SAVSKILL

A Methodology to Measure and Monitor Biodiversity in Central African Savannas

edited by F. P. D. Cotterill

1995

Occasional Publications in Biodiversity No. 1

Biodiversity Foundation for Africa, Bulawayo, Zimbabwe

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A Methodology to Measure and Monitor Biodiversity in Central African Savannas

Scientific results and recommendations from a study to develop a methodology to measure and monitor biodiversity in south central Africa

Edited by F. P. D. Cotterill

1995

Study carried out by the Biodiversity Foundation for Africa with the support of the Canadian International Development Agency (CIDA)

Occasional Publications in Biodiversity No. 1

Biodiversity Foundation for Africa, P. O. Box FM730, Famona, Bulawayo, Zimbabwe

THE BIODIVERSITY FOUNDATION FOR AFRICA

The Biodiversity Foundation for Africa (BFA), a non profit making Trust, was formed in Bulawayo, Zimbabwe in 1992 by a group of concerned scientists and environmentalists, in collaboration with interested parties in North America, Europe and elsewhere in Africa.

The major objective of the Biodiversity Foundation for Africa is to undertake biological research into the biodiversity of subSaharan Africa, and to make the resulting information more accessible. It provides technical, ecological and biosystematic expertise toward this end.

The Constitution of the Biodiversity Foundation for Africa subscribes to and asserts the following declarations:

1. Biodiversity refers to the total variety of all life forms and life processes on Earth, and embraces three principal attributes - composition, structure and function. These characteristics are mutually interdependent and range from the genetic level though populations to ecological complexes in landscapes.

2. *In situ* conservation of ecological complexes in physical landscapes is the only means of maintaining representative portions of biodiversity in an intact state for future generations. Achievement of this aim demands the conservation of evolutionary vibrant, unique, and representative attributes of biodiversity and the ecological and evolutionary processes which maintain them.

3. Scientific knowledge about the environment is the crucial requirement for any strategy or activity aiming to conserve biodiversity.

4. Scientific knowledge of any attribute of biodiversity ultimately depends on biosystematics (taxonomy and systematics). In this context natural science collections held by institutions researching the phylogeny, biogeography and ecology of biodiversity constitute the central basis for any endeveour to understand biodiversity and maintain the resulting scientific knowledge. Insufficient knowledge, the severe threats and urgent need for conserving Africa's biodiversity requires priority support for biosystematics research and the resources supporting it; and decrees expansion and support for natural history collections of Afrotropical biodiversity.

5. Scientific study of biodiversity and the availability of reliable and representative knowledge to conserve the biosphere is an urgent priority, especially for tropical Africa.

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PREFACE

The Canadian International Development Agency (CIDA) supported the Biodiversity Foundation for Africa to develop a methodology to monitor biodiversity in the savanna woodlands of the Zambezi Basin - the catchment and rivers of the Zambezi River. Allied to the development of a scientific research programme to assess and monitor components of terrestrial biodiversity, was the simultaneous development of a training component in these activities. Such experiential training is most important, since human skills are essential to all aspects of the assessment, monitoring and management of biodiversity in ecological landscapes.

Phase One of SAVSKILL constituted a year's study, beginning in April 1994 and ending in May 1995. The main component was the multidisciplinary field work conducted in south western Zambia. Field work consisted of two separate expeditions in August and December 1994 (each travelling 1 500 km by road - the return distance from Bulawayo to Kalomo).

This report focuses on the significance of these inventories, and examines practical and theoretical implications for improving on these activities to assess and monitor savanna ecosystems in south-central Africa. The overall research programme, with its multidisciplinary methodology, was designed in extensive discussions among the participating biologists. The central property, and strength, of SAVSKILL is this integrated methodology: the multidisciplinary inventories characterising a spectrum of target organisms in savanna ecosystems. Taxonomic skills form the foundations of SAVSKILL strength, with ecology welding them together: standardized methodologies designed to repeatedly assess targetted components of biodiversity.

Ecology is undergoing a welcome, and much needed, paradigm shift. This shift is, firstly, the adoption of a spatial perspective to investigations of ecological phenomena, and secondly, a trend to pluralism - integrating biological subdisciplines. BFA has gleaned considerable insights from new developments in biodiversity research reported on in the exploding literature in ecology, taxonomy and conservation biology. Invaluable insights were provided from Woody Cotterill's attendance of an intensive course - The Second Biodiversity Measuring and Monitoring Course in May 1994 at the Smithsonian Institution - also funded by CIDA. Practical successes relied heavily on the expertise of the nine principal biologists - their collective experience totalling over 220 years of research activities in tropical Africa.

ACKNOWLEDGEMENTS

The is project was made possible with funding from the Canadian International Development Agency (CIDA), and BFA is profoundly grateful for this support. The knowledge presented in this report is based on nearly 10 000 organisms representing hundreds of species of organism: all collected from an Intensive Study Site north of Kalomo in south western Zambia. These data were collated by a team of 12 biologists and 10 technical officers, whose efforts were considerably assisted by 16 high school pupils, and the leaders of the expedition. Considerable thanks are due to Alan Sparrow who coordinated and managed the CIDA funded project under which this biodiversity assessment was carried out. Financial officer and legal advisor to BFA, Tony Morris Davies, provided essential guidance and administrative inputs. Woody Cotterill compiled this report on behalf of BFA and also helped with planning the expeditions toKalomo.

The fieldwork relied on close collaboration with the Natural History Museum of Zimbabwe and the National Herbarium of Zimbabwe - these institutions now house all the voucher specimens collected in Kalomo. Technical Officers, R. Chiwanda, B. Magwizi, A. Mapaura, C. Masango, the late F. M. Masiyandima, P. Mhlanga, A. Micho, F. Nyathi, the late A. N. Sango and E. Tshuma are thanked for their contributions to specimen processing and fieldwork. E. Bruce Millar, and J. Smith provided similar help. G. A. Macdonald and A. Bancroft ably supported the surveying of the permanent plot.

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The Biodiversity Foundation for Africa thanks Falcon College and the Natural History Museum of Zimbabwe for their support of the Zambian expedition. Niel Tood and Charlie Aust at Falcon provided essential help. Support from Mr and Mrs B. Duckworth, Mr and Mrs B Hollins, Mr and Mrs Burke, Mr G. di Palma, Mr and Mrs T. R. Evans, Hillside Service Station, Caltex Oil, Datlabs, Fawcetts Security, Tilbar Butchery, Lobels Biscuits, Haddon & Sly and Mobil Oil is gratefully acknowledged. Mr J. Stakesby Lewis facilitated the loan of the Isuzu truck from the Zimbabwe Schools Exploration Society, which reliably ferried several tonnes of equipment between Kalomo and Bulawayo.

In organizing the July Expedition, Gordon Macdonald's efforts extended over several months in organizing participants, logistics and supplies. Tony Bancroft was also of considerable assistance in these activities. Napoleon is often quoted for his observation that an army marches on its stomach; Heather Macdonald and Joan Bancroft unfailingly delivered ample food to the ravenous pursuers of flora and fauna. Their organisation of the catering, aided by shifts of schoolboys, was vital to fieldwork.

In Zambia, Mike Arnold, Ian Brooks, Ivan Stubbs, John Stubbs and Patrick Dankwerts provided considerable support, not least in providing fresh food. A special thank you to Guy and Lindsay Robinson for like support and especially for facilitating the permits and surmounting other bureaucratic hurdles. Major J. Colbrook-Robgent provided valuable insights into Zambian avi-fauna. Paddy Bruce Millar and Ian Bruce Millar and family, of Imamba Ranch, were most hospitable and kidnly allowed access to their game ranch. Tony and Eva Middleton provided the principal site, with fine *in situ* logistics, and excellent facilities. BFA is most grateful to you all for essential help and support.

ITINERARY OF MAIN ACTIVITIES IN 1994

- 1st May to 2nd June : Second Biodiversity Measuring and Monitoring Course: Smithsonian Institution
- 29th July to 10th August : Principal Expedition to establish Biodiversity Study Site north of Kalomo, Zambia
- 27th to 28th October : Multidisciplinary Workshop in Bulawayo
- 2nd to 15th December : Invertebrate Expedition to Biodiversity Study Site north of Kalomo, Zambia

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Chapter 1

INTRODUCTION

F. P. D. COTTERILL

This document presents the scientific issues, results and recommendations for the Phase I of a regional project to develop a methodology to assess and monitor biodiversity in the Zambezian region. This programme goes under the acronym of SAVSKILL - in reference to the twinned objectives of measuring biodiversity in Afrotropical savannas, and developing human skills to do this work. The core of the programme focuses on multidisciplinary inventories of savanna biodiversity. The impetus for SAVSKILL arose from a growing need for scientific biological knowledge of Africa's ecosystems, so as to support environmental planning and management. The individual reports produced by each discipline are collated in this report.

To succeed and perform efficiently, a multidisciplinary scientific inquiry like SAVSKILL needs clear objectives - a requirement which applies to all biodiversity studies. BFA's objectives in the First Phase of the Regional Assessment and Monitoring of Biodiversity in the Zambezi Basin were:

- Identify and develop the methodology to representatively assess the composition of savanna ecosystems, and provide indexes of ecological processes.
- Develop and refine efficient sampling techniques to repeatedly census target components of biodiversity; and from this monitoring, generate standardized and thus comparable results.
- Explore possible options to improve human skills to perform this research, and related work, and raise awareness of its relevance.
- Perform these activities so as to provide scientific knowledge which supports informed decisions on environmental management; where management objectives are to maintain the ecological integrity of savanna landscapes.

The impetus for a reliable knowledge of biodiversity to maintain the ecological integrity of tropical landscapes deserves some attention. Managers of biodiversity need to maintain intact the principal processes in ecosystems, and the ability of ecosystems to maintain these processes. Such a process-orientated strategy requires:

- Sound knowledge of the resistance of ecosystems. For example, how much can the properties of a savanna landscape be changed before its ecological processes are adversely or irreversibly affected?
- A reliable knowledge of how ecosystems respond to disturbances, especially those caused by human activities; for example, understanding an ecosystem's resilience - the rate of its recovery following perturbations. This requires elucidation of the mechanisms determining ecological resilience and resistance.
- The understanding of how to maintain ecological processes at a landscape scale. Decision makers need to know how human impacts change habitats in landscapes, and how changes in landscape pattern influences ecological processes and biological complexes therein. This requirement applies to all land categories, which together form landscape mosaics. Ecological complexes should be maintained in such landscapes if biodiversity to be conserved.

This report presents the scientific results of exploratory inventories in Kalomo, southern Zambia, conducted during Phase I of SAVSKILL. The standardized techniques used to collect and analyze this information are described. These methods form a multidisciplinary "toolbox", and the design of SAVSKILL, with its multidisciplinary philosophy and methodology, resulted from extensive discussions among BFA's biologists. Based on surveys of target groups of organisms, selected on the criteria of ecological roles and suitability for efficient inventory - the goal being to obtain a profile of the biodiversity in an intensively studied portion of African

savanna. These standardized methods, if used repeatedly to sample selected groups of target organisms, can efficiently generate comparable biodiversity information.

The overall aim of SAVSKILL is to generate hitherto unavailable scientific knowledge of an intensively studied portion of landscape - to reliably estimate the composition of the biodiversity it contains. Taxonomic skills form the core of SAVSKILL's strength, with ecological perspectives and techniques welding the whole together. This report discusses practical and theoretical implications of the methodology, and the relevance of the knowledge generated by SAVSKILL to reliably characterize terrestrial biodiversity. Recommendations are made to improve on the existing methodology.

Five of the eight chapters form the bulk of this report. Each describes different sets of methods used to survey different organisms, and results from exploratory inventories of respective target groups in Kalomo are presented. It is planned that these will be repeated, and all these results (with a detailed description of the study area) published separately. Chapter Two discusses some of the theoretical issues underlying the measuring of biodiversity, and is a theoretical argument for the strategy developed by BFA. The final chapter presents conclusions and recommendations for SAVSKILL, as developed in Phase I, with suggestions for modifying future work. This chapter also discusses how the knowledge generated from SAVSKILL might be developed integrated into policies and plans to manage biodiversity in tropical landscapes.

An important attribute of the Kalomo dataset lies in its simultaneous assessments of vascular plants and no less than six Orders of animals (including all vertebrates). These results were collected, over a comparatively short period, from the same locality at equivalent scales of space and time. Equally importantly, individual methodologies are complementary, and have been standardized. Raw data has been published in appendices. Such duplication of primary scientific information is most important in biodiversity studies - especially of tropical ecosystems. It permits comparisons between studies of ecosystems which exhibit rapid change from escalating human impacts (Janzen, 1986).

Ecology is currently undergoing a paradigm shift, involving four interrelated changes. Perhaps the most important of these developments has been an increasing cognisance and adoption of a spatial perspective in investigations of ecological phenomena, with special attention to matters of scaling. Secondly, the application of theories of non linear dynamic systems (commonly termed chaos theory) has changed our perceptions of ecosystems. These complex assemblages, traditionally perceived as stable systems exhibiting deterministic behaviour, are now considered to behave stochastically (possessing irreversible properties) arising from the unpredictable changes in their components - different populations of interacting organisms. Since the 1980s, chaos theory has expanded to studies of complex dynamic systems. With a central mission to understand and predict the properties of the biosphere - perhaps the ultimate in complex, dynamic systems - ecology could benefit considerably from this development. Thirdly, possibly allied with the multidisciplinary synergy in complexity science, is the trend to pluralism in ecology - integrating subdisciplines of biology and other sciences. Fourthly, ecologists and systematists have responded to the seriousness of the biodiversity crisis, and especially to urgent needs for scientific knowledge to wisely manage the biosphere and maintain its biodiversity. These tensions and issues considerably influence theoretical and practicable aspects of studying biodiversity, and have influenced BFA's philosophy and development of SAVSKILL.

1.1 BIBLIOGRAPHY

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Chapter 2

SOME THEORETICAL ISSUES UNDERLYING THE MEASURING AND MONITORING OF TERRESTRIAL BIODIVERSITY

F. P. D. COTTERILL

2.0 INTRODUCTION

This chapter discusses theoretical issues and the scope of SAVSKILL (BFA's research and training programme) to assess and monitor savanna biodiversity. The theoretical underpinnings of SAVSKILL are presented, and the focus of this review explores the interface between theoretical biology and the knowledge society needs to manage biodiversity in the landscapes where it occurs. An important question is what components of biodiversity should biologists measure and monitor so as to understand biodiversity with adequate precision: precise knowledge being a prerequisite to predict the consequences of human impacts on ecosystems. This is the key issue underlying the theoretical issues, challenges and objectives of biodiversity research and management.

Before these topics can be discussed we need to know a little more about the study area and objects of research interest of SAVSKILL. So the principal properties of the target of this research - central African savannas, and specifically miombo woodland - are introduced in the next section.

2.1 THE MIOMBO SAVANNAS OF CENTRAL AFRICA

Research and monitoring priorities of the Biodiversity Foundation for Africa are on savannas, which cover over 20% of Africa, a large portion of which is miombo woodland (White, 1983; Scholes & Walker, 1993). Miombo is the Nyanja (a Malawian dialect) word for the tall, open savanna woodlands dominated by deciduous trees of the genera *Brachystegia*, *Julbernardia* and *Isoberlinia*. Miombo woodlands, or dry forests dominate the watersheds of the central African plateau; particularly on comparatively infertile soils derived from Precambrian rocks (Cole, 1986). The area contains numerous endemic species and unique floral associations. Miombo, of diverse and varying floristic composition, occupies a major portion of the Zambesiaca region (Fig. 2.1).

Miombo was selected by BFA as suitable for developing a methodology to survey biodiversity in savannas, with sufficient flexibility to be used on other vegetation types in central Africa. The regional extent and local variability in miombo, and human pressures on this landscapes, were important criteria in this choice. BFA's operations were limited by time and resources which precluded attention to other, equally important habitats, such as mopane (*Colophospermum mopane*) woodland and dambos (grassy wetlands).

Although miombo woodland is a principal component of the savanna biome in tropical Africa, most tourists and visitors (including many biologists) have negative perceptions of the landscape. Their attentions invariably gravitate towards forests and acacia savannas, and particularly toward the charismatic vertebrates which occur in them. Adams and McShane (1992) in suggesting that "miombo is quite possibly the greatest dry forest on earth.", encapsulate the pervading negative impression of miombo woodland in the phrase: "miles and miles of bloody Africa" - attributed to a colonial official disenchanted with the heat, tsetse flies and uniformity when travelling through this endless and apparently sterile landscape.

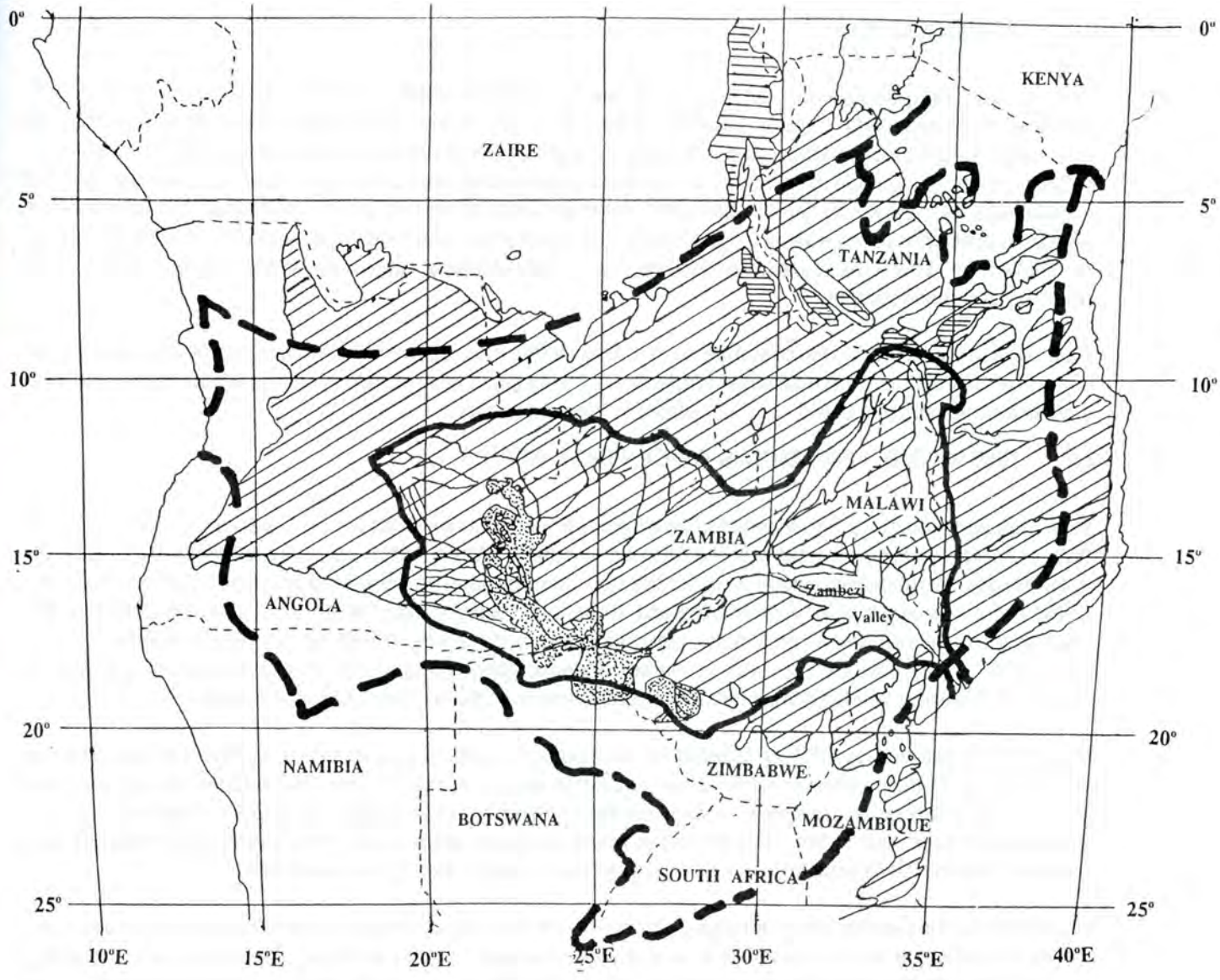
Boundaries of the Zambezian Phytochorion.

Extent of the catchment of the Zambezi River.

Zambezian teak woodlands, dominated by *Baikaea plugifura*.

Brachystegia woodlands

Figure 2.1. Map of south-central Africa illustrating the extent of *Brachystegia* woodland (including miombo woodland dominated by trees of the genera *Brachystegia, Isoberlinia* and *Julbernardia*), and Zambezian teak woodlands. Extent of the *Brachystegia* woodlands shown in relation to the catchment of the Zambezi River, and the Zambezian phytochorion (geographical area of floristic endemism) defined by White (1983). Figure adapted from Benson & Irwin (1966) and White (1983).



Humans evolved, in part, in Africa's savannas, and have modified miombo woodlands and other savannas for tens of thousands of years. Besides hunting and foraging, our greatest impact has been the deliberate use of fire, originally as a foraging tool (Adams & McShane, 1992; Kingdon, 1993). Africa's human populations in tropical Africa increasingly adopted subsistence agriculture over the past three thousand years, while most recently, colonization and industrial development of modern African countries has brought the impacts of commercial agriculture and mining on savannas and other ecosystems (Walker, 1987). The impacts of these changes on the ecological integrity of these landscapes is incompletely understood.

In addition to plants, many endemic invertebrates and vertebrates are restricted to miombo. Examples of endemics species include spiders such as the Zodariidid, *Hermippus loricatas* (Jocque, 1986) and nymphalid butterflies of the Genus *Charaxes* (Henning, 1986). Endemic vertebrates are better known. At least 20 species of birds are endemic to miombo, and it is the preferred habitat of 24 other species (Benson & Irwin, 1966). Several species of mammals are intimately associated with the *Julbernardia/Brachystegia* woodland: a good example is Lichtenstein's Hartebeest, *Sigmoceros lichstensteini*; a relict species representing an early antelope radiation (Bigalke, 1978).

2.2 TOWARD ECOSYSTEM MANAGEMENT

Environmental management is a controversial issue which receives increasing attention from scientists and society. This awareness is a direct result of the considerable concern engendered over the simplification, modification, and pollution of ecosystems worldwide. In addition to central Africa, human modifications of the biosphere has generated an exacerbating problem of global proportions (Hannah, *et al.*, 1994; Morris, 1995). Rectifying damages to ecosystems, such as soil erosion from agroecosystems, holds exorbitant economic costs (Pimentel, *et al.*, 1993).

African landscapes are undergoing widespread and rapid changes. Large areas of savannas, including miombo, have been significantly changed to supply agricultural land, and biological resources - particularly fuel and plant products. Mining activities, industry and urbanization have had more locallized but more intense impacts. Most appareent impact of these modifications is the removal or simplification of the natural vegetation. The effects of these wholesale alterations of landscapes ramify through time, and extend over years and decades. For example, widespread removal of indigenous vegetation quickly changes the composition of arthropod and vertebrate communities aboveground, whilst changes to the soil fauna may occur more slowly (Hunter, 1994).

Simplifications and modifications of ecological landscapes (at national, regional and global scales) are an emergent consequence of the many independent decisions humans make at local scales. Exploring its economic implications, Kahn (1966) originally termed this phenomenon "the tyranny of small decisions". Local decisions by farmers, miners and other users of biological and natural resources modify savanna landscapes for their immediate, short-term benefit. These small decisions ramify into large scale environmental changes, which are difficult to regulate or reverse. This is especially the case where the tragedy of small decisions affects unmanaged common resources (Hardin, 1985).

The situation is confounded by insufficient biological knowledge of the ecosystems and especially the organisms which comprise them, especially in central Africa. The premise of BFA's philosophy is to obtain such information in order to manage ecological landscapes, whilst maintaining the evolutionary integrity of ecological complexes and processes. Although the maintenance of ecosystems and their processes is a central objective of conservation biology (Noss, 1991; Walker, 1992; Smith, *et al.*, 1993; Grumbine, 1994); keeping alive the options represented in the evolutionary products of biodiversity is equally vital to satisfy future human requirements (Janzen, 1993; Reid, *et al.*, 1993; Lovejoy, 1994).

2.3 BIODIVERSITY - OF PIVOTAL CONCERN, OR MERELY A BUZZWORD?

Since the 1980s, the term biodiversity has been rapidly adopted by the media, public, and biologists. This interest is part and parcel of concerns about environmental problems, increasing over the past two decades, and most notably since the signing of the UNCED Treaties at the Earth Summit in 1992. Biodiversity is an umbrella term for the total variety of life forms and life processes on earth (Harper & Hawkesworth, 1994), and is defined by the Convention on Biological Diversity as "the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems" (UNEP, 1992). Harper & Hawkesworth (1994) argue that biodiversity is most feasibility partitioned into its genetic, organismal and ecological compenents - and this approach is followed here. The integrated values of biodiversity have immediate and potential importance to the quality and continuity of human life (Mittermeier & Bowles, 1993; Lovejoy, 1994), because biodiversity provides:

- Ecological processes and products which humans need to survive: these include food, fresh water, and clean air.
- Biotechnological products: both direct substances, such as ethnobotanical products, and biological information which is used to synthesize biochemicals and biomaterials.
- Economic benefits from the aesthetic values placed on natural areas and wildlife. For example, African savanna ecosystems support a rapidly expanding safari and tourism industry.
- Maintenance of all these properties, and their benefits, despite contingent disturbances. Interactions between diverse organisms maintains the integrity of ecosystems in the face of changes in climates, socio-economic systems, and internal dynamics.

All such benefits would cease if critical processes operating in ecosystems are markedly perturbed. These critical processes include those recycling soil nutrients, water and the biogeochemical cycles regulating atmospheric composition (Wilson, 1992; Harper & Hawkesworth, 1994; Hawkesworth, 1995a). The sustainability of these services relies on the persistance of ecological processes despite disruptions. Disturbances affect any ecosystem, and include meteorological phenomena, fires, alien species which invade established food webs, and of course, human activities. Disturbance primarily alters ecological processes by modifying the abundance and distributions of the different organisms, whose collective interactions (with their environments) generate ecosystem processes (Huston, 1994; Jones & Lawton, 1995).

