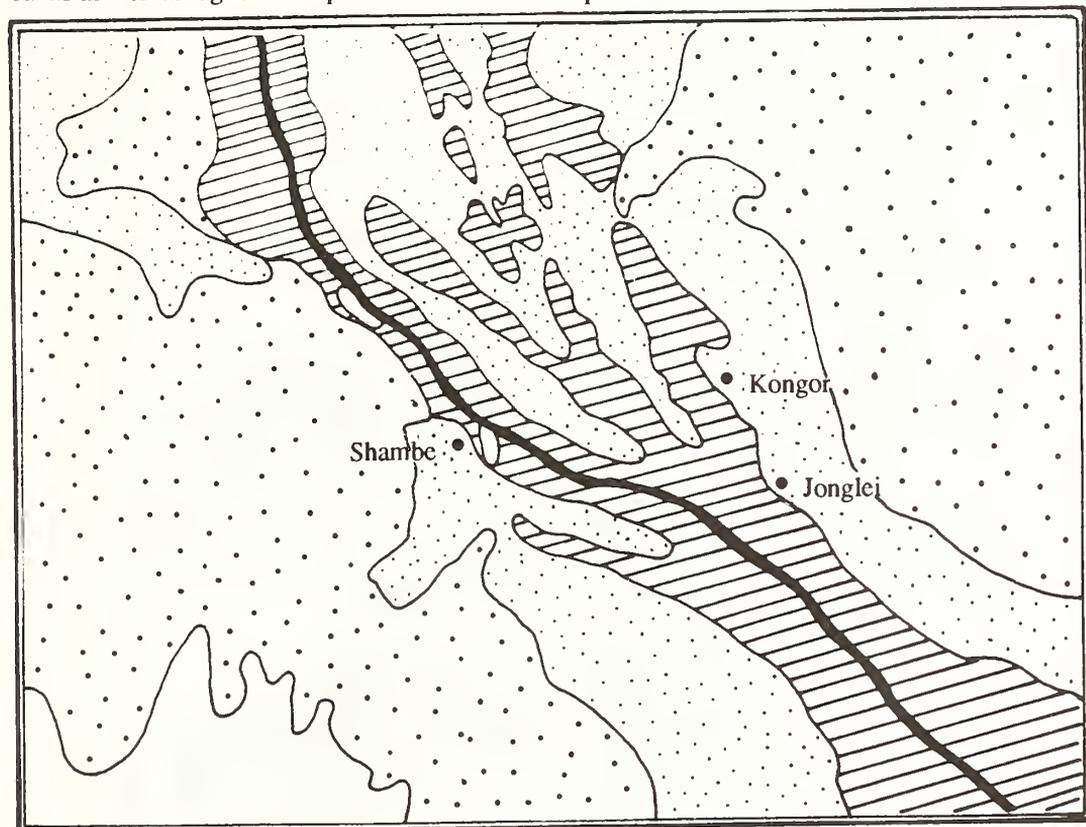


Figure 3. General profile of White Nile floodplain

All these features can be seen in one portion of a floodplain on the Nile in southern Sudan (Fig. 4). Here two lakes, Lakes Nvong and Shambe, are seen along the course of the main river channel, the Bahrel Jebel, a branch of the White Nile. Perennial papyrus swamps line the river banks as well as lagoons and pools which are seen in profusion.



 Permanent swamp

 Medium to deep flooded

 Shallow flooded

 High ground (after Welcomme, 1979)

Figure 4. One section of the White Nile Sudd region between Shambe and Kongor (68°N ; $30\text{-}31^{\circ}\text{E}$)
Two small lakes (Nuong and Shambe) are shown along with several towns

The pools and lagoons in an African floodplain are dynamic ecosystems in themselves. Their physical features change dramatically with the wet and dry seasons when they often either dry up or fill up. This is clearly seen in a sequence shown for the Senegal River (Fig. 5), based on Reizer's (1974) work, where he shows a flooding sequence which leaves behind only one large lagoon, Vindon Edi Lagoon, which persists for some time.

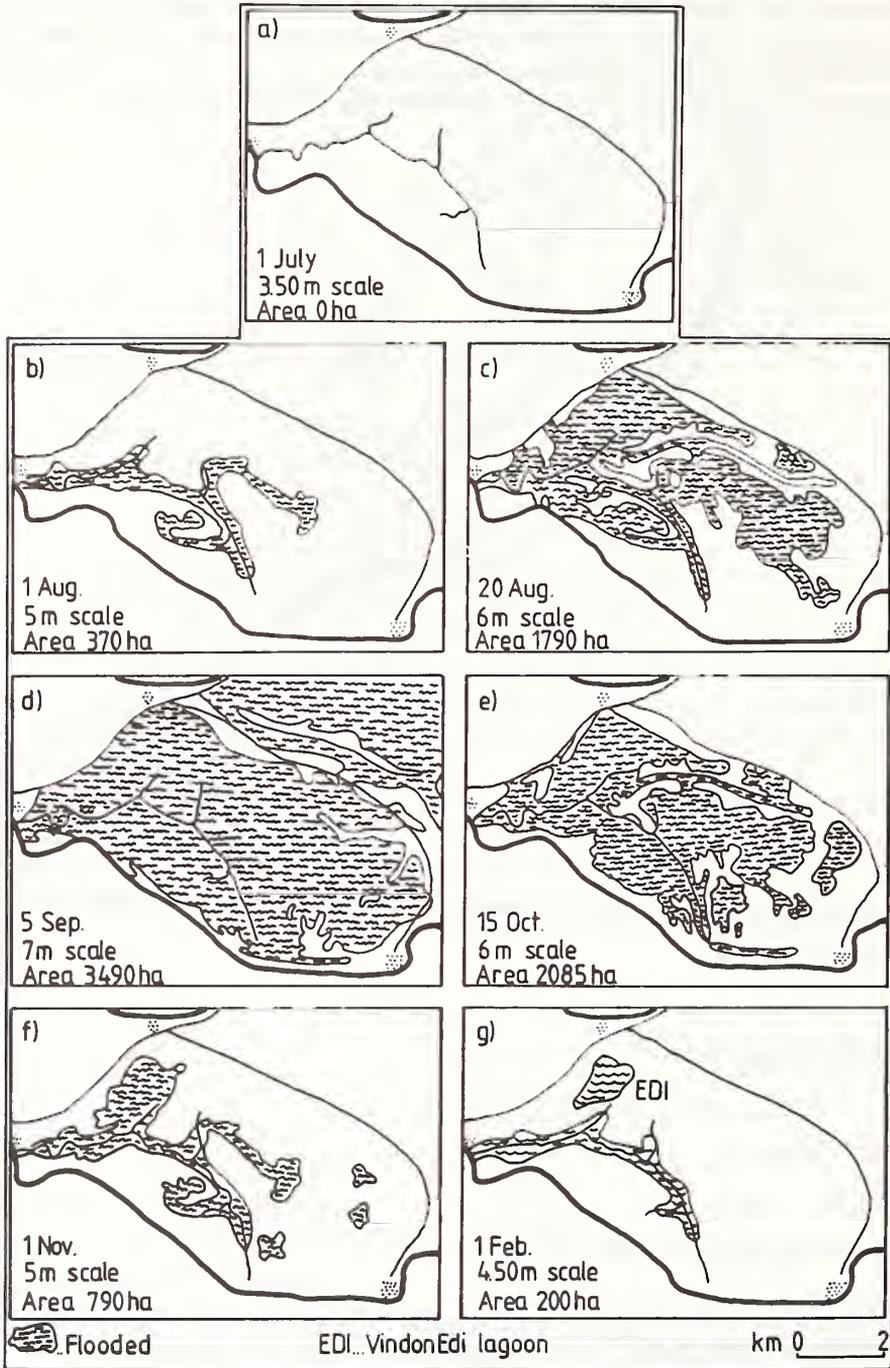


Figure 5. Annual flooding cycle of Senegal River floodplain (after Reizer, 1974)

Major African floodplains

African floodplains of 1,000 kms² or more are listed in Table 2 and located on Fig. 6. The largest are internal deltas which occur when a river system encounters some geological barrier causing lateral spread over very large alluvial plains. Good examples are: the Sudd region (Fig. 4), Yaerés Floodplain (Figs 7 & 8), Niger Central Delta (Fig. 9), and the Okavango Delta (Fig. 10). The total area of these major flooded wetlands, 290,000 km² is reduced during low water periods by approximately 85% to only about 43,500 km², but as Thompson (1985) points out, the total areas flooded each year in continental Africa will be difficult to calculate. If the countless smaller regions are included, the estimated total would greatly exceed the below figure.

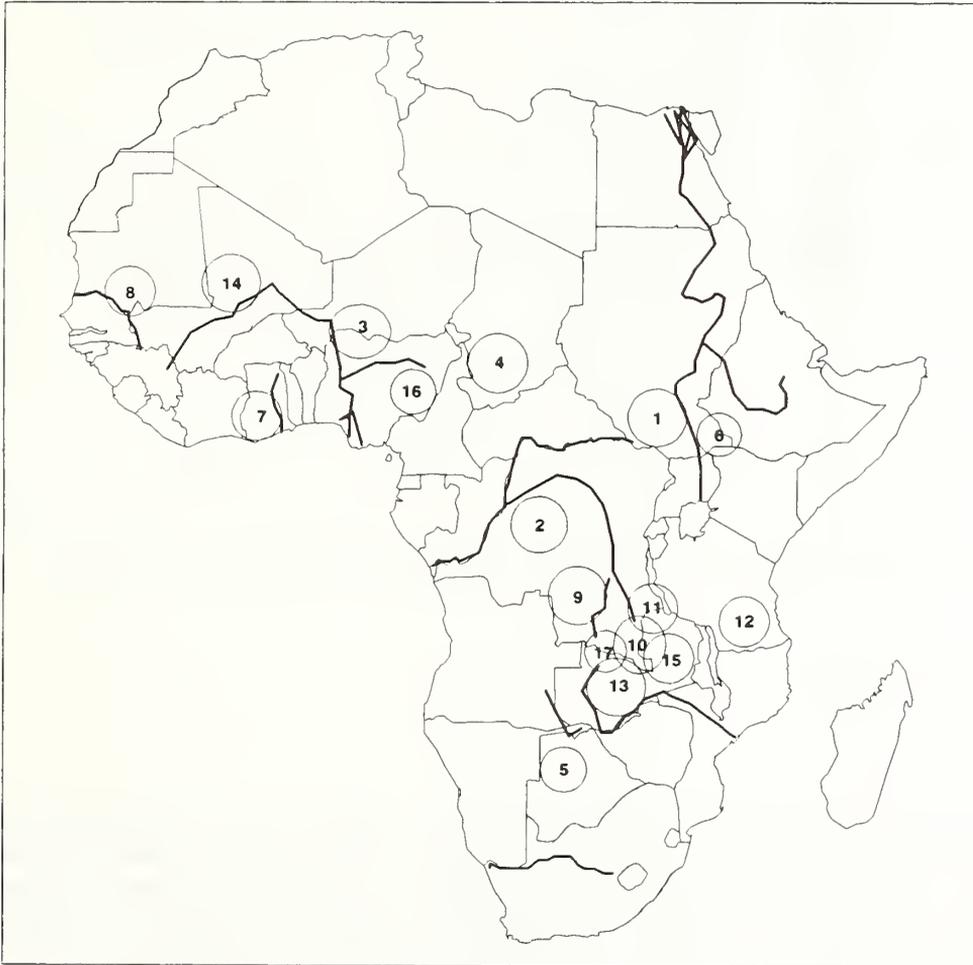


Figure 6. Sketch map of Africa showing the location of major floodplain regions. Main African herbaceous wetlands and waterbodies located as follows:

1. Sudd Swamps of Upper Nile; 2. Middle Congo Swamp Region; 3. Niger Central Basin; 4. Lake Tchad Basin and Yaerés Floodplain; 5. Okavango Delta; 6. Kenamuke Swamp, Sudan; 7. Volta River; 8. Senegal Floodplain; 9. Upemba Basin, Lualaba River; 10. Barotse Plains; 11. Laupula Floodplain, Bangweula Swamp; 12. Rufiji Kilombero Swamp; 13. Kafue Floodplain; 14. Niger River Floodplain; 15. Luiwa Floodplain, Zambia; 16. Benue Floodplain; 17. Lukanga Swamps.

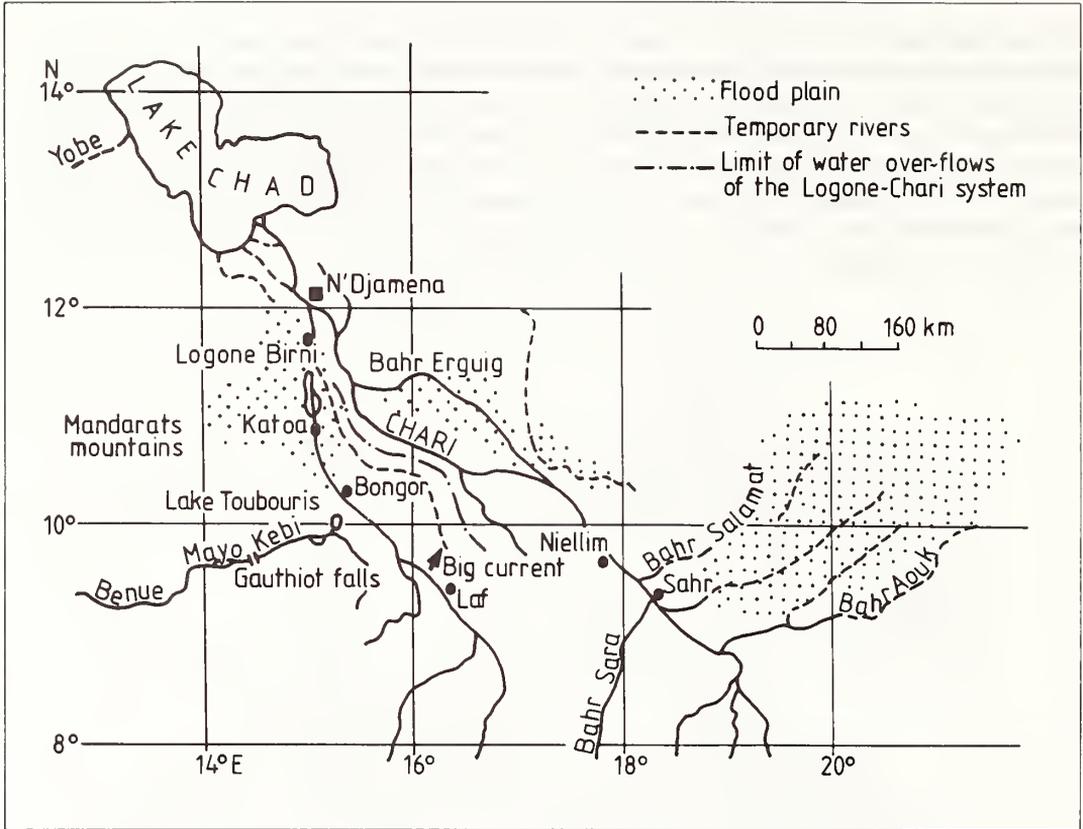


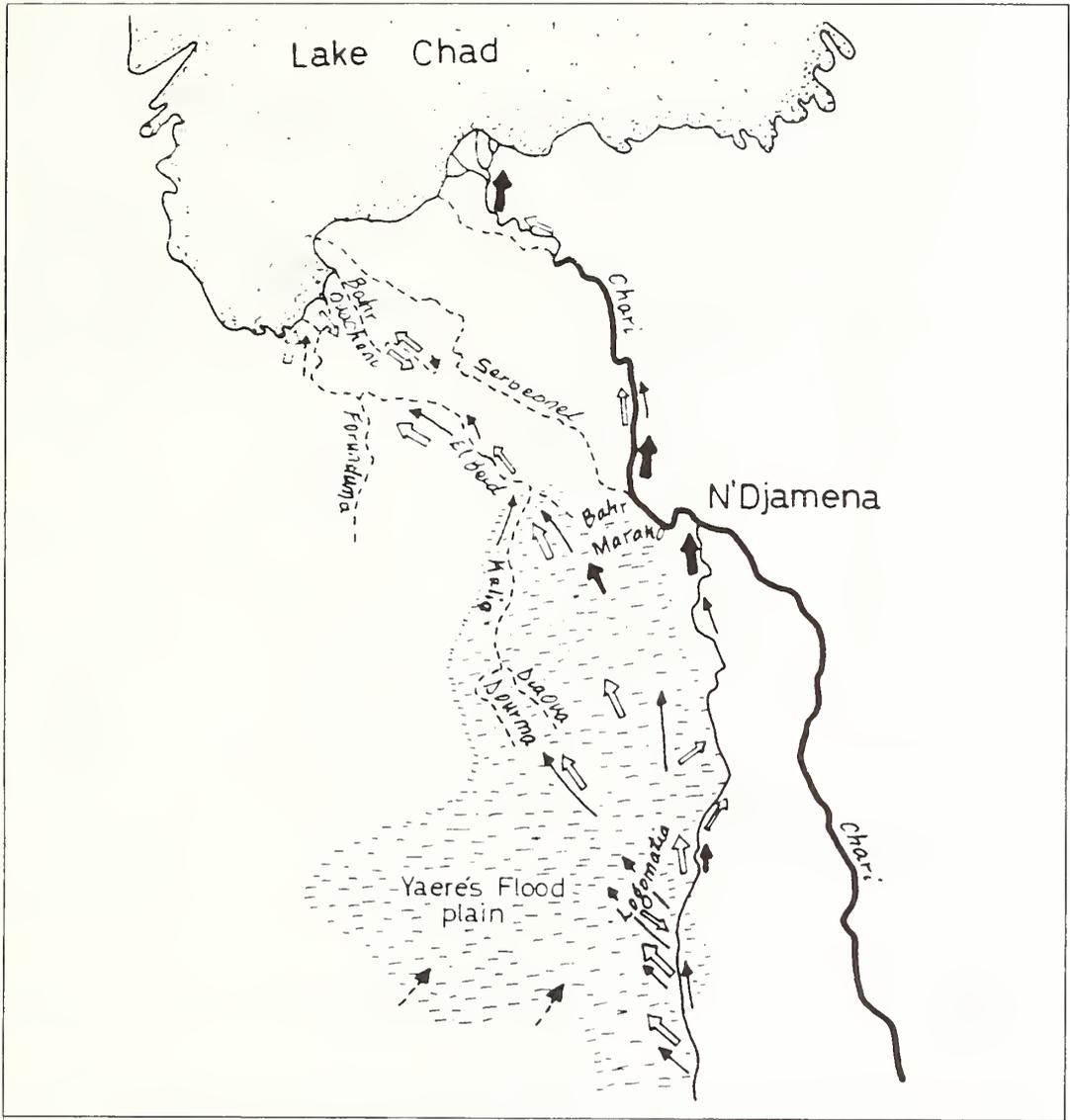
Figure 7. Yaerés floodplain on the Chari and Logone rivers (after Carmouze *et al.*, 1983)

Water and nutrients

Water relations

When dealing with such enormous regions in remote areas where only spot meteorological records are available, only rough estimates can be made of water relations. In large wet regions, the water balance would be complicated by local climatic conditions. Welcomme (1979) noted that precipitation on the floodplain itself saturates the soil, causing local flooding which often precedes the main overspill flood from the river. This is dramatically true in the Sudd region where the rain falls on impervious soil on either side of the river and then drains toward the channel. Extensive flooding may be evident even before the annual river flood occurs.

The inundation of the upper Chari Basin and most other floodplains such as those of the Niger, Lualaba, Zambezi, Volta, Senegal and Kafue, follows similar patterns. However, there are exceptions to the general rule. In the Okavango Delta, peak rainfall coincides with periods of low water and high evaporation in the floodplain; also, local rainfall is so erratic that no regular floodplain saturation may occur before the annual river flood. The water deficit here may be so large that on occasion no water comes out of the system.



- Seasonal watercourses
- Main directions of water flow
- - - → Minor direction of water flow
- ⇨ Main direction of migrating juveniles
- ⇨ Secondary movements of juveniles
- ⇨ Main direction of migrating adults
- ⇨ Secondary movement of adults

0 50 km



Figure 8. Yaerés floodplain showing annual fish migration routes (after Welcomme, 1979)

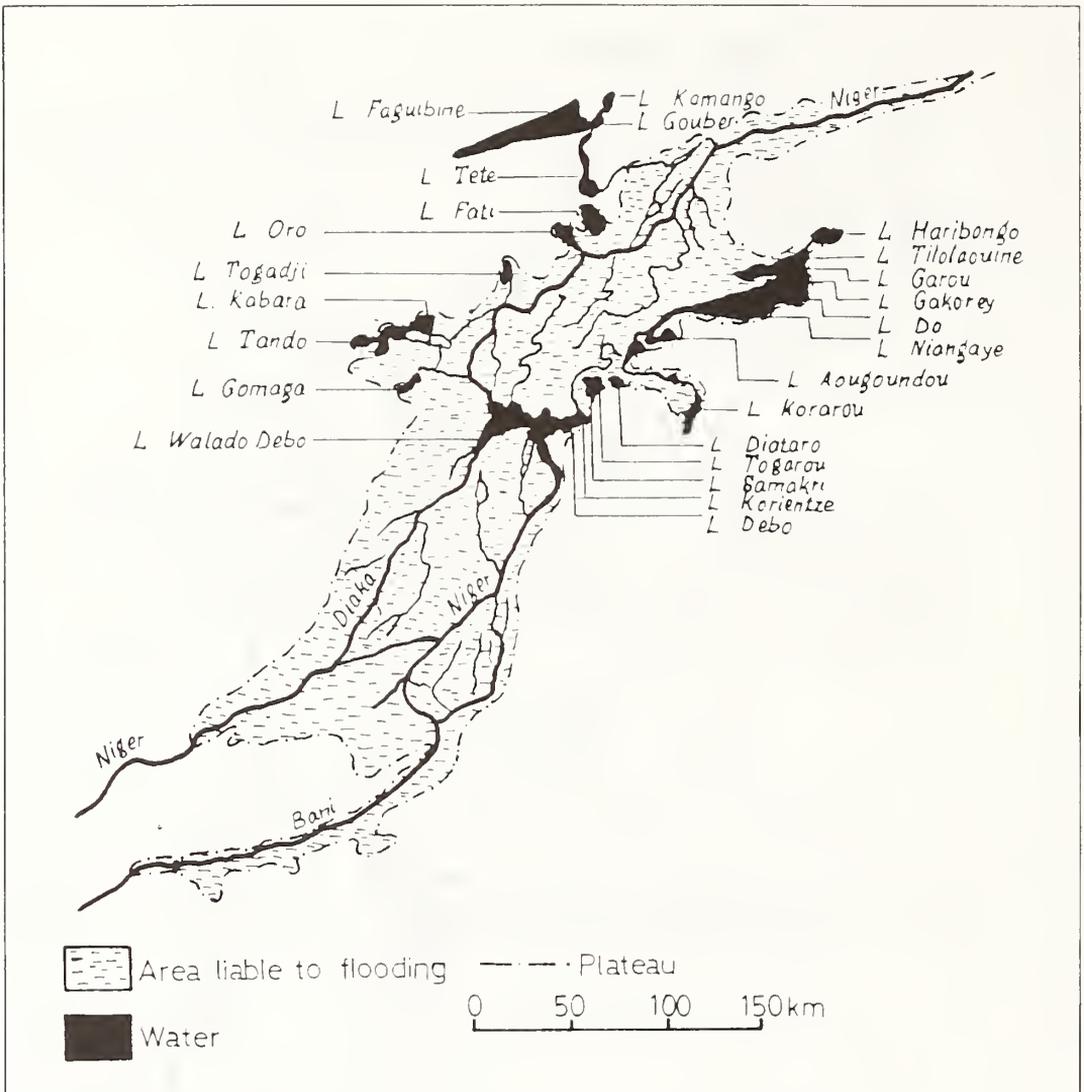


Figure 9. Internal delta of the Niger River showing numerous lakes within the system (after Welcomme, 1979)

Several workers concur that in Africa the evaporation rate in floodplains exceeds precipitation and in general a water loss can be expected during river passage through a floodplain (Table 3). This loss, 46-96% is due to evaporation from open water, evapotranspiration from emergent vegetation, and seepage loss. However, in most areas it is difficult to conceive of seepage loss as being significant because the fine clay deposits typical of floodplain areas would seem to act as a natural barrier to ground water loss. It is true that in some areas, such as the Okavango or Chari regions sand deposits are more prevalent and these would be conducive to ground water loss, and such ground water loss does occur in the Okavango region where the water tables slope away from the main flow channels. Water and mineral balance studies in the Lake Chad region also point to

about 8% seepage loss in the sandy substrata in the southern part of the lake (Carmouze *et al.*, 1983). In many areas, including Lake Chad, the underlying substrate is a mud or compacted clay, or the surrounding soil may be so impervious, as in southern Sudan that water remains on the ground after rain, slowly moving downslope, a phenomenon referred to as “creeping flow” by local hydrologists.

Evaporation and evapotranspiration (ET) in floodplains are even more controversial topics than seepage. Evaporation would occur from a variety of surfaces such as: open water, dry soil or wet mud and would be complicated by advected energy, which is high in open areas low inside the vegetation. Albedo also will vary with degree of wetness, burning of vegetation and other factors. The ET of papyrus has been shown to be less than that of open water (Rijks, 1969), possibly because it forms a closed canopy. On the other hand, open stands of an emergent macrophyte, e.g. *Phragmites sp.* will lose water at rates considerable in excess of those expected from open water (Imhof & Burian, 1972).

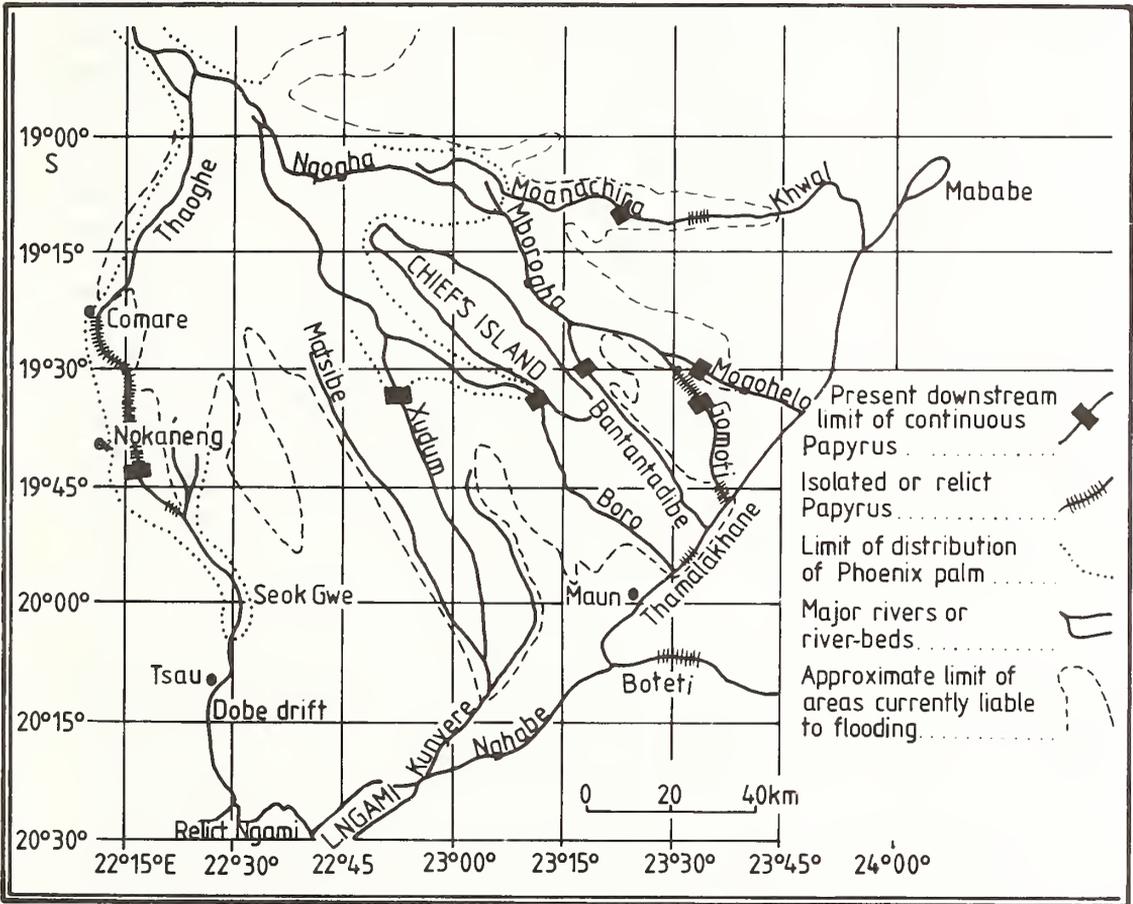


Figure 10. Distribution of papyrus and phoenix palm associations in the Okavango Delta (after Smith, 1976)

Table 3: Annual water balance in several floodplains
(data from Welcomme, 1979 and Thompson, 1976)

Floodplain	Station	Precipitation (mm)	Evaporation (mm)	Input (mm)	Output ($\times 10^{10} \text{m}^3$)	Net Loss %
Niger	Bamako, Mali	1120	2150	7.11	3.82	46
Nile (Sudd)	Wau, Sudan	1100	1900	2.70	1.40	48
Okavango	Maun, Botswana	434	1800	1.18	0.06	95

Water chemistry and nutrient dynamics

Generalizations about water chemistry in floodplains are difficult to make because of inter- and intrahabitat complexity. The most often measured floodplain parameter is conductivity (see Table 2), but measurements are usually taken in open standing water and may not be a useful indicator of floodplain conditions. Conductivity in the main channel seems mostly influenced by: dilution with flood or rain water; solution input from land; swamps or floodplain drainage; evaporation; uptake by the biota; and absorption by sediments. Welcomme (1979) pointed out that all of these effects tend to produce higher conductivities in the dry season both in lagoons and river channels resulting in an inverse relationship between water depth and conductivity in African rivers. A secondary conductivity maximum due to solution input occurs when the river water invades the floodplain. The conductivity rise is usually accompanied by a pH drop due to acid swamp water input. The Niger central delta is an exception with a pH rise which remains unexplained. The conductivity rise and pH decrease is also accompanied by a decrease in dissolved oxygen which is typical during stagnant swamp or floodplain conditions. During dry seasons standing water in floodplains becomes stagnant, and this stagnation is strongly stratified due to a lack of strong wind effects and intense insolation. Sudden reductions in air temperature association with a cold front or a strong wind storm can break down this stratification. This results in an upwelling or "overturn" which can raise the oxygen deficit and cause chemically reduced bottom waters, and fish kills often result (Welcomme, 1979). Overturns and fish kills can also be caused during the entry of river floodwater at the beginning of the flood season. This is an indication of how strongly reduced the bottom water can be in floodplains.

One way of looking at changes in water chemistry in a floodplain is to compare the input to the output and assume all net changes can be ascribed to the overall system, that is, by using a "black box" approach. In floodplains or other large wetlands this approach is taken more out of futility than anything else. For example, longitudinal transects of water chemistry were done by Talling (1957) and Bishai (1962) along a 1,000 km stretch of the Nile river where it passes through the Sudd region along the Bahr el Jabel. In this section of the river the results of both Talling and Bishai show that conductivity, alkalinity, calcium and chloride levels were erratic and did not follow any distinct pattern. This agrees with a study by Gaudet (1978) who found that tropical swamps had little effect on the salinity of the through-flow, as long as the water passed freely through the system. Both Talling and Bishai did find some effects on water chemistry along the 1,000km stretch of the Nile in that there were decreases in oxygen, sulphate and pH, and a rise in carbon dioxide, silicate, ammonia and iron in the river. Many of these changes could be explained on the basis of decomposition effects, the sort of general effects that are typical of mires and floodplains (Howard-Williams & Gaudet, 1985).

A recent study was carried out in the Sudd Region to determine the ecological impacts of the Jonglei Canal (Anon, 1983). Part of the study was devoted to determining the effects of the Sudd on the chemistry of the water passing through. Because of the complexity of the system, earlier

results as above and the enormous overriding effect of evaporation (a 50% loss of water occurs while it transits the Sudd) it was assumed that the effects of the whole system would be of limited magnitude. The study therefore concentrated on only a small portion of the whole Sudd. Two permanent sampling stations were set up, one at Bor, where the White Nile can be sampled prior to entering the Sudd and one downstream at Dhiam-Dhiam where a branch of the main White Nile river (the Atem) has passed through 75 km of floodplain and swamps. The effects noted (Table 4) were not much different from those noted in previous studies. The authors used the general model proposed by Gaudet (1979) for East African wetlands which proposes that three phases could be detected in the papyrus swamps on the northern edge of Lake Naivasha in Kenya, that is: stagnation, through-flow and drying. Apparently the Sudd region below Bor follows a remarkably similar pattern to the Lake Naivasha system. This even includes a rough correspondence of annual cycles. The results of the Sudd study show an overall decline in oxygen and pH, with increases in dissolved carbon dioxide. A decrease also occurred in nitrate, phosphate and sulphate as expected. It is significant that high levels of dissolved silicon were found entering and leaving the system. All of these results are similar to those found by Gaudet working on papyrus swamps in Uganda and Kenya (Howard-Williams & Gaudet, 1985).

Table 4: Summary of the processes at work in the Sudd wetlands, and the overall effects on water passing through the system (based on Anon, 1983)

Phase	I	II	III
Status	Stagnation	Through-flow	Drying
Season	Late dry	Wet	Late wet-Early dry
Water balance	Low river input, Minimal outflow	Early pulses of river water inflow	Minimal inflow with continued drainage
Processes in operation	Decomposition and evapotranspiration	Flushing due to influx of river water	Stagnation begins
Water chemistry increase, rise in phosphate and iron	Turbidity decrease, colour	Alkalinity increase	Rise in conductance
Effect on receiving waters	Very little outflow	Early flush of high alkalinity, later flush is more dilute	General outflow of high conductance water

The Sudd study concluded "the Sudd is unlikely to act as a long-term nutrient trap," because most of the nutrient inputs into the Sudd will be taken up into the organic plant fraction and this will be recycled within the wetlands or flushed out into the river. However, the Sudd wetlands do have an ability to take up large amounts of nutrients on a short-term basis and this phenomenon is important in that the wetlands involved can act as a buffer to prevent large flushes of nutrients from entering receiving waters.

The amounts that can be taken up can be estimated if we assume that much of the swamp and floodplain production is turned into detritus. This process would remove large amounts of soluble nutrients from the water passing through the system, and this in turn would affect the chemistry of water downstream. A rough estimate based on this assumption (Table 5) shows that the Sudd could have less effect on major inorganic ions such as Sodium (Na), Potassium (K), Calcium (Ca),

Magnesium (Mg) and Chloride (Cl), than on nutrient ions which are present at much lower concentration levels, such as Nitrogen (N), Phosphorous (P), Sulphur (S) and Iron (Fe). the nutrient ions would be even more strongly affected than this estimate because they would be in great demand by the river biota. In theory, the swamps and floodplain would completely remove nutrient ions from the river and flood water. In practice, however, the vegetation in these habitats probably takes up much of its Phosphorous (P), Sulphur (S) and Iron (Fe) from local floodplain soils and the large nitrogen demand is probably met by Nitrogen-fixation, a process that has been suggested by other authors to be a common feature of wetlands (Bristow, 1974). All of the nutrients so trapped in organic matter will be released later if and when the organic matter is degraded downstream.

Table 5: Potential effect of one part of the Sudd on the chemistry of Nile river water

Element	Rate of removal by detritus ¹ (g/m ²)	Vegetation ² (tonnes x 10 ³)	Removal by from river ³ (tonnes x 10 ³)
N	67.83	678	3
P	2.61	26	1
S	31.71	317	46
Fe	7.39	74	12
Na	7.48	75	230
K	5.823	58	81
Ca	1.13	11	173
Mg	3.65	37	55
Cl	0.70	7	152

¹ Based on Gaudet (1978, 1979)

² Assuming an immediate low water area of 10,000 km²

³ Concentration of Nile above Sudd region, based on Talling (1957), Bishai (1962), and Kilham (1972). Also assumes a discharge of 23 x 10⁹ m³ (Rzoska, 1976)

Table 6: Effect of drought conditions on water chemistry and phytoplankton in a seasonally inundated part of the Okavango Delta (data from Reavell, 1979) based on 13-37 samples

Date	Total discharge from delta (m ³ s ⁻¹)	Total P (gl ⁻¹) (a)	Total N (gl ⁻¹) (b)	Temp (°C)	Surface O ₂ (mg l ⁻¹)	Phytoplankton (cells l ⁻¹)
iii/1972	—	—	—	28.2	—	—
vi/1972	—	60	425	17.7	6.9	—
viii-ix/1972	9.32	95	604	21.4	6.3	—
ii-iii/1973	0	171	994	29.2	4.5	54,038
v/1973	0	252	2,772	24.2	7.5	683,961
ix-x/1973	3.48	86	652	25.2	—	41,103
xii/1973	0.33	86	277	26.4	7.0	17,889
ii-iii/1974	4.04	119	176	26.4	7.6	8,545
vi-viii/1974	11.16	60	214	19.6	6.4	7,121

(a) Sol. react. P plus org. P

(b) Total dissolved inorganic only

Internal recycling may also be possible because of the large amounts of nutrient material trapped within floodplains. In many floodplains evaporation leads to an increase in concentration of salts. This is obvious during droughts, such as the dramatic drought in the Okavango delta in 1973. At this time evaporative loss was not balanced by local rain input, and Reavell (1979) noted that as the floodplain and swamp water contracted in to discontinuous pools there was an increase in total dissolved solids from 83 to 223 mg⁻¹. Such water, when trapped during dry weather inside the floodplains, becomes a concentrated source of nutrients. This, along with the creation of still-water conditions, leads to an excellent growth environment for hypereutrophic algal species. Reavell (1979) documented this cycle in the Okavango delta (Table 6), and similar events are also known elsewhere in Africa. In the Chad basin when the Chari and Logone rivers overflow their banks and rapidly flood the Yaerés floodplain, the same nutrient flush is seen (Beadle, 1974). At that time, the dried organic and mineral matter, along with ashes from bush fires and droppings from animal herds which previously inhabited the dry river beds, begins to decompose and to dissolve. Within a few days an explosive growth of phytoplankton occurs, followed by a zooplankton bloom and later by growth of macrophytes. In this floodplain, grasses and emergents (Polygonaceae and Alismataceae) occur in shallow water, while the genera *Pistia*, *Nymphaea*, *Stratiotes* and *Utricularia* occur in the deeper portions. The floods later subside and leave great numbers of fish stranded within the vegetation-choked water. Later still the area begins to dry down again and is then accessible for dry season animal grazing until the next flood, when this "instant eutrophication", or nutrient build up, will again occur (Beadle, 1974).

Productivity

Production and biomass

Floodplains are dominated by herbaceous monocotyledons, the most predominant genera being the tropical wetland grasses, *Sporobolus*, *Echinochloa*, *Oryza*, *Vossia*, *Phragmites*, *Paspalum*, *Miscanthidium*, and *Panicum*. Sedges, especially *Cyperus papyrus* and Bulrush (*Typha* sp.) are also common in the deeper floodplain water.

Among these genera, the most well-studied are papyrus and bulrush. Net production rates determined for these two examples are very high. Papyrus net production on a sustained basis is 48-143 tonnes (dw) ha⁻¹y⁻¹ (Thompson *et al.*, 1979). For comparison, it should be noted that maize or sugar cane production can also be sustained at this rate, but only under heavy applications of artificial fertilizer. Papyrus maintains its high rate of production under natural, low nutrient conditions. *Typha domingensis* in the Lake Chilwa swamps averages 16 tonnes ha⁻¹y⁻¹ (Howard-Williams & Lenton, 1975). Net production rates for *Phragmites australis* have been predicted at 58 tonnes ha⁻¹y⁻¹ if growing under tropical conditions (Thompson *et al.*, 1979). Tropical wetland grasses (*Paspalum repens*) are known to attain 12-16 tonnes ha⁻¹y⁻¹ (Junk, 1970), while the estimated net production of seasonally-flooded grasslands would be about 10-20 tonnes ha⁻¹y⁻¹ (Thompson, 1976).

In addition to the dominant emergents, there is commonly a mixture of submerged and floating macrophytes at the river channel edge and in open areas of standing water. Indeed, pools and lagoons along the Nile and Zaire Rivers, and their attendant floodplains may be completely covered with *Pistia stratiotes* and/or *Eichornia crassipes* during stagnant water conditions in the dry season. *E. crassipes* alone is capable of 11-33 tonnes ha⁻¹y⁻¹ (Westlake, 1975). Overall, most African floodplains should be capable of a sustained net production approaching 20 tonnes ha⁻¹y⁻¹. On a continent-wide basis this would roughly amount to an annual net production of 0.8 x 10⁹ tonnes using the area estimated at low water. For comparison, the total annual net production of tropical grasslands on a worldwide basis would be between 4 and 30 x 10⁹ tonnes (Lieth, 1972)

The high rate of production in floodplains is certainly a factor in the overall productivity of these areas, especially in Africa where they support large numbers of domestic and wild animals, e.g. lechwe (*Kobus*) in the Kafue River floodplains (Werger & Ellenbroek, 1980). Another factor here is the quality of floodplain grasses. Van Rensberg (1971) found the Kafue flats floodplain grasses were "grasses of high fodder quality, containing a relatively high content of crude protein. They are also highly palatable, even when dry." In contrast, grass species from non-flooded areas lose their palatability on drying. Thus even in regions of similar grass production, the floodplain species will always be more attractive to herbivores.

Vegetation

Floodplain species

The general vegetation of floodplains includes a large range of life forms. Within standing water bodies, pools and rivers inside the floodplain we can find typical hydrophyte associations (obligate water-plants). At the other extreme are the terrestrial plants that can tolerate a degree of flooding. The majority of the species that occur are emergent amphibious plants. Their habit ranges from herbaceous to woody, but they more often than not are emergent rhizomatous monocotyledons, predominantly grasses and sedges. They fall within the main classes of species for African wetlands established by Thompson (1985). Among the major wetland types listed, (Table 7) we are dealing here with the seasonal types (section II(a) (2)

A good starting point for the study of a typical floodplain flora is the partial list from Lebrun's work in 1947 (Table 8). We see in this list a predominance of rhizomatous emergents (15 out of the 18 species). Many of the species mentioned are also common to perennial swamps. Thus, bulrush (*Typha* sp.) and papyrus (*C. papyrus*) exist within the floodplains of large internal deltas. In addition to these typical species, it would also be appropriate to list several floating Sudd species which are common to floating meadows, or floating islands, such as *Vossia cuspidata*, *Saccolepis interrupta*, *Echinochloa scabra* (= *E. stagnina*), *Oryza longistaminata* and *Jardinea congoensis*. These can often be seen inside floodplains during high water.

Major floodplain associations

The easiest way of describing floodplain associations has been the use of profiles drawn to scale, transecting the major channels or rivers concerned. The larger floodplains, however, defy description using such methods. They often are simply traced from satellite imagery. The result is that we are left today with very general descriptions of African floodplains which often cover large geographic areas. A case in point are the diagrams shown in Vesey-Fitzgerald (1973) (Fig. 11). He outlined several floodplains common to the valley grasslands along the Kafue River. In the upper part of the river, valley grasslands drain freely to allow a gradual drying and a distinct association develops (Fig. 11 a). However, there are many areas especially in the Kafue flats where drainage is impeded because of silt deposition (Fig. 11 b). Here, in addition to the valley grasslands the floodplain supports associations dominated by *E. pyramidalis*, *E. haploclada*, and *V. cuspidata* and closer to the mainstream along the levées one finds *E. scabra*.

Table 7: Main classes of plant species, and communities in African wetlands (Thompson 1985)

I. MAJOR CLASSES OF SPECIES

- A. Monocotyledons
 - 1. Graminae
 - a. Large wetland grasses
 - b. Small wetland grasses
 - 2. Other herbaceous genera
 - 3. Woody genera
- B. Dicotyledons
 - 1. Herbaceous
 - 2. Woody
- C. Gymnosperms
- D. Pteridophytes
- E. Bryophytes

II. MAJOR WETLAND TYPES

- A. Freshwater herbaceous wetlands
 - 1. Permanent
 - a. Reed swamps
 - b. Bog fen and moorland
 - 2. Seasonal
 - a. Black clays, pans and dambos
 - b. Floodplains and valley grasslands
 - c. Alkaline grasslands
- B. Freshwater swamp forests
 - 1. Permanent
 - 2. Seasonal
 - a. Floodplain forests
 - b. Riverine and gallery forests

III. MAJOR WETLAND PLANT COMMUNITIES

- A. Sudd communities
- B. Reed communities
 - 1. *Vossia* swamps
 - 2. *Cyperus* swamps
 - 3. *Miscanthidium* swamps
 - 4. *Cladium*, *Phragmites* and *Typha* reed swamps
- C. Edaphic grasslands
 - 1. Hydroseres
 - 2. Secondary grasslands
 - 3. Black clay, pan and dambo communities
 - 4. Alkaline grasslands and swamps
- D. Edaphic forests
 - 1. Permanent swamp forest
 - 2. Seasonal swamp forest
 - 3. Riverine and gallery forests secondary forests
- E. Montane wetlands

Table 8: Species common to flooded regions in Central Africa (after Lebrun 1947)

SEDGES:

Cyperus papyrus L.
C. haspan L.
C. articulatus L.
C. dives Del
Pycneus mundtii Nees.

GRASSES:

Leersia hexandra Swartz
Phragmites mauritianus Kunth.
Echinochloa pyramidalis (Lam.) Hitch. & Chase
E. scabra (Retz) Beauv. (= *E. stagnina*)
Vossia cuspidata (Roxb.) Griff.
Oryza longistaminata A. Chev. & Roehr
Paspalidium geminatum (Forssk.) Stapf
Sporobolus robustus Kunth.

BULRUSH:

Typha australis Schum. & Thonn.

HERBS & SHRUBS:

Aeschynomene elaphroxylon (Guill. & Perrot) Taub
Mimosa asperata L.
Pluchea ovalis (Pers.) DC.

The typical occurrence of *V. cuspidata* and *E. scabra* close to the mainstream or in deep-flooding habitats will be discussed below in relation to the Sudd region. But first, it would be of interest to consider the most common successional types, hydroseres, within the floodplains. Thompson (1985) has pointed out that in the savanna regions of Africa, the most common hydrosere is *Vossia-Oryza-Hyparrhenia*. He noted that this sequence from an aquatic emergent grass to a typical savanna terrestrial type occurs in the Sudan, the Kafue Flats, the Bangweulu floodplain and generally throughout the West African river systems. The relative proportion of each component within the hydrosere varies from site to site, e.g., *Vossia* predominates in the fringing wetlands of the Zaire river, *Oryza* sp. dominates in the Kafue Flats, *E. scabra* is most important in the inland delta of the Niger River (Mali), and *E. pyramidalis* dominates in many of the Central African valley floodplains.

Thompson (1985) also made the point that there is much variation within each locality. Many other grass species are usually found at any one site. A good example is shown in Fig. 12, where two Zambian floodplains are compared. We see here that in addition to the inevitable *Vossia* and *E. scabra*, there is a whole range of grass species within each floodplain. Unfortunately, in such a diagram there is a tendency to compress the species so that the mosaic pattern is not evident. In reality the mosaic or patchwork pattern is obvious and quite important. In the mosaic we can often see large differences in the distribution of non-dominant, minor species. Thompson pointed out that certain non-dominant floodplain grasses show great diversity, inhabiting a number of important niches. For example, *Cynodon dactylon* can exist as an understory grass within a community dominated by *E. pyramidalis*, either as an associate of water-meadow grasses, as a sward-former in its own right, or as a member of the marginal community in a floodplain grass mosaic.

Differences in species composition or dominance will also be related to local differences in soil

type and flooding conditions. Regarding soil types, Reizer (1974) showed a clear difference in floodplain species along the Senegal River where there were large differences in soil types (Fig. 1, 3A, B, and C).

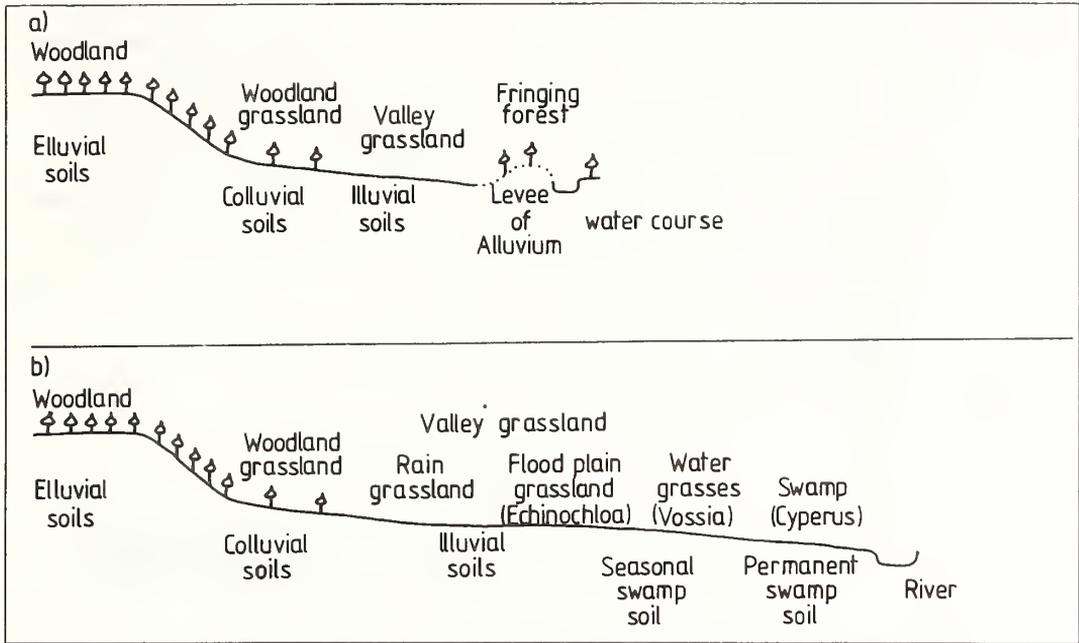


Figure 11. A. Diagram of a section downslope into a valley with free drainage and distinct levées on either side of the main channel
 B. Diagram of the gradual change along a slope with impeded drainage. Both sections in central East Africa (after Vesey-Fitzgerald, 1973)

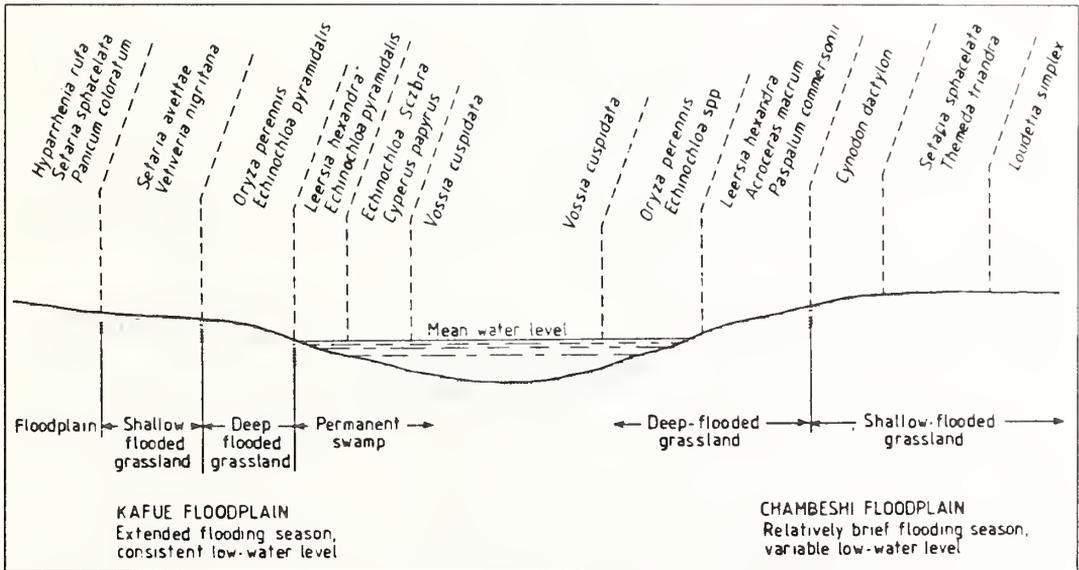


Figure 12. Composite of two Zambian floodplains. Each site had different flooding regimes and different soil types but extensive grass associations occur in both cases (after Thompson, 1985, from Astle, 1965 and Van Rensburg, 1968)

Species distribution

Certain large obvious species within floodplains have been studied because of their value as indicator plants. Smith (1976) in a study of the Okavango Delta used both papyrus and a phoenix palm as indicators. Because of the difference in rates of colonization between the two species their limits of distribution (see Fig. 10) at different periods of time indicated changes in permanent high water tables.