2.4 BIOLOGICAL KNOWLEDGE

The lack of knowledge is a serious problem which afflicts any decision on all aspects of biodiversity. The composition of all ecosystems is very poorly known and scientists simply do not know how many and what kinds of organisms occur in them, nor the contributions of these different organisms to ecological phenomena (Wilson, 1992; Embley, *et al.*, 1994; May, 1994). There are people who query such knowledge and question its relevance, or the importance of improving it. It is pertinent in this case, as eloquently argued by Moore (1982), to endorse the need for scientific knowledge to support environmental policy and decisions, since this requirement is so poorly appreciated by most of society. In fact, human ignorance contributes to environmental degradation and the biodiversity crisis (Ulfstrand, 1992; Ludwig, 1994). The need for scientific studies to monitor human impacts, especially of developmental projects, has also been endorsed (Kremen, *et al.*, 1994).

A reiteration of the importance of scientific knowledge is timely. Governments and development agencies, engaged in environmentally-orientated projects, invariably neglect scientific imperatives. This problem has increased since the Earth Summit (di Castri, 1994; Willers, 1994; Hawkesworth, 1995b). Sustainable develop-

ment and associated concepts, are glibly perpetuated by governments and environmental organizations, yet rest on weak scientific foundations. The latter have been soundly challenged. and in some cases, when critically examined, many of the concepts falling under the aegis of sustainable development open themselves to criticism (Beckerman, 1995).

The premise of this report, and the operations producing the information it synthesizes, is that objective knowledge (*sensu*, Popper, 1972) is vital to maintain ecosystems and the suite of processes and products required by humans. Societies' problems are strongly correlated with environmental problems. Scientific knowledge is required to find and apply solutions, hence there is no difference between the, so-called, pure and applied subdisciplines of ecology and the other life sciences. Actually, they are mutually supporting activities of the same science, artificially divided, largely on administrative criteria. This project is consistent with biology's overall objectives are to build a robust scientific knowledge which adequately describes and reliably predicts the properties and behaviours of complex biogeophysical systems (Likens, 1995).

2.5 A LANDSCAPE FRAMEWORK FOR ECOLOGY

"Ecology is the scientific study of the processes influencing the distribution and abundance of organisms, the interactions among organisms, and the interactions between organisms and the transformation and flux of energy and matter." (Likens, 1995). The term, ecosystem, is a conceptual abstraction which describes the participants and processes encapsulated in Likens' definition. Elucidating ecosystems' properties, such as depicting food webs and quantifying flows of energy and nutrients across trophic levels, has sustained the enquiries of generations of ecologists (Pomeroy, *et al.*, 1988). Typically in ecosystem terms, processes are described independently of space and time. Yet, populations of specific organisms occur in certain domains of space and time. The micro-processes, generated by organisms' interactions, are consequently constrained to finite domains in which these specific populations occur. As the emergent properties of many different micro-processes, macro-processes transfer matter and energy transfer through much larger spatial domains (Anderson, 1995).

It needs to be emphasised that variations in ecological phenomena are strongly scale dependent. The spatial domains, in which ecological processes occur, extend from the microscopic through to synoptic scales, and outward to the biosphere. Similarly, the properties of ecosystems also fluctuate through equivalent magnitudes of space in time (Wiens, 1995). A cognizance of the differences in scale, where organisms interact and across which macro-processes occur, is indispensible if we are to realistically interpret ecological phenomena (Wiens, *et al.*, 1993). Objective characterizations of ecological complexes (including their processes) requires that organisms, and the domains of space and time in which their interactions occur, be objectively described and compared. This requires the characterization of ecological entities and processes in spatially explicit terms. Unfortunately, ecologists do not always observe this imperative (Shugart & Urban, 1988; Wiens, *et al.*, 1993).

Scale dependent properties of ecosystems are expressed in many different types of ecological phenomena. These include properties of food webs (Martinez, 1995); patterns of availability of resources utilized by organisms (such as nutrient patches and prey items) in terms of resource abundance and distribution in space and time (Wiens, *et al.*, 1993); and the impacts of disturbance events generated within ecological systems (Huston, 1994). Wiens (1995) suggests that this scale dependency dictates that ecologists work within the context of ecological landscapes, since investigations of ecological phenomena (whether depicted as entities, processes, or mechanisms) requires clear reference to the spatial attributes of organisms' properties, and the ecological and physical complexes in which organisms occur.

2.6 THE IMPORTANCE OF ECOLOGY

Ecology generates the knowledge of how a diversity of organisms interact in complex ways, and process energy and matter (Huston, 1994; Lawton, 1994; Jones & Lawton, 1995). This science is undergoing active growth and changes in its philosophy, and in the orientation of its research paradigms. This evolution of ecology also involves a synthesis among a number of subdisciplines, including biosystematics, systems theory, thermodynamics, natural history, palaeontology, and the information and computer sciences (Schrader-Forchette & McCoy, 1993; Hawkesworth, 1995a,b). The unique feature of biology, and especially ecology in its central focus on organisms, is that every organism and population is a unique product of historical processes (Darwin, 1869). This fundamental property of uniqueness creates challenges to the study and elucidation of ecological complexes and individual components of the living world which sets biology apart (Lewin, 1982; Mayr, 1982).

Ecological systems appear to be driven by unpredictable changes in the physical environment. These changes effect ecosystems at different scales of space and time (Botkin, 1991). Events with exceptionally significant impacts on ecological landscapes occur more intermittently; at intervals ranging from decades to tens of thousands of years. Pimm (1991) suggests that ecosystems are asymmetrically influenced by these episodic events. This pattern of their occurrence can be visualized as "reddened spectra". Such phenomena are difficult for ecological studies to detect, since the durations of most investigations are too short, and limited to small areas.

Like all the life sciences, ecology is supported on the foundations of biological classifications elucidated by systematics, and constructed by taxonomy. Taxonomic classifications are information management systems. They are essential to collate, store, process and disseminate any information pertaining to all biological knowledge. Systematics can elucidate and build accurate classifications to describe evolutionary relationships among organisms. These reconstructed phylogenies are essential to elucidate the historically derived properties of organisms (both extinct and extant) and the complexes they form (Small, 1989; Cotterill, 1995; Wheeler, 1995).

The pluralistic synthesis (among many disciplines) in ecology is perhaps allied to the emergence of the new science of complexity. Complexity theory aims to explain how emergent, and more extensive and persistent phenomena arise out of the many minor interactions within systems of numerous different entities, occurring at localized scales of space and time. Examples of complex systems are human societies, economies and ecosystems (Lewin, 1992; Kauffmann, 1993; Cowan & Pines, 1994). As it currently stands, the discipline's focus on (in its "crude looks at") emergent properties of complex dynamic systems (Brown, 1995) is an existing weakness in complexity theory. This deficiency especially applies to ecosystems. Complexity theory ignores variation among organisms; the individual uniqueness of these entities, in short it lumps together their idiosyncratic properties.

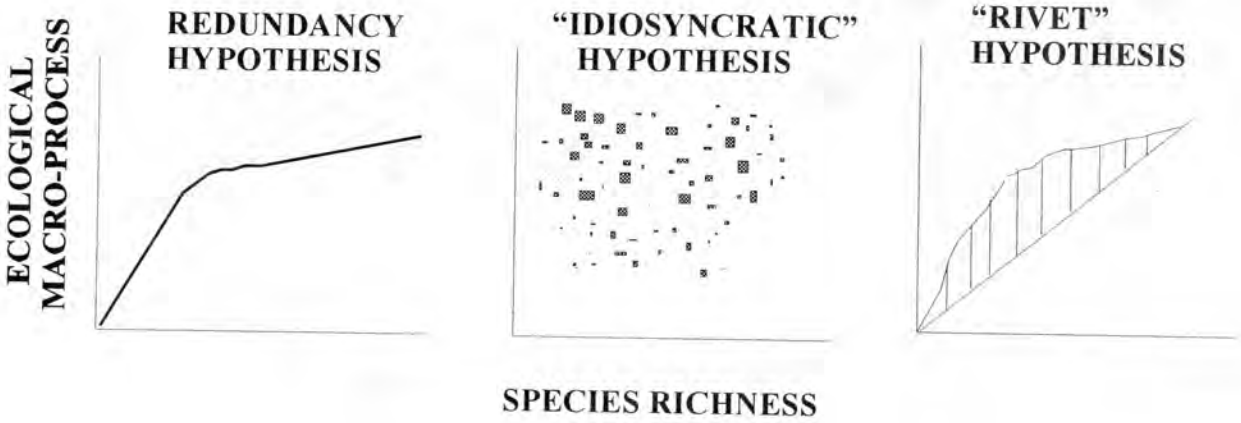
Understanding the variety of micro-processes generated by a very large diversity of disparate organisms, is a principal activity in ecology. These enquiries have a central dependence on taxonomy. It is equally important to elucidate how these summed interactions generate ecosystem processes across large spatial scales. Wiens (1995) has stated that these scale dependent enquiries - extending from organisms to landscapes - are a singular research agenda for ecology. And this knowledge is fundamental; for we need a foundation on which to plan and implement sustainable management plans for biodiversity in the landscapes humans rely on for survival.

Very poor knowledge of the taxonomy and natural history of living organisms (Embley, *et al.*, 1994; May, 1994) weakens the life sciences, particularly their inability to understand and predict the properties of complex biological systems. Extending from its theoretical limitations for the life sciences, the lack of knowledge of the basic properties of biodiversity has serious implications for managing biodiversity in natural and human-modified landscapes:

- The existing poor understanding of the relationship between ecosystem performance and species diversity particularly applies to ecosystems which have, or are experiencing, a radical change in their structure and composition. This problem is widespread in tropical Africa, and of considerable importance to all biological research.
- It is exceedingly difficult to predict how losses of biodiversity will effect ecological processes in years ahead. Using existing biological knowledge, we cannot predict, with confidence, how humans' modifications of the biodiversity in habitats and landscapes (the abundance and diversity of organisms therein) will effect ecosystems, notably their future properties and integrity.
- Insufficient scientific knowledge has profound implications for environmental managers, because they cannot predict how much ecosystems can be modified (for example, by reducing biodiversity) before ecological processes are negatively or irreparably altered. For example, how much can humans changes the species diversity of an ecosystem before water, nutrient and decomposition cycles are adversely altered?
- Inadequate knowledge obviously weakens decisions on how ecosystems should be utilized and managed. It exacerbates threats to the future integrity of biodiversity on which the quality of human life depends.

Human impacts on ecosystems differ considerably, and are greatly influenced by different forms of land use. Management priorities also vary with spatial scale and in the geographical context in which human-modified ecosystems are embedded. Land management practices and conservation priorities for 100 Ha of intensively managed cropland (converted from miombo) clearly differs from that required for 10 000 Ha of a similar landscape utilized for extensive livestock production. Maintaining the integrity of watersheds, within which such agricultural lands are located (to ensure water quality and quantity along with other benefits), would also have

Figure 2.2. Graphical depiction of three different relationships hypothesised to exist between the species composition of ecosystems and the performance of an ecosystem. In these hypothetical examples, the axes of the graphs have no units. (After Lawton, 1994).



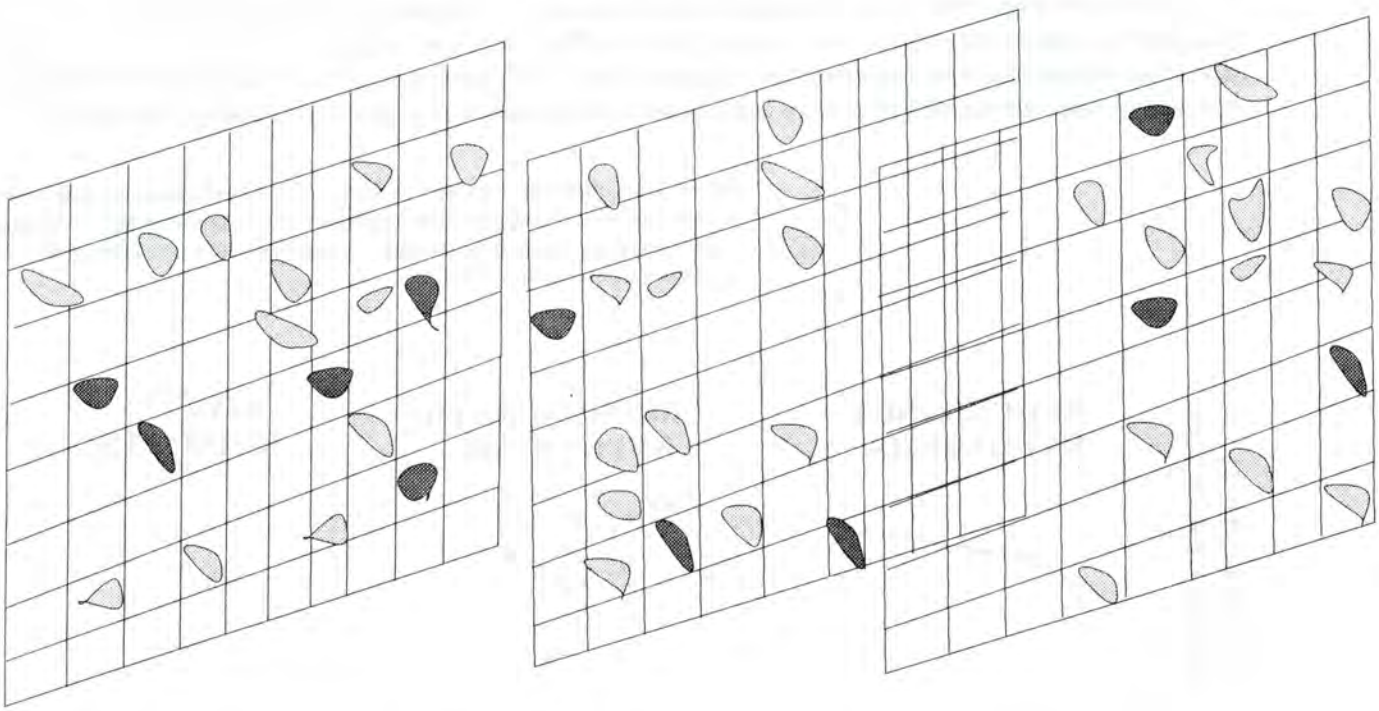
different conservation priorities. The management of ecosystems over even larger scales, for example, across international regions to maintain the integrity of large wetland ecosystems, is equally different.

Nevertheless, management priorities for all these landscapes (despite differences in spatial and biological properties and socio-economic circumstances) are interlinked. Interdependent ecological processes, operating within and across different portions of the landscape, are the crux of these linkages.

2.7 HOW MUCH BIODIVERSITY DO ECOSYSTEMS NEED?

Ideally, land management practices should minimise impacts on essential ecological processes; especially the processes and ecological complexes responsible for maintaining soil fertility, sufficient supplies of potable water, and a stable atmospheric composition require knowledge of these processes. If this is not available (which is the prevailing situation) then the encompassing objective is to maintain a high level of biodiversity across a range of spatial scales within inter-connected landscapes (Noss, 1990; Lovejoy, 1994). Exactly what defines 'a high level of biodiversity' and how it should be maintained in inter-connected landscapes is presently incompletely understood, and is the subject of vigorous debate (Hudson, 1991; Noss & Cooperrider, 1994).

Figure 2.3. Schematic rendition of a hypothetical ecological landscape at different times. Total area represents the total domain of an ecological macro-process, such as water cycling. Shaded areas show the relative roles of different species (micro-processes) under a changing environment. "Driver" species are darkly shaded.



The arguments, both for and against this policy, centre on the relationships between species richness and ecological processes: with a focus on the connectivity between organismal biodiversity and ecological biodiversity (*sensu* Harper & Hawkesworth, 1994). The research to answer these questions has to explore how ecological processes arise out of organisms' interactions (Lawton, 1994). The inherent complexity in the composition of ecosystems complicates these endeavours. The roles of individual species (actually the activities of constituent organisms) are complemented in ecosystems: more than one type of organism performs the same activity (Ulanowicz, 1986). For example, many species of herbivorous insects may feed on the leaves of a single species of plant. These organisms form complex webs connected through their interactions and interdependencies (Jones & Lawton, 1995). There is, however, considerable uncertainty about the specific properties of diverse communities assembled from interacting organisms and how such communities evolve (Ricklefs & Schluter, 1993). Arguments over the relationship between species richness and ecosystems' properties are divided between three hypotheses (Fig. 2.2); centred around the concepts of "species redundancy" and "connectivity".

- The redundancy hypothesis (Walker, 1992; Lawton & Brown, 1993) suggests that only a subset, the "driver" species of the total biotic assemblage, are essential to maintain ecological processes (Walker, 1992). This hypothesis considers redundant "passenger" species to be superfluous - unnecessary to maintain ecological processes. Losses of passenger species will not significantly alter an ecosystem's properties.
- The idiosyncratic hypothesis (Vitousek & Hooper, 1993; Lawton, 1994) acknowledges that ecological processes are dependent on species richness but suggests that modifications in species composition produce unpredictable changes to ecological processes. In its exploration of species diversity and ecosystem processes, the idiosyncratic hypothesis moves beyond studies of blanket changes in species richness of ecosystems, which demands knowledge of the specific details of effects of organisms invasions and extinction in ecosystems. Measures of relative abundance and of different species' autecologies are essential to study these phenomena.
- The connectivity hypothesis (Ehrlich & Ehrlich, 1981; Vitousek & Hooper, 1993) argues that the loss of species from an ecosystem is like randomly removing rivets from an aircraft. There are risks in such mining of rivets - inherent uncertainty as to when a vital section of fuselage will fall off the flying plane. And since biodiversity is so poorly known, we do not know which species are of particular ecological significance. Loss of a few, or even one species, may jeopardize a critical ecological process. Evidence of these impacts may be difficult to detect, and processes may only deteriorate after long periods of time. In its extreme form, the rivet hypothesis maintains that all species are essential to sustain an ecosystem's integrity.

There is merit in the extreme view of the rivet hypothesis, because the analogy based on aircraft rivets can be extended: it is difficult to predict what violent aerial manoeuvres an aircraft might suddenly perform, in thunderstorms, for example. Such unpredictable manoeuvres, unexpectedly required of such an aircraft, are analogous to ecosystems' responses to the chaotic and unpredictable behaviour of the environments in which they exist, and have evolved. The redundancy in any ecosystem's composition is a product of its evolutionary history. An ecosystem may perform adequately with only a subset of species under mundane conditions. The roles of driver species will be obfuscated, or expunged entirely, following stochastic disturbances, or after climates abruptly shift to new states.

Ecological roles of species vary with organisms' relative abundances and distributions in space and time, which is determined by a variable suite of biotic and abiotic processes. Most importantly, the ecological significance of an individual population depends on how and where different organisms process energy and matter, and how these micro-processes change properties of ecological landscapes (Huston, 1994; Lawton, 1994). Unexpected changes in climate may radically alter regional environments. This is when the rich species

composition (redundancy) of an ecosystem becomes essential, not only to sustain principal macro-processes, but for the humans relying on them (Fig. 2.3). Our current knowledge makes it impossible to know which species will become essential for ecological processes under unforeseeable, possibly extreme, future conditions. (Unequivocal detection of driver or "keystone" species is problematic, because all ecosystems are so poorly known, Janzen (1994).)

We need to unequivocally define which properties of a macro-process in an ecosystem are relevant to enquiry, and to maintaining the integrity of the ecosystem. Is it the rate and spatial extent of the process, or its resistance and persistance (maintaining performance despite fluctuating physical conditions) that should be measured? These different properties can be expected to be influenced by different organisms in very different ways. These distinctions are not always made, and further confuse comparisons and theoretical discourse on the topic. Nevertheless, viewpoints, arguing that researchers focus attentions on elucidating roles of driver species in maintaining ecosystems' properties (Walker, 1992) naively divorce the central property of complementarity in ecosystems. All organisms and populations are unique products of historical processes (Lewin, 1982; Mayr, 1982). We cannot ignore uniqueness as this central property of the living world, yet many biologists appear to ignore this axiom, as evidenced in viewpoints of ecological "redundancy". Such ignorance segregates this fundamental property from studies of biological systems and considerably weakens the scientific relevance of the discipline (Brown, 1995; Cotterill, *in press*).

Insufficient empirical data exacerbates the problems of understanding ecological biodiversity, and especially in answering questions of how much biodiversity is needed in ecosystems. Although the elucidation of unambiguous answers is very difficult, recent studies (notably from the Ecotron experiments at Silwood Park in the UK) have provided unprecedented insights into ecosystem properties and species diversity. These tests, conducted under controlled and replicated environments, have demonstrated diverse ecosystems (assembled from a wider variety of organisms) to be more productive (Lawton, 1994). It appears that understanding intricate details of how species are removed, or added to ecosystems - how these complex systems are assembled and broken down - is as important as generalized investigations of species richness and emergent properties of ecosystems (Pimm, 1991; Drake, *et al.*, 1993). Ecologists, given the time and resources to conduct multidisciplinary research on these complex and dynamic systems, face considerable challenges in elucidating these interwoven phenomena.

2.8 WHAT SHOULD ECOLOGISTS DO?

One difficulty in measuring ecological properties, such as resistance and resilience, is collating empirical data on the properties of a representative spectrum of organismal biodiversity (Pimm, 1991). To placate decision makers, some authorities attempt (on the basis of a mediocre knowledge of a few species generated over a few years) to predict the properties of entire ecological assemblages into future decades (Edwards, 1995). The value of ecological knwoledge would improve considerably if we could identify key mechanisms which determine ecosystems' properties before, during, and after monitored disturbances (Holling, 1992; Wiens, *et al.*, 1993), and so predict (within the guidelines of empirically derived parameters) with a quantified degree of confidence, the future properties of ecosystems.

The theoretical challenges facing ecologists, into the next century, can be summarized in four paragraphs:

1 Clear, robust understanding of ecosystems' properties requires a combination of descriptive studies of ecosystems, and experimental investigations of their properties. A synergy of multidisciplinary description and experiment is essential to elucidate the ecological mechanisms determining the properties of biodiversity.

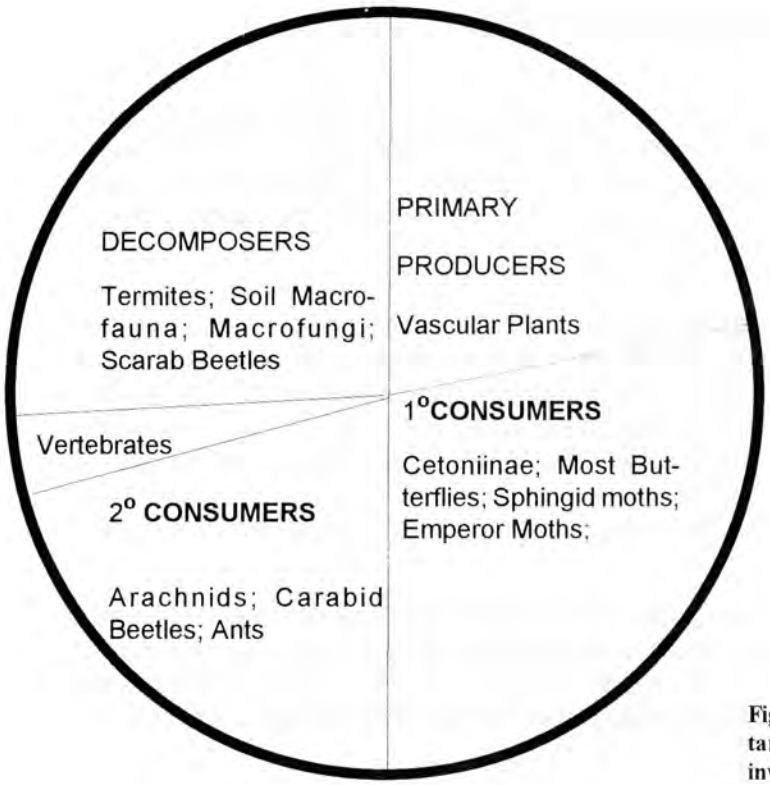


Figure 2.4. Schematic depiction of trophic roles of target groups in miombo savanna for intensive inventory in SAVSKILL methodology

2 Fundamentally, ecologists need to identify the mechanisms by which ecological complexes are produced and maintained by the activities and interactions among organisms (Wiens, *et al.*, 1993; Jones & Lawton, 1995).

3 It is especially important that ecological processes, and the ecological complexes where they occur, are studied and described in spatially explicit terms. This is because ecological patterns and the processes which cause them, vary tremendously with spatial scales. The physical and biological processes, determining these spatial properties (patterns) of ecological landscapes, also vary considerably through time. This scale dependent variation is closely tied to the heterogeneity and complex properties of ecological phenomena (Wiens, 1995).

4 Biology has to discover and build, through rigorous research, the conceptual and theoretical knowledge which incorporates the complexities and unique properties of biological systems, yet identifies their common emergent features (Brown, 1995). Ecosystems are evolutionary products. Investigations of any ecological complex has to account for the historical context in which the system, and its constituents, evolved (Luh & Pimm, 1993; Ricklefs & Schluter, 1993).

It needs to be emphasized that research requirements centre on evaluating and comparing, through space and time, the micro-processes caused by organisms in ecosystems. The challenge is to explain how this multitude of micro-processes are linked to the processes (including geochemical cycles) generated at larger scales in ecosystems (Holling, 1992; Levin, 1992; Wiens, *et al.*, 1993; Jones & Lawton, 1995). Much of this research must focus on the ecological properties of mosaics of habitats in landscapes (Wiens, 1995).

2.9 MONITORING BIODIVERSITY IN SAVANNA ECOSYSTEMS

Before we can begin to assess effects of human impacts (modifying biodiversity) on ecological landscapes, we must have a representative knowledge of the biodiversity in comparatively intact ecosystems (Dallmeier, 1992; Davis, 1993). Profiles of such intact systems provides benchmarks, which are essential to compare intact and human-modified landscapes. Such studies should furnish relaible knowledge of biodiversity - of its structural, compositional and functional properties (*sensu* Noss, 1990).