Other indicator plants in floodplains which are often cited, are the salt-tolerant species that favour alkaline saline floodplains. In West African profiles, for example, Reizer (1974) described a *Phragmites-Sporobolus-Tamarix* association which was clearly indicative of saline conditions. In fact, *Sporobolus* is often cited as the most adaptable genus in African alkaline saline floodplains (Thompson 1985). In Central and East African floodplains another useful indicator of saline habitats is *Cyperus laevigatus*. This is clearly seen in the profile taken by Lebrun (1947) across a small river emerging from a saline spring (Fig. 13).

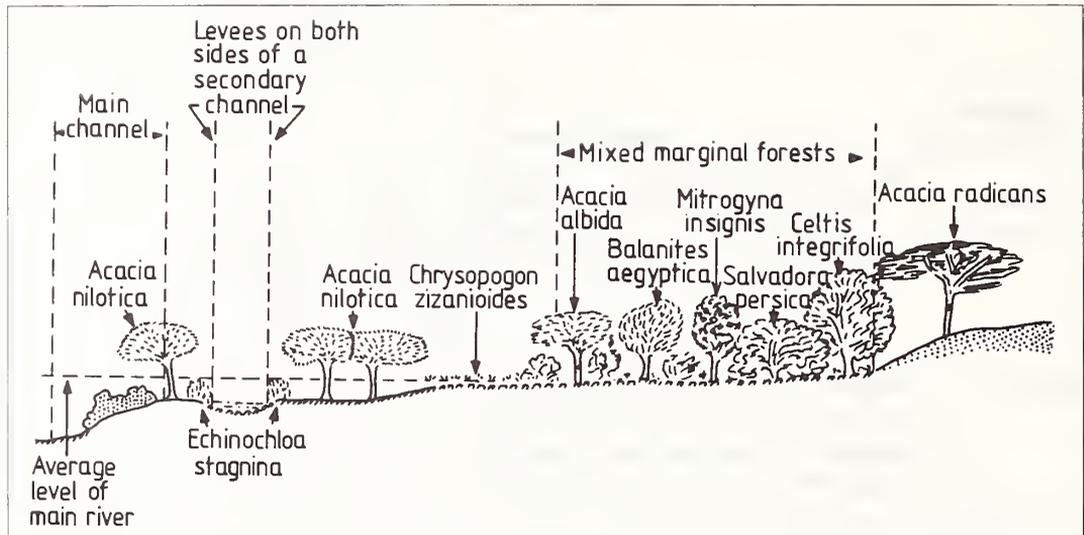


Fig. 13. Transect through the Senegal River floodplain (after Reizer 1974), where *E. scabra* can be found along levées in secondary channels in association with a small tree, *Acacia nilotica*.

A comparison of lists of species from different African floodplains can be seen in Thompson (1985). His consideration of several lists from diverse regions within Africa shows a certain common trend in the continental floodplain flora. This is expected because of the wide distribution of many freshwater macrophytes. Species lists and/or general descriptions of floodplain vegetation can be found in the references cited in Table 9. Here some distinction is made between major floodplains associated with large rivers and those present on smaller rivers and lakes.

The distribution of some tree species in floodplains is correlated with animal activity. Feely (1965) found that the hippopotamus (*Hippopotamus amphibius* L.) influences the establishment of *Acacia albida* (Del.) along the Luanga and Zambezi river valleys in Zambia. These animals along with other wildlife eagerly seek out the foliage and ripe pods of *A. albida*. The seed is dispersed and germination enhanced by passage through their digestive system. As a result of hippopotamus travel inside floodplains, the young trees are regularly associated with newly deposited silt along the river meanders. Feely considers this species a pioneer on the levées. Its roots tolerate submergence for several weeks or a few months, but the foliage must stay above the flood water for the young trees to survive. This is possible because of its fast growth rate during initial colonization (1.05 m yr^{-1}).

Some work has been done on differentiation of species within the complex mosaic typical of floodplains. The work of Sutcliffe (1976) stands as a landmark in this respect. Within the Sudd region on the White Nile in the region south of Bor (Fig. 14) he differentiated the following communities:

- a) grassland dominated by *Phragmites mauritianus*, containing *Echinochloa pyramidalis* and *Oryza longistaminata*;
- b) grassland composed of varying portions of *E. pyramidalis* and *E. scabra*
- c) semi-permanent swamp with *E. scabra* and *Vossia cuspidata*
- d) permanent papyrus swamp, and
- e) open water.

Each of these communities graded into one another along the river, but a fairly pronounced boundary was evident between "shallow-flooded" species (*P. mauritianus*, *E. pyramidalis* and *O. longistaminata*) and "deep-flooded" species (*C. papyrus*, *V. cuspidata*, and *E. scabra*). Off the main rivers in basins, the upstream region supported the shallow-flooded species, while the downstream end of the basin contained the deep-flooded species. Sutcliffe (1976) also calculated the percent plant cover along 16 transects (Fig. 14) at different vertical heights, the level of the substrate above mean datum. He found a correlation between height and percent cover for shallow-flooded species. Here *Phragmites* occupied the highest level while *E. pyramidalis* and *Oryza* sp. were present at lower levels. Deep-flooded species, on the other hand, showed no evident correlation between level and cover. But in the deep-flooded communities the species composition depended on position rather than level, e.g. at the lower, wetter levels *E. scabra* was widespread in the floodplains, while *Vossia* sp. and *Papyrus* preferred sites near the rivers, with papyrus near the lower end of each basin.

Table 9: References on floodplain vegetation associated with African water bodies (see also the annotated bibliography in Thompson. *et al.*, 1985)

	Country	Author
I. MAJOR FLOODPLAINS ON MAJOR RIVERS		
White Nile	Sudan	El Hadidi (1976), Anon (1983)
Niger	Nigeria	Cook (1968)
Okavango	Botswana	Smith (1976)
Zaire	Zaire & C. Afr Republic	Schmitz (1971), Germain (1952)
Zambezi	Zimbabwe	Muller & Pope (1982)
Volta	Ghana	Lawson (1963)
Senegal	Senegal	Reizer (1974)
Kafue	Zambia	Douthwaite & Van Lavieren (1977), Van Rensburg (1971)
II. OTHER FLOODPLAINS		
A. Smaller rivers		
Ruzizi	Zaire	Germain (1952)
Pongola, Tugela, Berg & Tuskei	South Africa	Musil <i>et al.</i> (1983), Harrison (1964), Oliff (1959), Allanson (1961)
B. Man-made lakes		
Lake Kainji	Nigeria	Chachu (1979)
Lake Volta	Ghana	Hall <i>et al.</i> (1971)
Lake Kariba	Zimbabwe, Zambia	Bowmaker (1973), Magadza (1970)
Lake Nasser-Nubia	Egypt, Sudan	El Hadidi (1976)
Lake Cabora Bassa	Mozambique	Jackson & Davies (1976)
Lake Nyumba-ya-Mungu	Tanzania	Welsh & Denny (1978)
C. Natural lakes		
Lake Naivasha	Kenya	Gaudet (1977)
Lake Sibaya	South Africa	Howard-Williams (1980)
Lake Chad	Chad	Leonard (1969), Iltis & Lemoalle (1979)
Lake Kivu	Rwanda, Zaire	Van der Ben (1959)
Lakes Mobutu & Edward	Uganda, Zaire	Van der Ben (1959)
Lake Chilwa	Malawi	Howard-Williams & Walker (1974)
Lake George	Uganda	Lock (1973)
Lake Bangweulu	Zambia	Verboom (1975)
Lake Victoria	Uganda, Kenya, Tanzania	Lind & Morrison (1974)

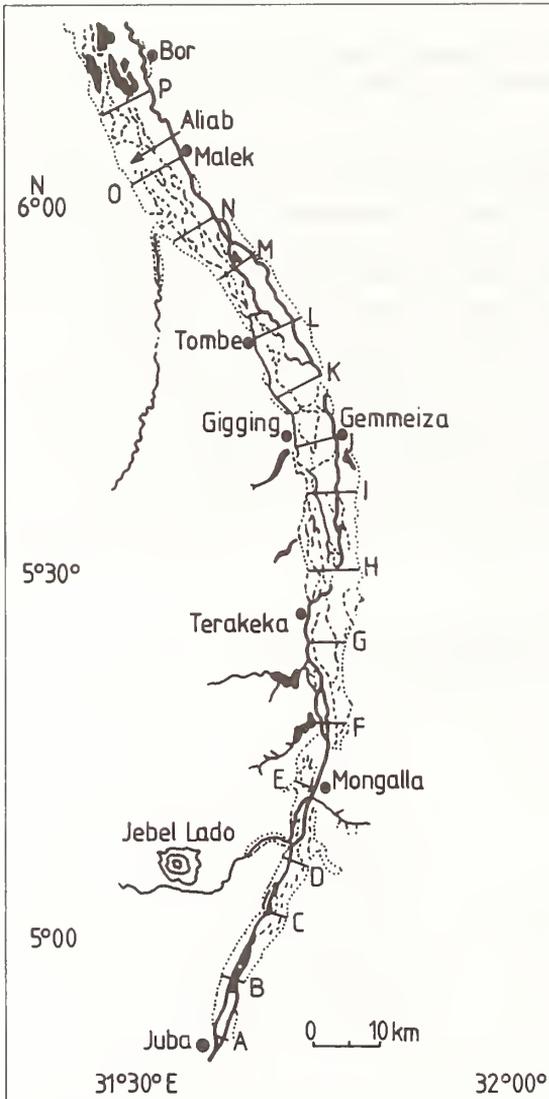


Figure 14. Floodplain on the White Nile from Bor to Juba showing 16 transects, A-P. This region is south of that shown in Figure 4.

occupies sites which are flooded for short periods and dry out to a greater depth. In deep-flooded species, distribution is more complex as it is not related to substrate level. *Vossia* and *E. scabra* are found in quiet water. Because papyrus was found both above and below the minimum levels of flooding, Sutcliffe (1957) concluded that its distribution was not as dependent on depth or duration of flooding as the other two deep-flooded species. He found that papyrus was restricted to sites where the depth of flooding (the difference between minimum and maximum water level during flood) is less than 150 cm. Greater levels can be tolerated by the other deep-flooded species such as *Vossia* until a range of 3 m is reached at which point open water prevails. The ability of *Vossia* to dominate deep-flooding sites, i.e., hydrologically unstable environments, was confirmed by Thompson (1985) who pointed out that it is reported from deep-flooding areas in Sudan, Chad, West African and East African rivers, Zaire and Zambia.

Sutcliffe (1957) also examined the distinct boundary which exists between the shallow- and deep-flooded communities. He found that the distance of the boundary from the river edges varied considerably but followed the water-slope very closely. The water-slope depended on: (a) the maximum depth of flooding; (b) the period of flooding; and (c) the water-table, which in turn is dependent on the river level. He ruled out water-table as a water-slope factor affecting plant distribution, because the boundary between the communities is quite distinct. If water-table were involved there would be little or no difference in the level at which each community occurs, and thus no clear boundary would exist. Also he found the period of flooding was not correlated with the boundary of these communities because the water surface during the period of his survey (10 April - 3 May 1952) did not coincide with the topography of the boundary. The maximum depth of flooding, on the other hand, was parallel to the boundary and appears to be the major factor determining this boundary between shallow- and deep-flooded communities. His levelling data indicated that sites where the annual depth of flooding does not exceed 130 cm for 10 days, or 118 cm for 30 days are ideal for shallow-flooded communities. Conversely, sites flooding in excess of 130 cm will only support deep-flooded communities.

Within the shallow-flooded communities he noted that the proportion of *Phragmites* increased going away from the rivers. In most cases the distribution of *Phragmites* depended on the depth of available water especially during the dry season. This in turn depends on the period of flooding, thus *Phragmites*

Table 10: Comparison of two floodplains (based on Thompson's UNDP review, 1974).

1. Floodplain:	White Nile Sudd region	Okavango Delta,
2. Local name:	Toiche	Molapo
3. Flooding and local climate:	4-5 month lag peak rainfall in Uganda and maximum flooding in toiche. Maximum precipitation in region coincides with peak floods and low PE.	5 month lag between peak rainfall in Angola and maximum flooding in molapo. Maximum precipitation occurs during low water and peak PE.
4. Flooding sequence:	Flooding caused by water level in main channels overtopping natural levées.	Flooding caused by overtopping of natural levées.
5. Grasses in floodplain:	<i>Vetiveria nigriflora</i> <i>Sporobolus pyramidalis</i> <i>Sorghum lanceolatum</i> <i>Paspalum scrobiculatum</i> <i>Setaria anceps</i> <i>Oryza longistaminata</i> <i>Loudetia superba</i>	<i>V. nigriflora</i> <i>Sporobolus sp.</i> <i>Sorghum sp.</i> <i>Paspalum sp.</i> <i>Setaria sphacelata</i> <i>Oryza sp.</i> <i>Cymbogon plerinodeus</i> <i>Digitaria eriantha</i> <i>Echinochloa scabra</i>
6. Wildlife:	Many birds and smaller animals. Sitatunga, Lechwe, crocodile and hippopotamus still found.	Many birds and smaller animals. Sitatunga, Lechwe, crocodile and hippopotamus evident.
7. Fisheries (m tonnes yr ¹):	**	400
8. Land use and human activity:	500,000 people and 700,000 cattle associated with region. Considerable use made of toiches for grazing promoted by burning.	12,000 people and 130,000 cattle in and around delta. Natural crown fires probably common, but otherwise burning is only practised within swamp areas for benefit of hunters and tourists .

Sutcliffe (1957), by a series levelling and surveying measurements was able to explain the distribution of emergent vegetation on the basis of maximum depth and range of flooding. His explanation is much simpler in concept and operation and is more consistent with available data than earlier explanations based solely on depth and duration of flooding. and therefore is more appealing His general results were recently confirmed by the Mefit-Babtie study of the Sudd region (Anon., 1983).

** Presently being assessed (long term study underway)

What is needed now is a more detailed and experimental approach which will distinguish between floodplain species using some system based on water relations. We also need to know more about the site preference of specific floodplain species, especially those floodplain grasses which were not included in this early work.

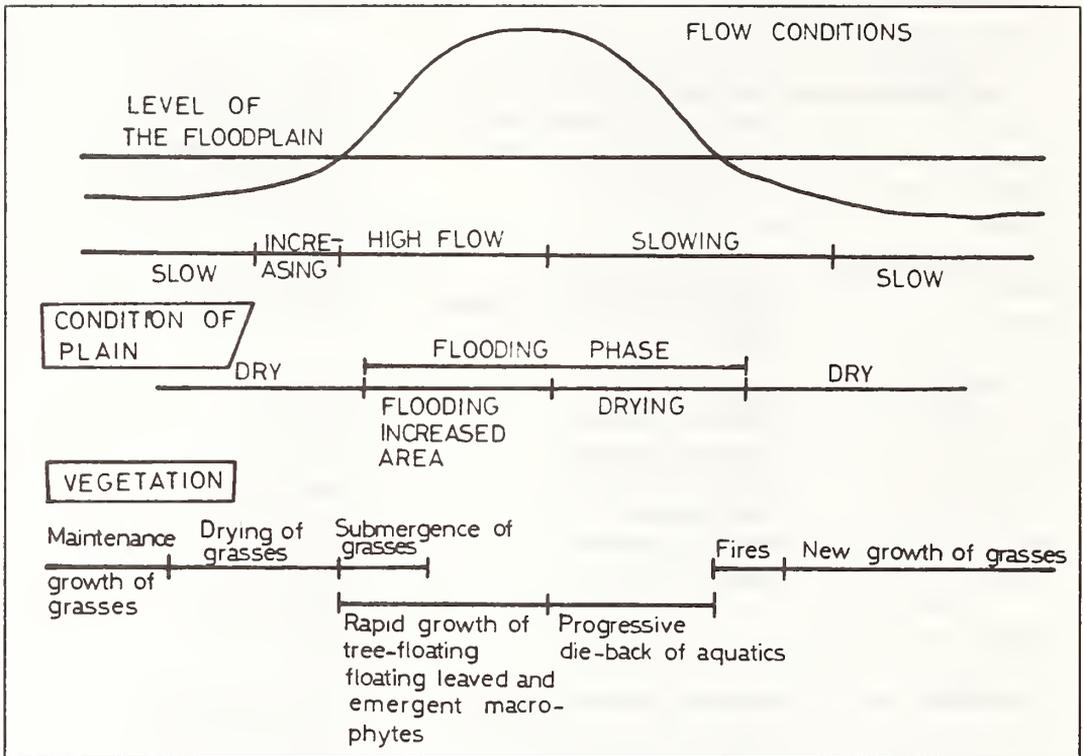


Figure 15. Summary diagram of floodplain cycle (modified from Welcomme, 1979)

CONCLUSIONS

Floodplains under normal conditions

The most impressive aspect of floodplains under normal conditions is the integration of physical and biological components within the system. Welcomme (1979) commented on this integration: "The traditional integrations of biological and human activities which make up the ecology of the floodplain river can only work if there is a community of micro-organisms, plants and animals which are adapted to the particular frequency of the environmental event which is fluctuating—in this case the flood."

Along large African floodplains the seasonal progression of events is similar. Thus, two examples north and south of The Equator, The White Nile Sudd (Figs. 4 & 14) and the Okavango delta (Fig. 10), although separated by 23-29 degrees of latitude follow similar cycles (Table 10). Fires occur in both and result in a fast recycle of ash nutrients but in a loss of volatile nutrients such as Nitrogen and Sulphur. The annual cycle shown diagrammatically in Figure 15 reflects a very productive system that is under a series of complex control mechanisms. However, because of their high rate of natural production, floodplains are attractive to developers and in many places in Africa, floodplains are being brought under management.

Floodplains under management

Welcomme (1979) gives many examples where water regulation, especially flood control, has allowed productive irrigation and fish farming to take place within floodplains. This is especially true in West Africa. In the closing section of this paper, I would like to look not at these well-known examples, but at some different cases, especially among major floodplains which have been put under stress as a result of river basin development. The subsequent results provide us with a valuable experience from which many African countries can benefit.

The most publicized example of floodplain management in Africa is the enormous scheme which was started in the southern Sudan to conserve water by canalization of the main flow through the Sudd region on the White Nile. At present the scheme has been halted due to political disturbances in the south of the country.

However, an ecological impact assessment was completed (Anon. 1983), and this outlined the major effects to be expected on completion of the canal. The basic options for management in this case will rest on future discharge levels in the White Nile itself. The canal can be operated either at high discharge levels such as have occurred since 1961 or at lower discharge levels such as occurred prior to 1961. Examples of both cases are shown in Fig. 16, and the resulting decrease in swamp and floodplain area is shown in Table 11. Under the best possible conditions, that is with river discharge levels remaining as high as they are now (in the 1980's-90's), the effects would be as follows:

1. The small lakes within the permanent wetlands will become shallower and susceptible to encroachment by vegetation. These lakes in the southern area of the Sudd will still remain permanent, however in the eastern area many will shrink in size and many will disappear;

2. Because of the decrease in turbidity of incoming water and the lower water depths that will occur, the growth of submerged vegetation will be encouraged along the banks and on the bed of the rivers flowing through the region. This will increase the retention of nutrients, but it will also encourage the growth of floating aquatic vegetation, such as water hyacinth (*E. crassipes*) and *Vossia* grass (*V. cuspidata*);

3. The aquatic grass *Vossia* will increase considerably because of its tolerance to deep-flooding sites. It will overgrow open water in those areas subject to falling water levels. This will create blockages in the main channels of the Sudd. Such blockages do not occur at present because steamer traffic keeps the channels open. With the diversion of this traffic into the canal the blockages by *Vossia* would be significant;

4. The area covered by Papyrus and *Typha* would be reduced because of contraction in their habitats. but as these permanent swamp types recede, their place will be taken by *Oryza*. The seasonally-flooded grasslands will also retreat and their place will be taken by grasses belonging to the genera *Sporobolus* and *Hyparrhenia*;

5. There would be little effect on present day fishing grounds and fish stocks, because at present these are very much underutilized. With the increased growth of floating vegetation, channel blockage will occur and this will cause interference in the access of barges to the fish collecting centres. It will also cause interference to the access of canoes into some of the fishing grounds. These effects can be mitigated as the fishing resources will still be more than adequate. The canal may even improve fishing effort because of the increased communication and travel to markets outside the affected region.

All of these effects may become more adverse if the effect of the canal is coupled with a fall in river discharge. If discharge levels decrease to those observed prior to 1961, the floodplain area will be so reduced (Fig. 16D) that many of the floodplain lakes would be lost and thus fish populations would decline. In that case significant socio-economic problems would certainly arise.

Another case in Africa is that of the Kafue flats (Fig. 17). Prior to the construction of the Kafue Gorge dam, the Kafue flats showed a classic floodplain profile (Fig. 17) and function. They had a gentle slope progressing from west to east with a loss of only 6 m elevation over 193 km. The soils in the flats are impervious clays. The Kafue river channel meanders over the flats and divides into occasional branches.

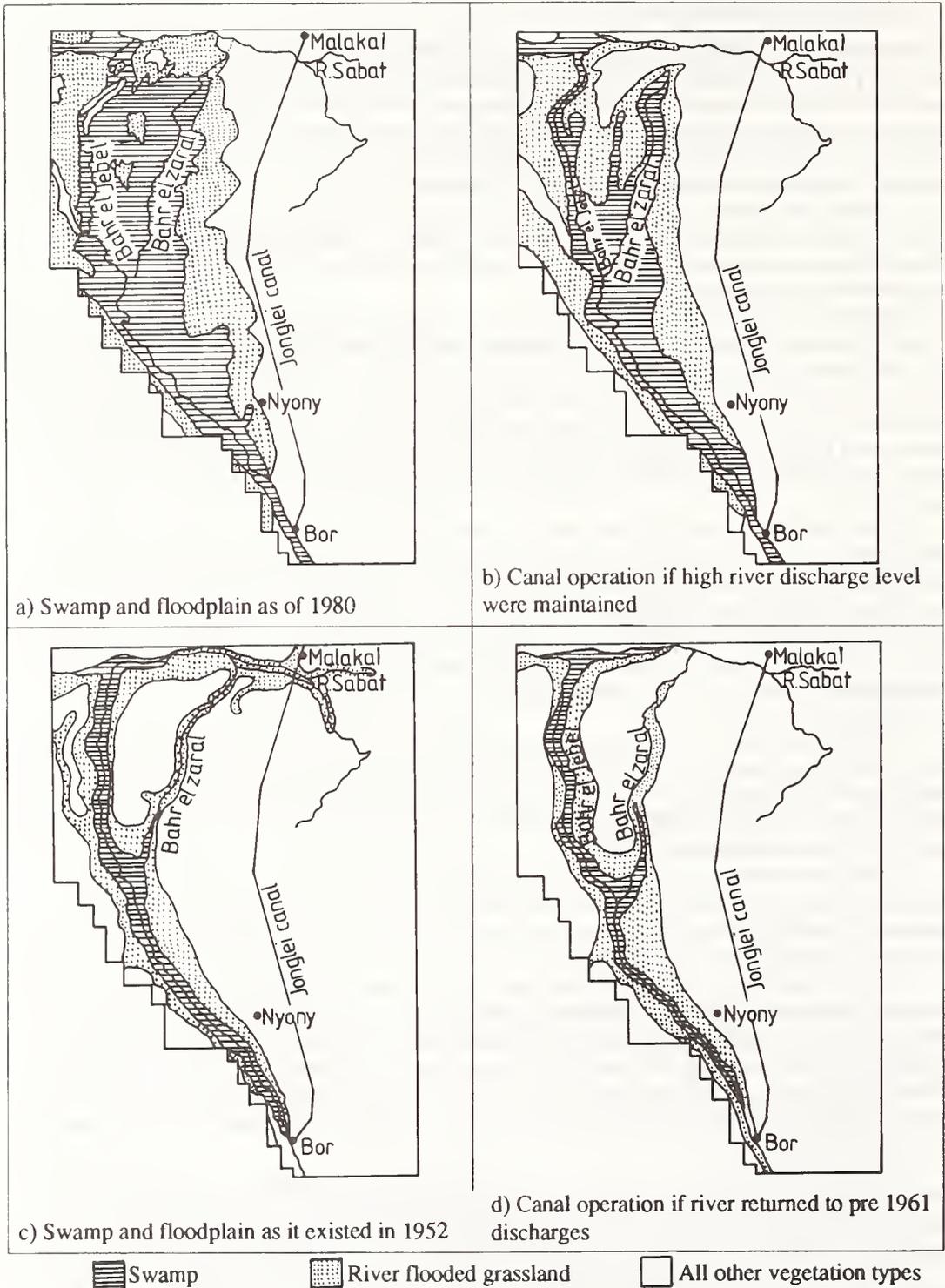


Figure 16. Comparison of swamp and floodplain during high water conditions on the Nile in 1980 and low water conditions (1953). The projected effects of the Jonglai Canal are shown (after Anon, 1983).

Table 11: Estimated effects of the Jonglei Canal on areas of flooding in the Sudd region (after Anon. 1983). When in operation the canal will divert 20 million m³ per day. Data from Mefit-Babtie study (1983)

	swamp km ²	area of decrease %	floodplain km ²	area of decrease %
No canal, estimated areas in 1980	16,357	—	15,476	
Operational canal, river remains at high discharge level	12,251	25.1	13,239	14.5
Operational canal, river returns to pre-1961 discharge level	3,688	77.5	7,624	50.7

The main river is bordered by natural levées so that when the river is running full, the water in the channel may be a metre higher than the surrounding land. Eventual overtopping of levées, flooding, subsequent natural drainage and drying completed the annual cycle (White, 1973).

The aquatic vegetation at Kafue flats is found within five general communities:

- a) open water bodies up to 8m deep;
- b) lagoons and river edges flooding to 4-6 m supporting an association of *V. cuspidata*, *E. pyramidalis*, *E. scabra*, *Leersia hexandra* and *C. papyrus*;
- c) flooded grassland, 1.5-6m depth dominated by *O. longistaminata*.
- d) shallow flooded grassland and levées with flooding depths of 0.25-25cm. Here tussock floodplain grasses occur such as *Vetivaria nigritana* and *Setaria avettae*; and finally
- e) floodplain marginal regions supporting a grass cover of *Hyparrhenia rufa*, *Panicum coloratum*, *V. nigritana* and *Setaria sphacelata*.

Two dams were planned in order to achieve control over the Kafue river (Fig. 17). The first, Kafue Gorge dam would dam the river below the flats and would impound enough water to allow hydropower production during the subsequent four years until a second dam could be erected upstream above the flats (Fig. 17). This dam (the Itezhitze dam) would provide enough control over the whole river and floodplain system so that annual flooding-drying cycles could still be achieved within the floodplain. However, there would be a four year period between construction of the dams, during which time 2,000 km of floodplain would be inundated. This region to be inundated supported an *Oryza* floodplain grassland, where the principal species normally produced enough new growth each year to keep pace with the rising flood. The tips of the leaves and the inflorescence of *Oryza* must be maintained above the water level or it will die back. White (1973) predicted that four years of inundation would disrupt the normal cycle and that over such a long period death and decomposition of *Oryza* would result. He also cautioned that the open water expanse would be taken over by sudd-forming species with the result that the floodplain species would later require a very long period to be re-established.

White (1973) recommended that as much of the annual flooding-drying cycle of the floodplains be maintained as possible over the 4-year period. Subsequently, the first dam was closed in 1972 and it was decided to maintain the floodplain cycles as much as possible. However, during the dry season in 1973 the Kafue River receded to one of its lowest recorded levels. The floodplain drained except for large lagoons, and the whole region was burned. Because of the expected increase in demand for water following this drought, and the need to have a larger storage for the subsequent year, it was decided to store more water. Thus, following the 1973-74 rains, the storage level was allowed to rise 1.2 m above normal. As a result 2,200 km of the floodplain was flooded (Magadza, 1977). The *Oryza* grass died off and a rapid growth occurred of sudd-forming species such as *V. cuspidata* in shallow water, and *Aeschynomene elaphroxylon* in open water.

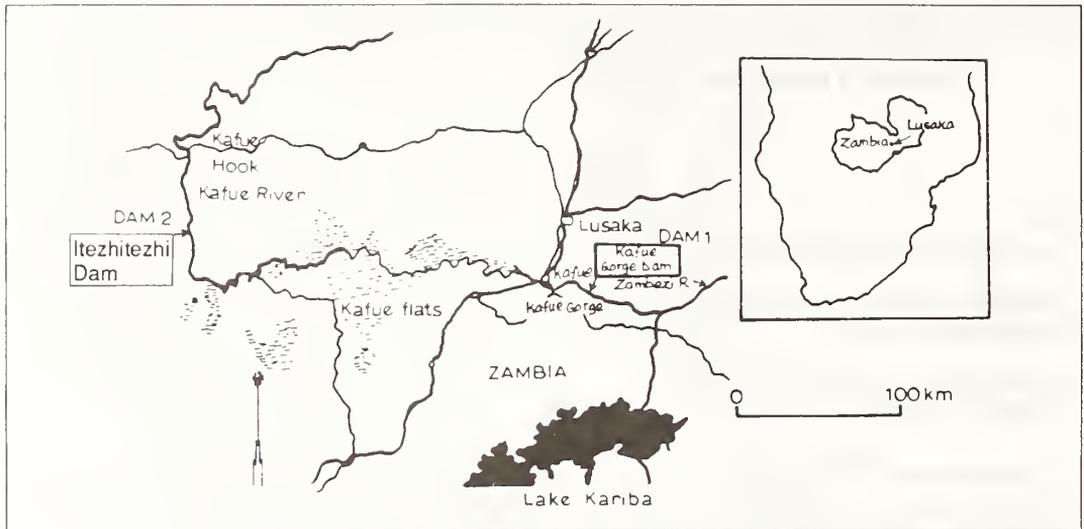


Figure 17. Kafue river with the floodplain, Kafue flats, and site of new dams:

1. Kafue Gorge dam
 2. Itezihitshi dam
- (after White, 1973)

The second dam was finally closed in 1977, with the result that the flooded area became smaller during the peak wet season, but during the dry season the inundated region remained permanently flooded (Werger & Ellenbroek, 1980). These effects were not predicted by the early models of the dam operations (White, 1973). In addition, the second dam developed structural faults due to geological activity and subsequently had to be drained. At present over 40% of the original Kafue flats floodplain still remains inundated with little hope of any change in the future.

Further downstream the Kafue enters the Zambezi which then flows east to the Indian Ocean. The Zambezi (at this point the mid-Zambezi) is dammed at Cabora Bassa in Mozambique and at Kariba between Zimbabwe and Zambia. Along a 100km stretch of the river between the two dams the Zambezi floodplain lies inside the Mana Pools Game Reserve (Fig. 18). In this floodplain (as in the Kafue flats) one typically finds *Oryza* grassland in the depressions and *A. albida* trees along the levées (Guy, 1977). This floodplain is of great importance to local wildlife during the dry season, it is the main grazing area of the mid-Zambezi Valley (Attwell, 1970). The whole floodplain region was earlier dramatically affected by the construction and operation of the Kariba dam in 1958.

Since that time:

- a) lesser amounts of silt have been deposited (most being trapped by the dam);
- b) lower level of flooding prevails resulting in a lack of natural flooding; and
- c) out-of-season low volume floods are common.

The terrestrial vegetation within the reserve is undergoing changes related to the changes in animal movement which in turn are caused by the changes in floodplain function. In the floodplain, even though there is still inadequate flooding, there is some evidence of colonization by *A. albida* on sandbanks and levées and regrowth of floodplain grasses, e.g. *Oryza* and *Setaria* species in the depressions. In other words, the floodplain vegetation is being re-established, but with much difficulty (Attwell, 1970).

It has recently been proposed that a third dam be built mid-way between Kariba and Cabora Bassa, at Mputa Gorge (Fig. 18). This dam would inundate all of the riverine stands of *A. albida* and the *Oryza* grasslands mentioned above. In other words, it would eliminate the floodplain in this part of the mid-Zambezi (Muller & Pope 1982).

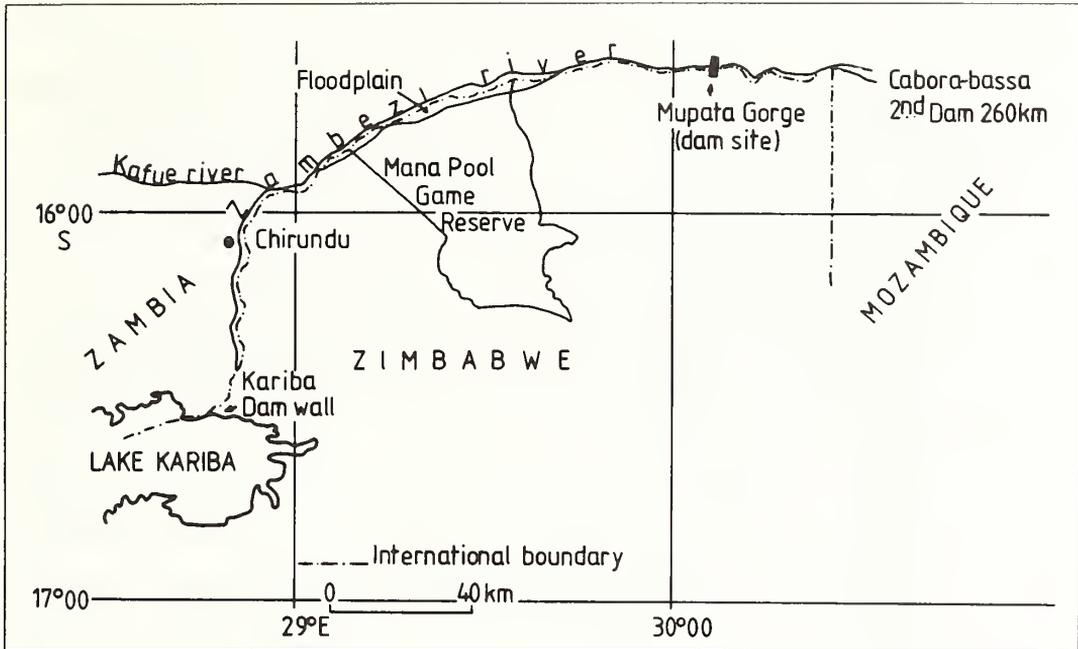


Figure 18. Zambezi floodplain downstream from Lake Kariba showing the Mupata Gorge (after Atwell, 1970)

The question now arises of whether or not any of the floodplains along the Kafue and Zambezi rivers will survive such development. Are there any development alternatives? In the case of the Kafue flats, even if the Itzehitezhi dam is put back into operation and even if it is operated in tandem with the Kafue Gorge dam, the floodplains may still not survive. The floodplain here needs an annual, 'close-to normal', flood-dry cycle. If this is to be achieved the two dams must be closely regulated in a careful, regular fashion which based on past experience, is obviously difficult to achieve.

In the case of the mid-Zambezi floodplains, there is an alternative to the Mputa dam, that is to utilize another site located in a gorge on the Upper Zambezi, 35 km below Victoria Falls. The reservoir created by this dam (Batoka Gorge dam) would be confined within the deep gorge and would have minimal impact on any existing floodplain and on Victoria Falls. Based on past experience, it would seem that the choice of this site would be a much better alternative than those management schemes that could result in the complete elimination of a valuable natural resource, the Mana Pools floodplain.

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JOURNAL OF THE EAST AFRICA NATURAL HISTORY SOCIETY AND NATIONAL MUSEUM

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A FLIGHTLESS GRASSHOPPER OF THE GENUS *UGANDA* BOLIVAR, FROM THE ABERDARES NATIONAL PARK, KENYA (ORTHOPTERA, ACRIDIDAE)

J. MARK RITCHIE
International Institute of Entomology,
56 Queen's Gate, London, SW7 5JR, UK.

ABSTRACT

A new species of the genus *Uganda*, *U. darlingtonae*, is described from moorland above 3000 m in the Aberdares National Park, Kenya. The habitat of the species is described and morphological characters distinguishing *U. darlingtonae* from the other montane species of the genus are described and figured with comparative measurements.

INTRODUCTION

The montane grasshopper fauna of Africa contains a number of short-winged species which are usually recognisably derived from lowland macropterous species, as for example in such genera as *Coryphosima* and *Eyprepocnemis*. Uvarov (1977) commented that *Paracinema* was replaced at higher altitudes by the closely related brachypterous genus *Uganda*.

The genus *Paracinema* was last revised by Key (1936) who recognised two species, *Paracinema luculenta* Karsch and *P. tricolor* (Thunberg). *P. luculenta* occurs in West and Central Africa (Togo, Ghana, Sierra Leone, Zaire) while *P. tricolor* occurs throughout the wetter parts of Africa and into Madagascar and southern Europe. In East Africa, *P. tricolor* occurs as subspecies *montana* Key in Ethiopia (Wouramboulchi, nr. Djem Djem), at around 2800 metres (Key 1936). Specimens of the nominate subspecies have been found at around 2400 metres in the Impenetrable (Bwindi) Forest, SW Uganda (Ritchie, unpublished) and material intermediate between the two subspecies was recorded from the same altitude in Ethiopia (Key 1936). Both species of *Paracinema* are macropterous although in *P.t. montana* the tegmina and wings only just exceed the hind knees in length.

The genus *Uganda* was described by Bolivar (1909) without any included species and was later placed by its author in the group *Paracinema* (Bolivar 1914). He cited two included species of which one, the type species, *U. kilimandjarica* (Sjöstedt), occurs at between 2300 and 4300 m on Mt. Kilimanjaro in Tanzania where the syntype series was collected at Kiboscho at 3000 m (Sjöstedt 1909). The other species, *U. acutipennis* Bolivar, was apparently collected at low altitude

on the Sesse Islands, Lake Victoria, Uganda (Bolivar 1914). It is not mentioned again in the literature after its original description by Bolivar. Since this species has not been recognised subsequently in collections from lowland southern Uganda, there must be some suspicion that it is not a member of the genus *Uganda* but a brachypterous representative of another acridine genus, such as *Gymnbothrus* or *Gymnbothroides*. The location of the type specimens is unknown to me, and no material referable to this species has been examined during this study.

The new species of *Uganda* described here was first brought to my attention by Dr Johanna Darlington, and is named in her honour. Most of the specimens were collected from the vicinity of Muir's Massif (0°17'S 36°37'E) at the northern end of the Aberdares Range, Kenya at altitudes ranging from 3250 to 3650 metres. Subsequently a single female was found to have been collected in 1934 at 3700 m on Mt. Kinangop at the southern end of the Aberdare Range.

RESULTS

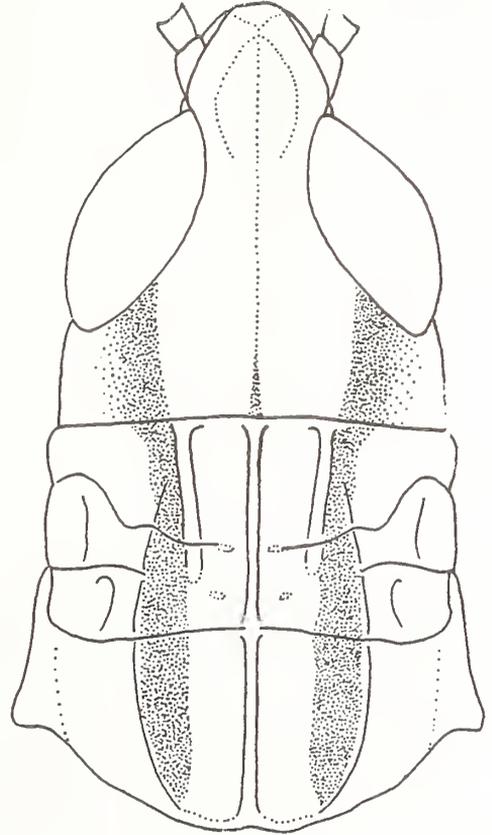
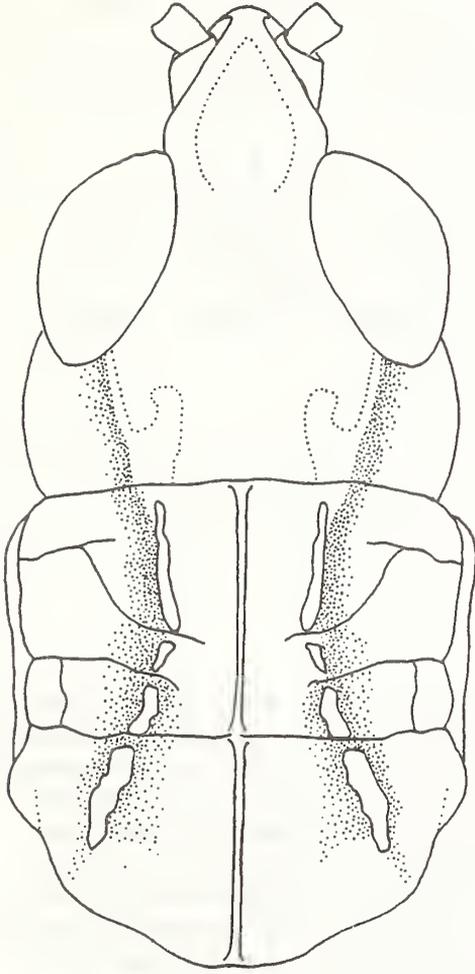
Key to montane species of *Uganda* Bolivar

1. Larger species (Table 1). Total length: male, 11.5 - 13.8mm (mean 12.99mm); female, 22.8 - 27.5mm (mean 24.32mm). Dorsum of pronotum with pale, raised, shiny lateral carinae, visible in metazona as well as prozona (Fig. 1). General colouration dark brown, with variable degree of green colour in some specimens; hind femur lower outer and inner areas and hind tibia distinctly orange-red. (Kilimanjaro) *U. kilimandjarica* (Sjöstedt)
2. Smaller species (Table 2). Total length: male, 10.1 - 11.3mm (mean 10.6mm); female, 18.1 - 20.9mm (mean 19.4mm). Dorsum of pronotum with pale, raised, shiny lateral carinae visible in prozona only (Fig. 2). General colouration greenish or straw; hind femur inner area and hind tibia sometimes faintly tinged with orange-red but lower outer area of femur never orange-red. (Aberdares) *U. darlingtonae* sp. n.

Table 1. Measurements (mm) of adult material of *Uganda kilimandjarica* (Sjöstedt) from Mt. Kilimanjaro, Tanzania

	Total length	Head width*	Pronotum length	Tegmen length	Femur length	Femur length
Male						
Mean	12.99	2.63	2.84	3.84	9.08	2.2
Range	11.55-13.8	2.4-2.9	2.7-3.1	3.4-4.2	8.6-9.9	2.15-2.25
Number measured	7	7	7	7	5	5
Female						
Mean	24.32	4.62	4.69	5.89	14.28	3.29
Range	22.8-27.45	4.3-5.35	4.15-5.6	5.0-7.8	12.35-17.5	3.05-3.7
Number measured	9	7	9	9	8	8

* across genae



2mm

Figure 1. *Uganda kilimandjarica* (Sjöstedt)

Figure 2. *U. darlingtonae* sp.n.

head and pronotum, male, dorsal view

Table 2. Measurements (mm) of all known adult material of *Uganda darlingtonae* sp. n.

	Total length	Head width*	Pronotum length	Tegmen length	Femur length	Femur length
Male						
Mean	10.57	2.19	2.39	3.39	8.37	1.84
Range	10.1-11.25	2.05-2.25	2.3-2.5	3.2-3.5	8.1-8.8	1.75-1.95
Number measured	4	4	4	4	4	4
Female						
Mean	19.4	3.7	3.79	5.15	12.73	2.84
Range	18.15-20.9	3.55-3.85	3.65-3.9	4.4-5.65	12.55-12.95	2.75-2.95
Number measured	5	5	5	5	5	5

* across genae

Description of new species

Uganda darlingtonae sp. n.

Male. Small species (total length 10.1 - 11.3mm) (Table 2.). Antenna with 18 segments, distinctly shorter than length of head and pronotum combined (longer in *Paracinema* species). Interocular distance little more than one third as long as long axis of eye. Frons oblique, curved; frontal ridge constricted at apex to half its basal width, slightly sulcate at median ocellus, smoothly convex above, meeting vertex in acutely rounded curve; fastigium of vertex lanceolate, angular in front, rounded behind, forming a shallow depression with rounded margins; fastigial foveolae absent. Pronotum weakly tectiform with obtuse median carina, crossed by posterior transverse sulcus; lateral carinae straight in prozona, diverging forwards, converging and obsolescent before posterior sulcus; metazona with obtuse excurved outer lateral carinae bordered internally by dark fascia (Fig. 2); metazona slightly shorter than prozona, with rounded posterior margin. Mesosternal interspace rectangular, distinctly wider than long (longer than wide in *Paracinema* species). Elytra and wings reduced; elytra lateral, lanceolate, touching or slightly overlapping dorsally, with reduced venation and reticulation (Fig. 3), shiny, reaching to middle of third abdominal tergite; tympanum well developed, covered by elytron. Hind femur about 4.5 times as long as maximum depth; lower lobes of hind knee rounded; hind tibia expanded in apical third, with 9 outer and 10 inner spines; tibial spurs unspecialised, arolium of normal size. Supra-anal plate spade-like, apically rounded, barely longer than wide; subgenital plate subconical with subacute apex. Cercus elongate, finger-like. Epiphallus variable (Figs. 4 & 5), of typical acridine form, subrectangular to rhomboidal, with widely-spaced ancorae and bilobate lophi; aedeagus slender and unspecialised, with ventral sub-apical lobe (absent in *P. tricolor* but present in *U. kilimandjarica* and *P. luculenta*).

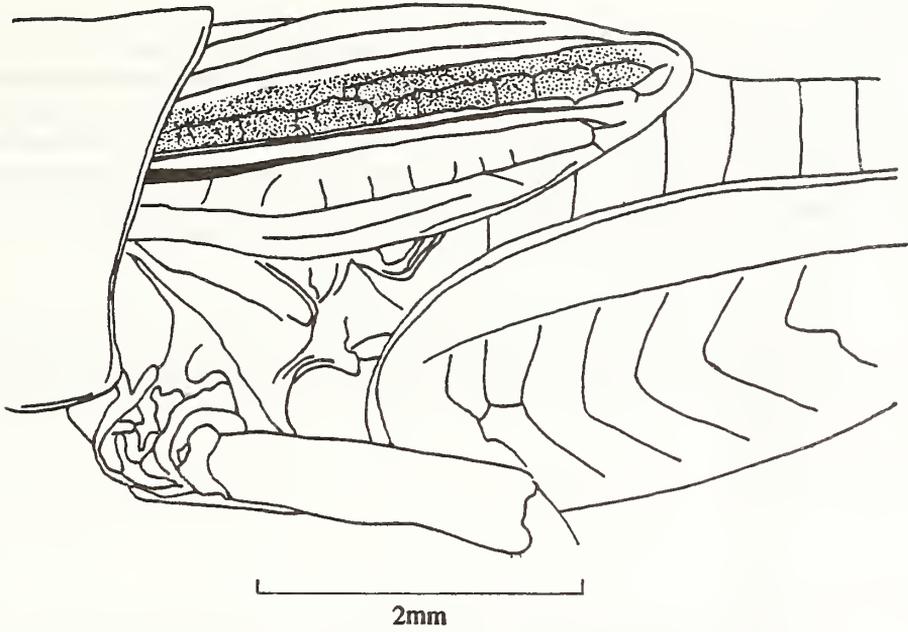


Figure 3. *U. darlingtonae* sp. n. thorax and left tegmen, lateral view

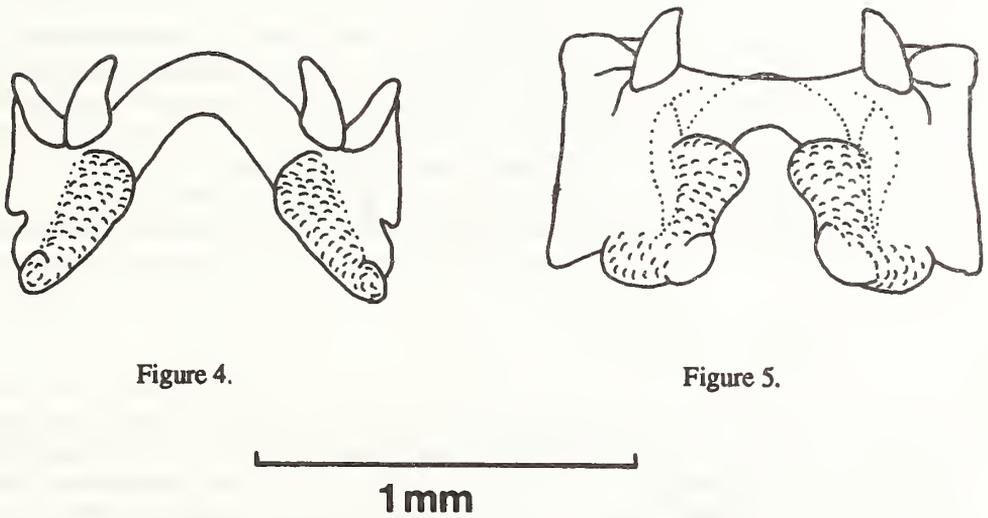


Figure 4.

Figure 5.

Figures 4 and 5: *U. darlingtonae* sp. n. epiphallus, dorsal view, showing the range of variability

Colouration

General colouration pale green fading to straw-coloured after preservation; antennae reddish-brown; head behind eyes and pronotum with longitudinal dark chocolate brown lateral fasciae (Fig. 2) continuing on elytra and abdominal tergites; lateral surfaces of pronotum, meso- and metanotum with indistinct dark markings; hind femur with dark longitudinal fascia along upper half of external medial area, fading to ground colour in lower half; internal ventral surface straw-coloured, sometimes faintly tinged with pale red; hind knee lunules dark brown; tibiae and tarsi straw-coloured with or without faint pale orange red tinge, spines black tipped.

Female

Similar to male but much larger and stockier (total length 18.1 - 20.9mm). Hind femur internal ventral surface and hind tibia distinctly flushed with pale orange-red. Ovipositor short with robust valves curving at apices.

Measurements

See Table 2.

Material examined

KENYA: Holotype male, 3 male, 4 female paratypes, 1 female nymph, Aberdares National Park, 0°14'S 36°35'30"E, *Alchemilla/Eleusine/Andropogon/Agrostis* moorland, SE foot of Chebuswa, alt. 3250 m, 19.iii.1987, (J.M. Ritchie) (1 male paratype in British Museum (Natural History) (BMNH), London, remainder in National Museums Kenya (NMK), Nairobi); 1 female paratype, Aberdares Nat. Pk, north end, Muir's Massif, 0°17'S 36°37'E, alpine moorland, alt. 3650 m, 7.ix.1985 (J.P.E.C. Darlington) (NMK); 1 female paratype, Aberdare Range, Mt. Kinangop, 12000 ft, 30.ix.1934, (F.W. Edwards) (BMNH).

DISCUSSION

The pronotal morphology of the new species allies it with *P. tricolor*, especially in the presence of anterior dorso-lateral carinae which reach only as far as the first transverse sulcus (Fig. 2). In *P. luculenta* there are no such carinae and in *Uganda kilimandjarica* the carinae continue posteriorly beyond the first sulcus (Fig. 1). The distinctive pair of dark longitudinal dorsal bands on the pronotum also allies *U. darlingtonae* to *P. tricolor*. However, the genitalia and general appearance of *U. darlingtonae* indicate a very close relationship with *U. kilimandjarica*. The epiphallus and aedeagus of the two taxa are not readily distinguishable, suggesting a recent common ancestry, perhaps during a period of climatic amelioration during the Pleistocene (<1 million years before present) which could have enlarged the available area of moorland habitat sufficiently to permit exchange of populations between Mt. Kilimanjaro and the Aberdare Range nearly 300 km apart.

The montane moorland habitat

The Aberdares Range, together with Mt. Kenya, 50km to the east, form the eastern highlands of Kenya separated from the Western highlands by the Gregory Rift Valley. The Aberdares are the highest mountain range in Kenya after Mt. Kenya and Mt. Elgon. The climate at above 3000m is extreme, with frequent night frosts. For much of the day the sun is concealed by cloud and rain falls almost daily. The temperature regime during March and April in a similar habitat on the west side of Mt. Kenya was examined by Beck *et al.* (1981) who found that in an average period of

24 hours, the air temperature at ground level was below 0°C for more than 6 hours and between 0° and 5° for a further 6 hours. Overall temperatures varied between -5°C and 25°C. At a depth of 20 mm below the soil surface the low temperatures were less severe, seldom falling below 0°C but averaging more than 12 hours between 0° and 5°C.

The vegetation on Muir's Massif is shown in Plate 1. This is typical of the habitat where *U. darlingtonae* was collected (3650 m) but with less bare ground and thicker vegetation than the slightly lower collecting locality at the foot of Chebuswa (3250 m). The afro-montane moorland of the northern Aberdare Range is an open habitat with dwarf shrubs, herbs and grasses.