In developing SAVSKILL, the BFA identified a suite of taxa occurring in miombo biodiversity for intensive studies of their relative abundances (Fig. 2.4). This methodology is founded on a broad classification of organisms into functional groups (see Korner, 1993; Huston, 1994); selecting suitable taxa as practicable targets for inventories. SAVSKILL aims to use data on the relative abundance of different organisms as an index of ecological processes. One important dichotomy in this classification distinguishes between *structural* and *interstitial* species (*sensu* Huston, 1994), which are influenced by different sets of ecological processes, and correspondingly differ in their effects on the composition, structure and dynamics of biodiversity in savanna landscapes:

- Structural species augment the physical structure of the ecological landscape; generating new resources - primarily space, where interstitial species, for example arthropods, can live. Vascular plants are the most important group of structural species in terrestrial ecosystems. Assessing and monitoring this functional group is considered essential for investigations into savanna biodiversity. Plants occupy pivotal roles in the interaction webs on these landscapes.
- Interstitial species are the primary and secondary consumers in both producer and decomposer food webs (Pimm, 1991). In terms of diversity and representation, invertebrates (second to the microbial fauna - which are extremely difficult to study) are the principal interstitial species (Embley, *et al.*, 1994; Huston, 1994).

The Scope of Organisms' Interactions and Implications for Sampling Biodiversity

Faced with the mind-boggling complexity in ecosystems, biologists have to make hard decisions (Stork, 1994). What organisms should be selected, which can not only be feasibly studied, but also significantly contribute to macro-processes in ecological landscapes? The majority of the species occurring in habitats are rare. Species abundance curves which compare similar functional and taxonomic groups of species are skewed by the high numerical abundance and widespread occurrences of many organisms belonging to comparatively few species. In fact, biological communities are dominated by a few such widely distributed and numerically abundant species, whilst most species are either sparsely distributed or intermittently abundant. Although objective definition and descriptions of this phenomenon is difficult, rarity is a predominant property of biological communities (Gaston, 1994), which designers and implementors of biodiversity inventories cannot ignore.

Estimations of patterns of abundance of different organisms in landscapes measures their contributions to ecological processes. This is important since organisms differ in their relative participation in nutrient and water cycles in specific domains of space and time (Wiens, *et al.*, 1993). Millipedes and scarab beetles, for example, are important members of interactive webs in the decomposition cycles of savanna soils, whilst insectivorous bats are principal nocturnal predators of flying insects, and arachnids are important terrestrial predators, especially of other invertebrates.

The mechanisms by which different organisms' affect ecological processes is complex; and is not just limited to who or how they eat. Food webs only comprise a subset of interactions, because organisms also transfer mechanical energy (Jones, *et al.*, 1993; Martinez, 1995) and information (Dusenbury, 1992). This diversity of micro-ecological effects compunds the task of selecting target taxa to measure biodiversity. Some organisms directly or indirectly control the availability of resources to other organisms in an ecosystem, and are termed ecosystem engineers. Their activities regulate resource availability, especially of space and micro-habitats. Ecosystem engineers modify temporal and spatial patterns of abundance and distribution of these resources (Jones, *et al.*, 1993; Lawton, 1994). Excellent examples of ecosystem engineers, influencing ecological properties in African savannas, are:

- Antbears (aardvarks), *Orycteropus afer*. Antbears' excavations have important mechanical effects. They modify soil structure and processes therein (such as water absorption) and supply micro-habitats for many other organisms.
- Isoptera (especially *Macrotermes* spp.). Integral to nutrient cycling in savannas, termites are of considerable importance. In miombo savannas, termites' architectures (with building of successive colonies extending to hundreds of years on a single site) concentrate soil nutrients into the fine grained, elevated soils of large termitaria. The geometry and spatial distributions of termitaria profoundly influences the diversity and abundance of vascular plants (Malaisse, 1978).

Table 2.1 Desirable Properties of Target Organisms selected from Monitoring Savanna Biodiversity (modified from di Castri, *et al.*, (1992) with additions).

CRITERIA	PROPERTY	BENEFITS
1. Selection and Comparisons	Monophyletic group	Ecological comparisons not compounded by historical influences
	Widespread in distribution and distribution and abundance comparatively homogenous across a range of spatial scales in ecological landscapes	Comparisons of study sites possible between and within biomes
2. Sampling and Research	Taxonomy and ecology is comparatively well understood	Efficient estimates of relative abundance and alpha diversity
	Sampling methods are relatively cheap and do not significantly disrupt the ecosystem	Minimise sampling costs and researchers' impacts
3. Representation	Significant contributors (members) of ecological guild (e.g. insect herbivores)	Contribution and signifiance of organismal biodiversity in ecological macroprocesses is significant
	Taxon sensitive to anthropogenic changes to landscapes	Allow scientific tests of human impacts on biodiversity

Strategies which seek to reliably sample biodiversity cannot be limited only to organisms which dominate trophic processes but should account for other sets of interactions. Objective characterization of biodiversity must account for engineering effects - their interactions and impacts (Martinez, 1995). An equally diverse subset of interactions exists among organisms in how they sense and process information from their environments. Pollinators are good examples, as they transfer genetic information between plants. This suite of interactions incorporates the sensory ecology of organisms - responding to and processing information from their environments (Dusenbury, 1992). Objective reviews of engineering (chemical and mechanical), trophic and sensory ecologies among organisms, co-occurring in ecological landscapes, are more comprehensively described in interactive webs which incorporate the true scope and diversity of associations (Martinez, 1995).

Objectives of Monitoring: Choosing Targets

1 Characterize biodiversity (alpha taxonomy and relative abundance) for each target group.

2 Determine the relative roles of target taxa (their relative contributions) in specific ecological processes.

3 Estimate the total species richness of functional group in a prescribed study area. Use extrapolative techniques and complementarity (for examples; see Colwell & Coddington, 1994).

4 Compare these properties for each group of target organisms between different sites.

Target Organisms for Biodiversity Monitoring

With a focus on miombo savannas, Phase I of SAVSKILL conducted intensive investigations into a localized area (Fig. 2.5). Species lists of vertebrates and plants were compiled in a landscape of 100 kms^2, within which an Intensive Study Area (ISA) of 50Ha was selected and permanently marked. A permanent vegetation plot, of smaller area, was established (following SI/MAB standards, see Dallmeier, 1992) within the ISA. The relative abundances of target taxa, representing a spectrum of biodiversity are determined in a series of inventories.

Plants are obvious targets, as the principal structural species in terrestrial landscapes. Important taxonomic groups of interstitial species, selected by BFA as monitoring targets, includes: all vertebrates; soil macrofauna; Lepidoptera; selected Families of arachnids, ants and beetles; termites; and macrofungi. Selection of these taxonomic groups, of known functional significance, is primarily based on the feasibility of repeated censuses, and most importantly on the availability of taxonomic resources to identify them. The extent over which vertebrates influence ecological processes within the ISA is larger, and frequencies of vertebrate impacts are more intermittent in smaller spatial domains. Obviously, inconsistencies arise in coordinating inventories of small-bodied invertebrates with those of larger and more mobile vertebrates. To represent their large ecological neighbourhoods (*sensu* Addicott, *et al.*, 1987), vertebrates were censused both in the ISA and within the adjacent landscape - a total area of $\pm$ 100 kms^2.

2.10 CONCLUSIONS

The theoretical framework, underlying scientific measurement of biodiversity in ecological landscapes, has yet to mature. Nevertheless, our current understanding is sufficient to endorse a research focus on how the abundance and distribution of organisms affects ecosystems' properties. Organismal biodiversity has to be measured in ways which support extrapolations; to estimate their influences on ecological processes at landscape scales.

The multidisciplinary inventories developed and applied in the Kalomo Study generated insights into the relative abundances of a diversity of organisms. These samples provide a scientific knowledge of a spectrum of the biodiversity in miombo savanna. The following chapters discuss considerations and criteria in sampling specific target groups, and discuss the relevance of their results. A vexing question is how objective and accurate, in

a single word - representative - are these data. How reliably do these target taxa indicate the properties (especially ecological) of biodiversity in miombo savannas, especially at landscape scales? This pertinent issue is discussed in the final chapter.

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Chapter 3

BOTANICAL ASSESSMENT OF THE KALOMO STUDY AREA, ZAMBIA, AUGUST 1994.

J. R. TIMBERLAKE

3.1 INTRODUCTION

The study area is situated on Stepping Stones Farm, near Kalomo. The farm is characterised by broad interfluves with open miombo woodland (woodland dominated by *Brachystegia* and/or *Julbernardia* and *Isoberlinia* species with a well developed grass layer) interspersed with wide shallow grassy dambos (seasonally waterlogged broad drainage lines). Many of the interfluves have been cultivated in the past, but the dambos have been principally utilized by cattle and large mammals.

The dambos are essentially treeless, while those trees and shrubs at their margins are often stunted and of different species from the woodland proper. A characteristic feature of the landscape are the large termite mounds scattered through the woodland (density approximately one mound/Ha). The majority of termitaria are much more densely wooded (mainly shrubs and small trees and only few large trees) than the surrounding area. The species found on them are generally different from those found in the miombo woodland.

3.2 METHODOLOGY

After an initial viewing of air photos of the area and a walked reconnaissance, the boundaries of a six hectare plot (200 x 300m) was established on one of the wooded interfluves that did not appear to have been excessively disturbed. Within this 6 Ha plot, a one Ha (100 x 100 m) area was sub-divided into 25 quadrats (each 20 x 20 m).

Within each quadrat all woody stems over 3 cm diameter at breast height were marked with inscribed metal tags, and their diameters, heights and species recorded. The position of every stem within each quadrat was recorded using tapes. This methodology follows the SI/MAB standards (see Dallmeier, 1992) which describes the technique in precise detail. To aid future data capture, the four corners of the Kalomo plot have been permanently marked with hollow metal stakes (750x25mm galvanised steel tube) embedded in a matrix of reinforced concrete (buried 500 mm deep and flush with the ground surface).

Although termite mounds are a very important landscape feature of miombo woodland (occupying an important role in ecological processes, Malaise, 1978), only one entire termite mound was included in the 1Ha plot, so the vegetation on six additional termitaria in the vicinity was also recorded in detail. This provided a more representative characterisation of the vegetation on termite mounds. Stems were differentiated between those growing on termitaria, or not. All stems on the six termitaria were measured and tagged within the six Ha plot.

All data were entered into a spreadsheet (Quattro Pro) to facilitate analysis of relative species composition, size class distribution and biomass contribution. A comprehensive listing of all plant species within the intensive study area was complied. This includes the six Ha plot (including the one Ha plot) its immediate vicinity, the nearby dambos and termite mounds was also made. This list (which is only provisional as it was carried out in mid-dry season after a severe frost, thus many plants were dead or dormant) is given as an appendix.

Persons involved in the botanical studies were: Jonathan Timberlake (vegetation, ecology); Bob Drummond (floristics); Alan Micho (vegetation recording, Herbarium Technicial Officer); Antony Mapaura (vegetation recording, Herbarium technical Officer); Mike Bingham (plant identification) and Woody Cotterill (surveying and plot establishment). Various members of Falcon College staff and students also provided valuable assistance.

3.3 RESULTS

1 820 stems (over 3 cm dbh) were marked and identified. These occupy six termitaria within the 6 Ha plot, within which the 1 Ha plot was completely mapped and marked. It is planned to fully survey and completely map the 6 Ha plot, and expand the overall permanent vegetation plot to encompass 10 Ha (within the 50 Ha ISA). Resource and time constraints prevented achieving these objectives in Phase I.

2 The total number of woody species over 3 cm dbh within the one hectare plot was 37. This is not particularly high for miombo woodland, but is by no means low.

3 Stocking rate was 363 stems per hectare, which is rather low for woodland. Total volume was approximately 25.7 m^3 per hectare, again rather low.

4 Only 5 species had more than 20 woody stems present in the plot. Almost half of the individuals were of three species: *Brachystegia longifolia*, *Brachystegia spiciformis* and *Julbernardia globiflora*, all typical of miombo woodland. The dominant species was *B. longifolia* with 122 stems.

5 Over 80% of the total woody biomass was contributed by these three miombo species.

6 Brachystegia longifolia had many stems in the sapling size class, possibly indicating a good regeneration status. *B. spiciformis* and *J. globiflora* showed very few individuals in the smaller or sapling size classes, possibly indicating episodic regeneration or a diminution of their frequency due to an agent such as fire, grazing or poor soil drainage. However, this is speculative.

7 Total number of woody species on the termite mounds was 41, of which 36 could be said to be typical. Considering the limited extent of the mounds compared to the one hectare plot, this represents a much higher biodiversity.

8 The number of woody stems on the seven termite mounds was 452, a mean of 64.6 stems per mound, much denser than the surrounding woodland.

9 The major species on the termite mounds, either in terms of number of individuals or contribution to basal area, were: *Commiphora mollis*, *Albizia amara*, *Lannea discolor* and *Ziziphus mucronata*.

10 Total number of plant species recorded in the general area was 304, belonging to 67 families. This is probably less than three-quarters of the total number owing to the inappropriate time of year for such recording.

3.4 RECOMMENDATIONS

A Air photos are an important aid in identifying suitable study sites, and in ensuring that the permanent plot is correctly placed (i.e. not transgressing any environmental boundary).

B There will be a need to carry out supplementary recording if the environment is very heterogeneous or if it contains specific features, such as termite mounds or rocky hillocks, with distinctly different plant communities. Such sumplementary surveys will account for beta-diversity.

C For recording grassland composition or herbaceous cover, sub-plots within a larger plot will be required. It is not practical to record small plants over a large area.

D Transects across vegetation boundaries, e.g. from woodland into the dambo, although not tried out on the Zambia trip, may provide useful additional information on plant communities, and also assist in monitoring changes in their distribution.

E The procedure for listing plant species composition in an area is best done by recording by habitat type. Such work should be done at he appropriate time of year, i.e. in the mid-rainy season.

3.5 CHECKLIST OF PLANTS RECORDED ON INTENSIVE STUDY AREA - WILDLIVES RANCH, KALOMO, ZAMBIA (August 1994)

R. B. DRUMMOND and M. BINGHAM

The list that follows is a complete inventory of all the vascular plants on Wildlives Game Ranch that could be recognised in the week from July 29th to August 5th 1994. The recent frosts and the fact that it was th height of the dry season made it the worst possible time of the year to conduct a botanical survey. Nevertheless, over 300 species of vascular plants were recorded. It was only possible to collect very few voucher specimens of adequate quality.

Notes on BFA Policy on voucher specimens

Voucher specimens can be divided into two categories:

a. Those that are good fertile specimens, or if sterile, illustrate some interesting character(s) that contributes to the knowledge of the species.

b. poor or sterile specimens that do not add to the knowledge of the species or are not readily identifiable.

The herbaria interested in good specimens are K, LISC, MO, PRE and SRGH, and the national herbarium of the country in which the plant was collected (i.e. GAB, LMU or LMA, MAL and the National Herbarium of Zambia when it is decided where this will be). In the future perhaps Namibia, Angola, Zaire, Tanzania and Kenya may also be interested. Windhoek and Nairobi may already be in a position to deal with specimens. The BFA may consider whether they would also wish to keep a specimen when they have a suitable repository (ideally developed under the auspices of the Natural History Museum in Bulawayo). This means that seven sets or more of specimens should be collected if national herbaria begin to look across their borders and have storage facilities.

Poor and sterile specimens are not usually acceptable for retention in major herbaria. A fairly high level of expertise is required to determine specimens of doubtful affinities. Poor specimens should be discarded, or perhaps retained by BFA if required.

The families are divided into Dicotyledons and Monocotyledons, and then arranged alphabetically within these two categories. Genera are arranged alphabetically under families; and species are arranged alphabetically under their respective genera.

The first column, after the scientific name, gives the Tonga names. These were supplied to Mike Bingham by Mr Amon Mudende, a Game Ranger from Mapanza. The majority of species for which vernacular names are available are wild fruit trees or plants of economic significance.

The second column gives an indication of habitat:

a	aquatic plant
c	cultivated plant
D	dambo, dambo edge, river and dam edge
M	miombo woodland with *Brachystegia longifolia*, *B. spiciformis* and *Julbernardia globiflora* dominant
T	termitaria
w	weeds of disturbed area in woodland, roadsides or arable land

The third column indicates habit or life form:

a	annual herb
c	climber
e	epiphyte
p -	perennial herb
s -	shrub
sf	suffrutex, shrublet
t	tree

Tonga name

Habitat

habit

DICOTYLEDONS

ACANTHACEAE acanthus and barleria family			
Dicliptera sp.		M	a
Dyschoriste sp.		M	ps
Hypoestes forskalei *(Vahl) Roem. & Schult.*		M	p
Justicia elegantula *S.Moore*		D	p
Lepidagathis dicomoides *Hutch.*		M	p
Lepidagathis persimilis *S.Moore*		M	p
Thunbergia kirkiana *T. Anders.*		M	p
AMARANTHACEAE pigweed family			
Achyranthes aspera *L.*			
Achyranthes aspera var. sicula *L.*		Tw	a
Aerva leucura *Moq.*		M	p
Amaranthus lividus *L.*		w	a
Celosia trigyna *L.*		Mw	a
Centemopsis gracilenta *(Hiern) Schinz*		M	a
Pupalia micrantha *Hauman*		MT	a
ANACARDIACEAE mango, cashew and sumach family			
Lannea discolor *(Sond.) Engl.*	musamba	MT	t
Lannea edulis *(Sond.) Engl.*	mumba	M	s
Lannea schweinfurthii *(Engl.) Engl.*		T	t
Ozoroa insignis *Delile*			
Ozoroa insignis subsp. reticulata *(Baker f.) Gillett*	mulilila	M	ts
Rhus kirkii *Oliv.*		M	st
Rhus lucens *Hutch.*		M	st
Rhus tenuinervis *Engl.*	mwingantoto	MT	ts
ANNONACEAE custard apple family			
Annona stenophylla *Engl. & Diels*			
Annona stenophylla subsp. nana *(Exell) N.Robson*	mulolo	D	s
Friesodielsia obovata *(Benth.) Verdc*	muchinga	T	st
Hexalobus monopetalus *(A.Rich.) Engl. & Diels*			
Hexalobus monopetalus var. obovatus *Brenan*	futwe		
APIACEAE carrot and parsnip family			
Diplolophium zambesianun *Hiern*		M	p
Steganotaenia araliacea *Hochst.*	mutobolo	T	st

APOCYNACEAE periwinkle family			
Carissa edulis *(Forssk.) Vahl*	mutenge	T	s
Diplorhynchus condylocarpon *(Muell.Arg.) Pichon*	muntowa	D	t
ARISTOLOCHIACEAE dutchman's pipe family			
Aristolochia hockii *De Wild.*		M	p
ASCLEPIADACEAE milkweed family			
Ceropegia sp.		T	p
Cryptolepis oblongifolia *(Meisn.) Schltr.*		M	s
ASTERACEAE blackjack and everlasting family			
Aspilia natalensis *(Sond.) Wild*		D	p
Aspilia pluriseta *Schweinf.*		M	p
Bidens pilosa *L.*		w	a
Bidens schimperi *Sch.Bip.*		M	a
Blumea crispata *(Vahl) Merxm.*	mutandomasenya	M	a
Bothriocline laxa *N.E.Br.*		w	a
Conyza albida *Spreng.*		w	a
Conyza stricta *Willd.*		w	a
Cotula anthemoides *L.*		D	a
Denekia capensis *Thunb.*		D	a
Dicoma anomala *Sond.*		M	p
Dicoma sessiliflora *Harv.*			
Dicoma sessiliflora subsp. kirkii *(Harv.) Wild*		M	p
Elephantopus scaber *L.*		M	p
Epaltes gariepina *(DC.) Steetz*		D	a
Gnaphalium polycaulon *Pers.*		D	a
Gutenbergia gossweileri *S.Moore*		D	a
Helichrysum argyrosphaerum *DC.*		w	a
Helichrysum candolleanum *Buek*		M	ap
Helichrysum kraussii *Sch.Bip.*		M	ps
Hirpicium gracile *(O.Hoffm.) Roessler*		w	a
Inula glomerata *Oliv. & Hiern*		M	p
Melanthera albinervia *O.Hoffm.*		T	a
Pleiotaxis eximia *O.Hoffm.*		M	p
Pseudognaphalium luteo-album *(L.) Hilliard & Burtt*		D	a
Pseudognaphalium oligandrum *(DC.) Hilliard & Burtt*		D	a
Schistostephium artemisiifolium *Baker*		M	p

Senecio venosus *Harv.*		M	p
Tagetes minuta *L.*		w	a
Tithonia rotundifolia *(Mill.) Blake*		w	a
Vernonia adoensis *Walp.*		D	p
Vernonia amygdalina *Delile*		M	st
Vernonia aurantiaca *(O.Hoffm.) N.E.Br.*		T	s
Vernonia glaberrima *O.Hoffm.*		M	s
Vernonia perrottetii *Walp.*		w	a
Vernonia petersii *Oliv.*		M	a
Vernonia poskeana *Vatke & Hildebr.*		w	a
BIGNONIACEAE jacaranda family			
Markhamia obtusifolia *(Baker) Sprague*		D	t
BORAGINACEAE borage family			
Cordia goetzei *Gürke*		T	t
Ehretia amoena *Klotzsch*		T	st
Trichodesma ambacense *Welw.*			
Trichodesma ambacense subsp. hockii *(De Wild) Brummitt*	mulebelebe	D	p
BURSERACEAE frankincense and commiphora family			
Commiphora africana *(A.Rich.) Engl.*		T	t
Commiphora mollis *(Oliv.) Engl.*		T	t
CAPPARACEAE caper family			
Boscia angustifolia *A.Rich.*			
Boscia angustifolia var. corymbosa *(Gilg.) DeWolf*		T	t
Boscia salicifolia *Oliv.*		T	t
Capparis tomentosa *Lam.*	chiwehehe	T	cs
Cleome hirta *(Klotzsch) Oliv.*		w	s
Maerua juncea *Pax*			
Maerua juncea subsp. juncea		T	s
CARYOPHYLLACEAE carnation family			
Polycarpaea corymbosa *(L.) Lam.*		M	a
CELASTRACEAE spindle and maytenus family			
Maytenus heterophylla *(Eckl. & Zeyh.) N.Robson*		M	st
Maytenus senegalensis *(Lam.) Exell*		M	st
Mystroxylon aethiopicum *(Thunb.) Loes.*		T	ts
Pleurostylia africana *Loes.*		M	st

CHRYSOBALANACEAE mobola plum family			
Parinari capensis *Harv.*	mubula tachonto	D	sf
Parinari curatellifolia *Benth.*	mubula	D	t
COMBRETACEAE (combretum family			
Combretum adenogonium *A.Rich.*	mulama	D	t
Combretum apiculatum *Sond.*		M	ts
Combretum collinum *Fresen.*		M	t
Combretum hereroense *Schinz*		M	st
Combretum molle *R.Br.*	mukangala	M	t
Combretum platypetalum *C.Lawson*		D	sf
Combretum zeyheri *Sond.*		M	t
Terminalia brachystemma *Welw.*	mususu	M	t
Terminalia sericea *DC.*	mususu	M	ts
Terminalia stenostachya *Engl. & Diels*	mususu	M	ts
CONNARACEAE zebra-wood family			
Rourea orientalis *Baill.*		T	s
CONVOLVULACEAE sweet potato and morning glory family			
Evolvulus alsinoides *(L.) L.*		M	a
CRASSULACEAE crassula and stonecrop family			
Kalanchoe brachyloba *Britten*		T	a
Kalanchoe lanceolata *(Forssk.) Pers.*		T	a
DIPTEROCARPACEAEdipterocarp family			
Monotes engleri *Gilg*		M	t
Monotes glaber *Sprague*		MT	t
Monotes katangensis *(De Wild.) De Wild.*		M	t
EBENACEAE ebony family			
Diospyros lycioides *Desf.*		T	st
Diospyros mespiliformis *A.DC.*	muchenje	T	t
Euclea divinorum *Hiern*		T	st
EUPHORBIACEAE spurge or euphorbia family			
Acalypha villicaulis *A.Rich.*		M	p
Bridelia cathartica *G.Bertol.*		M	st
Erythrococca menyharthii *(Pax) Prain*		T	st
Euphorbia ingens *Boiss.*	muzundulu	T	t
Flueggea virosa *(Willd.) Voigt*	mulizyakalumbo	MT	st
Phyllanthus engleri *Pax*		T	st

Phyllanthus sp.		M	a
Pseudolachnostylis maprouneifolia *Pax*	mugunka	M	t
Uapaca kirkiana *Muell.Arg.*		M	t
Uapaca nitida *Muell.Arg.*		M	t
FABACEAE pea, bean or legume family			
subfamily CAESALPINIOIDEAE musasa and mopane subfamily			
Bauhinia petersiana *Bolle* subsp. petersiana		M	st
Brachystegia cf. B. x longifolia *Benth.*)	mubombo	M	t
Brachystegia spiciformis *Benth.*	musiwe	M	t
Burkea africana *Hook.*	siachibula	M	t
Cassia abbreviata *Oliv.*	mululwe	M	t
Colophospermum mopane *(Benth.) J.Léonard*	mupane	D	t
Julbernardia globiflora *(Benth.) Troupin*	muumba	M	t
Peltophorum africanum *Sond.*	mwandwamvura	M	t
Piliostigma thonningii *(Schumach.) Milne-Redh.*	musekese	M	t
Senna singeana *(Delile) Lock*	mulolwe mushonte	M	t
Swartzia madagascariensis *Desv.*	muyongolo	M	t
Tylosema fassoglense *(Schweinf.) Torre & Hillc.*	madamina	M	p
subfamily FABOIDEAE cowpea and lucerne family			
Crotalaria alexandri *Baker f.*		M	a
Crotalaria pallidicaulis *Harms*		M	s
Dalbergia arbutifolia *Baker*		T	l
Dalbergia melanoxylon *Guill. & Perr.*		M	st
Desmodium barbatum *(L.) Benth.* var. dimorphum *(Baker) B.G. Schub.*		M	ps
Eriosema englerianum *Harms*		D	ps
Erythrina abyssinica *DC.*		M	t
Indigofera antunesiana *Harms*		M	p
Indigofera arrecta *A.Rich.*		M	p
Indigofera setiflora *Baker*		M	a
Lonchocarpus capassa *Rolfe*		M	t
Neorautanenia mitis *(A.Rich.) Verdc.*		M	p
Pericopsis angolensis *(Baker) Meeuwen*	mubanga	M	t
Pterocarpus angolensis *DC.*	mulombe	M	t
Pterocarpus rotundifolius *(Sond.) Druce* subsp. polyanthus *(Harms) Mendonça & E.C.Sousa*	mulombe	M	t