In the more open areas of true moorland at the foot of Chebuswa hill the flora is dominated by grasses, of which 10 - 20% cover is accounted for by tussocks of *Eleusine jaegeri* Pilg., 20 - 30% by *Andropogon amethystinus* Steud. and 10% by *Eragrostis schweinfurthii* Chiov. *Festuca abyssinica* A. Rich. occurs occasionally and the dwarf shrub *Alchemilla argyrophylla* Oliv. is also present. Up to 20% of the area is bare soil as a result of the activities of mole rats (*Tachyoryctes splendens* (Rüppell). Forbs include *Anagallis cf. serpens* D.C., *Trifolium cryptopodium* A. Rich. (common), *Anthemis tigrensis* A. Rich., *Geranium arabicum* Forssk. (frequent), *Gnaphalium luteoalbum* L. and *Trifolium rueppellianum* Fresen. In this habitat *U. darlingtonae* was found but was less common than another flightless grasshopper, *Coryphosima* sp., which is perhaps the most noticeable invertebrate at this altitude.

Within the open moorland habitat, some denser patches of vegetation occur, with up to 75% cover of *A. argyrophylla* and 20% cover of a small tussock grass, *Agrostis cf. gracilifolia* C.E. Hubbard. Herbs and bare ground make up the remaining 5%, with *Euphorbia brevicornu* Pax. (common), *Satureja kilimandschari* (Guerke Hedb.) (frequent), and *Polygonum afro-montanum* Greenway. *T. rueppellianum* and young *Hypericum revolutum* Vahl ssp. *keniense* (Schweinf.) N. Robson as occasionals. Here also *U. darlingtonae* was present, but only emerged from the dense *Agrostis* tussocks and *Alchemilla* and became active when the sun had been shining for half an hour and the air temperature had begun to feel pleasantly warm (c.15°C). The onset of rain towards midday caused the insects to disappear once again.

Near Chebuswa Hill the moorland grades into a *Hagenia* woodland/*Stoebe* bushland mosaic with scattered trees of *Hagenia abyssinica* (Bruce) J.F. Gmel. Here the common shrubs are *Stoebe kilimandscharica* O. Hoffm. var *densiflora* O. Hoffm., *H. keniense* and *A. argyrophylla*, *P. afro-montanum*, *Erlangea fusca* S. Moore, *Hebenstretia dentata* L. and *Clutia kilimandscharica* Engl.* The herbs include at least nine species and there are four scramblers and climbers. *U. darlingtonae* was not found within this formation though it may well occur. In such an extreme habitat it is likely that a graminivorous grasshopper like *Uganda* would tend to spend most of its periods of activity in more open areas with grasses offering greater opportunities to bask and feed during the infrequent periods of bright sunshine.

ACKNOWLEDGEMENTS

I am indebted to Dr Henk Beentje for his company on a collecting trip to the northern Aberdares and for identifying the principal plant species occurring in the moorland habitat of *P. darlingtonae*. Thanks are also due to Dr Johanna Darlington who provided a photograph of the moorland below Muir's Massif. I am grateful to the Director, Wildlife Conservation and Management Department, Ministry of Tourism and Wildlife, Kenya, for permission to work in the Aberdares National Park. Mr. Quentin Luke kindly provided the plant authorities.

* The type specimen has been destroyed. This is probably *Clutia robusta* Pax, but would be called *C. kilimandscharica* Engl. if it could be proved that they are synonymous.

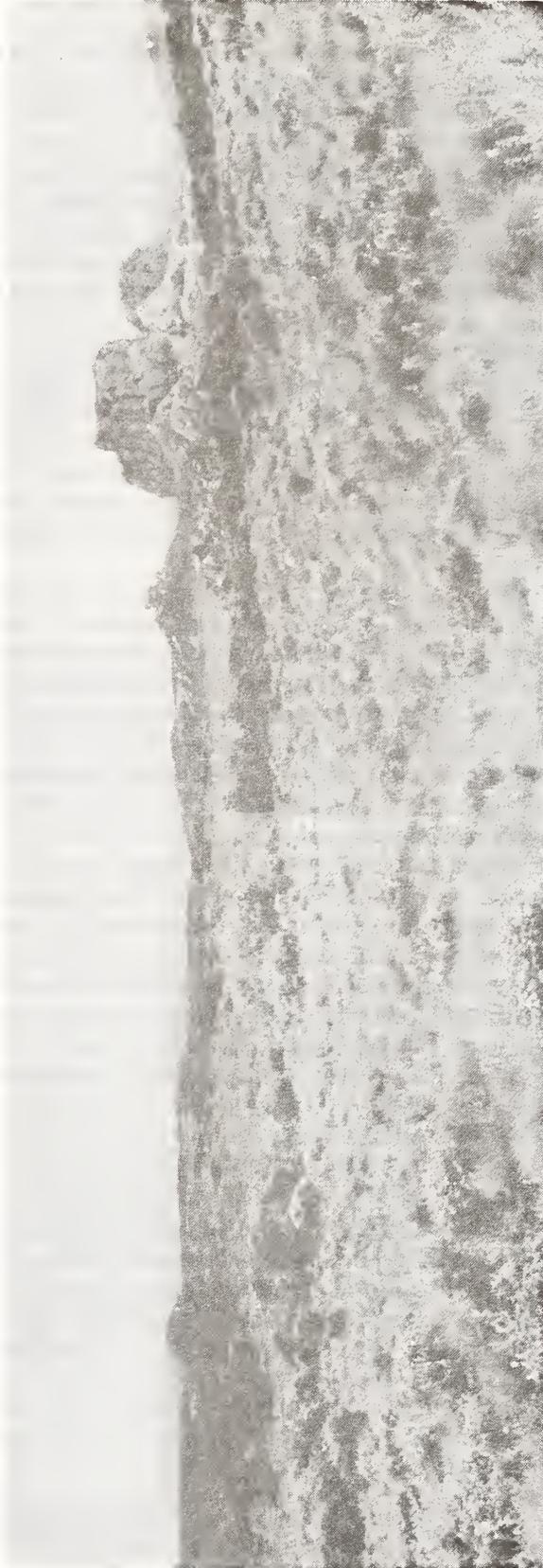


Plate. 6. Muir's Massif, northern Aberdare Range, Kenya, looking north west towards Lake Ol Bolossat. Afroalpine moorland, altitude 3650 m.
Photo J.P.E.C. Darlington.

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A CHECK-LIST AND IDENTIFICATION KEY FOR SUCCULENT PLANTS IN GENERAL CULTIVATION IN NAIROBI

LEONARD E. NEWTON and PAUL K. MBUGUA

Department of Botany, Kenyatta University, P.O. Box 43844, Nairobi, Kenya

ABSTRACT

Following a survey of succulent plants in the gardens of 50 organisations and institutions in Nairobi, a check-list of over one hundred commonly cultivated species and varieties is presented. An identification key is provided, with characters described in non-technical language.

INTRODUCTION

In its situation on the eastern side of the Kenya highlands, Nairobi has a climate that includes long periods of drought, during which unwatered lawns turn brown and many herbaceous plants die if neglected. For this reason, succulent plants have long been regarded as eminently suitable for cultivation in public and private gardens in the city. Succulent plants have water reserves in special tissues, developed in either the stems or the leaves, and are adapted by evolution for surviving long periods of drought. Leaf succulents are valued as evergreen foliage plants. In most stem-succulents the leaves are reduced or absent, and the stems are green as they have taken over the functions of the leaves. As the stems enlarge to accommodate the stored water they often grow into bizarre shapes. In addition to the decorative value of their stems and leaves, many succulent plants produce abundant colourful flowers.

The succulent plants to be seen in cultivation in Nairobi include some indigenous species, which have been collected from the wild by residents. Most are exotic, the majority having been imported during early colonial days. The exotic species are mainly from the Republic of South Africa (R.S.A.), Madagascar, and the American continent. There are also some species from neighbouring countries in north-east Africa. With such diverse origins, there is no single guide to the identification of these plants. Indigenous species can be identified with the aid of the *Flora of Tropical East Africa* (Turrill *et al.*, 1952-), though accounts of some families that include succulent species, notably the Aloaceae, Asclepiadaceae and Compositae, have not yet been published.

Commonly cultivated exotic species are mentioned in the Flora, but are not included in the identification keys, and are not described. In order to identify exotic species, therefore, it is necessary to turn to monographs, if they exist for the families or genera concerned, and to foreign floras, if the country of origin is known. Another problem is that it is not easy to prepare herbarium specimens of succulent plants. Consequently, most species are not well represented in herbaria, and many of the specimens that do exist give a very poor idea of what the living plant is like. This makes it difficult to identify succulent plants by comparison with herbarium specimens. It should also be borne in mind that in cultivation spontaneous hybridisation can occur between plants that originate from different places, and the resulting hybrids can cause confusion in attempts at identification unless their hybrid nature is recognised.

METHODS

A survey of succulent plants in cultivation in Nairobi was carried out with the aim of determining the species grown, and preparing an identification key. Fifty sites were examined, including public gardens, private gardens, and gardens in the grounds of hotels and educational institutions. Samples of each species were collected for further study in cultivation at Kenyatta University. Voucher specimens have been deposited in the East African Herbarium (National Museums of Kenya, Nairobi) and their reference numbers are indicated after the names in the checklist. This survey concentrated on species in general cultivation. Specialist collections built up by gardeners interested in growing succulent plants as a hobby were excluded.

Numerous literature sources were used for identifying the plants, but in the following check-list most names are those given by Backeberg (1977) for members of the Cactaceae, and Jacobsen (1977) for succulents in other families. The choice of these two works as standards for names was based on the fact that they represent comprehensive surveys of succulent plants, and are generally available in libraries. Later names are used for some species in the check-list, but earlier and better-known names are also given where appropriate. It should be remembered that plant names are often subject to change as a result of taxonomic research, and even some fascicles of the *Flora of Tropical East Africa* are already out of date. Exotic species were found to be poorly represented in the East African Herbarium, and as the type specimens for these species are scattered around the world's herbaria final checking with type specimens to confirm the accuracy of the names was beyond the scope of this survey.

The check-list includes a number of 'borderline succulents', *i.e.* plants that are only slightly succulent, or are not strictly succulent but have enlarged organs that resemble those of succulent plants. Examples are *Chorisia speciosa* and *Plumeria acuminata*, which are trees with thick trunks and branches. Such species are included if they are featured in succulent plant literature. The geographical origin is given for each species, if known. The origin of some species is unknown because they were already in cultivation, with no record of their origin, when coming to the attention of taxonomists.

As far as possible, vegetative characters were used to construct the key, to facilitate identification of plants without flowers. Terminology is simplified as much as possible, to allow use of the key by readers without botanical training, and specialised technical terms have been used only where an alternative expression would be very lengthy.

CHECK-LIST

Agavaceae

Agave amaniensis Trel. & Nowell (origin unknown) (*Mbugua 147*)

Originally described from material found in cultivation in Tanzania. All members of this genus are from the American continent, but the exact origin of this species is unknown.

Agave americana L. cv. Marginata (Mexico) (*Mbugua 148*)

Agave angustifolia Haw. cv. Marginata (origin unknown) (*Mbugua 16*)

Agave attenuata Salm-Dyck (Mexico) (*Mbugua 81*)

Agave bourgaei Trel. (Mexico) (*Mbugua 88*)

Agave expansa Jacobi (Mexico) (*Mbugua 84*)

Agave sisalana Perr. (Mexico) (*Mbugua 73*)

Grown commercially for the fibres in the leaves, but occasionally seen in gardens.

Aizoaceae

Aptenia cordifolia (L. f.) Schwant. (R.S.A.) (*Mbugua 20*)

- Carpobrotus edulis* (L.) Bol. (R.S.A.) (*Mbugua 9*)
Lampranthus roseus (Willd.) Schwant. (R.S.A.) (*Mbugua 106*)

Aloaceae

Formerly included in the Liliaceae, but to be treated as a separate family in the *Flora of Tropical East Africa*.

- Aloe bainesii* Th. Dyer (R.S.A.) (*Mbugua 149*)
Aloe graminicola Reyn. (East Africa) (*Mbugua 85*)
 Very close to *A. lateritia*, and possibly not a distinct species.
Aloe lateritia Engl. (East Africa) (*Mbugua 70*)
Aloe nyeriensis Christian (East Africa) (*Mbugua 150*)
Aloe secundiflora Engler (East Africa) -
Haworthia fasciata (Willd.) Haw. (*Mbugua 121*)

Apocynaceae

- Adenium obesum* (Forsk.) Roem. & Schult. (East Africa) (*Mbugua 79*)
Plumeria acuminata Ait. (Mexico) (*Mbugua 141*)

Asclepiadaceae

- Caralluma dummeri* (N.E.Br.) White & Sloane (East Africa) (*Mbugua 31*)
Stapelia leendertziae N.E.Br. (R.S.A.) (*Mbugua 54*)

Bombacaceae

- Chorisia speciosa* Saint Hil. (Brazil) (*Mbugua 144*)

Bromeliaceae

- Dyckia sulfurea* C. Koch. (Brazil) (*Mbugua 104*)

Cactaceae

- Cereus peruvianus* (L.) Mill. (South America) (*Mbugua 98*)
Cereus peruvianus (L.) Mill. f. *monstrosus* DC. (South America) (*Mbugua 56*)
Epiphyllum anguliger (Lem.) G. Don. (Mexico) (*Mbugua 92*)
Epiphyllum hybrid (*Mbugua 91*)
Heliocereus sp. (Guatemala/Mexico) (*Mbugua 135*)
Mammillaria elongata DC. var. *stella-aurata* (Mart.) K. Sch. (Mexico) (*Mbugua 117*)
Opuntia cylindrica DC. (Ecuador & Peru) (*Mbugua 43*)
Opuntia durangensis Br. & R. (Mexico) (*Mbugua 22*)
Opuntia microdasys (Lehm.) Pfeiff. (Mexico) (*Mbugua 113*)
Opuntia prasina Speg. (Argentina) (*Mbugua 97*)
Opuntia subulata Engelm. (Chile & Argentina) (*Mbugua 58*)
Opuntia vulgaris Mill. (Central America) (*Mbugua 39*)
Pachycereus orcuttii (K. Brand.) Br. & R. (USA) (*Mbugua 44*)
Schlumbergera bridgesii (Lem.) Loeffgr. (Brazil) (*Mbugua 86*)
 Formerly called *Zygocactus truncatus* (Haw.) K. Sch.
 Probably of hybrid origin.

Commelinaceae

- Tradescantia sillamontana* Matuda (Mexico) (*Mbugua 82*)

Compositae

- Senecio aizoides* (DC.) Sch. Bip. (R.S.A.) (*Mbugua 11*)
Senecio crassissimus H. Humb. (Madagascar) (*Mbugua 61*)
Senecio hildebrandtii Bak. (Madagascar) (*Mbugua 64*)
Senecio jacobsonii Rowl. (East Africa) (*Mbugua 6*)
Senecio sempervivus (Forsk.) Sch. Bip. (East Africa) (*Mbugua 47*)

Crassulaceae

- Aeonium arboreum* (L.) Webb & Berth. cv. *Atropurpureum* (Mediterranean region) (*Mbugua 87*)
Aeonium haworthii (SD.) Webb & Berth. (Canary Islands) (*Mbugua 52*)
Cotyledon coruscans Haw. (R.S.A.) (*Mbugua 50*)
Cotyledon orbiculata L. (R.S.A.) (*Mbugua 59*)
Crassula argentea Thunb. (R.S.A.) (*Mbugua 65*)
Crassula multicava Lem. (R.S.A.) (*Mbugua 7*)
Crassula perfoliata L. (R.S.A.) (*Mbugua 15*)
Crassula portulacaea Lam. (R.S.A.) (*Mbugua 49*)
Crassula sarmentosa Harv. (R.S.A.) (*Mbugua 17*)
Crassula schimperii Fisch. & Mey. (East Africa) (*Mbugua 14*)
Echeveria columbiana v. Poelln. (Columbia) (*Mbugua 28*)
Echeveria pulvinata Rose (Mexico) (*Mbugua 99*)
Echeveria tolimanensis Matuda (Mexico) (*Mbugua 142*)
Graptopetalum macdougallii Alexander (Mexico) (*Mbugua 138*)
Graptopetalum paraguayense (N.E.Br.) Walth. (Mexico) (*Mbugua 76*)
Graptopetalum pusillum Rose (Mexico) (*Mbugua 32*)
Kalanchoe beharensis Drake & Castello var. *aureo-aeneus* Jacobs. (Madagascar) (*Mbugua 80*)
Kalanchoe beharensis Drake & Castello var. *beharensis* (Madagascar) (*Mbugua 34*)
Kalanchoe delagoensis Eck. & Zeyh. (Madagascar) (*Mbugua 1*)
 Formerly called *K. tubiflora* (Harv.) Hamet
Kalanchoe diagremontiana Hamet & Perr. (Madagascar) (*Mbugua 143*)
Kalanchoe fedtschenkoi Hamet & Perr. (Madagascar) (*Mbugua 3*)
Kalanchoe gastonis-bonnierii Hamet & Perr. (Madagascar) (*Mbugua 2*)
Kalanchoe hametorum Hamet (Mozambique) (*Mbugua 100*)
Kalanchoe longiflora Schltr. var. *coccinea* Marn.-Lap. (Tropical Africa) (*Mbugua 23*)
Kalanchoe longiflora Schltr. var. *longiflora* (Tropical Africa) (*Mbugua 5*)
Kalanchoe marmorata Bak. (East Africa) (*Mbugua 42*)
Kalanchoe marnieriana Jacobs. (Madagascar) (*Mbugua 89*)
Kalanchoe millottii Hamet & Perr. (Madagascar) (*Mbugua 90*)
Kalanchoe nyikae Engl. ssp. *nyikae* (East Africa)
 As *Kalanchoe hemsleyana* Cuf. in Jacobsen.
Kalanchoe pinnata (Lam.) Persoon var. *calvicola* Perr. (Tropical Africa) (*Mbugua 145*)
Kalanchoe prolifera (Bowie) Hamet (Tropical Africa) (*Mbugua 26*)
Kalanchoe pumila Bak. (Madagascar) (*Mbugua 119*)
Kalanchoe rosei Hamet & Perr. (Madagascar) (*Mbugua 48*)
Kalanchoe scapigera Welw. (Angola) (*Mbugua 131*)
Kalanchoe thyrsoiflora Harv. (R.S.A.) (*Mbugua 94*)
Sedum dendroideum Moc. & Sesse (Guatemala, Mexico) (*Mbugua 8*)
Sedum guatemalense Hemsl. (Guatemala) (*Mbugua 45*)
Sedum pachyphyllum Rose (Mexico) (*Mbugua 4*)
Sedum morganiannum Walth. (Mexico) (*Mbugua 122*)
Sedum nussbaumerianum Bitter (Mexico) (*Mbugua 24*)

Sedum palmeri S. Wats. (Mexico) (*Mbugua 96*)

Dracaenaceae

Sansevieria caulescens N.E.Br. (East Africa) (*Mbugua 63*)

Sansevieria suffruticosa N.E.Br. (East Africa) (*Mbugua 103*)

Sansevieria robusta N.E.Br. (East Africa) (*Mbugua 30*)

Often referred to as *S. ehrenbergii*, but in Kenya that species occurs only in Coast Province.

Sansevieria trifasciata Prain cv. *Hahnii* (*Mbugua 102*)

Sansevieria trifasciata Prain var. *laurentii* (De Willd.) N.E.Br. (Congo Republic) (*Mbugua 72*)

Sansevieria trifasciata Prain var. *trifasciata* (Sri Lanka) (*Mbugua 12*)

Euphorbiaceae

Euphorbia arbuscula Balf. f. (Socotra) (*Mbugua 105*)

Euphorbia bussei Pax var. *kibwezensis* (N.E.Br.) Carter (East Africa) (*Mbugua 41*)

Formerly known as *E. kibwezensis* N.E.Br.

Euphorbia candelabrum Trem. (East Africa) (*Mbugua 101*)

Euphorbia milii Des Moulin (Madagascar)

A very variable species. Many varieties have been named, but hybrids between these have appeared in gardens and certain identification is difficult. The following varieties appear to be cultivated in Nairobi.

Euphorbia milii Des Moulin var. *bevilaniensis* (Croiz.) Ursch & Leandri f. *rubro-striata* Drake & Castillo (*Mbugua 108*)

Euphorbia milii Des Moulin var. *hislopii* (N.E.Br.) Ursch & Leandri (*Mbugua 60*)

Euphorbia milii Des Moulin var. *imperatae* (Leandri) Ursch & Leandri (*Mbugua 109*)

Euphorbia milii Des Moulin var. *longifolia* Rauh (*Mbugua 107*)

Euphorbia milii Des Moulin var. *splendens* (Boj. ex Hook.) Ursch & Leandri (*Mbugua 21*)

Euphorbia milii Des Moulin var. *tulearensis* Ursch & Leandri (*Mbugua 112*)

Euphorbia obovalifolia A. Rich. (East Africa) (*Mbugua 133*)

Euphorbia stenoclada H. Baill. (Madagascar) (*Mbugua 95*)

Euphorbia tirucalli L. (East Africa) (*Mbugua 37*)

Euphorbia 'heterochroma' (East Africa)

Ten species are now recognised in this group, all formerly called *E. heterochroma* Pax or *E. stapfii* Berger. Specimens in cultivation collected in different areas represent different species. The one growing naturally in the southern Rift Valley of Kenya, near Nairobi, is *E. scarlatina* Carter.

Jatropha podagrica Hook. (Guatemala) (*Mbugua 78*)

Monadenium stapelioides Pax (East Africa) (*Mbugua 136*)

Pedilanthus tithymaloides Poit. (Central America) (*Mbugua 33*)

Synadenium grantii Hook. (East Africa) (*Mbugua 47*)

Labiatae

Coleus spicatus Benth. (India) (*Mbugua 36*)

Liliaceae

Bowiea volubilis Harv. & Hook. f. (East Africa to R.S.A.) (*Mbugua 124*)

East African plants formerly distinguished as *B. kilimandscharica* Mildbr.

Bulbine frutescens (L.) Willd. (R.S.A.) (*Mbugua 38*)

Portulacaceae

Portulaca cv. *Grandiflora* (origin unknown) (*Mbugua 10*)

Probably of inter-specific hybrid origin, but parent species unknown

Vitaceae*Cissus quadrangularis* L. (East Africa) (Mbugua 35)**IDENTIFICATION KEY**

- Water storage in fat, fleshy stems, leaves less fleshy and commonly deciduous, reduced or absent:stem succulents, Group I
- Water storage in fat, fleshy \pm persistent leaves, which are at least more succulent than the stems:leaf succulents, Group II

GROUP I - Stem succulents

1. Stem angled, flat or grooved.....2
- Stem not angled, flat or grooved, \pm cylindrical22
2. Stem with milky latex3
- Stem without latex7
3. Stem spiny or thorny4
- Stem neither spiny nor thorny*Euphorbia arbuscula*
4. Stem 3-angled.....5
- Stem with more than 3 angles6
5. Stems and leaves variegated*Euphorbia obovalifolia*
- Stem and leaves not variegated.....*Euphorbia bussei* v. *kibwezensis*
6. Stem diameter over 7.0 cm, over 3.0 m high*Euphorbia candelabrum*
- Stem diameter about 1.5–2.0 cm, under 3 m high.....*Euphorbia 'heterochroma'*
7. Stem flattened or jointed8
- Stem angular, grooved or tuberculate14
8. Stem spiny or thorny9
- Stem neither spiny nor thorny12
9. Spines weak, up to 1 cm long, or absent10
- Spines strong, over 2 cm long*Opuntia vulgaris*
10. Spines present, accompanied by a few minute barbed bristles11
- Spines absent, stem with numerous minute yellow barbed bristles*Opuntia microdasys*
11. Stem joints over 35 cm long, spines more than 1 cm long*Opuntia prasina*
- Stem joints less than 22 cm long, spines less than 1 cm long.....*Opuntia durangensis*
12. Stem with hairs13
- Stem without hairs*Epiphyllum hybrid*
13. Stem divided into short joints, 4–7 cm long.....*Schlumbergera bridgesii*
- Stem not divided into short joints.....*Epiphyllum anguliger*
14. Stem spiny or thorny15
- Stem neither spiny nor thorny19
15. Stem with more than 4 vertical grooves, no aerial roots.....16
- Stem with only 3 vertical grooves, and aerial roots.....*Heliocereus* sp.
16. Young spines covered in woolly outgrowths*Cereus peruvianus*
- Young spines not covered in woolly outgrowths17
17. Spines 1–4 together.....18
- Spines more than 4 together21
18. Stem tips with needle-shaped succulent leaves, 2.5–4.0 cm long*Opuntia subulata*
- Stem tips with leaves 1–2 cm long, that soon fall*Opuntia cylindrica*
19. Stem with tendrils, climbing*Cissus quadrangularis*
- Stem without tendrils, erect or creeping20

20.	Stem hairy, with teeth 0.2 cm long	<i>Stapelia leendertziae</i>	
	Stem not hairy, with conical teeth up to 1.4 cm long	<i>Caralluma dummeri</i>	
21.	Stem with parallel, vertical and continuous grooves, weak spines	<i>Pachycereus orcuttii</i>	
	Stem with discontinuous, zig-zag grooves, very firm spines	<i>Cereus peruvianus f. monstrosus</i>	
22.	Stem thorny or spiny		23
	Stem neither thorny nor spiny		32
23.	Stem with milky latex		24
	Stem without latex		31
24.	Stem with numerous tubercles, and 2–3 small backward curved spines per tubercle	<i>Monadenium stapelioides</i>	
	Stem without tubercles.....		25
25.	Inflorescence bright to dull red		26
	Inflorescence bright to greenish-yellow		30
26.	Stem 2 cm or more in diameter, leaf more than 10 cm long	<i>Euphorbia milii v. hislopii</i>	
	Stem less than 2 cm diameter, leaf less than 5 cm long		27
27.	Floral bracts yellowish-red striate	<i>Euphorbia milii v. bevilaniensis f. rubro-striata</i>	
	Floral bracts entirely red or yellow		28
28.	Leaves more than 3 times longer than wide	<i>Euphorbia milii v. longifolia</i>	
	Leaves less than 3 times longer than wide		29
29.	Stems 5 mm diameter	<i>Euphorbia milii v. imperatae</i>	
	Stems at least 10 mm diameter		30
30.	Thorns soft, 5–10 mm long	<i>Euphorbia milii v. tulearensis</i>	
	Thorns firm, more than 10 mm long	<i>Euphorbia milii v. splendens</i>	
31.	Tree with conical thorns on trunk; leaves palmate	<i>Chorisia speciosa</i>	
	Dwarf plant with clusters of needle-like spines on stem tubercles; leaves absent	<i>Mammillaria elongata v. stella-aurata</i>	
32.	Stem with milky latex		33
	Stem without milky latex		36
33.	Leaves variegated		34
	Leaves (when present) not variegated		35
34.	Stem with whitish-cream vertical bands	<i>Pedilanthus tithymaloides</i>	
	Stem without bands, pinkish to greenish bark	<i>Synadenium grantii</i>	
35.	Leaves persistent, to 20 cm long	<i>Plumeria acuminata</i>	
	Leaves short-lived, when present 1.0–1.5 cm long	<i>Euphorbia tirucalli</i>	
36.	Green shoots non-succulent, growing from bulb	<i>Bowiea volubilis</i>	
	Green shoots succulent and not distinct from storage organs		37
37.	Leaves 20 cm or more long, lobed, stem surface rough	<i>Jatropha podagrica</i>	
	Leaves less than 2 cm long, simple spatula-shaped, stem surface smooth	<i>Adenium obesum</i>	