Rhynchosia totta *DC.* var. venulosa *(Hiern) Verdc.*		M	p
Sphenostylis marginata *E.Mey.* subsp. erecta *(Baker f.) Verdc.*	mukululu	M	p
Sphenostylis ephrosia radicans *Baker*		M	p
Tephrosia sp.		M	p
Vigna nuda *N.E.Br.*		M	p
Vigna pygmaea *R.E.Fr.*		M	p
Zornia glochidiata *DC.*		M	a
subfamily MIMOSOIDEAE acacia and wattle family			
Acacia gerrardii *Benth.*		D	t
Acacia nilotica *(L.) Delile*			
Acacia nilotica subsp. kraussiana *(Benth.) Brenan*		T	t
Acacia sieberiana *DC.*	mutubetube	M	t
Albizia amara *(Roxb.) Boiv.*			
Albizia amara subsp. sericocephala *(Benth.) Brenan*	mukangala	T	t
Albizia antunesiana *Harms*	siachibula	M	t
Albizia harveyi *Fourn.*		D	t
Dichrostachys cinerea *(L.) Wight & Arn.* sensu lato	mweye	M	st
FLACOURTIACEAE flacourtia family			
Flacourtia indica *(Burm.f.) Merr.*	mutumbulwa	M	t
Oncoba spinosa *Forssk.*	mukumbuzu	T	st
GENTIANACEAE gentian family			
Sebaea pentandra *E.Mey.*var. burchellii *(Gilg) Marais*		D	a
LAMIACEAE mint family			
Englerastrum sp.		T	a
Leucas martinicensis *R.Br.*		w	a
Ocimum sp.		w	ps
Plectranthus esculentus *N.E.Br.*			
Tinnea sp.		M	s
Tinnea sp.		M	ps
LOBELIACEAElobelia family			
Lobelia erinus *L.*		R	a
LOGANIACEAE strychnos family			
Strychnos cocculoides *Baker*	muwi	M	ts
Strychnos potatorum *L.f.*		T	ts
Strychnos pungens *Solered.*		D	t
Strychnos spinosa *Lam.*	muntamba	M	ts

LORANTHACEAE loranthus or showy-mistletoe family			
Agelanthus sp.		M	s
Plicosepalus kalachariensis *(Schinz) Danser*	churukira	T	s
LYTHRACEAE loosestrife family			
Nesaea heptamera *Hiern*		D	p
MALVACEAE hibiscus family			
Azanza garckeana *(F.Hoffm.) Exell & Hillc.*	mutobo, muneko	M	ts
Hibiscus meeusei *Exell*		w	a
Hibiscus ovalifolius *(Forssk.) Vahl*		T	sp
Hibiscus rhodanthus *Gürke*		D	p
Sida alba *L.*		w	a
Wissadula rostrata *(Schumach.) Hook.f.*		M	s
MOLLUGINACEAE mollugo family			
Glinus lotoides *L.*		D	a
MORACEAE mulberry and fig family			
Ficus thonningii *Blume*		T	t
OCHNACEAE ochna family			
Ochna puberula *N.Robson*		T	st
Ochna pulchra *Hook.*		M	t
Ochna schweinfurthiana *F.Hoffm.*	futwe	M	ts
OLACACEAE olax family			
Ximenia americana *L.*	mung'omba	T	ts
Ximenia caffra *Sond.*			
var. caffra	mung'omba	M	ts
OXALIDACEAE oxalis family			
Biophytum petersianum *Klotzsch*		M	a
PEDALIACEAE sesame family			
Ceratotheca triloba *(Bernh.) Hook.f.*	derere	w	ap
Sesamum indicum *L.*		c	a
Sesamum sp.	wenfo		
PLUMBAGINACEAE plumbago family			
Plumbago zeylanica *L.*		T	s
POLYGALACEAE milkwort family			
Polygala albida *Schinz*		M	a
Securidaca longipedunculata *Fresen.*		M	ts

POLYGONACEAE buckwheat, dock and rhubarb family				
Persicaria senegalensis *(Meisn.) Sojak*		D	a	
Polygonum plebeium *R.Br.*		D	a	
Polygonum setosulum *A.Rich.*		D	a	
PROTEACEAE protea family				
Faurea saligna *Harv.*		M	t	
Faurea speciosa *(Welw.) Welw.*	munchenya	M	t	
Protea angolensis *Welw.* var. angolensis	munchenga	D	s	
Protea gaguedi *J.F.Gmel.*		M	ts	
RANUNCULACEAE buttercup family				
Clematis welwitschii *Kuntze*		M	p	
RHAMNACEAE buckthorn and musawu family				
Berchemia discolor *(Klotzsch) Hemsl.*		D	t	
Ziziphus mucronata *Willd.*	mujejete	MT	t	
RUBIACEAE madder and coffee family				
Agathisanthemum bojeri *Klotzsch*		M	ps	
Catunaregum spinosa *(Thunb.) Tirveng.* subsp. taylori *(S.Moore) Verdc.*			M	s
Crossopteryx febrifuga *(G.Don) Benth.*	mureyambezo	D	ts	
Fadogia ancylantha *Hiern*	mensoampongo	M	s	
Feretia aeruginescens *Stapf*		T	ts	
Gardenia ternifolia *Schumach. & Thonn.*		M	ts	
Gardenia volkensii *K.Schum.*				
subsp. spatulifolia *(Stapf & Hutch.) Verdc.*	chijoromatanga	T	ts	
Leptactina benguellensis *(Benth. & Hook.f.) R.D.Good*		M	s	
Oldenlandia herbacea *(L.) Roxb.*		D	a	
Pavetta gardeniifolia *A.Rich.*		MT	st	
Pavetta schumanniana *K.Schum.*		M	st	
Pentanisia schweinfurthii *Hiern*		M	p	
Psydrax livida *(Hiern) Bridson*		MT	st	
Rytigynia umbellulata *(Hiern) Robyns*		T	s	
Spermacoce senensis *(Klotzsch) Hiern*		w	a	
Spermacoce sp.		M	a	
Tapiphyllum discolor *(De Wild.) Robyns*		M	s	
Tarenna neurophylla *(S.Moore) Bremek.*		T	t	
Tricalysia cacondensis *Hiern*		M	s	
Tricalysia ruandensis *Bremek.*		T	ts	

Vangueriopsis lanciflora *(Hiern) Robyns*	musumo	M	ts
RUTACEAE citrus or lemon family			
Teclea rogersii *Mendonça*		T	s
SAPINDACEAE litchi and soapberry family			
Allophylus africana *Beauv.*		T	ts
Pappea capensis *Eckl. & Zeyh.*		T	t
Zanha africana *(Radlk.) Exell*		M	t
SCROPHULARIACEAE foxglove and witchweed family			
Buchnera sp.		D	p
SOLANACEAE potato and tomato family			
Datura stramonium *L.*		w	a
Solanum delagoense *Dunal*		w	p
Solanum incanum *L.*	mutuntula	w	sp
STERCULIACEAE cocoa and kola family			
Dombeya rotundifolia *(Hochst.) Planch.*		M	t
Hermannia glandulifera *K.Schum.*		M	ps
Sterculia quinqueloba *(Garcke) K.Schum.*	mubungubungu	M	t
Waltheria indica *L.*		M	p
TILIACEAE jute and grewia family			
Grewia bicolor *Juss.*		M	st
Grewia decemovulata *Merxm.*		M	s
Grewia flavescens *Juss.* var. flavescens		M	st
Grewia monticola *Sond.*	mwingiri	T	st
Triumfetta dekindtiana *Engl.*		M	sp
VERBENACEAE verbena and lantana family			
Clerodendrum capitatum *(Willd.) Schumach. & Thonn.*		T	cs
Clerodendrum glabrum *E.Mey.*		M	ts
Lippia javanica *(Burm.f.) Spreng.*		Mw	s
Vitex mombassae *Vatke*		M	st
VITACEAE grape family			
Cyphostemma junceum *(Webb) Wild & R.B.Drumm.*		M	p
MONOCOTYLEDONS			
AMARYLLIDACEAE daffodil and vlei lily family			
Boophone disticha *(L.f.) Herb.*		M	p

ANTHERICACEAE chlorophytum family			
Chlorophytum blepharophyllum *Baker*		M	p
ARACEAE aroid family			
Stylochiton puberulus *N.E.Br.*		T	p
ASPARAGACEAE asparagus family			
Asparagus africanus *Lam.*	kajakansya	M	p
COMMELINACEAE ommelina or spiderwort family			
Cyanotis sp.		M	p
CYPERACEAE sedge family			
Bulbostylis burchellii *(Ficalho & Hiern) C.B.Clarke*		M	p
Bulbostylis hispidula *(Vahl) R.W.Haines*		M	a
Bulbostylis macra *(Ridl.) C.B.Clarke*		M	p
Cyperus amabilis *Vahl*		D	a
Cyperus angolensis *Boeck.*		M	p
Cyperus digitatus *Roxb.* subsp. auricomus *(Spreng.) Kük.*		R	p
Cyperus obtusiflorus *Vahl*		M	p
Kyllinga alba *Nees*		M	p
Schoenoplectus corymbosus *(Roem. & Schult.) J.Raynal*		a	p
Schoenoplectus sp.		Da	a
DIOSCORACEAE yam family			
Dioscorea quartiniana *A.Rich.*		M	cp
DRACAENACEAE mother-in-law's tongue family			
Sansevieria pearsonii *N.E.Br.*	mugusa	T	p
HYACINTHACEAE hyacinth and scilla family			
Ornithogalum tenuifolium *Delaroche*		M	p
Urginea altissima *(L.f.) Baker*		M	p
ORCHIDACEAEorchid family			
Ansellia africana *Lindl.*		M	ep
Eulophia sp.		M	p
Habenaria sp.		M	p
POACEAE grass family			
Aristida canescens *Henr.* subsp. canescens		M	p
Aristida junciformis *Trin. & Rupr.* subsp. junciformis		D	p
Bewsia biflora *(Hack.) Goossens*		M	p
Cynodon dactylon *(L.) Pers.*	zinza	DTw	p
Dactyloctenium giganteum *B.S.Fisher & Schweick*		w	a

Digitaria milanjiana *(Rendle) Stapf*		M	p
Diheteropogon amplectens *(Nees) Clayton*		M	p
Eleusine coracana *(L.) Gaertn.*			
subsp. africanus *(Kenn.-O'Byrne) Hilu & De Wet*	macuta	w	a
Enteropogon macrostachys *(A.Rich.) Benth.*		M	p
Eragrostis namaquensis *Schrad.*		Dw	a
Eragrostis patens *Oliv.*		w	a
Eragrostis racemosa *(Thunb.) Steud.*		M	p
Eragrostis viscosa *(Retz.) Trin.*		w	a
Heteropogon contortus *(L.) Roem. & Schult.*		Mw	p
Hyparrhenia filipendula *(Hochst.) Stapf*	buhyu	M	p
Hyparrhenia sp.	buhyu	M	p
Loudetia simplex *(Nees) C.E.Hubb.*		DM	p
Melinis sp.		M	p
Microchloa kunthii *Desv.*		D	p
Miscanthus junceus *(Stapf) Pilg.*		D	p
Panicum maximum *Jacq.*		D	pa
Perotis patens *Gand.*		Mw	a
Perotis vaginata *Hack.*		D	a
Phragmites mauritianus *Kunth*		D	p
Pogonarthria sqarrosa *(Roem. & Schult.) Pilg.*		M	p
Schizachyrium jeffreysii *(Hack.) Stapf*		M	p
Setaria pumila *(Poir.) Roem. & Schult.*		Mw	a
Setaria sphacelata *(Schumach.) M.B.Moss*		D	p
Sporobolus pyramidalis *Beauv.*		MDw	p
Sporobolus welwitschii *Rendle*		D	p
Stereochlaena cameronii *(Stapf) Pilg.*		M	p
Trachypogon spicatus *(L.f.) Kuntze*		M	p
Tristachya nodiglumis *K.Schum.*		D	p
Tristachya superba *(De Not.) Schweinf. & Aschers.*	masanga	M	p
Zea mays *(L.)*	mapopwe	c	a
TYPHACEAE bulrush family			
Typha sp.		D	p

Chapter 4

ASSESSMENT OF SOIL MACROFAUNA IN THE KALOMO STUDY AREA

J.M. DANGERFIELD

4.1 INTRODUCTION

Soil animals are an important component in the assessment and monitoring of biodiversity in both natural and managed ecosystems for two reasons. Firstly, species composition and relative abundance changes rapidly with disturbance either as a response to changes in edaphic conditions or resource availability. Secondly, soil animals are key regulators of decomposition processes both directly through comminution and their effects on soil microbe populations and indirectly through their influence on soil structure and translocation of organic resources (see review by Anderson 1988). In essence, soil fauna play a key role in making nutrients available to plants.

This report outlines the methodology development, field testing and revised recommendations for the sampling of soil animals in the context of the overall assessment of biodiversity in miombo woodland as developed by the BFA. Training opportunities that occurred in the initial exercise and those that can be incorporated into future projects are also discussed.

Some general comments on methodology development are included in Appendix 4.1 and data on herbaceous layer biomass and litter mass are given in Appendix 4.2.

4.2 METHODOLOGY DEVELOPMENT

The nature of the substrate, aggregated distribution patterns, the extreme range in body size and the wide variety of life forms present among the soil fauna make estimates of total species richness difficult to obtain. Similarly, absolute estimates of abundance often require at least taxa and often species specific methods (see Southwood 1978, chapter 5).

The taxonomy of soil animals is poorly known, especially for important groups such as the beetle larvae, certain termites and mesofauna (less than 2mm body length). This creates an additional problem for the estimation of species richness.

Given these difficulties it is necessary to be specific about the objectives of the sampling programme before a methodology is selected. The following objective was chosen:

to provide a standardised method that is comparable between sites and will estimate the species richness and relative abundance of soil macrofauna for both inventory and monitoring.

The main method chosen to achieve this was mechanical hand-sieving of a known volume of soil isolated through the use of a steel monolith 25cm x 25cm x 30cm. This mechanical approach has been recommended by the Tropical Soil Biology & Fertility Programme as a component of site characterisation (Anderson & Ingram 1993). It does not require the technology and access to mains power used in most behavioural methods (e.g.

Hassall *et al.* 1988) and results are obtained rapidly in the field. It is labour intensive as many samples are needed but cost effective in situations where field labour is inexpensive.

Soil macrofauna, i.e. animals living in the soil with body length greater than 2mm, were selected as they are easily seen and removed from sandy substrates at an efficiency of up to 90% (Dangerfield 1990). Soil mesofauna and microfauna are not easily recorded quantitatively but an estimate of the presence of mesofauna can frequently be obtained. The method is not ideal for any particular soil fauna group but provides the best overall estimate of the composition and structure of the soil fauna assemblage. A further strength is that the method is reproducible between different habitat types and results are not significantly affected by current weather conditions, although seasonal effects are significant (J.M. Dangerfield, unpublished data).

It is advisable to include more than one sampling method in the estimation of any ecological parameter hence in the study of soil animals two further methods were tested. Firstly the use of medium scale pitfall traps (17cm diameter plastic bowls) to catch nocturnal and diurnally active invertebrates and secondly toilet roll baits to attract termites.

4.3 FIELD TESTING

Sampling Procedure

On the permanent plot the approximate centre of each 20x20m sub-plot was located and a monolith placed on the undisturbed vegetation. The monolith was hammered 5-10cm into the soil to isolate the litter fauna and litter around the outside of the monolith was cleared. Standing vegetation within the box was clipped at soil level and placed, along with leaf litter, in plastic trays. This material was hand sorted and any animals collected and placed in a vial containing approximately 3ml of 70% alcohol. The vegetation and litter was placed in a plastic bag and returned to the field laboratory where it was sorted into live, standing dead and litter fractions and weighed.

The soil within the monolith was loosened with a spade or panga, placed on a plastic tray and sifted carefully for soil animals. The soil was spread evenly on the tray and observed carefully. Most soil fauna are readily conspicuous against the soil being either white (e.g. some beetle larvae) or mobile. The soil on this particular site had dried to a hard pan and was difficult to excavate hence the depth of sample was taken to 20cm.

On the permanent plot a total of 25 monoliths were sorted, one in each of the 20x20m sub-plots. A further 5 samples at 20m intervals were taken in each of the following habitats representative of the area:

1. an arable field recently cleared for cultivation,
2. an arable field under tobacco, rotated with wheat and sorghum, since 1987,
3. a stand of miombo woodland on sandy soil and
4. a stand of miombo woodland on similar soil to the permanent plot.

Pitfall traps were set at 3m intervals in a grid pattern adjacent to the permanent plot. Each trap was set flush with the soil surface having first cleared the vegetation and litter from a circular area of 60-70cm diameter. Care was taken to ensure that the trap did not sit above the soil surface so that the natural tendency for invertebrates to move swiftly through open areas would not be interrupted. Animals caught in the traps were collected every morning (0800) and evening (1800) and preserved in 70% alcohol.

Results

A total of 45 soil monoliths were sorted; 25 of which were located in the permanent plot. Geometric mean abundance of soil fauna was between 80 and 123m^{-2} in the miombo woodland habitats, less than 50m^{-2} in the recently cleared arable field and only 22m^{-2} in the ploughed field (Chapter 8, Appendix 4.1). Differences in mean abundance between the habitats was not significant (ANOVA on logN+1 transformed data, $F_{4,44}$=1.28, P=0.290).

These abundance estimates for miombo woodland are around 47% less than dry season estimates for closed canopy woodland sites and 30% less than open canopy sites in Botswana (J.M. Dangerfield, unpublished data). This result is surprising given the higher rainfall in the present study area but may be due to more acid soils (pH 4.7) and a severe frost event prior to sampling.

Overall biodiversity, measured crudely as Orders per sample, was between 2.6 and 2.8 for the miombo woodland, 2.2 for the recently cleared field and 1.4 in the ploughed field where only adult beetles, beetle larvae, Hemiptera, fly larvae and an arachnid were recorded. Again there was no significant difference in mean diversity between sites ($F_{4,44}$=1.06, P=0.390). These results compare with a mean number of orders of 4.3 for wet season samples in miombo woodland near Marondera, Zimbabwe (Dangerfield 1990). Although order level diversity appears to remain high, species level diversity is likely to be lower in the soils with lower overall abundance as species richness is expected to be a function of abundance. More detailed taxonomic work is needed on the preserved specimens.

The samples from the permanent plot were randomly assigned to groups of five samples (e.g. samples from sub-plots 1-5, 6-10, etc..). ANOVA on the means from these sub-sets were also not significant although a spatial analysis of abundance (Fig. 4.1a) suggests that there are several levels of spatial scale variation in soil fauna abundance that are likely to have different effects on the overall biodiversity and functioning of miombo woodland. These results and those for spatial variation in the mean number of orders per sample (Fig. 4.1b) support observations made in Kenyan agro-ecosystems (Dangerfield 1993).

There were no significant correlations between abundance (logN+1) of soil fauna and the fresh mass of leaf litter (r=0.170, P0.1) or fresh mass standing dead herbaceous material (r=-0.055, P0.1) across the habitats (Fig. 4.2a). Similarly diversity (orders per sample) was not correlated to litter mass (r=0.153, P0.1) or standing dead material (r=0.083, P0.1; Fig. 4.2b). The opportunity to test hypotheses of how important resource inputs are to the abundance and diversity of soil fauna are considerable in these systems where animals can be readily extracted from the soil.

In deep soils that have received little moisture many soil animals burrow to considerable depths to locate equitable conditions. The normal sample depth of 20cm may have been inadequate. In five of the permanent plot samples a further 10cm was excavated (20-30cm) which resulted in collections of 5,1,0,1 and 0 additional specimens, an average 10.1% increase in abundance per sample. However, the average increase in diversity (orders per sample) of 6.6% was due entirely to the collection of two fly larvae at 23cm depth in one of the five monoliths. In the ploughed field, where the disturbance to the soil allowed samples to be taken to 30cm without difficulty, one fly larva and one termite were recorded between 20 and 30cm in five monoliths.

In hard pan soils, or where labour is limited, there is only limited benefit in adding extra depth to what would still be shallow samples. More accurate data would be gained by spending the time in further replicates, as the monolith method provides an index and not an absolute measure of soil fauna diversity. Nevertheless, validation of the technique to take into account seasonal variation in depth of soil animals would be valuable.

Various adult beetles, Thysanura, spiders, ants, Collembola, Homoptera and a solifugid were collected in the pitfall traps. Once the taxonomic anaylses is complete, these samples will provide a valuable additional index of diversity of surface active invertebrates.

Toilet roll baits were less effective. Only *Microtermes* spp. were collected, although *Macrotermes falciger, M. subhyalinus* and various *Odontotermes*spp. were expected. The depression in *Macrotermes* foraging during the winter months (G. Schuurman, pers. comm.) may account for failure of foraging parties to locate the baits.

4.4 REVISED METHODOLOGY

Recommendations:

1) Soil monoliths

One sample should be taken in the centre of each sub-plot within the permanent plot and a further five samples, at 20m intervals, in each of the main habitat types as identified by the vegetation survey. Samples sorted to a depth of 20cm except where soils are easily worked.

2) Pitfall traps

An array of 10 traps in each of the major habitat types with catches assessed on the bases of trap hours.

3) Termites

An array of 10 toilet roll baits in each of the key habitat types and an assessment of the overall distribution of surface features (mounds, vents and carton on trees within the permanent plot)

4) Millipedes

A series of collections using a 1m square quadrat to assess abundance in litter during the rainy season coupled with visual inspections of the main habitat types.

5) Methodological development

A more detailed assessment of spatial scale variation in soil fauna distribution and diversity using the monolith sampling method would provide valuable information of the effects of these animals in miombo woodland and opportunities for post-graduate level training.

4.5 TRAINING OPPORTUNITIES

All of the schoolboys and several of the technicians on the Zambia expedition used the sampling method. The rationale of the method as well as its strengths and weaknesses were explained to each group and, in particular, the need for replication was stressed.

A commentary on the role of soil macrofauna in savanna ecosystems was given to each group and the biology and functional role of the animals collected was discussed. Although familiar with the concept of plant nutrients, soil organic matter and decomposition most of the students were not aware of the importance of soil animals in regulating the rates of such processes. Indeed a realisation by the students of the overall complexity of soil systems, in addition to the taxonomic variety, was a useful product of the training exercise.

One of the benefits of the method is that it is easy to use. It is quite feasible that a technician can supervise casual labour in the collection of the samples. Technical support can, therefore, be used to its full potential in

the field. Associate expertise is only needed in the training phase, for detailed taxonomy and to collate and interpret the data.

Although the methods described have been used extensively there remains much to be discovered about their subtleties and relevance to miombo woodland ecosystems. There is considerable scope for undergraduate training and post-graduate research using these methods. For example, contiguous soil monoliths, combined with sampling at different distances, would say much about the spatial scale of soil fauna distributions and hence their effects on ecosystem processes.

4.6 BIBLIOGRAPHY

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Appendix 4.1

General Recommendations

The following represent some general thoughts on the sampling exercise

1) *Handbook of Methods*

It would be very valuable to have an in-house handbook of methods: a "cook book" that describes all the methodologies that are to be used. There should be sufficient detail that another specialist (?non-specialist) could follow exactly the procedures to obtain the field data.

2) *Relative abundance*

Not all the methods used give reasonable estimates of relative abundance. This is an important omission because relative abundance will change much faster than species richness in most cases and will provide the "rapid response" we are looking for in our monitoring exercise.

3) *Carbon Budget*

Given the data set collected on above ground vegetation, above-ground and below-ground fauna it would require relatively little effort to construct a simple carbon budget for the permanent plot, at least in terms of relative pool sizes. This would be particularly valuable when we compare sites with different management practices.

The key missing pools and those that need more data, together with simplest methods for measurement, are:

- soil organic matter (acid digests or combustion),
- roots (soil cores and hand sieving),
- herbaceous layer and litter (50x50cm quadrats, sorting, drying & weighing).

The rest can be gleaned from the data gathered as part of the diversity assessment and suitable use of the literature (e.g. biomass allometry for trees).

Fluxes between pools would require considerably more effort to estimate, for example many require repeated measures, but should certainly be attempted for the 50ha plot.

Such data would give a real handle on the resilience of the miombo system to different disturbances. This information, gathered under the premise of organism interactions and ecosystem functioning, should be one of the main products of biodiversity research.

Appendix 4.2

Herbaceous and litter layer biomass

Collections of leaf litter and standing dead herbaceous material from the monoliths (25cm x 25cm) were made and the material weighed to 0.1g on a Sartorius balance.

Although these estimates are for fresh mass, the dry condition on the vegetation at this time would suggest a moisture content for litter and plant material of less than 10%.

All data are means (1 standard deviation) in g/m^2.

Habitat	litter mass	standing dead herbaceous : mass
Permanent Plot	**209 ± 27**	**52 ± 2**
Camp miombo	**1223 ± 867**	**46 ± 67**
'sandy' miombo	**598 ± 260**	**26 ± 29**
Recently cleared arable	**98 ± 218**	**160 ± 51**
Ploughed arable	**0**	**0**

These values can be compared to 1209 g/m2 litter mass and 53 g/m^2 herbaceous mass estimated for miombo woodland at Marondera, Zimbabwe (Campbell, *et al.*, In prep)

Bibliography

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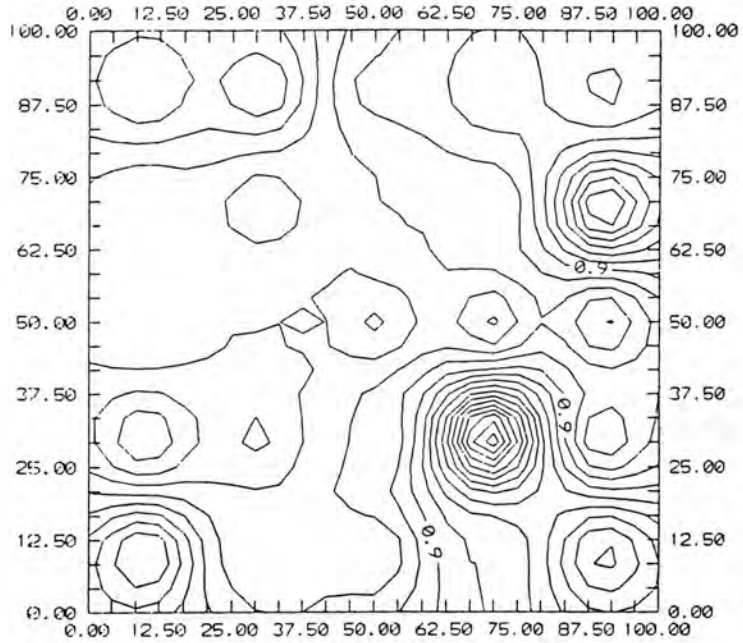
Figure 4.1 Contour maps for a) overall abundance and b) orders per sample of soil fauna based on data from 25 soil monoliths taken on the permanent plot at Wildlive Game Farm. Kalomo, Zambia.



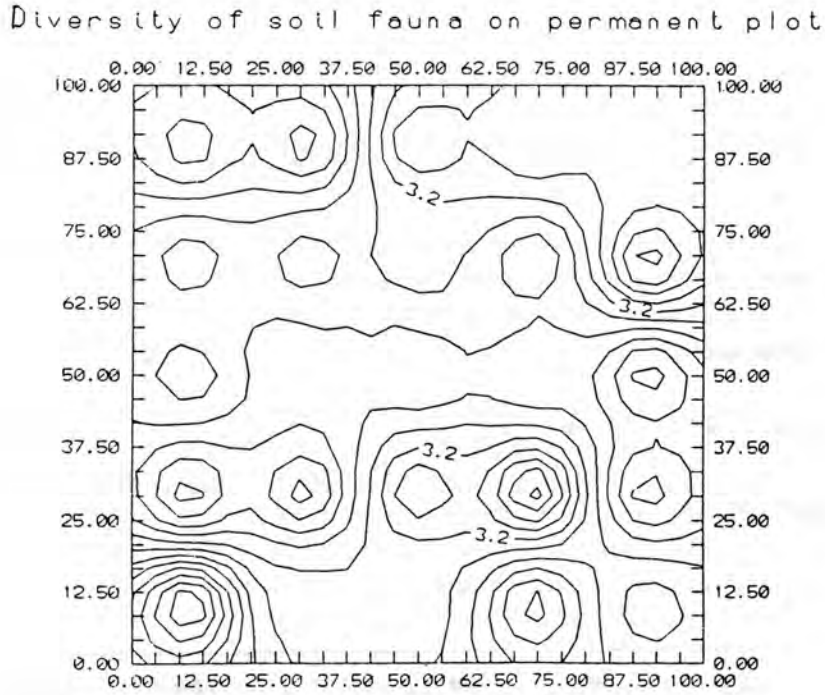
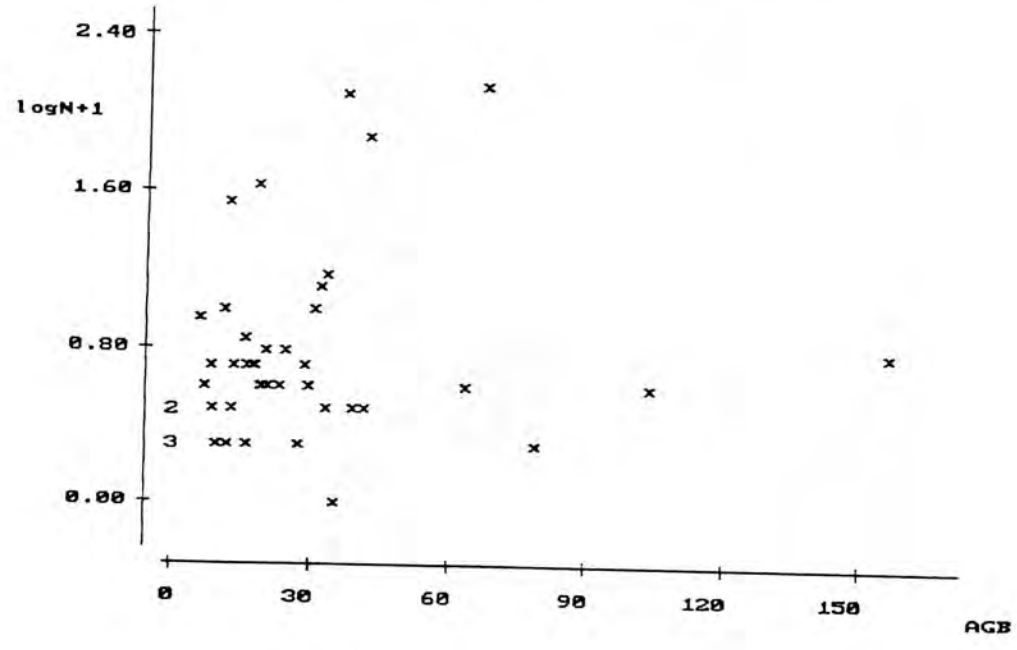
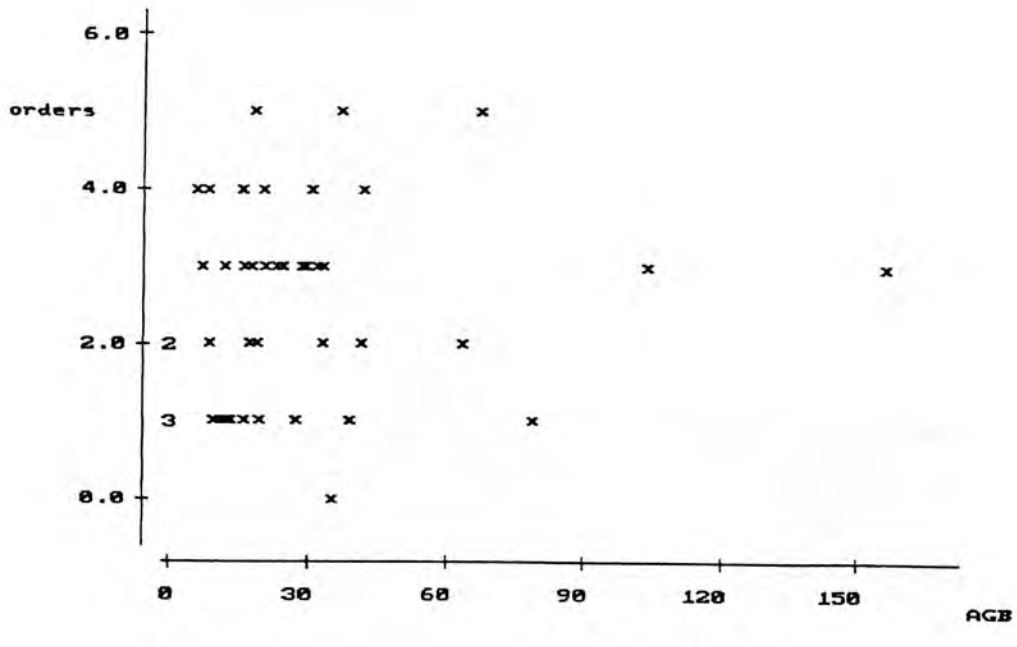


Fig. 4.2. Relationships between

a abundance and

b orders per sample of soil fauna and above ground biomass of herbaceous layer plus litter mass (AGB) from samples taken in a range of habitat types on Wildlive Game Farm, Kalomo, Zambia.





Chapter 5

INSECT FAUNA : ENTOMOLOGY

RESULTS OF THE KALOMO EXPEDITIONS

A. J. GARDINER

5.1 INTRODUCTION

A trip to the Southern Province of Zambia was undertaken to refine established techniques into an integrated methodology suitable for repeated measures of arthropod diversity in miombo savannas. The site on Wildlives Farm, Kalomo, was chosen to represent comparatively intact miombo woodland. The data from this site allow for comparisons with other datasets, especially from habitats which have been significantly modified by humans.

5.2 COLLECTING METHODS AND FOCAL TAXA

Sampling took place within a six hectare plot which formed part of the 50 Ha Intensive Study Area and overlapped with the Permanent Vegetation Plot. The positions of trapping stations are illustrated in Figure 5.1.

For any biodiversity study identification to species level is an essential requirement. Where taxonomic resources allow, certain taxa were chosen for focal indicator groups. These are listed in Table 5.1.

Isoptera and Formicidae

For these two taxa a general survey was undertaken. A search for colonies was made in all microhabitat types. Representative specimens from a population were collected and stored in alcohol (one unit). The specimens collected await identification.

Scarabaeinae

Three transects each containing three baited pitfall traps were set (Fig. 5.1.). The traps were baited with three different baits a fine dung (cattle dung), a coarse dung (zebra dung) and crushed millipedes. The cattle and zebra dung were left on the trap for a 24 hour period. As few specimens were caught with the millepede bait on the first day the traps were left for a further two days. All large specimens were pinned while voucher specimens of smaller species were mounted on card. All specimens were identified and representative specimens kept and labelled.

Cetoniini

Three transects each containing three baited bucket-traps were set. The traps were hung from trees and baited with rotten fruit. In addition specimens were collected from the trap nets used to collect certain groups of butterfly. All specimens were kept and identified to species.

Table 5.1. Focal taxa and experts for characterization of miombo insect diversity. These taxa are feasible to both inventory and efficient characterisation. These indicators of organismal biodiversity correspond to Taxonomic Working Inventory Groups (TWIGs) 1 & 2 (See Section 7. 6 for detailed discussion).

Taxon	Focal taxon	Collaborator
Isoptera	all families	M.Dangerfield, (National University, Gaborone, Botswana)
Scarabaeidae	Scarabaeinae,Cetoniini	E. Marais (State Museum, Windhoek Namibia)
Cerambycidae?		
Lepidoptera	Rhaplocera, Saturnidae, Bombycidae, Eupterotidae	R. Oberprieler (South African National Collection, Pretoria)
Lasiocampidae		R. Oberprieler
Sphingidae		
Neuroptera	Myrmeleontidae	M. Mansell (South African National Collection, Pretoria)
	Ascalaphidae	M. Mansell
Hymenoptera	Formicidae	H. Robertson (South African Museum, Cape Town)

Cerambycidae and Neuroptera

Two battery operated light traps were set in the 6 ha plot, the position of these traps is shown in Figure 6.1. All Cerambycids, attracted to the light traps, were collected and pinned. Similarly, all Neuroptera attracted to lights were collected and preserved in envelopes. In addition any specimens caught by handnet in the three transects were collected. These specimens await identification.

Rhaplocera (butterflies)

Each day the three transects were walked for a minimum of three hours and all butterflies collected. In addition three trapnets were set in each transect for the collection of Nymphalidae, each day the trapnets were set and specimens collected. All specimens were killed and identified to species. Representative voucher specimens were retained for the Natural History Museum in Bulawayo.

Bombycoidea (Bombycidae, Saturnidae, Lasiocampidae and Eupterotidae) and Sphingidae

All specimens from these groups were collected from the light traps. Easily identified specimens were marked with tippex and released. For each species voucher specimens were kept.

Labelling and Data Entry

Each specimen kept has a insect Locality Label and identification label. The locality labels were pre-printed and only the date had to be filled in.

Both I.D. number and specimen name were entered into a spreadsheet (Lotus 123: for example; 1 A 1 5 1 *Onthophagus aeruginosus*). The information provided by the identification number is shown as an example:

Plot	Transect	Trap No.	Date	Specimen No.	I.D. No.
1A		15	11	A152	A15300

5.3 RESULTS

A total of 5 980 specimens belonging to 137 species have been identified, the majority of specimens were Scarabaeinae. Results are presented for the four groups indicated in Table 5.2. Results for Bombycoidea (all families) and Sphingidae have been grouped together.

Table 5.2. Relative abundance of four principal focal taxa used to assess arthropod community in Intensive Study Site, Kalomo.

Taxa	No. of specimens	No. of species
Bombycoidea and Sphingidae	133	18
Butterflies	154	33
Cetoniini	35	12
Scarabaeinae	5658	74
TOTAL	5980	137

1. Bombycoidea and Sphingidae

From these taxa 18 species were caught, Fig. 5.2 suggests a higher species richness should be obtained for this group. The graph suggests a total of about 20 species but little confidence can be placed on this result. The abundance rank plot arranges the 18 species on the horizontal axis, ranked from the most abundant species to least abundant (Fig. 5.3).

2. Butterflies

More confidence can be placed in the estimate of about 34 species for the 6 hectare plot (Fig. 5.4). The abundance rank plot arranges the 33 species caught on the horizontal axis (Fig. 5.5).

3. Cetoniini

Again as for butterflies one can be fairly confident of the figure which suggests that 13 species of fruit feeding Cetoniini occur in the ISA in December (Fig. 5.6). The abundance rank plot arranges the 12 species caught on its horizontal axis (Fig. 5.7).

4. Scarabaeinae

As different baits were used to attract Scarabaeinae in order to get an estimate of species richness using these attractants, species accumulation curves have been drawn for each attractant type (Fig. 5.8). The estimated total species richness for beetles attracted to cattle dung (58) and zebra dung (47) are likely to be reliable. Less confidence can be placed on the results for species richness extrapolated for beetles attracted to millipede traps (+ 25 species). Approximately 80 species of Scarabaeinae should be present in the 60 hectare plot (species attracted to the above three attractant types, Gardiner, *unpublished data*). The abundance rank plot (Fig. 5.9) arranges the 74 species of scarabaeinae caught on the horizontal axis (Table 5.3).

Figure 5.1 Plan of Intensive Study Area (ISA) in the Study Site at Wildlives Farm, Kalomo. Positions of trapping stations are shown (georeferences are given in Appendix 8.1.

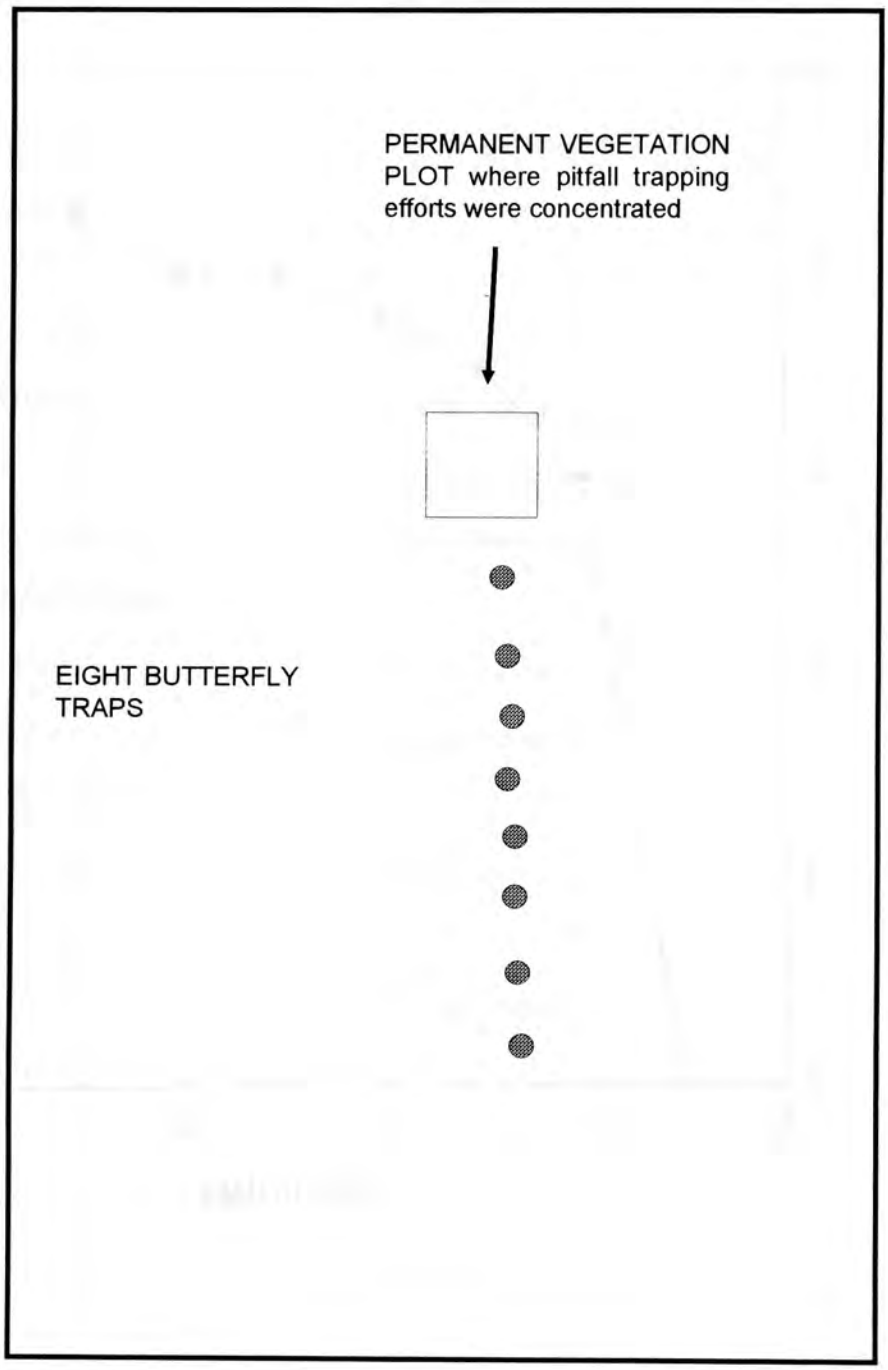


Figure 5.2. Cumulative abundances of Bombycoidea collected at Kalomo Intensive Study Area (December 1994).

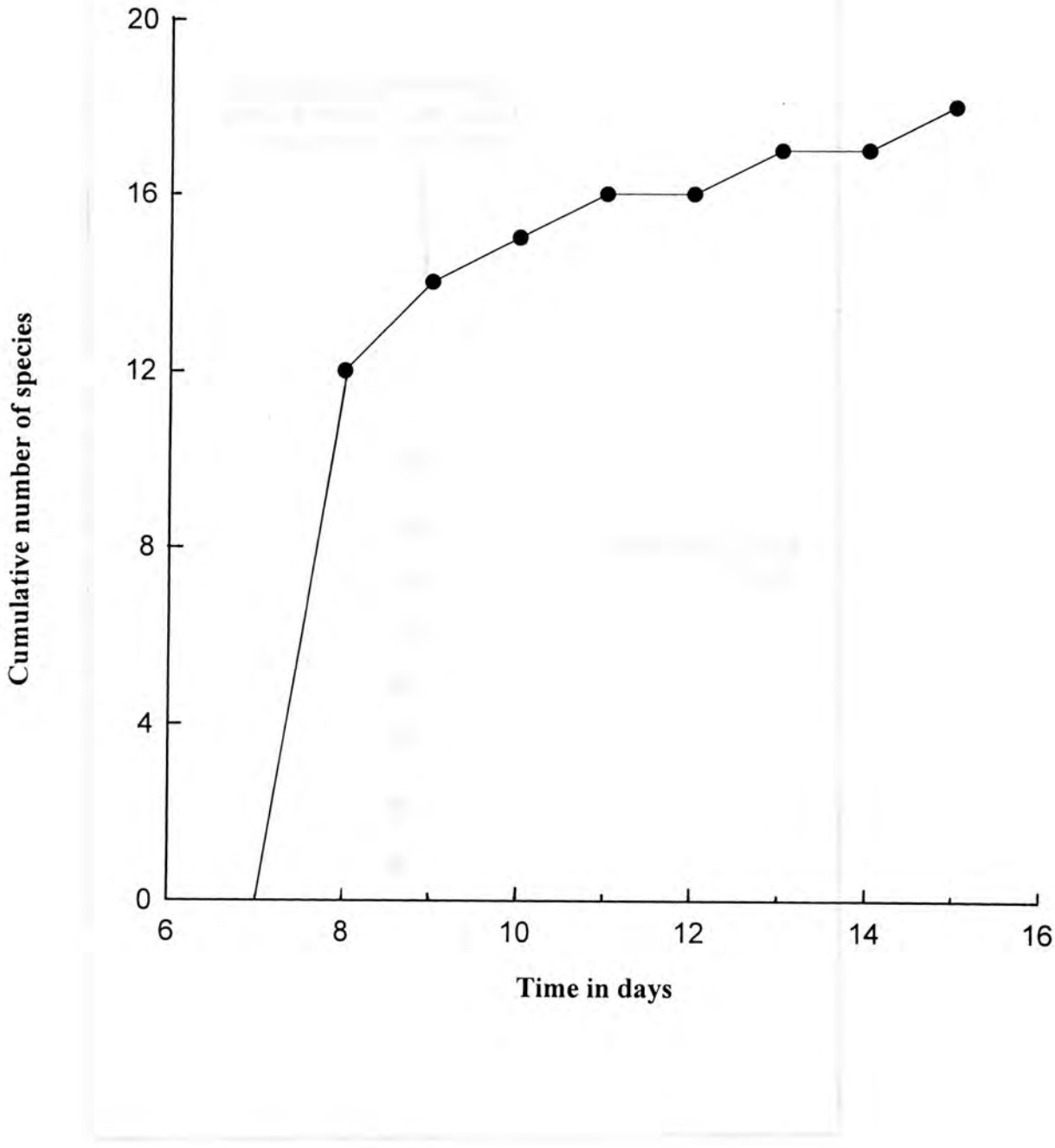


Figure 5.3. Relative abundances of Bombycoidea collected at Kalomo Intensive Study Area (December 1994).

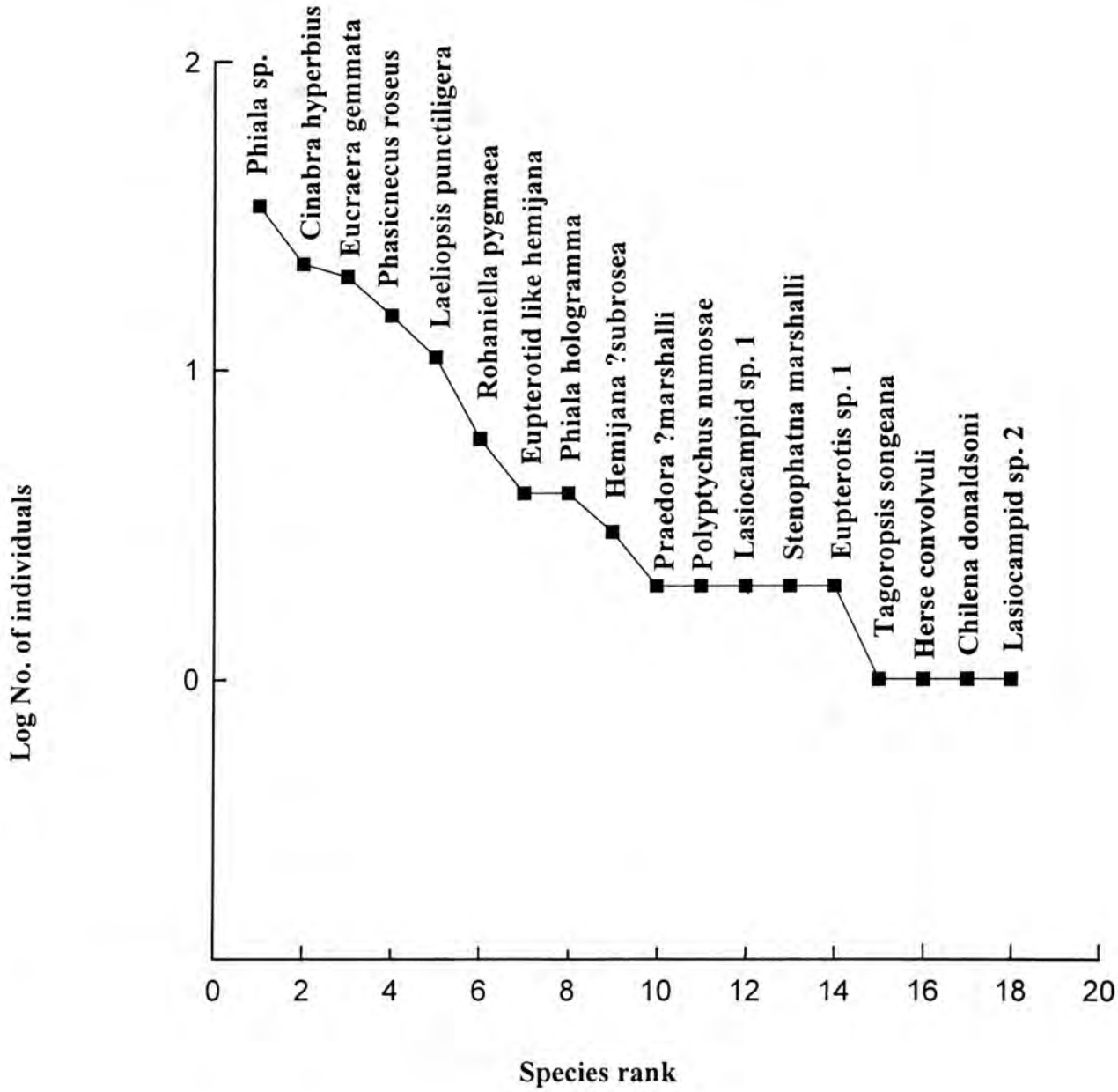


Figure 5.4. Cumulative abundances of butterflies (Rhaplocera) collected at Kalomo Intensive Study Area (December 1994).