GROUP II - Leaf succulents

1.	Leaves simple	2
	Leaves compound	75
2.	Leaves thorny or spiny, sometimes with apical spine	3
	Leaves neither thorny nor spiny (but may have a hardened tip, e.g. <i>Sansevieria</i> spp.)	14
3.	Margin thorny or spiny	4
	Margin neither thorny nor spiny, but apical spine present	<i>Agave sisalana</i>
4.	Plant with obvious stem above ground	13
	Plant without obvious stem above ground	5
5.	Leaves tough, fibrous, not snapping cleanly when folded	6
	Leaves scarcely fibrous, snapping cleanly when folded	9

6.	Leaves with longitudinal coloured bands	7
	Leaves without coloured bands	11
7.	Leaves with longitudinal ridges, slightly rough	<i>Agave amaniensis</i>
	Leaves without ridges, smooth	8
8.	Leaves 2.4–2.6 m long	<i>Agave americana</i> cv. Marginata
	Leaves 0.5–0.6 m long	<i>Agave angustifolia</i> cv. Marginata
9.	Leaves with white spots	10
	Leaves without spots	<i>Aloe secundiflora</i>
10.	Lower leaf surface with white oblong spots except near tip	<i>Aloe lateritia</i>
	Lower leaf surface with white spots for whole length	<i>Aloe graminicola</i>
11.	Leaves with numerous, small greenish-yellow vertical lines	<i>Dyckia sulfurea</i>
	Leaves without lines	12
12.	Leaf surface rough, white-gray	<i>Agave expansa</i>
	Leaf surface smooth, grayish-green	<i>Agave bourgaei</i>
13.	Stem covered with old leaves	<i>Aloe nyeriensis</i>
	Stem not covered with old leaves	<i>Aloe bainesii</i>
14.	Leaves ± cylindrical, may be strap-shaped at base	15
	Leaves with at least 1 flat surface	27
15.	Leaves produced in opposite pairs	16
	Leaves produced singly	18
16.	Stem with hairs at nodes	<i>Portulaca</i> cv. Grandiflora
	Stem without hairs	17
17.	Leaf with grayish-black spots	<i>Kalanchoe delagoensis</i>
	Leaf without spots	<i>Crassula schimperii</i>
18.	Leaf tip rounded	19
	Leaf tip pointed	21
19.	Stem hanging	<i>Sedum morganianum</i>
	Stem upright	20
20.	Leaves with thick waxy bloom, greenish-white	<i>Sedum pachyphyllum</i>
	Leaves without waxy bloom, bright green	<i>Sedum guatemalense</i>
21.	Leaves sheathed	22
	Leaves not sheathed	25
22.	Leaves containing fibres	23
	Leaves not containing fibres	<i>Bulbine frutescens</i>
23.	Leaf with groove near base	<i>Sansevieria robusta</i>
	Leaf with groove extending from base to over half-way up	24
24.	Leaves 9–15 cm long	<i>Sansevieria suffruticosa</i>
	Leaves 60–90 cm long	<i>Sansevieria caulescens</i>
25.	Stem with spines	<i>Opuntia subulata</i>
	Stem without spines	26
26.	Leaves with thick waxy bloom	<i>Senecio aizoides</i>
	Leaves without waxy bloom	<i>Senecio hildebrandtii</i>
27.	Leaves with 1–2 flat surfaces (underside may be rounded)	28
	Leaves with 3 flat surfaces (trigonus, especially at tips)	74
28.	Leaf margin regular	29
	Leaf margin irregular	59
29.	Leaf under surface ± rounded (esp. in young leaves)	30
	Leaf upper and under surfaces ± flat	37
30.	Leaves hairy or scaly	31
	Leaves smooth, without hairs or other ornamentation	32

31. Leaves hairy, giving grayish colour *Echeveria pulvinata*
 Leaves not hairy *Haworthia fasciata*
32. Upper leaf surface \pm concave (esp. at base) 33
 Upper leaf surface completely flat 36
33. Leaf with keel, edge sharp 34
 Leaf without keel, edge rounded *Cotyledon coruscans*
34. Leaf 8–15 cm long 35
 Leaf 5.0–6.5 cm long *Graptopetalum pusillum*
35. Leaf tip extended into a bristle *Echeveria tolimanensis*
 Leaf tip not extended into a bristle *Graptopetalum paraguayense*
36. Leaves with thick waxy bloom *Echeveria columbiana*
 Leaves without waxy bloom *Sedum nussbaumeranum*
37. Leaves with fibres 38
 Leaves without fibres 41
38. Leaves with gray-green transverse bands 39
 Leaves without bands *Agave attenuata*
39. Leaves with yellowish-white stripes along the margins *Sansevieria trifasciata* v. *laurentii*
 Leaves without stripes 40
40. Leaves with parallel sides, to 90 cm long *Sansevieria trifasciata* v. *trifasciata*
 Leaves with rounded sides, to 10 cm long *Sansevieria trifasciata* cv. *Hahnii*
41. Stem lying on ground 42
 Stem upright 44
42. Plant hairy *Tradescantia sillamontana*
 Plant not hairy 43
43. Leaves produced in opposite pairs, tips pointed *Aptenia cordifolia*
 Leaves produced singly, tips rounded *Senecio jacobsenii*
44. Plant with milky latex 45
 Plant without latex 46
45. Leaves variegated gray-green *Pedilanthus tithymaloides*
 Leaves not variegated *Monadenium stapelioides*
46. Leaves produced in opposite pairs 47
 Leaves produced singly 55
47. Leaf tips rounded 48
 Leaf tips pointed (at least in young stage) 50
48. Leaf surface marked with minute spots 49
 Leaf surface without minute spots 52
49. Leaves with pinkish-green tips *Crassula portulacaea*
 Leaves dark green throughout *Crassula multicava*
50. Leaf base extended as two rounded lobes
 below attachment to stalk *Kalanchoe marnieriana*
 Leaf base entirely above attachment to stalk 51
51. Leaves clasping the stem, 10–15 cm long, 7–9 cm wide *Kalanchoe thyrsiflora*
 Leaves not clasping the stem, 7–9 cm long, 4–6 cm wide *Cotyledon orbiculata*
52. Leaves with velvety hairs *Kalanchoe scapigera*
 Leaves not hairy 53
53. Leaves with stalks 54
 Leaves without stalks *Crassula perfoliata*
54. Plant with thick waxy bloom *Kalanchoe hametorum*
 Plant without waxy bloom *Crassula argentea*

55.	Leaves without stalks	56
	Leaves with stalks	57
56.	Leaf tip pointed	<i>Graptopetalum macdougallii</i>
	Leaf tip rounded	<i>Sedum palmeri</i>
57.	Leaf surface horny	<i>Senecio crassissimus</i>
	Leaf surface not horny	58
58.	Leaf veins visible on both surfaces	<i>Senecio sempervivus</i>
	Leaf veins not visible on upper surface, only major vein visible on underside	<i>Sedum dendroideum</i>
59.	Stem with 4 angles	60
	Stem ± cylindrical	61
60.	Plant hairy	<i>Coleus spicatus</i>
	Plant not hairy	<i>Kalanchoe longiflora</i> v. <i>longiflora</i>
61.	Leaves stalked	62
	Leaves not stalked	71
62.	Leaves smooth	63
	Leaves with fine hairs	70
63.	Leaf base extended as two rounded lobes below attachment to stalk	64
	Leaf base entirely above attachment to stalk	65
64.	Leaves ovate	<i>Kalanchoe fedtschenkoi</i>
	Leaves lanceolate	<i>Kalanchoe rosei</i>
65.	Leaf stalk attached to lower surface of blade	66
	Leaf stalk attached to edge of blade	67
66.	Leaf margins wavy	<i>Kalanchoe beharensis</i> v. <i>beharensis</i>
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67.	Leaves with thick waxy bloom	68
	Leaves without waxy bloom	69
68.	Leaf margin teeth with bluish-pink base (especially on old leaves)	<i>Kalanchoe hemsleyana</i>
	Leaf margin teeth same colour as blade at the base	<i>Kalanchoe pumila</i>
69.	Leaf surface marked with minute spots	<i>Crassula sarmentosa</i>
	Leaf surface without minute spots	<i>Kalanchoe longiflora</i> v. <i>coccinea</i>
70.	Leaves and stem (esp. young stems) velvety	<i>Kalanchoe beharensis</i> v. <i>aureo-aeneus</i>
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71.	Leaves produced in opposite pairs	72
	Leaves produced singly	73
72.	Leaf tip with pointed elongation	<i>Kalanchoe gastonis-bonnierii</i>
	Leaf tip rounded	<i>Kalanchoe marmorata</i>
73.	Leaves light gray-green	<i>Aeonium haworthii</i>
	Leaves dark-brownish purple	<i>Aeonium arboreum</i> cv. <i>Atropurpureum</i>
74.	Leaves 2–4 cm long	<i>Lampranthus roseus</i>
	Leaves 8–10 cm long	<i>Carpobrotus edulis</i>
75.	Stem 4-angled (esp. in youngest parts), diameter 4–6 cm	<i>Kalanchoe prolifera</i>
	Stem ± cylindrical, diameter 2–3 cm.	<i>Kalanchoe pinnata</i> v. <i>calcicola</i>

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ALPINE VERTEBRATES OF MOUNT KENYA, WITH PARTICULAR NOTES ON THE ROCK HYRAX

1990

Truman P. Young

Calder Conservation and Ecology Center, Fordham University
Box K, Armonk, NY, 10504, U.S.A.

Matthew R. Evans*

Department of Zoology, University of Cambridge
Downing Street, Cambridge, CB2 3EJ, U.K.

INTRODUCTION

Various observers over the years have contributed to our knowledge of Mount Kenya's alpine vertebrates. There is only limited evidence that traditional cultures visited alpine Mount Kenya (Coe 1967), and no records of what they found there. Sharpe (1900) and Thomas (1900) made the first lists of animals on Mount Kenya, followed shortly by Loring and Heller (in Roosevelt 1910). Hollister (1919) provided a description of mammals collected from East Africa, including those of Mount Kenya.

However, it was not until Moreau (1944) that a systematic description of the vertebrate fauna was attempted. Since then, a great deal has been added to our understanding of the vertebrates of alpine Mount Kenya. Coe and Foster (1972) made a considerable contribution to our knowledge of the mammals of the northern slopes, in particular the smaller mammals (rodents and shrews). Williams (1978) provided an extensive list of birds and mammals of Mount Kenya National Park. Coe (1967), Coe and Sale (1971), Fayad (1981), and Young (1991) gave brief summaries of the alpine faunas of Mount Kenya and Kilimanjaro. Numerous other authors have provided information on individual species and groups. Mount Kenya has been the subject of considerable botanical, zoological, and ecological research over the last thirty years (see Rehker 1989, Young 1990). Nonetheless, it has been half a century since the last comprehensive description of Mount Kenya's alpine vertebrate fauna (Moreau 1944). It is therefore appropriate to update our knowledge of the alpine vertebrates of Mount Kenya.

In this review, we have drawn on published literature and on personal communications with both visitors and those familiar with the mountain. However, much of the information below is drawn from personal experience. Between 1977 and 1990, TPY spent over 500 days and nights above treeline on Mount Kenya. Most of this time was spent in the Teleki Valley, but also included one to several visits to

*Present address: Edward Grey Institute of Field Ornithology, Department of Zoology, Oxford University South Parks Road, Oxford, OX1 3PS, U.K.

each of the Hobley, Hinde, Gorgeš, Hohnel, Mackinder, Liki, Sirimon, Kazita, and Marania Valleys. In 1989–90, MRE spent over 200 days on Mount Kenya, mostly in the Teleki Valley.

In the descriptions below, the 'research camp' (of TPY) was located at 4180 m in the Teleki Valley, near the Ranger Station. 'Northern slopes' refers to the area above treeline between the Hinde and the Sirimon Valleys (mainly the drainages of the Marania and Kazita rivers). The 'Treeline' occurs at 3000–3300 m. Elevations are probably accurate to ± 100 m. Except where noted, all of the observations below are ours.

At least 15 of the 112 species listed below have not been previously recorded from alpine Mount Kenya. In addition, species previously thought to be only alpine visitors have been identified as at least partly resident in the alpine zone (e.g., Slender-billed Starling, Lion and Zorilla). There are also several new altitudinal limits for Africa (Spotted Hyaena, Zorilla, Bongo, Sykes' and Colobus Monkeys, Yellow-crowned Canary, and *Rana wittei*). We have accepted the nomenclature of specialised literature (reptiles and amphibians: Loveridge 1957; birds: Britton 1980, Lewis and Pomeroy 1989; mammals: Dorst and Dandelot 1972 and Kingdon 1974).

ALPINE VEGETATION OF MOUNT KENYA

The Mount Kenya forest varies with aspect. It is wettest on the south-eastern slopes and driest on the northern slopes, with bamboo favoring the wettest sites (Hedberg 1951, Young 1990). However, at higher altitudes (above treeline), the western slope (Naro Moru track) and southern slope (Kamweti track) are wetter than either the northern slope (Sirimon and Timau tracks) or eastern slope (Chogoria track). In general, rainfall increases with altitude up to 2500–3200 m, and then decreases with altitude (Winiger 1986).

Numerous attempts have been made over the years to describe the vegetation of Mount Kenya (Hedberg 1951, 1964; Coe 1967), but only recently has an alpine vegetation map been produced (Rehder *et al.* 1988, 1989) and a quantitative analysis of plant community composition done (Young and Peacock 1992). Common to all descriptions is the recognition of the importance of altitude and topography on the alpine vegetation. A well defined timberline occurs at 3000–3300 m on all but the northern slopes. (On the northern slopes we have arbitrarily set 3000 m as the lower limit for alpine records). Many plant species have their lower or upper altitudinal limits at timberline.

Immediately above the forest boundary there is a band of ericaceous scrub whose composition and breadth vary with aspect. This vegetation band is narrowest and least diverse on the wetter and steeper slopes to the west and south, and is widest and contains the greatest diversity of shrubs on the drier and gentler northern and eastern slopes. Vast areas between the Marania and Hinde Valleys are covered by this little-explored vegetation. Fires are a regular occurrence in this habitat (Bill Woodley, Phil Snyder, personal communication), perhaps occurring at intervals of several years (Bongo Woodley, personal communication).

At higher altitudes (3400–3700 m) this ericaceous scrub merges gradually into the classic afroalpine vegetation, with its characteristic giant rosette plants (*Lobelia* and *Senecio* spp). The more level valley bottoms and (except at great altitude) ridges are wetter and contain a more lush vegetation than the slopes, which are characterised by sparser vegetation cover and drought resistant species (Young and Peacock 1992). At nearly all alpine sites above the heather, the tussock grass *Festuca pilgeri* is the dominant plant. In some sites it forms virtual monocultures of large tussocks, especially on wetter aspects between 3600 and 4100 m. The greatest diversity of plant species appear to be at middle alpine altitudes (3900–4200 m), at least on the western slope. Above 4100 m, the vegetation gradually becomes sparser, and plants are rare above 4500 m.

In addition to altitude and topography, the age of *Senecio keniodendron* stands is a key determinant of plant community composition. This species occurs as single-sized (and presumably single-aged) stands on mid-altitude slopes. In the Teleki Valley, the understoreys of younger stands are characterised by *Festuca pilgeri* and *Helichrysum* spp, and the understoreys of older stands are characterised by nearly monospecific stands of *Alchemilla* spp (Young and Peacock 1992). The latter appear to be favorite resting spots for Grimm's Duiker.

In addition, virtually all major drainages contain running water throughout the year, and there are numerous permanent tarns, occurring at altitudes of 3000 to 4500 m.

MOUNT KENYA'S ALPINE VERTEBRATES

Fish (3 spp)

Salvelinus alpinus (Arctic Char, American Brook Trout)

Not native; stocked in Lake Hohnel in 1949, but apparently failed to breed there (Copley 1953, Watson 1988). They are extinct there now (John Omira Miluwi, personal communication).

Salmo trutta (Brown Trout)

Not native; stocked in the Ontilili, Hinde, and Sirimon rivers (Coe and Sale 1971, Watson 1988).

Salmo gairdnerii (Rainbow Trout)

In addition to the two species above, Mills (1971) reports that Rainbow Trout were introduced to Kenya. This species is present in the Teleki Valley (Naro Moru River), and perhaps also in the Marania and Kazita rivers. The upper Naro Moru River in Teleki Valley has been heavily fished in the past (J. Omira, personal communication), but was supporting fair numbers of fish in 1989–90, when MRE was given a gravid female weighing 1 kg. The trout in the Marania and Kazita rivers are numerous and under-sized (TPY, personal observation). Bongo Woodley reports that this species has been recently released into Rutundu, Alice, Ellis and Carr Lakes, where they do not breed due to a lack of flowing water. At these lakes, 1–2 kg fish are commonly caught, and a 3.5 kg trout was caught in Lake Alice (Bongo Woodley, personal communication).

Amphibians (2 spp)

Phrynobatrachus kinangopensis Angel

Loveridge (1957) reports this species as high as 3350 m. In addition to this and the following species, Tom Madsen (personal communication) suggests there are others just above timberline on the Sirimon Track.

Rana wittei Angel

This species is the common larger (body length 5 cm) frog in the lower alpine on the Timau Track, where it breeds in the Kazita River. It also occurs on the Sirimon Track (T. Madsen, personal communication). A sighting of probably this species by Alan Smith and TPY at 3800 m in the Hinde Valley is apparently an altitude record for an amphibian in East Africa. Bongo Woodley reported frogs from Lake Alice and the Nithi River in August 1993 (personal communication).

Reptiles (6 spp)*Algyroides alleni* Barbour (Alpine Meadow Lizard)

Algyroides alleni is common throughout the drier parts of the mountain. TPY has encountered them in the Sirimon, Liki, Marania, Kazita, Hinde, Gorges, and Hobley Valleys at altitudes of 3400–4600 m, but not in the wetter Teleki or Hohnel Valleys. However, MRE has seen one just down the ridge from Two Tarn Hut. Their upper limit is represented by a population just south of Kami Hut at the head of the Mackinder Valley, and may be an altitude record for an East African reptile. At this site, the lizards live amongst the rocks, whereas at lower altitudes they are usually found in and on grass tussocks of *Festuca pilgeri*. Coe (1969) found eggs of this species at 3800 m.

Mabuya irregularis Lonberg (Skink)

TPY found this skink at 3600 m in dry scrubby grassland 4 km north-west of Ithanguni Peak in 1982. Its alpine distribution is not known. The genus is currently under taxonomic review, and it is possible that the alpine form is a distinct species (T. Madsen, personal communication).

Chameleo schubotzi Sternfeld (Kenya Side-striped Chameleon)

The type of this species (then *C. bitaeniata schubotzi*) in 1912 is recorded as being collected from 14,000 feet (4200 m) on Mount Kenya (Loveridge 1957), but such an extreme height seems unlikely. In June 1978 Alan Smith and TPY found an individual at 3850 m on the ridge west of the Hobley Valley. It was on the leaf of a *Senecio keniensis (brassica)* rosette about 0.5 m tall. James Hebrard (1981) reports that they are not uncommon in the ericaceous scrub just above treeline on Mount Kenya, and prefer the scrub layer less than two meters above the ground.

Chameleo hohnelii Steindachner (Hohnel's Chameleon)

This species appears to be restricted to the ericaceous scrub just above treeline, and prefers the vegetation more than two meters above the ground (Hebrard 1981).

Vipera hindei Boulenger (Hinde's Viper)

This snake, which is reportedly not uncommon in the alpine grassland of the Aberdare Mountains (A. McKay, personal communication), also occurs in alpine Mount Kenya. Individuals have been reported from the northern slopes by Raymond Hook (Moreau 1944), Phil Snyder, and Nigel Trent (personal communications). With Tim Tear, TPY photographed a small individual on the Timau Track at 3400 m in September 1982. Bongo Woodley found two Hinde's Vipers (13 and 20 cm long) on the shore of Lake Alice in March 1993 (personal communication).

Psammophylax variabilis multisquamis Loveridge (Striped Grass Snake)

Reported from Mt Kenya's 'high grass moorlands' (Sprawls 1978). Bongo Woodley saw a long thin snake along the Nithi River above the roadhead on the Chogoria Track in March 1993 (personal communication), perhaps of this species.

Birds (58 spp)*Tachybaptus (Poliiocephalus) ruficollis capensis* (Pallas) Salvadori (Little Grebe or Dabchick)

Reported by Moreau (1944) from Lake Ellis (3450 m).

Scopus umbretta Gmelin (Hamerkop)

Reported from the Chogoria Track above treeline in March 1984 by Tim Tear (personal communication).

Anastomus lamelligerus Temminck (Open-billed Stork)

On at least two occasions, Open-billed Storks have visited the upper Teleki Valley. Coe and Sale (1971) reported a dead individual at the head of the valley (4180 m). In September 1976, a group of several birds landed in the valley in the vicinity of the Teleki Hut (4000 m) and, apparently unable to regain flight the next day, died there (John Omira Miluwi, personal communication). TPY saw several of these dead birds in 1977. Open-billed storks are regional migrants (Williams and Arnott 1980), and may occasionally mistake the boggy alpine valley bottoms for hospitable habitat, with fatal results.

Ciconia ciconia L. (White Stork)

Reported as an occasional visitor on migration by Williams (1978).

Bostrychia (Lamprolaima) olivacea akeleyorum (Dubois) Chapman (Green Ibis)

This high forest bird, recorded from 2000–3700 m (Britton 1980) is suspected of being at least partly nocturnal (Williams and Arnott 1980). Small groups are frequently heard and seen at dusk flying above the forest near the Met Station (3000 m) on the Naro Moru Track. Jackson (1938) quotes Akeley as seeing them on “Mount Kenya from 6,000–12,000 feet (timber line)”. In November 1979, John Imhof reported several pre-dawn encounters with honking, long-necked birds flying down the Teleki Valley at 4000 m. These birds may have been Green Ibises.

Anas sparsa leucostigma (Eyton) Rüppell (African Black Duck)

There are several resident pairs of Black Ducks on the tarns at 4000–4400 m. TPY found an abandoned nest with five eggs at Teleki Tarn (4300 m). It was located at the water's edge and made out of grass (*Festuca pilgeri*), lined with down, and covered by a layer of grass. TPY also saw a pair of adults with ducklings at Thompson's Tarn (4400 m). Coe (1967) reports other records of Black Ducks nesting on alpine tarns. They have also been seen on the Nithi River near Lake Ellis (Bongo Woodley, personal communication)

Oxyura maccoa Eyton (Maccoa Duck)

TPY found a male and three females on Lake Rutundu (3000 m) in September 1982.

Sagittarius serpentarius Miller (Secretary Bird)

TPY has seen only one individual, on the Timau Track at 3400 m in 1980, although other sightings by Bongo Woodley, Helen Young and Vince Fayad (personal communications.) between 1978 and 1993 imply they may not be uncommon along the Timau and Sirimon Tracks. Raymond Hook also reported one at 3960 m (Moreau 1944).

Gyps rueppellii Brehm (Rüppell's Vulture)

Occasional wanderer to the moorlands (D.A. Turner, personal communication)

Gypaetus barbatus meridionalis (L.) Keys. & Blas. (Lammergeyer)

Lammergeyers have been repeatedly sighted along the Sirimon Track near Sendeyo and Tereri Peaks. We have each seen one flying high above the Teleki Valley, in different years. These birds may be resident.

Circus aeruginosus L. (Eurasian Marsh Harrier)
Reported as a migrant visitor by Williams (1978).

Circus macrourus Gmelin (Pallid Harrier)
Reported as a migrant visitor by Williams (1978).

Circus pygargus L. (Montagu's Harrier)
Reported as a migrant visitor by Williams (1978). Reported as high as 3700 m by Meinertzhagen (1937).

Aquila rapax Temminck (Tawny Eagle)
Occasional visitor to the moorlands (D.A. Turner, personal communication)

Aquila nipalensis Hodgson (Steppe Eagle)
Occasional visitor to the moorlands (D.A. Turner, personal communication)

Aquila verreauxii Lesson (Verreaux's Eagle)
The distribution of Verreaux's Eagle in the alpine zone of Mount Kenya is patchy, and apparently related to the distribution of the Augur Buzzard. To our knowledge, the two species do not co-occur in any locality on Mount Kenya. Verreaux's Eagles are residents in the Gorges Valley, and can be seen in the Teleki Valley above 4200 m. We have both seen aggressive encounters between these two species. Whenever a Verreaux's Eagle entered the main Teleki Valley, it was almost immediately set upon by one or two resident Augur Buzzards and was driven out. On one occasion TPY saw an Augur Buzzard drive a Verreaux's Eagle away from a hyrax the latter had cornered on the ground.

Verreaux's Eagles reportedly feed mainly on hyrax, and this appears to be the case on Mount Kenya. TPY has seen several unsuccessful attacks on hyrax on the Teleki Valley, and flushed a Verreaux's Eagle off a recently killed hyrax in the Gorges Valley. The hyrax had been disemboweled.

Buteo (rufofuscus) augur Rüppell (Augur Buzzard)
Augur Buzzards are common above treeline on Mt Kenya. We have seen them in all valleys except Gorges. Alan Smith and TPY found a nest built between the rosettes of a *Senecio keniodendron* Fries & Fries plant five m tall at 4200 m in the Hinde Valley. The nest was composed mostly of twigs and was about 50 cm in diameter. It contained three eggs. The nest and eggs were first visited in June 1978, and had been abandoned by July. Chris Laine (personal communication) and MRE have also seen Augur nests in *S. keniodendron* trees. In August 1980 TPY observed a nesting pair at 4000 m in the Liki North Valley. Their nest was located high on a vertical rock face. They appeared to be feeding young.