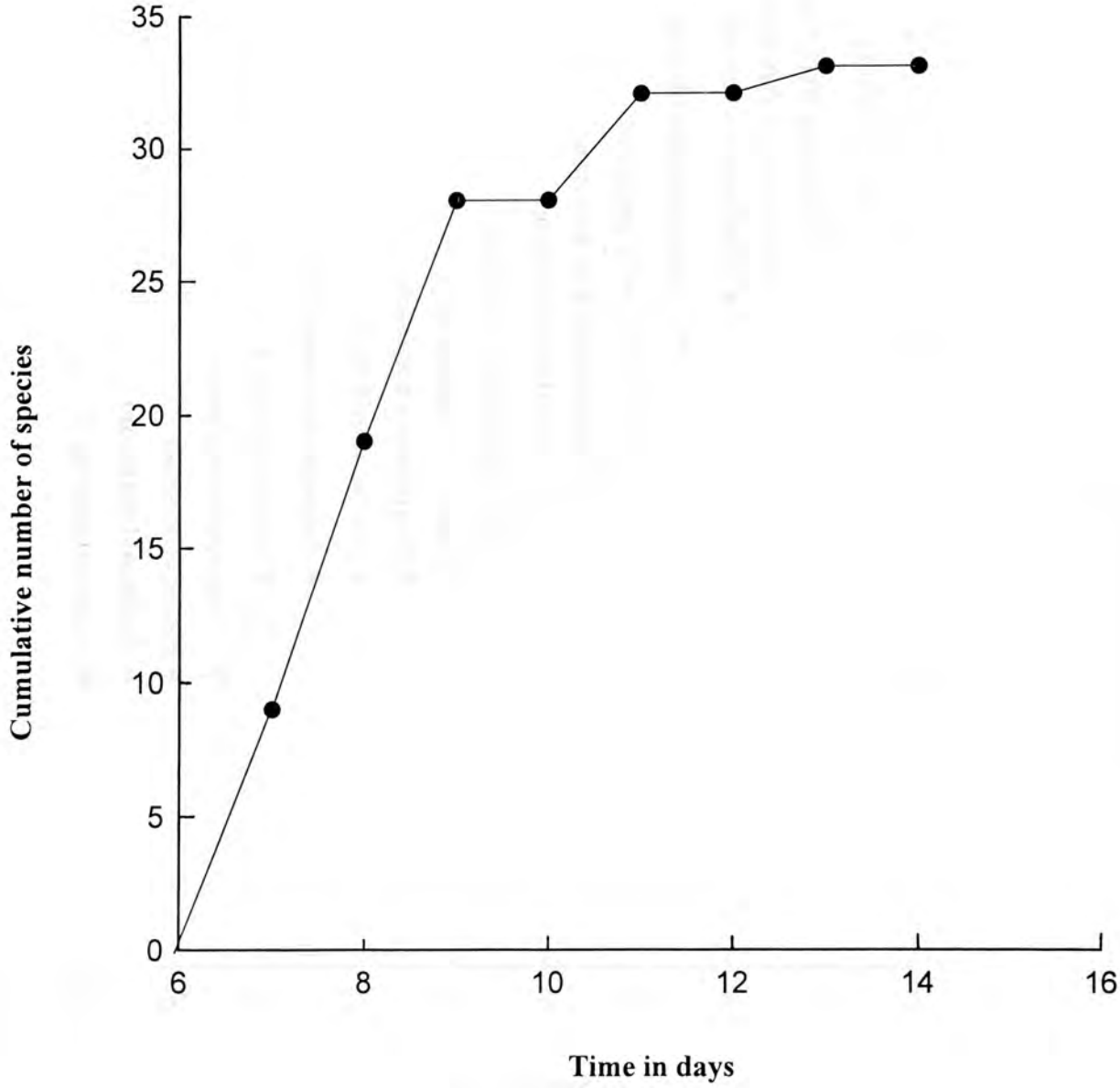


Figure 5.5. Relative abundances of butterflies (Rhaplocera) collected at Kalomo Intensive Study Area (December 1994).

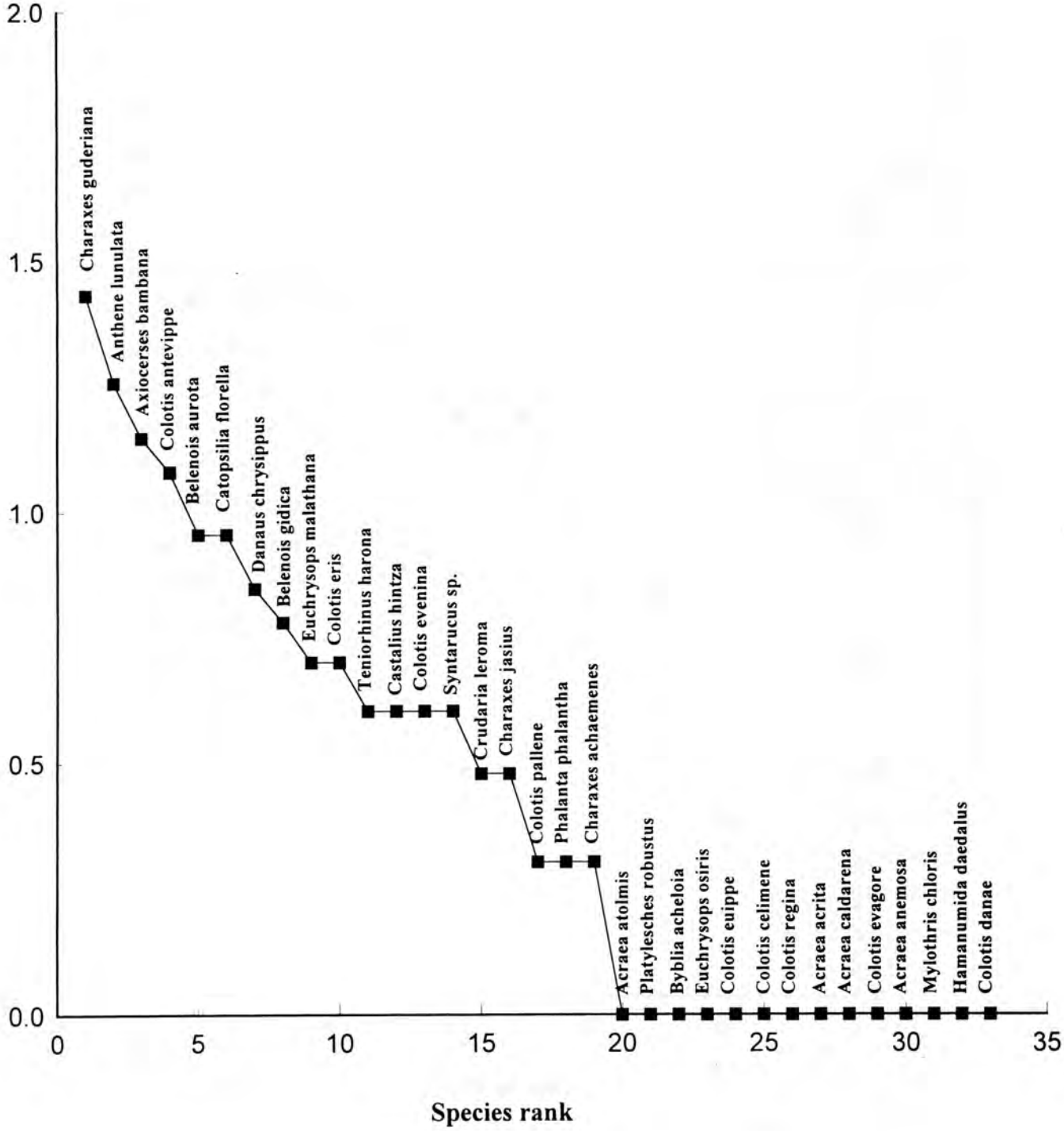


Figure 5.6. Cumulative abundances of chafer beetles (Cetoniini) collected at Kalomo Intensive Study Area (December 1994).

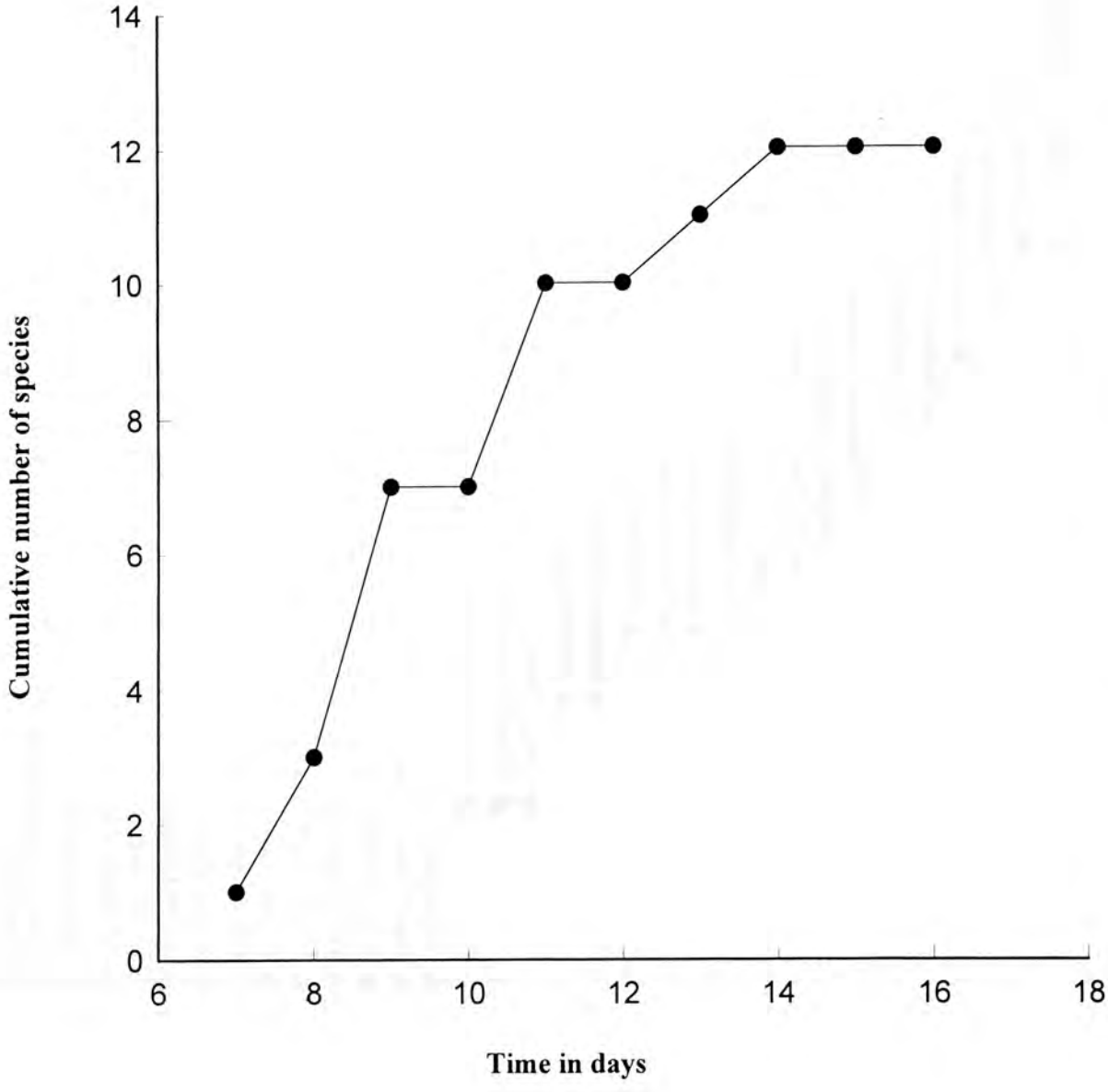


Figure 5.7. Relative abundances of chafer beetles (Cetoniini) collected at Kalomo Intensive Study Area (December 1994).

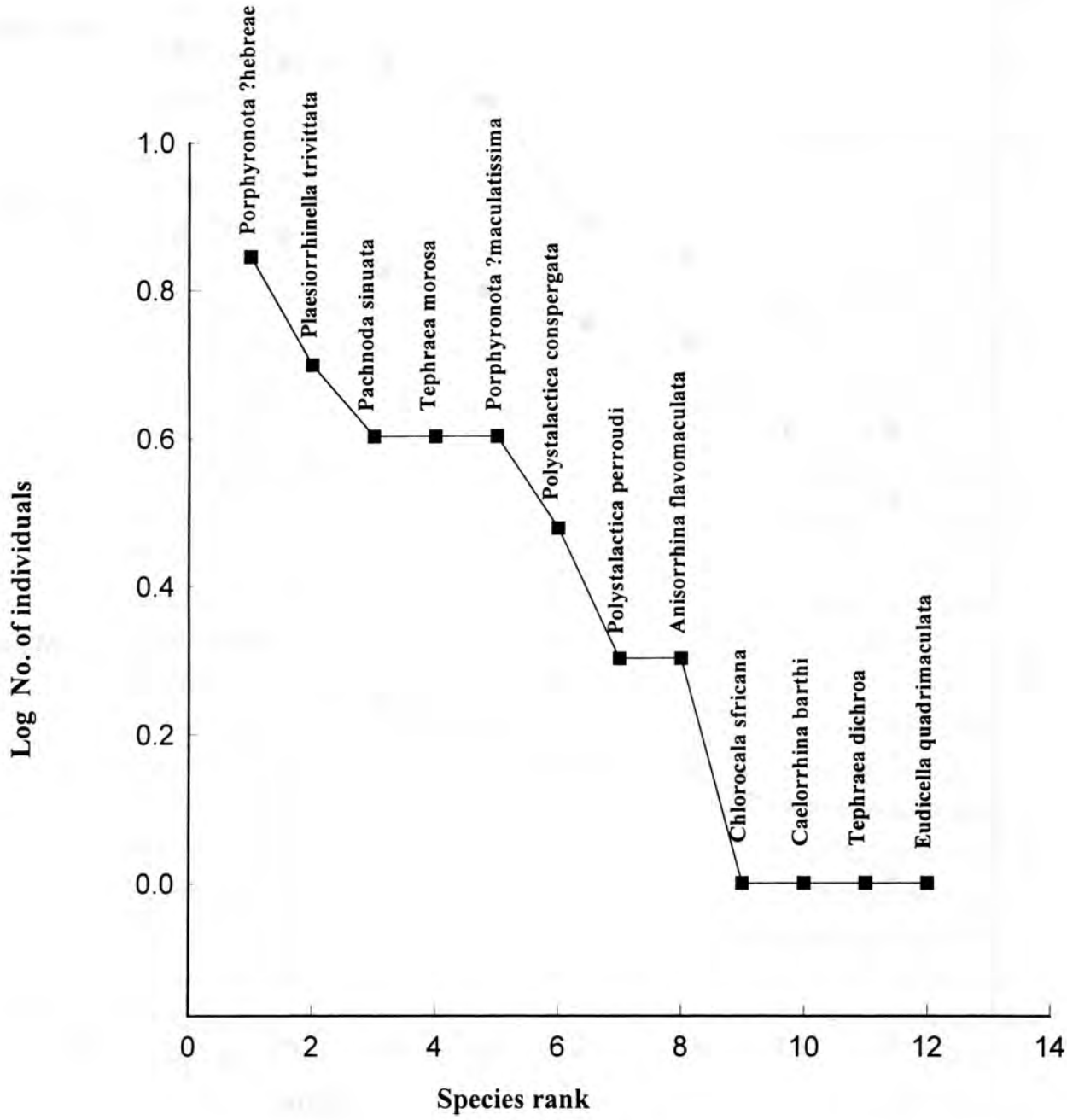


Figure 5.8. Cumulative abundances of Scarabininae collected at Kalomo Intensive Study Area (December 1994). Cumulative abundances have been compiled for the three different sampling techniques (which use different baits).

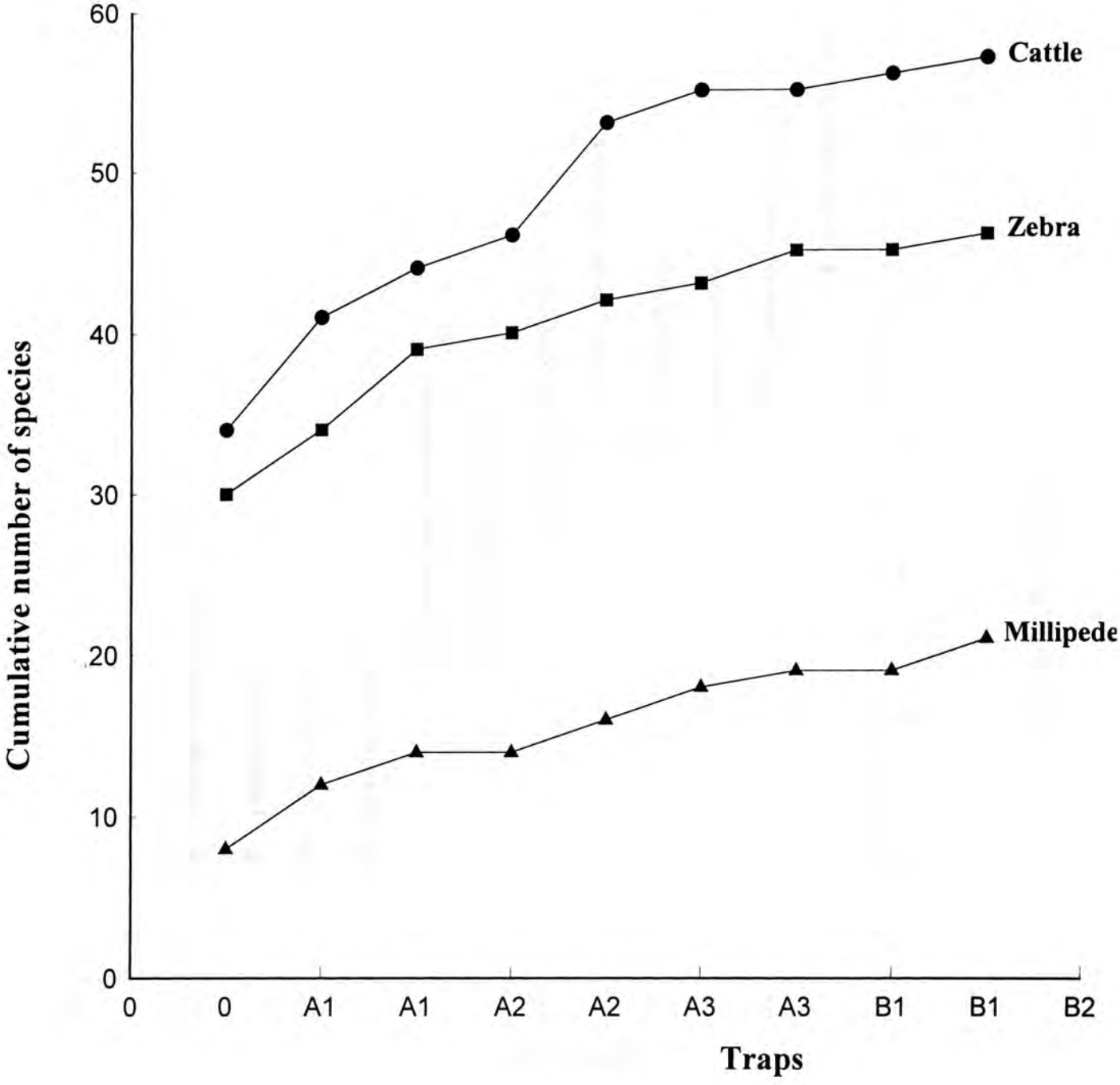
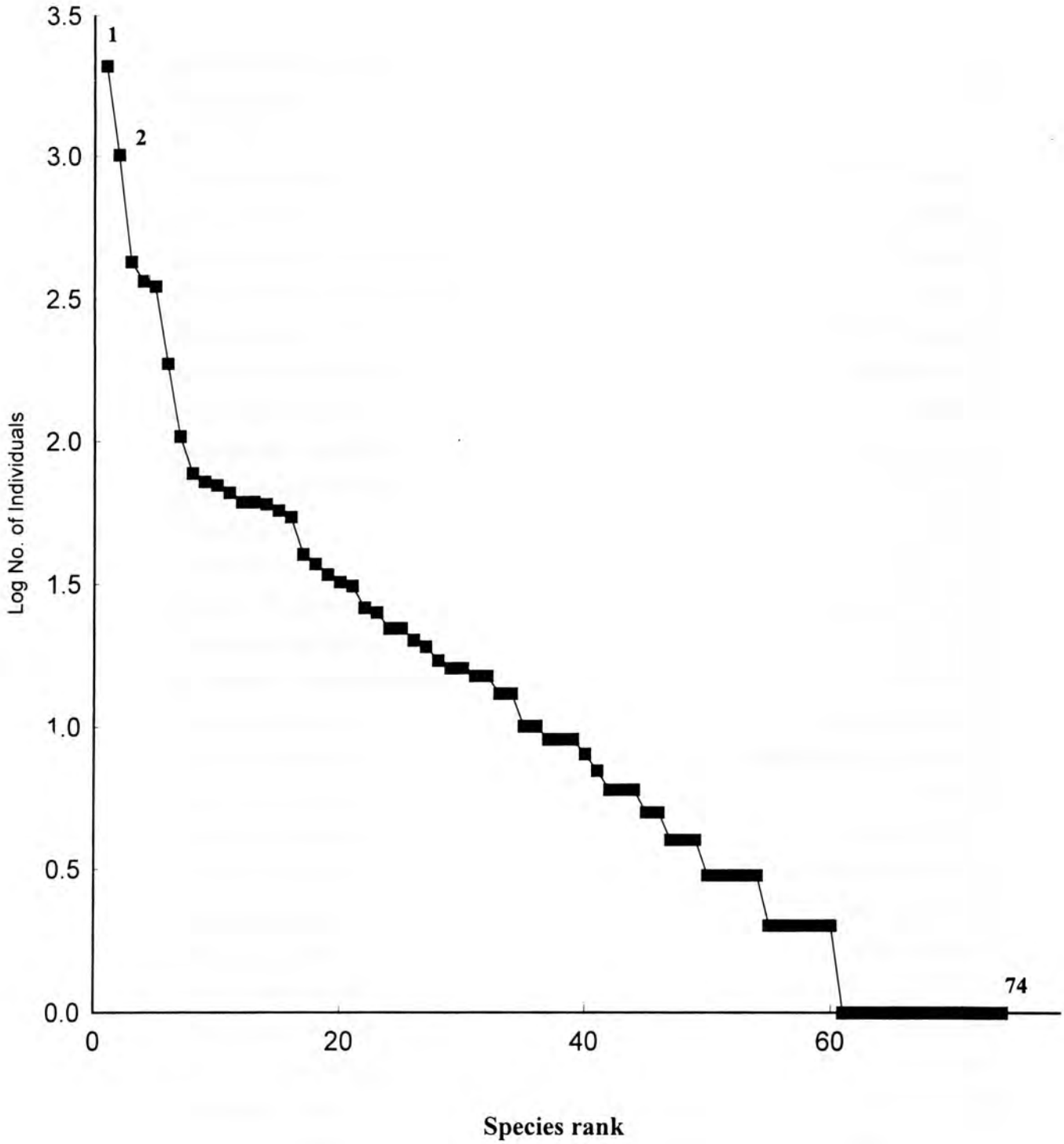
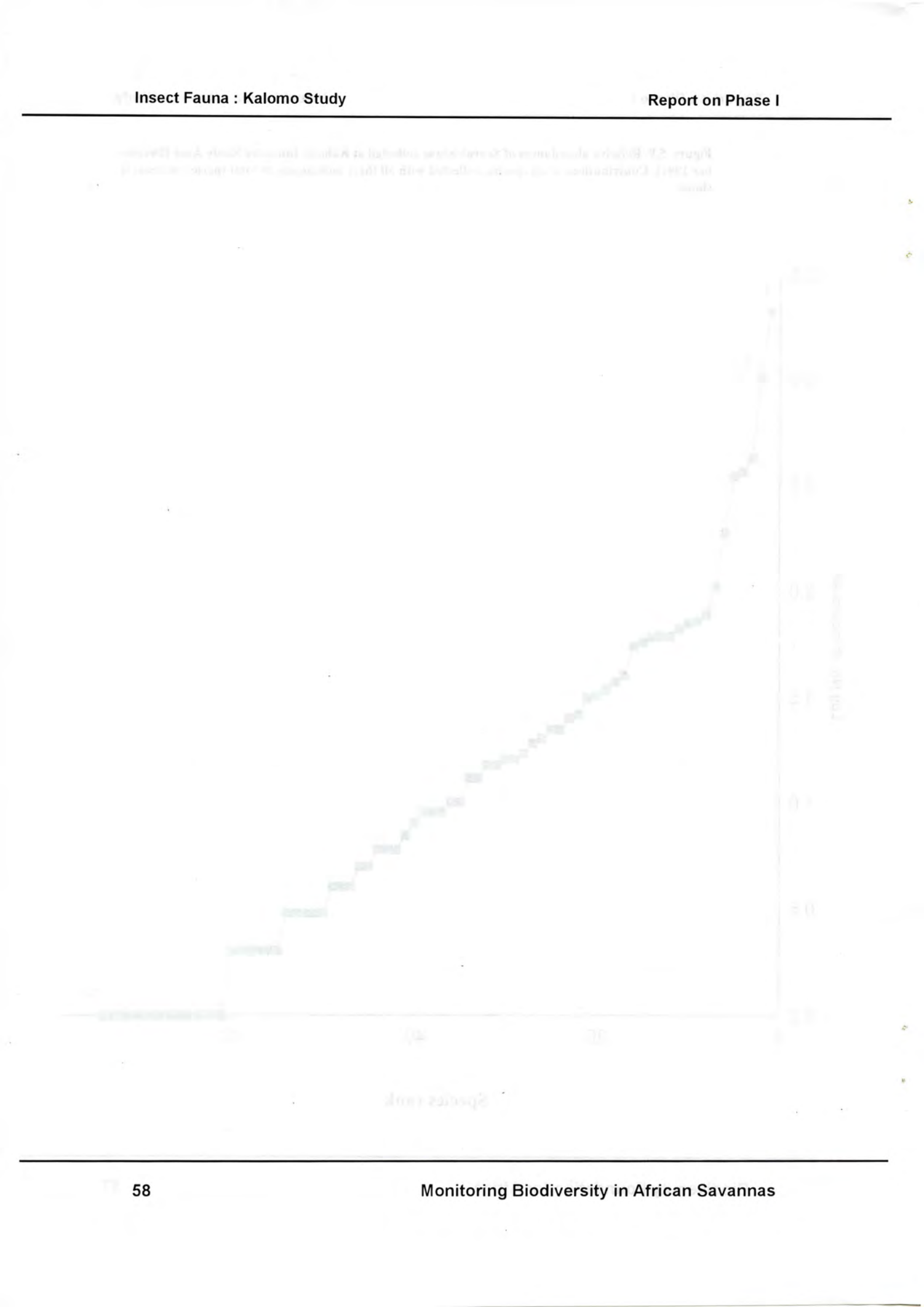


Figure 5.9. Relative abundances of Scarabininae collected at Kalomo Intensive Study Area (December 1994). Contributions of all species, collected with all three techniques, to total species richness is shown.





Chapter 6

SURFACE ACTIVE SPIDERS AND SPIDERS FROM THE TREE AND GRASS LAYERS

M.J. FITZPATRICK

6.1 INTRODUCTION

Information on the ecology and diversity of African spiders is relatively sparse compared to information on the temperate regions. Lotz, Seaman and Kok (1991) listed all published work on Afrotropical spiders prior to 1991; they include a mere ten papers. The majority of these papers report on year long surveys based on monthly samples, and only one of these reports is based on a twelve day trapping period. In all of these studies only small pitfall traps (with a different diameters of containers) were used. In Kalomo, various techniques were tested in search of a set of standard techniques appropriate for future censusing of target groups of Arachnids.

6.2 METHODS

The survey was carried out between 8th and 14th December 1994 in the B.F.A. permanent plot (QDS 1626D3) Choma, Zambia. Little rain had fallen prior to this period and there was no new grass cover, however, the trees had flushed with new growth.

This arachnid survey used the same three transects, through the permanent plot, as selected for inventories of insects.

(1) *Surface active spiders*:

Surface active spiders were collected using two types of pitfall traps:

(a)Small traps 7 cm in diameter placed flush with the soil surface. 13 traps were placed 7 m apart along each of the three transects. The traps were emptied every day. The catch for the entire period of each trap was collected in one bottle containing 70% ethyl alcohol.

(b)Three drift fence pitfall traps with an array of four twenty litre buckets were placed in the same sites as the August 1994 field trip: one in the permanent plot, one in the dambo, and one at the camp site. These traps were emptied everyday and the daily catches kept separate in 70% ethyl alcohol.

(2) *Tree layer*:

Twenty trees along each of the three transects were beaten 3 times daily. The spiders were collected using a beating tray

1 m x 1 m. The daily catch from each transect were kept separately. The deficiencies of beating as a sampling method are discussed by Southwood (1978), however, it is a simple and quick method to sample active arthropods so that an estimate of their numbers can be obtained.

(3) *Grass and Herb layer*:

This layer was sampled using a standard sweepnet 50 cm in diameter with a 75 cm handle. Each sweep covered an arc of approximately 180° through the vegetation. 200 sweeps were taken every day along each transect and the daily catch from each transect was kept separate. The deficiencies of the sweepnet as a sampling method are discussed by Turnbull (1973) and Southwood (1978). Sweepnetting, like beating is only a relative collecting method for most groups.

Most samples were taken between 08h00-11h00. Specimens were transferred to 70% alcohol. All the material collected has been deposited in the National Collection at the Natural History Museum, Bulawayo.

6.3 RESULTS AND DISCUSSION

During the sampling period of seven days a total of 1074 Araneae (15 families, 121 species) were collected (459 spiders using pitfall traps, 432 with sweepnets and 183 from trees by beating). Four Chilopoda, 30 Diplopoda, 11 Solifugae, 21 Mites, 8 Ticks, 15 Opilionida, and 2 Pseudoscorpionida were collected. A check list of all Araneae collected is presented in Table 6.1.

Most spiders collected were adults, but it is not possible to identify all the spiders because of the existing taxonomic problems within several groups of spiders and these have been identified and are distinguished by the assignment of codes A, B, C etc.

Surface-Active Spiders:

A total of 61 spider species were collected using the pitfall traps (Table 6.1) and of these, 20 species are represented by only a single specimen. The species composition varies between the woodland and the dambo. The two dominant species from the woodland, Gnaphosidae; *Setaphis* "A" (173 specimens) and Lycosidae "C" (60 specimens), are replaced by a single dominant species Lycosidae "K" (23 specimens)(see Appendices 6.1 - 6.4 in Chapter 8 for the list of daily catches). The family composition of the spiders caught in the pitfall traps as a whole is shown in Table 6.2. In terms of total numbers of species caught the Gnaphosidae (12), Lycosidae (12) and Zodariidae (10) were the most diverse.

There is a definite overlap between the species caught in the two different trap designs in the plot (see Appendices 6.1 and 6.2), and only the composition of rarer species differs. The drift fence pitfall trap in the plot collected less individuals than the small pitfall traps, however, the drift fence pitfall traps collected the larger Dipluridae, Theraphosidae, Solifugae and Diplopoda. It is suggested that for future monitoring and population censuring that three drift fence pitfall trap arrays be placed in each monitoring site and that the traps be emptied twice a day, morning and late afternoon to distinguish nocturnal and diurnal catches and to prevent predation in the traps.

Tree Layer:

A total of 34 species were collected from beating trees (Table 6.1) and of these 11 species are represented by only a single specimen and the four most abundant species are Thomisidae; *Tmarus cameliformis* (52 specimens), Oxyopidae "D" (18 specimens), Oxyopidae "E" (18 specimens) and Salticidae "F" (18 specimens) (see Appendix 6.5 for species daily catch). The family composition of specimens caught by beating trees is shown in Table 6.3. In terms of total numbers of species caught Araneidae (11 species) and Thomisidae (9 species) were the most diverse.

Grass and Herb Layer:

Sweeping the grass and herb layer collected the greatest diversity (55 species) and the most specimens (432) compared with the other two collecting methods. Only 13 species are represented by a single specimen (Table 6.1). The most abundant species are Philodromidae *Tibellus gerhardi* (64 specimens), Araneidae "B" (48 specimens), Thomisidae *Monaeses austrinus* (30 specimens), Araneidae "H" (23 specimens) and Salticidae

"H" (22 specimens) (see Appendix 6.6 for species daily catch). The family composition of specimens caught by using a sweepnet is shown in Table 6.3.

On the 12th December the grass and herb layer was swept again in the afternoon and a greater number of specimens and different species were collected (see Appendix 6.6). In future monitoring trips it is recommended that this exercise, and also beating of the trees, be carried out twice daily, morning and late afternoon.

A cumulative species richness curve has been produced for those activities which the daily catch was kept separate, namely the drift fence pitfall traps, beating, and sweeping (Fig. 6.1). It is evident that the alpha diversity cannot be measured in a seven day period and it is suggested that 15 days would be adequate. Figure 6.2 is the species rank curve for the first 31 most abundant spider species. The dominant spider families are the Gnaphosidae, Thomisidae, Lycosidae, Salticidae, Araneidae and Oxyopidae. Of these, there are only working keys for some of the Thomisids, Gnaphosids and Zodariids, and many species of these families could also not be identified. The Lycosidae, Araneidae, Zodariidae and Salticidae are under revision by other Taxonomists who will be requested to assist in proper identification. The most dominant species *Setaphis "A"* is likely to be a new species, and the genus is currently under revision by Platnick (U.S.A.) and Murphy (U.K.).

CONCLUSIONS

The target groups suitable for future inventories are the Thomisidae, Gnaphosidae, Lycosidae, Araneidae, Oxyopidae, Zodariidae, and Salticidae. A reference collection for future monitoring work in Miombo savanna woodlands can be only be established once all spiders have been conclusively named.

Techniques to be used in surveys are:

(a)Three drift fence pitfall trap arrays with 4 twenty litre buckets per monitoring site to be emptied twice daily (these arrays are also used for some insects, herpetofauna amd small mammals).

(b) Beating 20 trees each on each transect twice a day

(c) Sweeping the herb and grass layer 200 times per transect, twice a day.

This recommended increase in collecting activities will require a second collector.

Surveys should be conducted once rains have set in and be 15 days in duration.

6.4 BIBLIOGRAPHY

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Southwood, T.R.E. 1978. ***Ecological Methods***. 2nd Ed. University Printing House, London.

Turnbull, A.L. 1973. Ecology of the true spiders (Araneomorphae). ***Ann. Rev. Ent.*** 18: 305-348.

Figure 6.1. Cumulative species abundance curve for all Aranae collected at Kalomo Intensive Study Area in 1994.

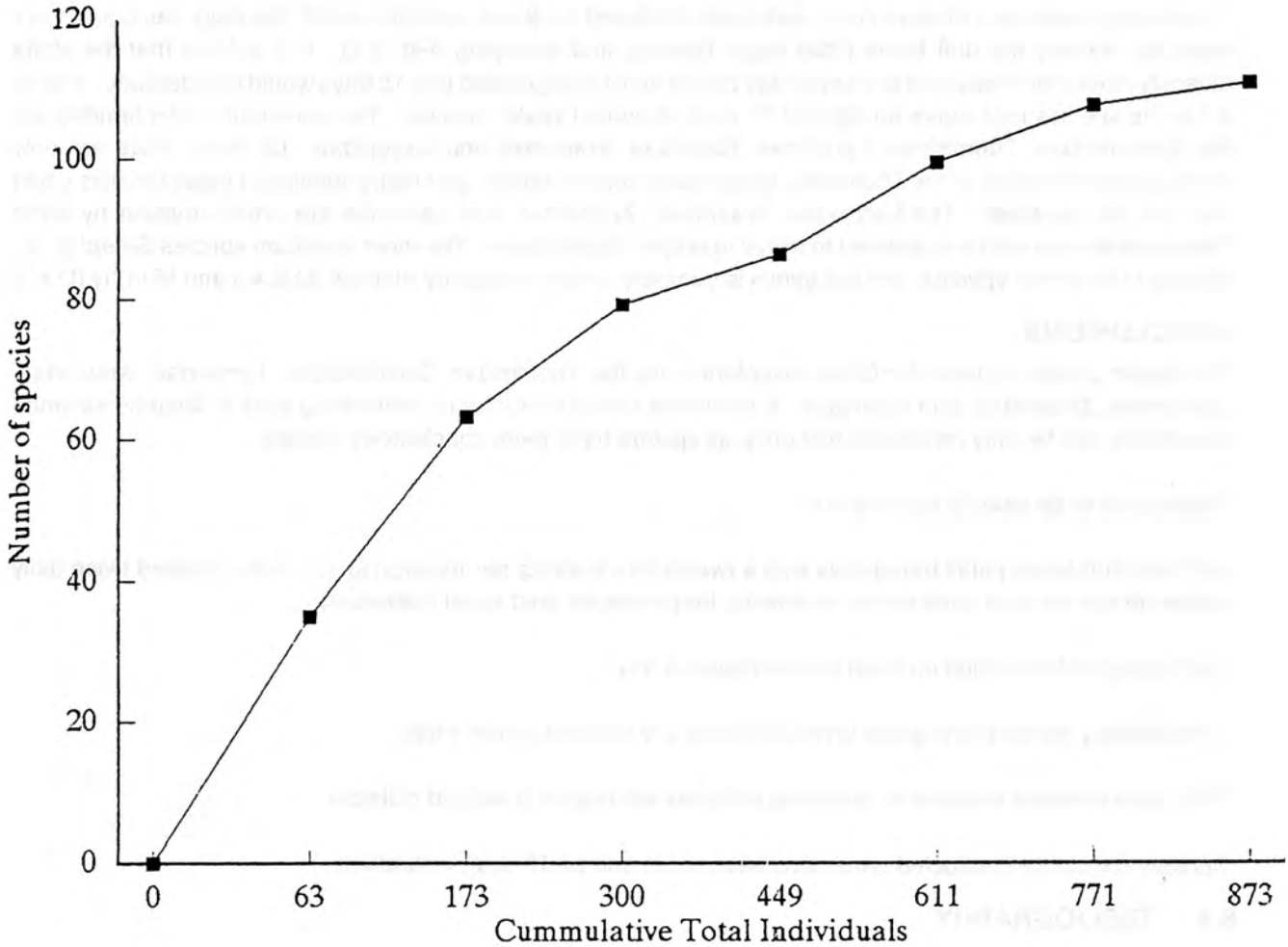
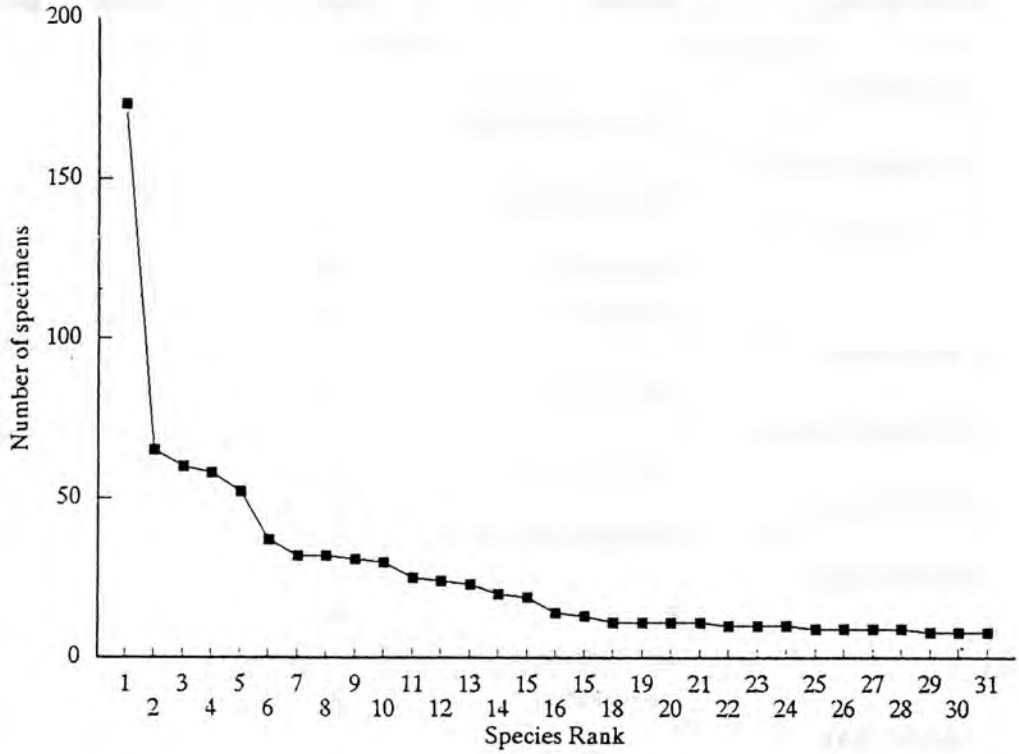


Figure 6.2. Species rank abundance curve for all Aranae collected at Kalomo Intensive Study Area in 1994.



Legend.

1.	Setaphis "A"	17.	Salticidae "I"
2.	Tibellus gerhardi	18.	Lycosidae "F"
3.	Lycosidae "C"	19.	Runcinia flavida
4.	Araneidae "B"	20.	Araneidae "I"
5.	Tmarus cameliformis	21.	Araneidae "P"
6.	Salticidae "F"	22.	Araneidae "N"
7.	Oxyopes "D"	23.	Pisauridae "A"
8.	Salticidae "B"	24.	Heteropidae "A"
9.	Lycosidae "B"	25.	Lycosidae "A"
10.	Monaese austrinus	26.	Diores "A"
11.	Salticidae "H"	27.	Tmarus sp
12.	Araneidae "H"	28.	Theridiidae "A"
13.	Lycosidae "K"	29.	Heteropodidae "B"
14.	Oxyopes "E"	30.	Salticidae "J"
15.	Asemesthes "A"	31.	Hermippus loricatus
16.	Scytodes "A"		

TABLE 6.1: Checklist of spiders recorded from Wildlives Farm, Choma, Zambia.

Family/Genus	Species	Total	Pitfall	Beating	Sweeping
DIPLURIDAE					
	Thelechoris karschi?	2	Y		
THERAPHOSIDAE					
	Pterinochilus sp	2	Y		
SCYTODIDAE					
	Scytodes "A"	14	Y	Y	Y
	Scytodes "B"	3	Y		
CAPONIDAE					
	Caponia sp	2	Y		
PALPIMANIDAE					
	Palpimanus sp	5	Y		
ULOBORIDAE					
	Miagrammops sp	1			Y
THERIDIIDAE					
	A	9			Y
	Latrodectus renivulatus	2			Y
ARANEIDAE					
	A	2	Y		
	B	58		Y	Y
	C	1		Y	
	D	2		Y	
	E	1		Y	
	F	1		Y	
	G	6		Y	Y
	H	24		Y	Y
	I	11		Y	Y
	J	1		Y	
	K	12		Y	Y
	L	1			Y
	M	1			Y
	N	10			Y
	O	5			Y
	P	11			Y
	Q	3			Y
	R	1			Y
	S	1			Y
	T	4			Y
	U	1			Y
	V	1			Y

Table 1. Continued.

Family/Genus	Species	Total	Pitfall	Beating	Sweeping
	W	1			Y
	X	4			Y
	Y	1			Y
	Caerostris sp	1		Y	
LYCOSIDAE					
	A	9	Y		
	B	31			Y
	C	60	Y		
	D	3	Y		
	E	4	Y		
	F	11	Y		
	G	1	Y		
	H	1	Y		
LYCOSIDAE					
	I	1	Y		
	J	9	Y		
	K	23	Y		
	L	1	Y		
	N	1	Y		
	O	3			Y
PISAURIDAE					
	A	10	Y		
	B	1	Y		
OXYOPIDAE					
	Oxyopes "A"	4	Y		Y
	Oxyopes "B"	1	Y		Y
	Oxyopes "C"	6	Y		Y
	Oxyopes "D"	32		Y	Y
	Oxyopes "E"	20		Y	Y
CLUBIONIDAE					
	Cheiracanthium "A"	14		Y	Y
	Cheiracanthium "B"	1		Y	
CORINNIDAE					
	Graptartia "A"	1	Y		
	Graptartia "B"	3	Y		
	Graptartia "C"	1	Y		
ZODARIIDAE					
	Cydrela "A" ?	7	Y		
	Cydrela "B" ?	3	Y		
	A	1	Y		
	B	3	Y		Y

Table 1. Continued.

Family/Genus	Species	Total	Pitfall	Beating	Sweeping
	C	2	Y		
	Diores "A"	9	Y		
	Diores "B"	5	Y		
	Hermippus loricatus	8	Y		
	Capheris sp	5	Y		
	Palfuria sp	1	Y		
GNAPHOSIDAE					
	Setaphis "A"	173	Y		
	Setaphis "B"	1	Y		
	Setaphis "C"	2	Y		
	Asemesthes "A"	19	Y	Y	
	Asemesthes "B"	1	Y		
	Zelotes sp	1	Y		
	Rhaeboctesis	1	Y		
	"Camillina" lutea	2	Y		
	Camillina cordifera?	1	Y		
	Camillina sp	1	Y		
	Xerophaeus "A"	1	Y		
	Xerophaeus "B"	1	Y		
HETEROPODIDAE					
	A	10	Y		
	B	8	Y		Y
	C	5		Y	Y
PHILODROMIDAE					
	Tibellus gerhardi	65		Y	Y
	Philodromus sp	1		Y	
THOMISIDAE					
	Heriaeus sp	2	Y		Y
	Avelis sp	1			Y
	Misumenops rubrodecorata	1			Y
	Monaeses austrinus	30			Y
	Monaeses gibbus	1			Y
	Monaeses quadrituberculatus	2			Y
	A	2	Y		
	B	5		Y	Y
	Pherecydes lucinae	2			Y
	Runcinia depressa	3	Y		Y
	Runcinia flavida	11			Y
	Simorcus sp	6	Y		Y

Table 1. Continued.

Family/Genus	Species	Total	Pitfall	Beating	Sweeping
	Synema "A"	6			Y
	Synema "B"	1	Y		
	Synema "C"	7		Y	Y
	Synema "D"	1		Y	
	Synema "E"	1		Y	
	Synema "F"	2		Y	
	Synema "G"	1		Y	
	Tmarus sp	9			Y
	Tmarus cameliformis	52		Y	
	Tmarus africanus	1		Y	
SALTICIDAE					
	A	1	Y		
	B	32	Y	Y	Y
	C	2	Y		
	D	5	Y		
	E	6		Y	Y
	F	37	Y	Y	Y
	G	2		Y	
	H	25		Y	Y
	I	13			Y
	J	8			Y
	K	3			Y

TABLE 6.2: Spiders collected at Wildlives Farm, Choma, Zambia using pitfall traps with number of species and percentage total number of spiders collected per family.

Family	Small Pit fall traps		Drift fence pitfall trap Arrays					
			Plot		Dambo		Camp	
	Nos.	%	Nos.	%	Nos.	%	Nos.	%
Dipluridae	-	-	1	0.88	-	-	1	1.51
Theraphosidae	-	-	1	0.88	-	-	1	1.51
Scytodidae	1	3.98	-	-	1	2.53	1	1.51
Caponidae	-	-	-	-	1	2.53	-	-
Zodariidae	4	3.98	5	15.93	3	6.33	5	18.20
Palpimanidae	1	1.49	1	0.88	1	1.27	-	
Araneidae	-	-	-	-	1	1.27	1	1.51
Oxyopidae	1	0.50	1	0.88	1	1.27	1	1.51
Pisauridae	-	-	1	2.65	2	8.86	1	1.51
Lycosidae	7	14.42	4	23.01	6	53.16	3	40.91
Gnaphosidae	7	68.16	4	38.05	4	11.39	7	22.73
Corinnidae	1	0.50	2	1.77	-	-	1	3.03
Heteropodidae	1	0.50	2	8.85	2	6.33	-	-
Thomisidae	1	0.50	2	4.42	3	2 3.80	1	1.51
Salticidae	5	5.97	2	1.77	1	1.27	2	4.55
Total specimens	201		113		79		66	
Total species	27		26		25		25	
Total Families	10		12		12		12	

TABLE 6.3. Spiders collected at Wildlives Farm, Choma, Zambia, by beating trees and sweepnets with number of species and percentage total number of spiders collected per family.

	Beating		Sweeping	
	Nos.	%	Nos.	%
Scytodidae	1	0.55	1	1.16
Zodariidae	-	-	1	0.23
Theridiidae	-	-	2	2.55
Araneidae	11	12.57	19	32.64
Oxyopidae	2	21.31	5	5.09
Lycosidae	-	-	2	7.87
Gnaphosidae	1	1.09	-	-
Clubionidae	2	7.65	1	0.23
Heteropodidae	1	2.19	2	0.46
Thomisidae	9	34.97	14	16.20
Philodromidae	1	0.55	1	14.81
Salticidae	5	19.13	7	18.50
Total specimens	183		432	
Total species	33		55	
Total families	9		11	

Chapter 7

VERTEBRATES

This chapter includes three subdisciplines and collates all data collected for terrestrial vertebrates.

7.1 AVIFAUNA

C. W. HUSTLER

The principal aim of the expedition from an ornithological perspective was to develop a methodology for the inventory of avian diversity in miombo savannas.

RESULTS

The avifauna of miombo woodland is characterized by feeding parties of variable species composition. The composition of these bird-parties varies seasonally and geographically, and also depends on whether some of species are breeding or not. Feeding parties move through the woodland at varying speeds, and this is also dependent on the species composition of these groups.

Consequently, the monitoring of avian diversity in miombo savanna on the basis of a fixed plot of predetermined size is entirely inappropriate. Likewise the time of year that the field work is being carried out can have an influence on the data gathered as migrants (Palaearctic and intra-African) may not have arrived yet.

Much time was spent moving along roads that transect the woodland searching for bird parties. When they were found they were followed and the diversity and numbers of individual species were recorded. Due to the time of year and the cold spell that was experienced just prior to our arrival at Kalomo, only two feeding parties (1 & 2) were encountered despite intensive searches. An additional party was found some distance from the study area (included as party 3). Details of bird parties are:-

Bird Party:	**1**	**2**	**3**
Number of Bird Species:	6	18	11
Number of Individuals:	15+	40+	22+

There were obvious omissions in all of the bird parties located. No Flycatchers or Black Cuckooshrikes were recorded; Spotted Creeper, which is a characteristic member of miombo woodland bird parties, was only recorded once. Very few ground feeding species were recorded, although in the largest bird party (2) a number of ground feeding species were found. This method does not take into account ground feeders which are less likely to join these feeding parties than the other species recorded. The number of passerines which feed on the ground in miombo woodland is low (in proportion to species feeding on the trees or in the canopy) and a relationship probably exists between the number of species using the trees and those ground feeders that require closed canopy woodland to feed in. This potential relationship could be investigated further in due course.

In addition to inventory of bird parties in some detail, a total list of the number of species recorded in the study area was compiled. This list is included as Appendix 7.1.

7.2 HERPETOFAUNA

D. G. BROADLEY

Collecting conditions for reptiles and amphibians were very poor, due to the very early end to the rainy season in February and the coldest winter for 20 years in the area. Dry conditions persisted into December and only a few specimens were trapped.

The main objective was to experiment with the use of plastic drift fences combined with pitfall traps (20 litre plastic buckets). Various arrays of fences and traps were tried out, but in most situations the most suitable seemed to be an array consisting of a central pitfall connected by 10 metre drift fences at 120$ to three more pitfalls (Fig. 11B). A few lizards were trapped, but fair numbers of spiders and other invertebrates were obtained.

Due to the dry conditions, no reptiles were found under logs or loose bark, but a few lizards were "winkled out" of rock crevices. One Mozambique Spitting Cobra was shot with the .410 shot pistol and some lizards were caught by hand.

A number of skeletal specimens were picked up in the bush, which helped to boost the herpetofaunal list. No amphibians were seen in the study area in July/August and only two were trapped in December.

Trapping of the two subadult *Ichnotropis capensis* in mid-winter is of particular interest, as this is an annual species in Zimbabwe (Broadley, 1967) and it survives the winter in the egg.

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7.3 MAMMALS

F. P. D. COTTERILL

Introduction

The objectives of this study was to assess the species richness of mammals in the Kalomo Study area, and to select suitable techniques for mammals which will contribute to multidisciplinary measures of savanna biodiversity, and allow for monitoring of its properties.