Our observations in the Teleki Valley and the examination of feeding perches (often dead *S. keniodendron* trees) and pellets indicate Augur Buzzards prey mainly on the rat, *Otomys orestes*. Coe (1967) and Peter Hetz (personal communication) report cases of Augur buzzards taking (young) hyrax, but we have seen no aggressive or apprehensive encounters between these two species. Two pairs of Augur Buzzards lived in the upper Teleki Valley (above 4000 m) in the late 1970s, each pair with a territory estimated at three to four km². Four pairs were present from 3900 m in the Teleki Valley in 1989. They defended these against other Augur Buzzards and against Verreaux's Eagles (see above).

There are several melanistic birds above treeline on Mt Kenya, but they do not appear to be more common there than lower on the mountain.

Buteo buteo L. (Common Buzzard)
Occasional visitor to the moorlands (D.A. Turner, personal communication) A. Forbes-Watson saw flocks above Sirimon Track at 3000–3200m in the 1950s (Bongo Woodley, personal communication).

Buteo (tachardus) oreophilus Hartert & Neumann (Mountain Buzzard)
Moreau (1944) reported them out over the moorlands as high as 3500 m.

Melierax (Micronisus) gabar Daudin (Gabar Goshawk)
MRE saw an individual in the Teleki Valley in February 1990.

Milvus migrans Boddaert (Black Kite)
Reported as an accidental visitor by Williams (1978), probably as a passage migrant.

Falco naumanni Fleischer (Lesser Kestrel)
Reported as a migrant visitor by Williams (1978).

Falco tinnunculus L. (Kestrel)
Regular visitor to the moorlands on migration (D.A. Turner, personal communication).

Francolinus jacksoni Ogilvie-Grant (Jackson's Francolin)
Jackson's Francolin has been described as mainly a forest bird, with the Montane Francolin replacing it in the moorlands (Williams and Arnott 1980, Lewis and Pomeroy 1989). However, we have found Jackson's Francolin to be common along the Naro Moru Track up to 4000 m, and have not seen any other francolin in the alpine zone of Mount Kenya (see also Nievergelt *et al.* 1987). Jackson's Francolin is also found on the Timau Track. At both localities, their calls can sometimes be heard late in the day.

Francolinus psilolaemus Gray (Moorland [Montane] Francolin)
This species is reported to be the Moorland Francolin on Mount Kenya by Williams and Arnott (1980), but we have seen only Jackson's Francolin above treeline (see also Nievergelt *et al.* 1987). D.A. Turner reports that this species is "known only from the northern slopes of the mountain where the wheat fields approach the lower level of the moorlands, with no forest belt in between. The birds seen on Mt Kenya probably belong to the race *theresae*, reported as high as 3900m by Meinertzhagen (1937)". This is the Shelley's Francolin (*Francolinus shelleyi*) of earlier literature.

Sarothrura affinis antonii Smith (Chestnut-tailed [White-spotted] Pygmy Crake)
Reported by Meinertzhagen (1937) from 3700 m and by Moreau (1944), though there are no recent records from Mt Kenya (D.A. Turner, personal communication)

Fulica cristata Gmelin (Red-knobbed Coot)
TPY saw two pairs of Red-billed Coots on Lake Rutundu (3100 m) in September 1982. One pair had five very young chicks. Also reported from Lake Ellis by Moreau (1944).

Vanellus melanopterus Cretzschmar (Black-winged Plover)
Reported as an uncommon visitor to the moorlands by Williams (1978).

Gallinago nigripennis Bonaparte (African Snipe)
The African Snipe is often flushed from wet moorlands at altitudes up to 3700 m (according to D.A. Turner, to 4000m). We have seen them on the Timau, Sirimon, and Naro Moru Tracks.

Tringa nebularia Gunnerus (Greenshank)
Reported as a visitor by Williams (1978), probably as an annual visitor.

Tringa ochropus L. (Green Sandpiper)

TPY saw a Green Sandpiper in September–November of each of 1979, 1980 and 1981, in the wetlands at the head of the Teleki Valley, probably on migration. Each visit lasted several days, and all may have been by the same individual.

Actitis hypoleucos L. (Common Sandpiper)

Tim Tear saw Common Sandpipers at Lake Rutundu in September 1982.

Columba guinea L. (Speckled Pigeon)

Pairs and small flocks of Speckled Pigeons appear to be residents in the Kazita and Hobley Valleys as high as 4000 m.

Tyto capensis Smith (Cape Grass Owl)

Reported from the marshy hollows on moorlands by Williams (1978). No recent records.

Asio capensis Smith (African Marsh Owl)

Reported from moorlands by Williams (1978). No recent records.

Asio otus graueri L. (Long-eared Owl)

Reported from thickets on moorlands by Williams (1978). D.A. Turner reports a “female collected at 3350 m in Hagenia woodland high on the Naro Moru Track 10 September 1961, while a large owl seen by the Park Warden (Bongo Woodley) flying over giant heath just above tree line in July 1992 may have been this species.”

Bubo capensis mackinderi (Smith) Sharpe (Mackinder’s Eagle-owl)

Common although rarely seen, Mackinder’s Eagle-owls were often heard at night as high as 4200 m. Sessions (1972) reports them from 2440–4270 m. When encountered by day, they are relatively unafraid of man, and can sometimes be approached to within a few feet (see also Sessions 1972). TPY has seen hyrax mobbing a Mackinder’s Eagle-owl that had landed in the vicinity of their burrows in the Teleki Valley. MRE’s analysis of ~50 pellets revealed a diet consisting of almost exclusively *Otomys*, with remains of shrews found in three pellets, and a duiker jaw in another. Sessions (1972) reports that “at the head of the Teleki Valley on Mt. Kenya I found nearly every pellet to contain the bone of the rock hyrax”.

Caprimulgus poliocephalus Rüppell (Montane Nightjar)

TPY heard nightjars flying around a camp at 4200 m Hobley Valley at dusk in 1978. Tim Tear saw one at dusk while camping at 3500 m in the Kazita Valley in 1982. Other possibilities include *C. abyssinica* (reported by Moreau (1944) from 3500 m) and *C. europaeus*. D.A. Turner reports *C. poliocephalus* as being common in timberline and ericaceous habitats (personal communication), and both he and A. Forbe-Watson (personal communication) believe it to be the present species.

Apus aequatorialis von Muller (Mottled Swift)

Resident alongside Alpine Swifts on alpine cliffs (D.A. Turner, personal communication)

Apus melba africana L. (Alpine Swift)

Alpine Swifts can be found along streams and tarns to 4300 m or higher, particularly around Two Tarn Hut. MRE has seen them in the Gorges Valley.

Schoutedenapus (Apus) myoptilus Salvadori (Scarce Swift)

Williams (1978) reports that Scarce Swifts “probably nests in crags on alpine moorlands”. D.A. Turner reports this species as commonly recorded over the moorlands (personal communication).

Merops sp. (unidentified bee-eater)

MRE has seen a flock of unidentified bee-eaters flying over the Teleki Valley in March 1989.

Possibilities include the migrants *M. apiaster* L. (Eurasian Bee-eater) and *M. albicollis* Vieillot (White-fronted Bee-eater).

Hirundo rustica L. (Eurasian Swallow)

Occurs regularly over the moorlands on migration (D.A. Turner, personal communication). TPY sighted a single individual in the upper Teleki Valley in early 1978. MRE caught one in the Teleki Valley in March 1989. This species is also listed by Williams (1978).

Riparia paludicola ducis (Vieillot) Reichenow (African Sand Martin)

African Sand Martins are apparently not uncommon along river courses on the northern slopes. TPY found individuals at nesting burrows in the banks of the southern Kazita River at 3800 m in 1982. We have also seen this species along the Naro Moru river around 4100 m. There are abandoned nesting holes, apparently of this species, in the bare vertical stream banks.

Psalidoprocne pristoptera Rüppell (Black Rough-wing Swallow)

Reported by Moreau (1944) as breeding only in the forest, but foraging as high as 4100 m. MRE has seen them foraging above the river in the Teleki Valley at 3900 m.

Oenanthe oenanthe L. (Northern Wheatear)

TPY sighted a single individual (on migration?) in the upper Teleki Valley in 1978. This species is also listed by Nievergelt *et al.* (1987) at 3800 m and by Williams (1978).

Cercomela (Pinachroa) sordida ernesti (Rüppell) Sharpe (Alpine or Mountain Chat)

A common resident of alpine Mount Kenya, Mountain Chats are aggressive camp scavengers, and have been reported as high as 4570 m (Meinertzhagen 1937). Coe (1969) reported a nest in a tussock of *Festuca pilgeri*, and MRE found three nests in *Festuca* tussocks. TPY found three nests excavated from the dense layers of leaves retained around *Senecio keniodendron* trunks, and one between the living leaves of a *S. keniodendron* rosette. All of the nests we have found contained three eggs. The nests were 1–2 m above the ground. We have seen these birds eating both seeds and insects, and visiting the flowers of *Lobelia deckenii keniensis* (Young 1982). White pollen slashes can often be seen on their foreheads where *L. d. keniensis* flowering is common. Although reported to be an alpine endemic (Williams and Arnott 1980), TPY has seen them as low as the town of Naro Moru (2000 m).

Bradypterus cinnamoneus Rüppell (Cinnamon Bracken Warbler)

Reported by Moreau (1966) as high as 3850 m on Mount Kenya.

Phylloscopus trochilus L. (Willow Warbler)

MRE caught an individual in the Teleki Valley in February 1989.

Cisticola hunteri Shelley (Hunter's Cisticola)

Hunter's Cisticola, easily identified by its distinctive duet, is common throughout the lower alpine zone, wherever taller ericaceous scrub is available (up to 4000 m).

Anthus cervinus Pallas (Red-throated Pipit)

An occasional visitor to the moorlands on migration (D.A. Turner, personal communication). An individual Red-throated Pipit visited the research camp in the Teleki Valley in September–October of 1979 and 1980.

Macronyx sharpei Jackson (Sharpe's Longclaw)

Vagrant to the lower moorlands (D.A. Turner, personal communication). Reported by Raymond Hook as high as 3950 m (Moreau 1944).

Onychognathus tenuirostris raymondi (Rüppell) Meinertzhagen (Slender-billed Chestnut-winged Starling)

Coe (1967) reports this species as a daily migrant from the forest to the alpine zone, usually in flocks of less than a dozen. This agrees with TPY's observations in the years 1978–80. However, during the May–August 1977 field season, an entirely different situation prevailed. Flocks of up to 100 starlings were regularly seen in the upper Teleki Valley. These large flocks were seen mobbing the resident Augur Buzzards on several occasions. Three starling nests were discovered in the rocky cliffs of the Naro Moru river around 4100 m. One of these nests contained three eggs. When visited six weeks later (in late July), all these nests were empty.

The starlings fed most frequently on *Lobelia deckenii keniensis* inflorescences. White pollen slashes were often seen on their foreheads (see also Meinertzhagen 1937). These inflorescences produce copious nectar and harbor large numbers of insects. The density of reproductive *L. d. keniensis* plants in 1977 was more than double the density in any of the next four years. In 1978–1983, *L. d. keniensis* inflorescences continued to be visiting starlings' main food source in the upper Teleki Valley.

The situation of 1977 was repeated in 1983–84, another mass flowering year for *L. d. keniensis*. In June 1983, TPY discovered an active starling nest at 4300 m in the Teleki Valley. It was located in a deep crevice at the top of a 15 m waterfall. Adults constantly flew into and out of this crevice, and the cries of chicks could be heard. These starlings normally nest around waterfalls in the forest (Williams and Arnott 1980). It appears the Slender-billed Chestnut-winged Starlings, which normally nest in the forest and only make occasional forays into the alpine, are attracted by the mass flowering of *L. d. keniensis* in 1977 and 1983 to become short-term residents of the alpine zone, and even nest there. Jackson (1938) cites Mackinder as reporting breeding birds high in the Hohnel Valley (in 1899). A. Forbes-Watson found starling nests at 4200 m in the Hinde Valley in early 1955, under rock overhangs (Bongo Woodley, personal communication).

MRE has seen small flocks flying up the valley, and larger flocks (up to 50 birds) flying down. He has seen them feeding around the cliffs below Lewis Glacier, and on the eastern side of Point Lenana.

Nectarinia johnstoni johnstoni Shelley (Scarlet-tufted Malachite Sunbird)

This sunbird is a common resident on Mount Kenya, visiting both *Lobelia telekii* and *L. deckenii keniensis* (Young 1982) throughout the alpine zone up to 4300 m, and *Protea kilimandscharica* in lower alpine areas on the northern slopes. They also hawk for small insects.

Evans (1991) considers their breeding season to be December to April. Williams (1951) reports their nesting periods as January–February and July–August. Mackinder found nestlings in August (Moreau 1944). TPY has seen nesting birds in December, January, June, and July. MRE believes their breeding season to be highly variable, e.g. the end of November in 1989–90 and the beginning of January in 1990–91. In agreement with Williams (1951) and Coe (1967), these nests usually contained only a single egg or nestling. MRE found only four nests (out of 100) with two eggs. Above 4100 m, the most common nesting sites TPY found were *Festuca pilgeri* grass tussocks, although there was one in an old *S. keniodendron* inflorescence, and one in an *Erica arborea* shrub. For other examples of the first two,

see Photos 1 and 2 in Williams (1951). MRE, working at lower elevations, found *Erica* shrubs to be the most common nesting sites, followed by *Lobelia telekii* inflorescences, grass tussocks, and *Senecio keniodendron* inflorescences. In his description of their nests, Williams reports that they were lined with 'vegetable down'. TPY identified similar material as the felty pubescence from the undersides of *Senecio keniensis* (*brassica*) leaves., and deposited a sample nest at the National Museums of Kenya.

Males are strongly territorial, without obvious seasonality. TPY estimated territory sizes around his research camp at 1000–2000 m², larger than the 60–250 m² reported by Williams (1951) and Coe (1961). Territory size may vary with environmental quality: territories were smaller in a year with high densities of *L. telekii* inflorescences than in a year with lower inflorescence density (Evans 1991). TPY found non-territorial males congregated in noisy groups of up to 10 on several occasions, accompanied by a few females and often some Mountain Chats (see also Williams 1951). Recently, an experimental study has been carried out in the Teleki Valley on the costs and adaptive values of the elongated tail feathers and bright red pectoral tufts (Evans 1991, Evans and Thomas 1992, Evans and Hatchwell 1992a, 1992b).

Nectarinia tacaze jacksoni Stanley (Tacaze Sunbird)

We have found Tacaze Sunbirds on Mount Kenya visiting both *Lobelia* spp at altitudes up to 4000 m.

Serinus canicollis Swainson (Yellow-crowned Canary)

The absence of these canaries from Alpine Mount Kenya puzzled Moreau (1944), who found it "astonishing to me because on the great mountains of northern Tanganyika the species ascends to the limits of vegetation and beyond". In response, Raymond Hook stated: "In my opinion on both Kenya and Aberdares, they go as high as the Compositae go. I would have said that they ate practically every kind of compositae, including the Giant Groundsel [*Senecio keniodendron*]" (Moreau 1944). TPY had never seen canaries above treeline before 1979. In 1978–79, the Giant Groundsel of Mount Kenya gregariously flowered, a rare occurrence (Smith and Young 1982). When these plants began to set seed, canaries began to appear in the lower alpine. By November 1979, there were hundreds of Yellow-crowned Canaries visiting fruiting stands of *S. keniodendron* up to 4200 m, feeding on the ground. A few were even seen feeding (on windswept seeds?) on the Lewis Glacier at 4700 m. The canaries disappeared from the alpine zone shortly thereafter. MRE saw occasional single birds in 1989–90 at 3800–4000 m.

Serinus striolatus striolatus Rüppell (Streaky Seedeater)

The Streaky Seedeater is a common resident throughout the alpine zone. TPY found an abandoned nest composed mainly of grass atop a *Festuca pilgeri* grass tussock at 4200 m in the Teleki Valley. It contained one dead chick and one unhatched egg. MRE has also seen many nests started, but none successful.

Corvus albicollis Latham (White-naped Raven)

Alan Smith reported a White-naped Raven at the research camp (4180 m) in 1984. Moreau (1944) also reports them as high as 3660 m. This species is a common camp visitor on the Shira Plateau on Kilimanjaro.

Mammals (43 spp)

Graphiurus murinus raptor Dollman (African Dormouse)

The Dormouse is commonly found in alpine huts, where its loud chattering vocalisations keep visitors awake at night. TPY saw an individual on the rocks below Lake Michaelson (3800 m) during the day in

September 1978. Dormice have been trapped up to 4180 m both on the northern slopes by Coe and Foster (1972) and in the Teleki Valley by TPY.

Dendromus insignis percivali Heller (Striped Tree Mouse)

Common in the alpine zone on all aspects at altitudes up to 4330 m (Moreau 1944, Coe and Foster 1972). This was the most common small rodent trapped at night at TPY's research camp (4180 m). Bongo Woodley reports rodents from 'Black Hole Bivvy' (4550 m) above the Teleki Valley in September 1991 (personal communication), perhaps of this species.

Lophuromys flavopunctatus Thomas (Harsh-furred Mouse)

Coe and Foster (1972) report this species is common on the northern slopes as high as 4100 m. MRE had a family living near in his lavatory at 3900 m.

Lemniscomys striolatus massaicus Pagenstecher (Striped Grass Mouse)

Not previously reported from the alpine zone (but see Moreau 1944), TPY saw one on the rocks near Lake Michaelson, and MRE has seen them feeding on *Lobelia telekii* seeds in the Teleki Valley.

Rhabdymus pumilo diminutus Thomas (Four-striped Grass Mouse)

This species was trapped as high as 3800 m on the northern slopes by Coe and Foster (1972).

Praomys (Hylomyscus) denniae (Climbing Wood Mouse)

Reported by Fayad (1981) from alpine Mount Kenya, and perhaps seen by MRE in a *Senecio keniodendron* stand in 1989.

Tachyoryctes splendens (rex) Rüppell (Mount Kenya Mole Rat)

The Mount Kenya Mole Rat is common throughout the northern slopes and the Hinde Valley at altitudes up to 4050 m on the northern slopes, and 3750 elsewhere (Jarvis and Sale 1971; personal observation). Their mounds are up to 6 m in diameter, and can be recognised at a distance by the strikingly different vegetation growing on them, dominated by *Alchemilla* spp (Jarvis and Sale 1971, Coe 1969, Coe and Foster 1972; personal observation). In some localities, the mounds are virtually overlapping. The animals themselves are rarely seen. There has been debate recently about whether the origin of 'mima-type' mounds in Kenya is due to the activities of termites or mole rats (Gakahu and Cox 1984, Martin 1988). There are no termites above treeline on Mount Kenya or the Aberdares, but this does not mean that all alpine mounds are caused by Mole Rats. Frost-thaw processes in the alpine zone can also produce vast areas of mounded terrain (Baker 1967).

They feed mainly on roots and subterranean stems. They appear to be the only mole rat in Kenya (out of three genera) that stores food. Roots and leaves of the alpine plant *Haplosciadium abyssinicum* were found in a food store at 3600 m on Mount Kenya (Jarvis and Sale 1971). *Otomys* entrances into *Tachyoryctes* burrows have been found on Mount Kenya (Jarvis and Sale 1971).

Otomys orestes orestes Thomas (Groove-toothed Rat)

The Groove-toothed Rat is probably the most common alpine rodent on Mount Kenya, occurring at all altitudes and aspects. It is the most common food item identifiable in the scat and pellets of Leopard, Augur Buzzard, and Mackinder's Eagle-owl. These rodents are often seen during the day along their conspicuous runs. TPY has seen several chases between adults, and they may be territorial. Reported as high as 4750 m (Moreau 1944, Coe 1967).

Otomys tropicalis tropicalis Thomas (Groove-toothed Rat)

This second alpine *Otomys* species is reported from 2280–4175 m (Hollister 1919). Coe and Foster (1972) found only *Otomys orestes*, and question the presence of *O. tropicalis*.

Hystrix sp. (Porcupine)

Fayad (1981) reports alpine porcupine, and Moreau (1944) found a quill at 3500 m above Nanyuki.

Lepus sp. (Hare)

The existence of a hare in the lower moorlands of Mount Kenya was suggested by Raymond Hook (Moreau 1944) who twice found their dung at 3350 m. Phil Snyder has reported seeing a hare just above timberline on several occasions. He described them as relatively large, and yellowish.

(Unidentified bat)

An unidentified species of bat occurs at Lake Rutundu (3000 m), perhaps the African Pipistrelle (*Pipistrellus nanus*) reported by Williams (1978) from high forest.

Crocidura allex alpina Heller (Alpine Pygmy Shrew)

Apparently common in the alpine zone. Coe and Foster (1972) report it as high as 4100 m on the northern slopes. TPY trapped an individual at night at 4180 m in the Teleki Valley in early 1978, and saw another in daylight at 3800 m in early 1980.

Crocidura fumosa Thomas (Dusky Shrew)

Coe and Foster (1972) trapped a single individual at 3800 m on the northern slopes, and report it to be common at lower altitudes. They also list *C. turba*.

Crocidura turba zaodon Osgood (Dusky Shrew)

Coe and Foster (1972) suggest that some of their *Crocidura* specimens may have been this subspecies. Reported by Moreau (1944) as high as 3260 m on Mount Kenya in forest.

Myosorex (Surdisorex) polulus Hollister (Mole Shrew)

Trapped by Coe and Foster (1972) at 3920 m on the northern slopes. Moreau (1944) reported it at altitudes of 2750–3680 m. Kingdon (1974), reporting it at altitudes of 2800–3600 m, states that it is the only endemic mammal on Mount Kenya.

Cercopithecus mitis Wolff (Sykes' Monkey)

In November 1979, TPY was shown a Sykes' Monkey found in the rocks below the Darwin Glacier (4600 m) by Vince Fayad. Its head and limbs were missing, and it was in a mummified state. Local climbers state that it had been at that location for at least a year. In December 1990, another Sykes' Monkey was reported from Top Hut (4800 m) by Clive Ward. It was complete, and only recently dead. We cannot explain the presence of these individuals (or the following) so high on the mountain.

Colobus polykomos Oken (Abyssinian Black-and-white Colobus Monkey)

A 'mummified' colobus on Point Peter (4700 m) has been reported by several mountaineering parties. It can only be this species.

Lycaon pictus Temminck (African Wild Dog or Hunting Dog)

Coe (1967) reports several packs as high as 4250 m, preying upon zebra and eland. As recently as the 1960s packs of Wild Dogs were taking sheep off the moorlands above Embori Farm, but not in the

1970s or early 1980s (Bill Halstead, personal communication). In January 1992, John Temple reported Wild Dogs on the Timau (3000 m) and Chogoria (3500 m) tracks (personal communication).

Canis mesomelas Schreber (Black-backed Jackal)

An unspecified species of jackel was reported by Raymond Hook at altitudes of up to 3660 m (Moreau 1944), and Fayad (1981) listed that Black-backed Jackals from the alpine zone.

Ictonyx striatus Perry (Zorilla)

Zorilla are apparently residents of the alpine zone of Mount Kenya. Raymond Hook reported them as high as 3660 m (Moreau 1944). Coe (1969) collected one at 4270 m on the northern slopes that had been feeding on *Otomys* rats. On the night of 7 October 1979, a visitor to TPY's research camp (4180 m) saw a live Zorilla. N. Barrah saw a Zorilla at the nearby Teleki Valley Ranger Station in September 1993, also at night (Bongo Woodley, personal communication). TPY found a Zorilla skull in the rocky moraine below Mackinder's Camp (4150 m) in 1978. This is now on deposit at the Department of Osteology, National Museums of Kenya (ref. # OM 6432). MRE saw one at his camp near this same site in February 1989. Judging by the repeated presence of a distinctive odor, especially early in the morning, TPY believes that a Zorilla lived in the rocky outcrop below the 12,000 foot rain gauge (at ~3600 m) on the Naro Moru Track, in the late 1970s.

Genetta tigrina Schreber (Large-spotted Genet)

Reported by Fayad (1981) from alpine Mount Kenya.

Herpestes paludinosus G. Cuvier (Marsh Mongoose)

Coe (1967, 1969) reported a pair of Marsh Mongooses from 3500 m in the Gorges Valley.

Herpestes sanguineus Rüppell (Black-tipped [Slender] Mongoose)

Fayad (1981) reports this species from the alpine zone.

Crocuta crocuta Erxleben (Spotted Hyaena)

Spotted Hyaena are apparently regular, if infrequent, visitors to the alpine zone. TPY has seen tracks as high as 4000 m in the Teleki Valley, and they have been reported much higher. Tracks that TPY saw on the Lewis Glacier (4800 m) in 1979 were probably also of hyaena. In 1986, Bongo Woodley found tracks coming up from the Teleki Valley, crossing near Austrian Hut (4800 m) and descending into Hogley Valley (personal communication). Bill Halstead reports that they visit the moorlands particularly during the rains. MRE had one around his camp (4100 m) daily in February–April 1989.

Acinonyx jubatus Schreber (Cheetah)

Nigel Trent reported seeing a cheetah at around 3500 m along the Timau Track in 1982. There have also been sightings of Cheetah from the Sirimon Track at and above 4000 m (Campbell 1983).

Felis serval Schreber (Serval Cat)

Serval Cats are common in the alpine zone of the Aberdare Mountains, and may also occur on Mount Kenya (see Moreau 1944).

Felis lybica Forster (Wild Cat)

The Wild Cat is known from the northern slopes up to 3800 m (Coe and Foster 1972), and may be common there (Coe 1969).

Panthera leo L. (Lion)

Lions are apparently occasional visitors to the alpine, and may stay for several weeks, such as the individuals that were seen repeatedly around the Sirimon roadhead in 1977. It is also possible that this is part of a small resident population. TPY has seen pug marks at 3600 m on the Naro Moru Track.

Panthera pardus L. (Leopard)

Leopard are resident in the alpine zone of Mount Kenya. We have found their tracks, droppings and cave shelters throughout the alpine. TPY has encountered a leopard only once in the alpine zone, but there have been numerous sightings of leopards by others (Martin Otieno, John Omira Miluwi, Phil Snyder, Lew Awodey), including a melanistic individual in the Teleki Valley (John Omira Miluwi). MRE has seen the pug marks of a female and her cub in the Teleki Valley. They apparently cross passes as high as 4800 m (Coe 1967).

TPY has found two duikers (one in the Teleki Valley at 4300 m, one in the Hinde Valley at 4100 m) apparently killed by leopards. Examination of several leopard dens (overhanging rocks) revealed large numbers of hyrax bones. Scats collected on Mount Kenya contained occasional hyrax bones and often the remains of Groove-toothed Rats.

Procavia johnstoni mackinderi Thomas (Mount Kenya Rock Hyrax)

Hyrax are the most conspicuous mammals of alpine Mount Kenya. There are several hundred in the upper Teleki Valley alone, where TPY estimates the average density to be in the neighborhood of 20–100 animals per km². A description of their habits is found in Coe (1962) and Sale (1965). Kingdon (1971) reports them as occurring at 3200–4650 m. They have been reported as high as 4700 m (Moreau 1944) and even higher (Dorst and Dandelot 1972), but we have seen no evidence of them living higher than 4300 m. Although most individuals are dark brown, there was one adult male on the south side of the Teleki Valley at 4200 m during the 1980s that had very pale fur. 'White' hyrax (*Heterohyrax brucei*) also occur in the Serengeti (Hoeck 1982).

The Mount Kenya subspecies has evolved darker and longer fur than its lowland relatives, apparently as adaptations to the extreme cold (Coe 1962, 1967; Sale 1967). In addition, they can often be seen basking in the sun and huddling together, traits they share with other Rock Hyrax.

On Mount Kenya, the distribution of rock hyrax is delineated by the presence of appropriate shelter—the rocky moraines in which hyrax make their homes. We have never seen hyrax more than 150 m from these rocky shelters, and believe that their overall numbers are limited by the availability of these moraines. TPY did once find tracks of a hyrax high on a ridge between the Teleki and Hoehnel Valleys far from any established colony. This may have been a dispersing male, if comparisons to ecologically similar marmots are appropriate, and these animals are likely to be easy prey in the open (Van Vuren 1990). TPY has found one small isolated moraine that was once inhabited by hyrax, judging by the skulls present, but that no longer supported them. Local extinction of small isolated populations may not be a rare event in hyrax (Hoeck 1982) or other species (Smith 1980, Berger 1990), and more isolated areas may be only rarely colonised (Smith 1980).

In the vicinity of inhabited moraines the vegetation is closely cropped, and hyrax colonies can be recognised from a distance by the bright green vegetation surrounding the rocky outcrops, which contrasts with the pale, uncropped alpine grassland. Mahaney and Boyers (1983) suggest that this close cropping by hyrax and groove-toothed rats can produce bare areas of solifluction desert by allowing greater cooling of the soil.

Hyrax eat a wide variety of plant species, but seem to avoid certain plants (*Anthoxanthum nivale*, *Sedum ruwenzoriense*, *Carduus keniensis*) that are therefore common near active burrows (see also Coe 1962). Mahaney and Boyer (1983) examined hyrax dung microscopically, and found that 92% of the identifiable fragments were monocotyledons, and only 8% were dicotyledons.

Experimental removal of spines from *C. keniensis* leaves renders them readily palatable to hyrax (Young and Smith, in press). Descriptive and experimental evidence indicates that hyrax may limit the distribution of the shrub *Alchemilla argyrophylla* around colonies (Young and Smith, in press). They occasionally feed on the toxic *Lobelia* spp (Coe 1962, Young 1985), and even Giant Senecio (Young and Smith, in press), especially during dry periods.

Rock hyrax are mainly diurnal and feed mostly at mid-morning and mid-afternoon (Sale 1965, Coe 1969). They seem to avoid rainy weather, but TPY has occasionally seen hyrax feeding both on moonlit nights (see also Coe 1962 and Dorst and Dandelot 1972) and during rain, particularly if there was rain during the normal afternoon feeding period (4–5 PM).

The most important predators of alpine rock hyrax on Mount Kenya are undoubtedly leopards, which apparently stalk colonies (John Omira Miluwi, personal communication). Verreaux's Eagles also take hyrax in certain localities. Mackinder thought that Mackinder's Eagle-owls were important predators (Moreau 1944), but we have examined numerous Eagle-owl pellets and found no identifiable hyrax remains. Coe (1967) reports seeing an Augur Buzzard take a hyrax, but we have seen no aggressive behavior between these species.

TPY has observed several females that had lost all of the hair on their rumps, and the skin itself was raw to the point of bleeding. We do not know what causes this, but it matches to symptoms of sarcoptic mange reported by Hoeck (1982) in Serengeti hyrax.

As elsewhere (Sale 1965, Hoeck 1982) the hyrax colonies of Mount Kenya consist of a single adult male and differing numbers of adult females and immatures. TPY has seen several fights between males, often resulting in the loss of blood and substantial clumps of hair. Older males are often heavily scarred around the face and ears. Both sexes contest over food. In these encounters, animals will often turn their backs to each other and try to push the other away.

Female Mount Kenya Rock Hyrax give birth synchronously within a colony, with up to six litters appearing within a period of less than two weeks. Most commonly, these births were in June or December. Each colony has only one birth season per year, and it is usually the same month each year. Similarly, in the Serengeti, individual colonies had one birth season per year (Hoeck 1982). For *P. johnstoni*, this was in March to May. For *Heterohyrax brucei*, individual colonies had birth peak in either May–June or December–January, as in the Mount Kenya *Procavia*. An interesting exception occurred in the colony near TPY's camp in 1979. In the previous year, the young appeared in June, but the resident male was displaced by another in late 1978, and the subsequent brood was not born until September 1979. Hyrax have very long gestation periods (7.5–8 months), and it is possible that the change in dominant males disrupted the pregnancies of the colony's females.

On at least two occasions, hyrax have been seen giving birth above ground during the day (John Omira Miluwi, personal communication, and an anonymous observer, personal communication). This is in conflict with earlier information about hyrax (Sale 1965), and needs confirmation. However, given the likely low sanitation of hyrax burrows and the low risk of diurnal predation, such birthing behavior may be reasonable. In both cases, the observers were attracted by the many adult and yearling hyrax that gathered around the scene.

Young hyrax are very playful, and seem to spend the majority of their time in play. They suckle for at least several months. TPY has seen one pair suckling at the age of nine months. Unless mothers tolerate other females' young, Mount Kenya hyrax do have at least occasional litters of more than one (but see Coe 1967).

Coe (1962) reported two kinds of vocalizations, but we distinguish at least seven:

- A long, loud call, usually beginning with coarse mewing sound and ending with a series of coughing noises, is given by multiple individuals when people (personal observation) or leopards (J. Omira, personal communication) are seen at a distance. Upon hearing this call, mountain

rangers have initiated successful scans of nearby slopes for leopard. When foraging hyrax hear this call, they stop and look and then often run back to the safety of their burrows. This call and the next are the ones most often heard by people in the vicinity of colonies.

- A very similar 'long call' is given by territorial males, particularly in the evening, and may serve to advertise occupancy of colonies. These two calls are distinguished by their context and participants.
- A loud, sharp call is given when an eagle attacks. This produces an instantaneous reaction among foraging hyrax, which dive for the nearest cover.
- When foraging in close proximity, adult hyrax make a quiet, grunting 'contact call'.
- Juveniles make high-pitched squeaks in a variety of situations.
- Adult females also make a high-pitched squeaking noise when involved in antagonistic interactions with other adults females or the dominant male. This may be an appeasement vocalisation.
- During serious fights and chases, adult males (and sometimes females) make loud grunting noises.

Fourie (1977) has documented over twenty noises made by captive *P. capensis*, of which three were limited to females giving birth, and two were not vocalisations (sneezing and teeth gnashing).

Loxodonta africana Blumenbach (African Elephant)

Elephants are apparently regular visitors to alpine Mount Kenya. Moreau (1944) reports two well-worn alpine elephant trails on the alpine northern slopes. TPY has seen them eating Giant Groundsel (*Senecio keniodendron*) at 4000 m in the Teleki Valley. Numerous visits to the alpine zone of northwest Mount Kenya occurred in the late 1970s and early 1980s (Mulkey et al. 1984). It is not known whether this is strictly a recent phenomenon. A dead elephant was found at 4600 m in the Hinde Valley in 1944 (Taffe 1944). This animal was identified as a female by Michael Rainey in 1979 (personal communication).

Diceros bicornis L. (Black Rhinoceros)

Rhinos have been sighted on several occasions above the treeline. Lew Awodey found a recently dead individual (horn intact) near the Sirimon river at 3700 m in 1978 (personal communication). In 1983, Nigel Trent reported three resident animals above Timau (personal communication). They may be extinct there now, although they still occur in the forest.

Equus burchelli Gray (Burchell's Zebra)

There is at least one resident herd of zebras on the northern slopes, and probably several. They can be commonly seen along the Timau Track. TPY has seen zebra tracks throughout the northern slopes, as far south as the northern ridge of the Hinde Valley and as high as 3700 m. Coe (1969) reports their droppings as high as 4300 m. An aerial survey in June 1993 counted 299 zebras between Mbara Crater and the Kazita River (Bongo Woodley, personal communication).

Alcephalus buselaphus cokii Pallas (Kongoni or Coke's Hartebeest)

Seen along the Timau Track repeatedly in 1980 as high as 3700 m (Helen Young, personal communication). Raymond Hook found a skeleton at 4000 m on the northern slopes (Moreau 1944).

Cephalophus nigrifrons Gray (Black-fronted Duiker)

Williams (1978) reports this species in bamboo zone and on moorlands.

Silvicapra grimmia altivallis L. (Grimm's or Bush Duiker)

Grimm's Duikers are resident throughout the alpine, and are most common on slopes where *Alchemilla* spp are found (see Young and Peacock 1992), perhaps because these shrubs provide cover (Coe 1969) or food (King 1975). On a single day in 1978, TPY saw seven individuals in the Hinde Valley, and MRE from one position saw twelve in the lower Teleki Valley. They usually occur singly or in pairs. On the Aberdares and Kilimanjaro, they occur at densities of about two per km² (King 1975). MRE has seen prolonged chases between individuals, running round and round in a particular area.

TPY found two Grimm's Duikers that were apparently victims of leopard predation, one each in the Teleki (4300 m) and Hinde (4100 m) Valleys. In January 1992, John Temple reported a dead duiker (probably this species) high (~4900 m) on the Lewis Glacier (personal communication).

Oreotragus oreotragus Zimmermann (Klipspringer)

Reported by Williams (1978) and Fayad (1981), but we tend to agree with Moreau (1944) that they do not occur in the alpine zone of Mount Kenya. Dorst and Dandelot (1972) report that they occur up to 13,000 ft in Ethiopia, and Haltenorth and Diller (1980) up to 4000 m.

Raphicerus campestris Thunberg (Steinbuck)

Although Moreau (1944) believed that Steinbuck were merely visitors to the northern slopes, we concur with Coe (1969) and Coe and Foster (1972) that they are probably resident. Whether they "replace Grimm's duiker" there, as the latter authors suggest, is open to question. TPY has seen both steinbucks and duikers at 3000–3500 m along the Timau Track.

Boocercus eurycerus Ogilby (Bongo)

In 1979, Vince Fayad and TPY found the skeleton of an adult male bongo at 'American Camp' at 4300 m in the Teleki Valley. We did not find the skull, and identification was made from a femur and lower jaw by the Department of Osteology of the National Museums of Kenya (Nina Mudida, personal communication). This location is far from the normal forest/bamboo habitat of bongo, but Haltenorth and Diller (1980) say, "seasonal wandering around to particular feeding places is possible; also from forest to forest or mountain to mountain".

Taurotragus oryx Pallas (Eland)

There are up to several herds of eland on the northern slopes. A large herd can often be seen at the Sirimon track roadhead. TPY has seen young in these herds, and believes they are breeding residents (but see Coe 1969). A herd of 70 elands, including many subadults, was seen from the air at 'Brigands Retreat' in late 1990 (Bongo Woodley, personal communication).

Syncerus caffer Sparrman (African Buffalo)

African Buffalos are regular visitors to alpine Mount Kenya. The carcass of a bull was found at 4700 m (Ross 1911). They are common visitors to Lake Hoehnel (4200 m), and Martin Otieno has seen them there on several mornings. We have seen droppings as far up the Teleki Valley as 4150 m. Buffalo tracks and droppings can be seen on all game trails on the mountain, both in forest and alpine. Buffalo

maintain a trail between the Teleki and Hausberg Valleys at an altitude of about 4100 m. Their visits to the Teleki Valley are mainly nocturnal, but M. Peacock and TPY saw a lone bull at 3900 m on the north slope of the valley at midday in January 1980.

DISCUSSION

The alpine environment on Mount Kenya is severe, with nightly freezing likely throughout the year, common dry periods, and low plant productivity (Hedberg 1964, Coe 1967, Smith and Young 1987). Nonetheless, a wide variety of vertebrate species occur there, and many seem to thrive. Some do so by using the alpine ecosystem only occasionally; others are permanent residents. Residents exhibit a variety of evolutionary adaptations and behaviours that help them to cope with the unique challenges of this environment. These include longer hair, darker colouration, basking in available sunlight, diurnal foraging patterns, and perhaps lowered reproductive rates.

Alpine Mount Kenya is a semi-isolated island ecosystem. The alpine habitats are very different from the forest surrounding them. This has led to a considerable amount of endemism and vicariance among the alpine plants (Hedberg 1957) and invertebrates (Salt 1987), but not among the alpine vertebrates. Of the species in Table 1, only the Mole-shrew (*Myosorex polulus*) is endemic to Mount Kenya, with vicariants on other East African mountains (Kingdon 1974). The Mount Kenya Rock Hyrax (*Procapra johnstoni mackinderi*) is an endemic subspecies.

Although the alpine habitats of Mount Kenya are island-like, there are three ways in which the alpine zone is accessible to animals from other ecosystems. First, birds can fly over the forest to reach the alpine zone. These may be altitudinal migrants (Yellow-crowned Canary), regional migrants (Open-billed Stork) or palearctic migrants (e.g., Harriers, Wheatear, European Swallow, Willow Warbler), as well as occasional visitors (e.g., Black Kite, Secretary Bird). The list of avian migrants and visitors is likely to increase in the future.

Second, resident forest species may venture out into the alpine moorlands, and even become partial residents there. Some of these visitors are difficult to explain, such as the Bongo, the two Sykes' Monkeys, and the Colobus Monkey. For others, the lower alpine zone may provide a suitable foraging habitat (e.g., Mountain Buzzards, Black-fronted Duikers, Green Ibises). Elephants, Buffalos and Slender-billed Starlings appear to be regular visitors from the forest to high in the alpine zone, with the latter occasionally nesting there.

Third, the treeless gap on the northern slopes has provided savanna species the opportunity to visit and colonise alpine Mount Kenya. This may be why Mount Kenya is the only alpine area in East Africa with populations of rock hyrax. It is possible that some of the larger mammals on the northern slopes were local migrants trapped by increasing development at lower altitudes, but their continuing success in the alpine suggests that this need not be the case. These species include Lion, Zebra, Eland, and Kongoni. Two highly endangered species, Black Rhino and Wild Dog, apparently still occur on Mount Kenya, the former perhaps restricted to the forest.

There are several other species whose status is unclear. These include those that have only rarely been reported (either because they are rarely seen or because they are nocturnal) or may have been misidentified: Striped Grass Snake, Green Ibis, Maccua Duck, Pygmy Crane, Montane and Shelley's Francolins, Long-eared Owl, Cape Grass Owl, Marsh Owl, an unidentified nightjar, Sharpe's Longclaw, Climbing Mouse, one of the Groove-toothed Rats (*Otomys tropicalis*), an unidentified hare, Porcupine, an unidentified bat, Jackal, Marsh Mongoose, Slender Mongoose, Genet Cat, and Serval.

As a conservative estimate, the confirmed resident vertebrate fauna of alpine Mount Kenya is as follows: two introduced fish, two frogs, two lizards, two chameleons, one snake, nineteen birds, seven rodents, three shrews, and ten larger mammals, for a total of 48. Two areas of the mountain in particular

are in need of more detailed information. The northeastern (and southwestern) slopes have only rarely been visited by biologists, who have concentrated their attention on the areas along the main tracks (Naro Moru, Sirimon, and to a lesser degree Chogoria). Also, the areas just above the forest, the ericaceous and lower alpine habitats, have been less studied relative to higher alpine areas. It is hoped that future studies of these areas will both increase and refine our knowledge of Mount Kenya's alpine vertebrates.

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Table 1. Alpine vertebrates of Mount Kenya. Upper altitudinal limits are based on the literature (questionable records not included) and personal observations. Lower altitudinal limits for Mount Kenya are included when they are known, but not if the records merge into a forest or lowland population. Status: First letter(s) indicate nature of occurrence: r= resident, v= visitor, m= migrant, i= introduced, x=accidental. An asterisk indicates evidence of breeding (courtship, nesting, young). The second letter(s) indicate abundance; a= abundant, c= common, o = occasional, r= rare, e= locally extinct.

SPECIES (112 spp)	Latin Name	Altitude (m)	Status
Fish (3 spp)			
Char	<i>Salvelinus alpinus</i>	up to 4300	i, e?
Brown Trout	<i>Salmo trutta</i>	up to 4000?	i*, c
Rainbow Trout	<i>Salmo gairdnerii</i>	up to 4200	i*, c
Amphibians (2 spp)			
Frog	<i>Phrynobatrachus kinangopensis</i>	up to 3350	r, c?
Frog	<i>Rana wittei</i>	up to 3800	r, c?
Reptiles (6 spp)			
Alpine Meadow Lizard	<i>Algyroides alleni</i>	3400–4600	r*, a
Skink	<i>Mabuya irregularis</i>	up to 3600	r?, or
Kenya Side-striped Chameleon	<i>Chameleo schubotzi</i>	up to 4200	r, c
Hohnel's Chameleon	<i>Chameleo hohnelii</i>	up to 3400	r, c?
Hinde's Viper	<i>Vipera hindei</i>	3000–3400	r, o
Striped Grass Snake	<i>Psammophylax variabilis</i>	?	?, ?
Birds (58 spp)			
Lesser Grebe (Dabchick)	<i>Tachybaptus ruficollis</i>	up to 3200	?, ?
Hamerkop	<i>Scopus umbretta</i>	up to 3200	v?, ?
Open-billed Stork	<i>Anastomus lamelligerus</i>	up to 4150	x, r
White Stork	<i>Ciconia ciconia</i>	?	x, ro
Green Ibis	<i>Bostrychia olivacea</i>	up to 4100?	v?, ro
African Black Duck	<i>Anas sparsa</i>	up to 4400	r*, c
Maccoa Duck	<i>Oxyura maccoa</i>	up to 3000	?, ?
Secretary Bird	<i>Sagittarius serpentarius</i>	up to 3500	v, o
Rüppell's Vulture	<i>Gyps rueppellii</i>	?	v, o
Lammergeyer	<i>Gypaetus barbatus</i>	up to 4300	r, o
Eurasian Marsh Harrier	<i>Circus aeruginosus</i>	?	m, ro
Pallid Harrier	<i>Circus macrourus</i>	?	m, ro
Montagu's Harrier	<i>Circus pygargus</i>	?	m, ro
Tawny Eagle	<i>Aquila rapax</i>	?	v, o
Steppe Eagle	<i>Aquila nipalensis</i>	?	v, o
Verreaux's Eagle	<i>Aquila verreauxii</i>	up to 4500	r, o
Augur Buzzard	<i>Buteo augur</i>	up to 4400	r*, a
Common Buzzard	<i>Buteo buteo</i>	?	v, o
Mountain Buzzard	<i>Buteo oreophilus</i>	up to 3500	?, ?

Table 1. *continued* Alpine vertebrates of Mount Kenya.

SPECIES	Latin Name	Altitude (m)	Status
Gabar Goshawk	<i>Melierax gabar</i>	4000?	m, r
Black Kite	<i>Milvus migrans</i>	?	v, r?
Lesser Kestrel	<i>Falco naumanni</i>	?	m, ro
Kestrel	<i>Falco tinnunculus</i>	?	m, o
Jackson's Francolin	<i>Francolinus jacksoni</i>	3400–4000	r, a
Moorland Francolin	<i>Francolinus psilolaemus</i>	up to 3900	r?, ?
Chestnut-tailed Pygmy Crake	<i>Saruthrura affinis</i>	up to 3700	r?, ?
Red-knobbed Coot	<i>Fulica cristata</i>	up to 3000	r*, ?
Black-winged Plover	<i>Vanellus melanopterus</i>	?	v, ?
African Snipe	<i>Gallinago nigripennis</i>	3450–3800	r, a
Greenshank	<i>Tringa nebularia</i>	?	m, r
Green Sandpiper	<i>Tringa ochropus</i>	up to 4180	m, r
Common Sandpiper	<i>Actitis hypoleucos</i>	up to 3000	?, ?
Speckled Pigeon	<i>Columba guinea</i>	up to 4000	rv, o
Cape Grass Owl	<i>Tyto capensis</i>	?	r?, ?
African Marsh Owl	<i>Asio capensis</i>	?	r?, ?
Long-eared Owl	<i>Asio otus</i>	?	r?, ?
Mackinder's Eagle Owl	<i>Bubo capensis</i>	up to 4200	r, c
Montane Nightjar	<i>Caprimulgus poliocephalus</i>	up to 4200	?, ?
Mottled Swift	<i>Apus aequatorialis</i>	?	r, o
Alpine Swift	<i>Apus melba</i>	up to 4500	r*, c?
Scarce Swift	<i>Schoutedenapus myoptilus</i>	?	r*?, o
Unidentified bee-eater	<i>Merops sp.</i>	4000?	m, r
Eurasian Swallow	<i>Hirunda rustica</i>	up to 4100	m, ro
African Sand Martin	<i>Riparia paludicola</i>	up to 4150	r*, c
Black Roughwing Swallow	<i>Psalidoprocne pristopectera</i>	up to 4100	v, om,
Northern Wheatear	<i>Oenanthe oenanthe</i>	up to 4150	m, ro
Alpine (Hill) Chat	<i>Cercomela sordida</i>	2000–4570	r*, a
Cinnamon Bracken Warbler	<i>Bradypterus cinnamomeus</i>	up to 3850	v?, o
Willow Warbler	<i>Phylloscopus trochilus</i>	4000?	m, r
Hunter's Cisticola	<i>Cisticola hunteri</i>	2600–4200	r*, a
Red-throated Pipit	<i>Anthus cervinus</i>	up to 4180	m, r
Sharpe's Longclaw	<i>Macronyx sharpei</i>	up to 3950	?, ?
Slender-billed			
Chestnut-winged Starling	<i>Onychognathus tenuirostris</i>	up to 4250	v & r*, o-c
Scarlet-tufted Malachite Sunbird	<i>Nectarinia johnstoni</i>	3450–4300	r*, a
Tacazze Sunbird	<i>Nectarinia tacazze</i>	up to 4000	r?, co
Yellow-crowned Canary	<i>Serinus canicollis</i>	up to 4700	v, r-c
Streaky Seed-eater	<i>Serinus striolatus</i>	2750–4200	r*, a
White-naped Raven	<i>Corvus albicollis</i>	up to 4180	v, r
Mammals (43 spp)			
African Dormouse	<i>Graphiurus murinus</i>	up to 4180	r, c
Striped Tree Mouse	<i>Dendromus insignis</i>	up to 4330	r, a

Table 1. *continued* Alpine vertebrates of Mount Kenya.

SPECIES	Latin Name	Altitude (m)	Status
Harsh-furred Mouse	<i>Lophuromys flavopunctatus</i>	up to 4100	r, ?
Striped Grass Mouse	<i>Lemniscomys striolatus</i>	up to 4300	r?, ?
Four-striped Grass Mouse	<i>Rhabdymus pumilo</i>	up to 3800	r, ?
Climbing Mouse	<i>Praomys (Hylomyscus) denniae</i>	?	r, a
Mount Kenya Mole Rat	<i>Tachyoryctes splendens (rex)</i>	up to 4050	r, c
Groove-toothed Rat	<i>Otomys orestes</i>	up to 4750	r, a
Groove-toothed Rat	<i>Otomys tropicalis</i>	up to 4175	?, ?
Porcupine	<i>Hystrix sp.</i>	up to 3500	?, ?
Hare	<i>Lepus sp.</i>	up to 3350+	?, ?
Bat	<i>(Pipistrellus nanus)?</i>	up to 3000	?, ?
Pygmy Shrew	<i>Crocidura alpina</i>	up to 4180	r, c
Dusky Shrew	<i>Crocidura fumosa</i>	up to 3920	r, ?
Dusky Shrew	<i>Crocidura turba</i>	up to 4100	?, ?
Mole Shrew	<i>Myosorex (Surdisorex) polulus</i>	up to 3920	r, ?
Shrew	<i>Soncus infinitesimus</i>	?	r?, ?
Sykes' Monkey	<i>Cercopithecus mitis</i>	up to 4800	x, r
Black and White Colobus	<i>Colobus polykomos</i>	up to 4700	x, r
Hunting Dog	<i>Lycaon pictus</i>	up to 4250	v(r), r
Black-backed Jackel	<i>Canis mesomelas</i>	up to 3660	?, ?
Zorilla	<i>Ictonyx striatus</i>	up to 4270	r, o
Large-spotted Genet	<i>Genetta tigrina</i>	?	?, ?
Marsh Mongoose	<i>Herpestes paludinosus</i>	up to 3500	?, ?
Slender Mongoose	<i>Herpestes sanguineus</i>	?	?, ?
Spotted Hyaena	<i>Crocuta crocuta</i>	up to 4800	v, o
Cheetah	<i>Acinonyx jubatus</i>	up to 4000+	v, r
Serval	<i>Felis serval</i>	?	?, ?
Wild Cat	<i>Felis lybica</i>	up to 3800	r, c
Lion	<i>Panthera leo</i>	up to 3600	v (r?), o
Leopard	<i>Panthera pardus</i>	up to 4600	r*, c
Rock Hyrax	<i>Procavia johnstoni</i>	3450–4700	r*, a
African Elephant	<i>Loxodonta africana</i>	up to 4600	v, o
Black Rhinoceros	<i>Diceros bicornis</i>	up to 3700	r, e?
Burchell's Zebra	<i>Equus burchelli</i>	up to 4300	r*, c
Kongoni	<i>Alcephalus buselaphus</i>	up to 4000	r?, o
Black-fronted Duiker	<i>Cephalophus nigrifrons</i>	?	?, ?
Bush Duiker	<i>Silvicapra grimmia</i>	3250–4300 (–4900)	r, c
Klipspringer	<i>Oreotragus oreotragus</i>	?	?, ?
Steinbuck	<i>Raphicerus campestris</i>	up to 3500	r, o
Bongo	<i>Boocercus eurycerus</i>	up to 4300	x, r
Eland	<i>Taurotragus oryx</i>	up to 3800	r*, c
African Buffalo	<i>Syncerus caffer</i>	up to 4700	v, c

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