Methodology

Well established sampling techniques (see de Blase & Martin, 1981) were used. Night hunting with the aid of a spotlight yielded several specimens. This method is most suitable for lagomorphs, spring hares (*Pedetes capensis*) and nocturnal carnivores. Live traps, baited for carnivores with rodent carcasses, had zero results, nor did they show any sign of having had attracted attention of carnivores.

Live traps and museum specials (snap traps) for rodents and small insectivores were laid in sites where capture success was assessed to be likely. A grid of live traps was established in the permanent study area. This consisted of a total of fifty trips set in two lines 10 metres apart (50 by 20 meters. Bait for all terrestrial mammal traps was peanut butter and rolled oats.

The pitfall trap arrays, established principally for herpetofauna, captured two shrews during the exercise. This technique has potential for capturing small mammals, particularly small rodents and shrews.

Bats were captured with standard mistnets (Kurta & Kunz, 1988). Harp traps, which have proved very successful elsewhere (Cotterill, *unpublished data*) captured no bats in this inventory.

Results

The results are based on an inventory of ten days effort, supplemented by visual records of large and medium sized mammals accumulated over several years. The overall inventory data provide some insight into the species richness of mammals influencing the ecology of the study area, notably the miombo woodland.

Captures of small mammals, particularly of bats, were poor. This was most probably due to cold temperatures, especially at nights. The winter of 1994 was the coldest recorded for the past 20 years, which may have also suppressed rodent populations. Trapping success for rodents was similarly disappointing, and shrews were scarce. No elephant shrews were recorded, although they are expected to occur.

Small carnivores, including viverrids and herpestids, appear well represented in the area. For example the mustelid, *Ictonyx striatus*, was seen on three separate occasions during nocturnal sampling. and nocturnal and diurnal mongooses were apparent.

A rich assemblage of ungulates, which are quite possibly representative of the historical fauna, have been introduced into the study area. Nevertheless, it is extremely difficult to realistically reconstruct the species richness of the large mammal community which occurred here in the last century. Certainly, elephant and both species of rhino would have been expected to occur.

This list is far from complete. In particular, species richness of small mammals (rodents, shrews and bats) is expected to be much higher. An representative species total for the Chiroptera, for example, would be expected to exceed 20 species for savanna woodland. Rodent species richness should be higher (Cotterill, *unpublished data*). Poor results for small mammals are quite possibly influenced by the exceedingly cold winter, and the exceptional dry spell, extending into December.

Conclusion and Recommendations

Further inventories of the bats and terrestrial small mammals in this study area are required. It is suggested that rodents be monitored on a permanent grid in the Intensive Study Area using live traps. This is a well established and standardized technique, which will yield valuable and comparable species abundance data on this important group. Estimates of total species richness (as performed in Chapters 4 & 5) should be obtained from mammal abundance data collated from such a grid, and from other techniques.

Abundances of large and medium sized antelope have been closely monitored by the owners of Wildlives Game Farm. Over time, this information will develop into a valuable dataset.

With the exception of rodents, smaller bodied mammal species should be monitored on their presence or absence in the area. It is difficult to apply standardized non-removal techniques to these populations without considerable sampling effort.

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VERTEBRATES: APPENDIX 1 AVIFAUNA

List of birds seen in miombo savanna on Wildlives Game Farm, inclusive of BFA'S Intensive Study Area, Kalomo

Phalacrocorax africanus	Reed Cormorant
Ardea cinerea	Grey Heron
Ardea alba	Great White Heron
Butorides striatus	Green-backed Heron
Scopus umbretta	Hamerkop
Ciconia nigra	Black Stork
Ephippiorhynchus senegalensis	Saddlebill
Mycteria ibis	Yellow-billed Stork
Alopochen aegyptiaca	Egyptian Goose
Anas erythrorhyncha	Red-billed Teal
Sarkidiornis melanotos	Knob-billed Duck
Sagittarius serpentarius	Secretarybird
Milvus migrans	Black Kite
Aquila rapax	Tawny Eagle
Hieraaetus spilogaster	African Hawk Eagle
Polemaetus bellicosus	Martial Eagle
Kaupifalco monogrammicus	Lizard Buzzard
Circaetus cinereus	Brown Snake Eagle
Circaetus pectoralis	Black-breasted Snake Eagle
Terathopius ecaudatus	Bateleur
Haliaeetus vocifer	African Fish Eagle
Accipiter ovampensis	Ovambo Sparrowhawk
Accipiter minullus	Little Sparrowhawk
Micronisus gabar	Gabar Goshawk
Melierax metabates	Dark Chanting Goshawk
Polyboroides radiatus	Gymnogene
Pandion haliaetus	Osprey
Francolinus coqui	Coqui Francolin
Francolinus shelleyi	Shelley's Francolin

Francolinus natalensis	Natal Francolin
Francolinus swainsoni	Swainson's Francolin
Numida meleagris	Helmeted Guineafowl
Charadrius tricollaris	Three-banded Sandplover
Vanellus coronatus	Crowned Plover
Vanellus armatus	Blacksmith Plover
Vanellus senegallus	Wattled Plover
Tringa hypoleucos	Common Sandpiper
Tringa glareola	Wood Sandpiper
Tringa nebularis	Greenshank
Burhinus vermiculatus	Water Dikkop
Cursorius temminckii	Temminck's Courser
Rhinoptilus cinctus	Three-banded Courser
Streptopelia semitorquata	Red-eyed Dove
Streptopelia capicola	Cape Turtle Dove
Streptopelia senegalensis	Laughing Dove
Oena capensis	Namaqua Dove
Turtur chalcospilos	Green-spotted Dove
Treron australis	Green Pigeon
Corythaixoides concolor	Grey Loerie
Centropus senegalensis	Senegal Coucal
Centropus superciliosus	White-browed Coucal
Strix woodfordii	Wood Owl
Otus scops	Scops Owl
Otus leucotis	White-faced Owl
Glaucidium perlatum	Pearl-spotted Owl
Glaucidium capense	Barred Owl
Bubo lacteus	Giant Eagle Owl
Ceryle rudis	Pied Kingfisher
Megaceryle maxima	Giant Kingfisher
Corythornis cristata	Malachite Kingfisher

Halcyon chelicuti	Striped Kingfisher
Merops pusillus	Little Bee-eater
Merops hirundineus	Swallow-tailed Bee-eater
Coracias caudata	Lilac-breasted Roller
Coracias spatulata	Racket-tailed Roller
Upupa epops	Hoopoe
Phoeniculus purpureus	Red-billed Wood Hoopoe
Rhinopomastus cyanomelas	Scimitarbill
Tockus nasutus	Grey Hornbill
Lybius torquatus	Black-collared Barbet
Pogoniulus chrysoconus	Yellow-fronted Tinker Barbet
Trachyphonus vaillantii	Crested Barbet
Indicator indicator	Greater Honeyguide
Indicator minor	Lesser Honeyguide
Campethera bennettii	Bennett's Woodpecker
Campethera abingoni	Golden-tailed Woodpecker
Dendropicos fuscescens	Cardinal Woodpecker
Thripias namaquus	Bearded Woodpecker
Mirafra africana	Rufous-naped Lark
Mirafra rufocinnamomea	Flappet Lark
Hirundo smithii	Wire-tailed Swallow
Hirundo dimidiata	Pearl-breasted Swallow
Hirundo semifura	Red-breasted Swallow
Hirundo abyssinica	Lesser Striped Swallow
Hirundo griseopyga	Grey-rumped Swallow
Coracina pectoralis	White-breasted Cuckoo-Shrike
Dicrurus adsimilis	Fork-tailed Drongo
Oriolus larvatus	Black-headed Oriole
Corvus albus	Pied Crow
Parus niger	Southern Black Tit
Parus leucomelas	White-winged Black Tit
Anthoscopus caroli	Grey Penduline Tit

Turdoides jardineii	Arrow-marked Babbler
Turdoides leucopygius	White-rumped Babbler
Pycnonotus barbatus	Black-eyed Bulbul
Chlorocichla flaviventris	Yellow-bellied Bulbul
Turdus libonyana	Kurrichane Thrush
Monticola angolensis	Miombo Rock Thrush
Thamnoleae arnoti	Arnot's Chat
Erythropygia leucophrys	White-browed Scrub Robin
Hyliota australis	Mashona Hyliota
Hyliota flavigaster	Yellow-breasted Hyliota
Apalis flavida	Yellow-breasted Apalis
Sylvietta rufescens	Long-billed Crombec
Eremomela icteropygialis	Yellow-bellied Eremomela
Eremomela scotops	Green-capped Eremomela
Camaroptera brachyura	Bleating Bush Warbler
Camaroptera stierlingi	Stierling's Barred Warbler
Cisticola juncidis	Fan-tailed Cisticola
Cisticola chiniana	Rattling Cisticola
Cisticola fulvicapilla	Neddicky
Prinia subflava	Tawny-flanked Prinia
Melaenornis pammelaina	Black Flycatcher
Melaenornis pallidus	Pallid Flycatcher
Batis molitor	Chinspot Batis
Motacilla aguimp	African Pied Wagtail
Anthus nyassae	Wood Pipit
Anthus vaalensis	Buffy Plain-backed Pipit
Urolestes melanoleucus	Long-tailed Shrike
Laniarius aethiopicus	Tropical Boubou
Dryoscopus cubla	Southern Puffback
Nilaus afer	Brubru
Tchagra australis	Brown-headed Tchagra

Tchagra senegala	Black-crowned Tchagra
Prionops plumatus	White Helmet Shrike
Prionops retzii	Red-billed Helmet Shrike
Lamprotornis chloropterus	Lesser Blue-eared Glossy Starling
Nectarinia shelleyi	Shelley's Sunbird
Nectarinia talatala	White-bellied Sunbird
Nectarinia senegalensis	Scarlet-chested Sunbird
Nectarinia amethystina	Black Sunbird
Zosterops senegalensis	Yellow White-eye
Passer griseus	Grey-headed Sparrow
Petronia superciliaris	Yellow-throated Sparrow
Ploceus cucullatus	Spotted-backed Weaver
Anaplectes rubriceps	Red-headed Weaver
Euplectes albonotatus	White-winged Widow
Euplectes macrourus	Yellow-mantled Widow
Vidua macroura	Pin-tailed Whydah
Vidua paradisaea	Paradise Whydah
Pytilia melba	Green-winged Pytilia
Lagonosticta rhodopareia	Jameson's Firefinch
Lagonosticta senegala	Red-billed Firefinch
Uraeginthus angolensis	Blue Waxbill
Estrilda astrild	Common Waxbill
Amandava subflava	Orange Waxbill
Spermestes cucullatus	Bronze Mannikin
Serinus mozambicus	Yellow-eyed Canary
Serinus sulphuratus	Bully Canary
Serinus reichardi	Stripe-breasted Canary
Serinus mennelli	Black-eared Canary
Emberiza cabanisi	Cabanis's Yellow Bunting
Emberiza flaviventris	Golden-breasted Bunting
Emberiza tahapisi	Cinnamon-breasted Rock Bunting

VERTEBRATES: APPENDIX 2 HERPETOFAUNA

List of Herpetofauna collected in miombo savanna on Wildlives Game Farm, inclusive of BFA Intensive Study Area, Kalomo ([sk] = skeletal specimen)

Taxa	Common Name	Numbers of specimens (season - dry:wet)
Order CHELONII		
Suborder PLEURODIRA		
Family PELOMEDUSIDAE		
Pelusios subniger subniger	Pan Hinged Terrapin	(1 [sk]: -)
Suborder CRYPTODIRA		
Family TESTUDINIDAE		
Kinixys spekii	Speke's Hinged Tortoise	(1 [sk]: -)
Order SQUAMATA		
Suborder IGUANIA		
Family AGAMIDAE		
Agama aculeata armata	Eastern Tropical Spiny Agama	(2: -)
Family CHAMAELEONIDAE		
Chamaleo dilepis	Common Flap-necked Chameleon	(1: -)
Suborder SAURIA		
Family GEKKONIDAE		
Pachydactylus bibronii	Turner's Thick-toed Gecko	(2: -)
Lygodactylus capensis capensis	Cape Dwarf Gecko	(3: -)

Family SCINCIDAE		
Mabuya varia	Variable Skink	(1: -)
Mabuya striata wahlbergii	Wahlberg's Striped Skink	(2: 1)
Panaspis wahlbergii	Wahlberg's Snake-eyed Skink	(3: 3)
Family LACERTIDAE		
Ichnotropis capensis	Cape Rough-scaled Sand-Lizard	(2: -)
Ichnotropis squamulosa	Mozambique Rough-scaled Sand-Lizard	(-: 1)
Suborder SERPENTES		
Family ELAPIDAE		
Naja mossambica	Mozambique Spitting Cobra	(1: -)
Family COLUBRIDAE		
Subfamily PSAMMOPHIINAE		
Psammophis phillipsii	Olive Grass Snake	(1 [sk]: -)
Subfamily COLUBRINAE		
Dispholidus typus typus	Boomslang	(1: -)
Crotaphopeltis hotamboeia	Herald Snake	(2: -)
AMPHIBIANS COLLECTED		
Order ANURA		
Family MICROHYLIDAE		
Breviceps poweri	Common Rain Frog	(-: 1)
Family HEMISOTIDAE		
Hemisus marmoratus	Mottled Burrowing Frog	(-: 1)

VERTEBRATES: APPENDIX 3 MAMMAL FAUNA

List of mammal species collected or seen in miombo savanna on Wildlives Game Farm, inclusive of

(Numbers of specimens are listed for each taxon. An asterisk refers to a visual record only.

1Only recorded from Imamba Farm, North of Choma, but this species is expected to occur in the Kalomo Site.

Order INSECTIVORA		
Family SORICIDAE		
Crocidura mariquensis	Maqwassie Musk Shrew	3
Crocidura sp.		1
Order CHIROPTERA		
Family PTEROPIDIDAE		
Epomophorus crypturus	Peter's Epauletted Fruit Bat	1
E. gambianus	Gambian Epauletted Fruit Bat	1
Family NYCTERIDAE		
Nycteris thebaica[1]	Egyptian slit-faced bat	1
Family VESPERTILIONIDAE		
Glauconycteris variegata	Butterfly bat	1
Family MOLOSSIDAE		
Tadarida aegytiaca	Egyptian free-tailed bat	3
Order PRIMATA		
Family LORISIDAE		
Galago moholi	Lesser bushbaby	1
Otolemur crassicaudatus	Greater bushbaby	3
Family CERCOPITHECIDAE		
Papio ursinus	Chacma baboon	*

Order CARNIVORA		
Family FELIDAE		
Felis serval[1]	Serval	1
Felis lybica	African wild cat	*
Family VIVERRIDAE		
Genetta tigrina	Large spotted genet	1
Civettictis civetta	African civet	*
Family HERPESTIDAE		
Atilax paludinosus[1]	Water mongoose	2
Galerella sanguinea	Slender mongoose	2
Helogale parvula	Dwarf mongoose	2*
Paracynictis selousi	Selous' mongoose	*
Family MUSTELIDAE		
Ictonyx striatus	Striped polecat	1
Aonyx capensis	Clawless otter	*
Order TUBILIDENTATA		
Orycteropus afer	Antbear	*
Family Equidae		
Equus burchelli	Burchell's zebra	*
Order ARTIODACTYLA		
Family BOVIDAE		
Subfamily CEPHALOPHINAE		
Sylvicapra grimmia	Grey duiker	*
Subfamily ANTILOPINAE		
Tribe NEOTRAGINAE		
Raphicerus sharpei	Sharpe's grysbuck	*

Subfamily AEPYCETINAE		
Aecyperos melampus	Impala	*
Subfamily HIPPOTRAGINAE		
Hippotragus niger	Sable antelope	*
Hippotragus equinus	Roan antelope	*
Subfamily ALCELAPHINAE		
Sigmoceros lichtenstieni	Lichtenstien's hartebeest	*
Subfamily TRAGELAPHIDAE		
Taurotragus oryx	Eland	*
Subfamily REDUNCIDAE		
Redunca arundinum	Southern reedbuck	*
Kobus leche	Red lechwe	*
Order RODENTIA		
Family SCURIDAE		
Paraxerus cepapi	Bush squirrel	4
Family PEDEDITAE		
Pedetes capensis	Springhare	1*
Family MURIDAE		
Aethomys chrysophilus	Red veld rat	5
Tatera leucogaster	Bushveld gerbil	9
Mastomys natalensis	Multimammate mouse	4
Dendromys melanotis	Grey climbing mouse	1
Mus minutoides	Pygmy mouse	3

Family BATHYERGIDAE		
Crytomys sp.	Molerat	1
Order Lagomorpha		
Lepus saxatilis	Scrub hare	3

Chapter 8

MEASURING AND MONITORING BIODIVERSITY IN AFRICAN SAVANNAS:

CONCLUSIONS, RECOMMENDATIONS AND THEORETICAL ISSUES

F. P. D COTTERILL

8.0 INTRODUCTION

This chapter is organised into two parts: the first of which (incorporating Sections 8.1 to 8.5) emphasises the relevance of SAVSKILL in measuring biodiversity and providing applicable knowledge of the properties of biodiversity. What I consider to be the key recommendations in further developments of this programme are highlighted. The second part summarises theoretical issues of measuring biodiversity which are relevant to consolidating and building on Phase I. The objective of Part II is to explore the issues of how well biodiversity can be, or has been, characterised. The quality of our knowledge of the biodiversity in any landscape depends on how representatively and reliably it is sampled. The key issue here is how reliably do these subsamples represent the landscape's biodiversity in its entirety.

Preamble: Scientific Solutions to Environmental Problems

The 1980s and the early 1990s has seen the scientific community identify with the biodiversity crisis. Eldredge (1992), Wilson (1988, 1992) and Noss & Cooperrider (1994) have identified solutions to the problem, and emphasised that professional and realistic environmental management, requires a greatly improved knowledge of the dwindling biodiversity which has to, for the health of nations, societies and individuals, be wisely utilized. Solutions must focus:

1 Maintaining ecosystem processes, and their evolutionary potential, in both intact and modified ecological landscapes. This requires conserving the complexes of organisms which generate these processes today, and those likely to do so tomorrow and in the future.

2 Halting the extirpation of biological diversity, especially of metapopulations occurring habitat mosaics in ecological landscapes. These losses of species destroy unique biological information - irretrievable evolutionary products.

Many recommendations, notably the Second World Conservation Strategy (IUCN, UNEP & WWF, 1991) and the *Global Biodiversity Strategy* (WRI, IUCN & UNEP, 1992) suggest activities by which different sectors of society to support wise use and stewardship of biodiversity. These recommendations have endorsed the conservation, and especially the sustainable use of biodiversity. It is strange that the vital requirements to assess and monitor biodiversity, let alone know, what biodiversity is to be used or conserved escapes priority, and is grossly unsupported. And this is despite unambiguous strategies for development agencies (notably NSF, 1992) being available, which identify priorities in scientific research on biodiversity.

The Development of Theoretical Ecology

Schulze & Mooney (1993) and Sandlund & Schei (1993) are two of many theoretical treatments reviewing aspects of the interface between theoretical biology and biodiversity management. Similarly to the increasing fragmentation of ecological landscapes which generate our concern, consensus and realistic research has

been obfuscated by a disturbing fragmentation in ecology, and other life sciences, into numerous subdisciplines. It has taken a long time for theoretical biology to orientate itself towards the imperative need for scientific characterizations of biodiversity in ecological landscapes - both intact and human derived landscapes.

Disagreement and constructive criticism are normally signs of a healthy science; but, as Botkin (1991) argues, refinement of the scientific strengths of ecology has been derailed by adoption of, and subscription to, vague concepts (such as competition theory and allegiance to a balance of nature), whose origins lie in surreal misconceptions of the natural world. This problem of incoherent concepts has been identified by other authors reviewing the state and future directions of ecology (Pimm, 1991; Peters, 1991; Shrader-Forchette & McCoy, 1993). The scientific problem is that ecologists, until recently, have been undecided over what they are actually trying to measure and understand.

As examples of a mending of this uncertainty, two publications, (Hannson, *et al.*, 1995; Jones & Lawton, 1995), summarise a swelling research paradigm in ecology, which should contribute toward more objective characterizations of biodiversity. The proposed All Taxa Biodiversity Inventories (ATBI's; Janzen & Hallwachs, 1993; Harper & Hawkesworth, 1994) are unprecedented attempts at encompassing studies of entire ecological landscapes. These recent advances respectively provide theoretical vigour and practicable direction to similar research agendas for ecology, such as those of the Sustainable Biosphere Initiative (Lybchenko, *et al.*. 1991). This progress provides much needed direction to ecologists, and is allied to the consolidation of conservation biology (Hunter, 1994). The fledgling National Biological Service in the US (NRC, 1993; Babbitt, 1995), and Costa Rica's national biodiversity inventory and its growing biodiversity industry (Janzen, 1991; 1992), are developments which biologists and other nations can learn from. Allied to, and underpinning all ecology, biosystematics has received a sorely needed injection of direction and a global mandate in the form of Systematics Agenda 2000 - to chart the biosphere (Anonymous, 1994). Nevertheless, left unchecked, the shocking neglect of systematics and taxonomy, and especially the extirpation of the taxonomic resources, on which all biology depends, will create most serious problems for ecology and all other life sciences (Cotterill, 1995, *in press*; Wheeler, 1995).

PART I

8.1 RELEVANCE OF SAVSKILL TO BIODIVERSITY STUDIES

1. The Biodiversity Foundation for Africa's SAVSKILL programme can provide a scientific assessment of biodiversity. This complements initiatives elsewhere in the world (see for example: Stork, 1991; di Castri, *et al.*, 1992; Janzen & Hallwachs, 1993; Longino, 1994). SAVSKILL integrates museum-orientated taxonomy and ecology. Taxonomists, seeking elucidation of the origins of populations, research historical phenomena in seeking to organise biogical variation within and among species (most biological collections reflect this bias). Conversely, ecologists seek to understand the interactions among organisms and their environments. Taxonomists collect representative samples of populations, whilst ecologists measure relative abundances of organisms and their cycling of energy and matter. Biodiversity research has to characterize both these interrelated phenomena if questions critical to the properties, and the future, of organismal and ecological biodiversity are to answered. With precedence on biosystematics, SAVSKILL focuses on the biology of whole organisms, a neglected scientific discipline which as Cracraft (1995) has emphasised, needs considerable investment, especially in developing countries.

2. The data on the identities and abundances of a wide diversity of organisms from Kalomo, are examples of the information which biodiversity studies need to collect. When analyzed and summarized, these data produce basic taxonomic and ecological knowledge to support decisions in environmental management.

3. Monitoring representative components of savanna ecosystems, which in this case form extensive watersheds of the Zambezi Basin, is essential to generate a fundamental knowledge of the complexes which generate and maintain ecological processes. It requires accurate descriptions of species' diversity and abundance, and clear understanding of which ecological processes maintain the integrity of these landscapes.

   Assessment and monitoring of comparatively intact ecosystems constructs a baseline against which human-modified landscapes can be compared, and human impacts on biodiversity assessed. These comparisons are obviously important, because agroecosystems are derived from savanna landscapes. Developing and refining a methodology (consisting of standardized sampling protocols and techniques) to assess and monitor biodiversity is the first step (Stork, 1994).

4. The value of this knowledge lies in comparisons between measurements; both within and between sampled sites. If inventories are repeated in a standardized manner, the resulting information will describe ecological biodiversity. It is crucial that comparisons and extrapolations can be reliably applied to these data (di Castri, *et al.*, 1992; Colwell & Coddington, 1994). Information generated from monitoring intact ecosystems is fundamental to generate basic scientific knowledge of the biosphere (Callahan, 1984; Miles, 1994; Cracraft, 1995; Condit, 1995). This report presents a partial assessment of miombo biodiversity, and quantifies relative abundances of indicator taxa. Inventories of species lists are limited to within a Study Site, with standardized measurements of relative abundance coordinated within a smaller Intensive Study Area (ISA). These data are a precursor for future comparisons.

8.2 ELUCIDATION OF ECOLOGICAL MECHANISMS AND THE APPLICABILITY OF BIODIVERSITY KNOWLEDGE

Representative monitoring of a spectrum of biodiversity can demonstrate that ecological processes have changed. Such information obtained from the monitoring of indicator species merely tells us that the ecosystem has changed, but does not say why this is so. Experimental manipulations, if carefully planned and executed, will reveal deep insights into these mechanisms.

Manipulative experiments are essential to elucidate mechanisms which change and maintain the properties of biodiversity. Field experiments on miombo savanna will considerably complement descriptive monitoring. The singular benefit of these trails is to extend the predictive power of ecological knowledge, and thus its scientific and practical relevance.

For SAVSKILL, manipulative experiments should mimic human impacts on ecosystems. They must be planned and performed under controlled conditions. Many authorities (including Hurlbert, 1984; Hairston, 1989; Gurevitch & Collins, 1994; Osenburg, et al., 1994; Underwood, 1994) have reviewed the protocols and design of field experiments, with respect to the scientific relevance of results they generate. The premise is that manipulations must adhere to robust experimental designs, which require careful planning. Using existing disturbances (especially recent and expanding human settlements) might provide convenient opportunities. Nevertheless, it is crucial that the integrity of control sites are maintained.

The singular objective of manipulative experiments is to test hypotheses. For SAVSKILL, these relate to the resistance and resilience of savanna ecosystems; identifying the key mechanisms which determine properties

of biodiversity, especially responses of these systems to disturbances. It is expected that the principle hypotheses for testing in experimental plots will be derived from the insights derived from monitored ISA's, which would also constitute controls for manipulated plots. Interspersion, and geometry, of both types of plots, must be designed to be complementary. Experiments must obviously mimic the spatial scale of human disturbances, but in a controlled manner in which treatments (mimicking disturbances) are replicated.

The biodiversity in manipulated plots must be assessed and monitored using exactly the same standardized methodologies applied to ISA's. Monitoring of both experimental and control plots must also be performed at the same time for meaningful comparisons. Over the longer term, this synergy of descriptive and manipulative investigations will provide hitherto unavailable insights into the persistence of ecological complexes in savanna landscapes.

8.3 EXTRAPOLATIONS FROM LOCAL DATASETS TO LARGER SPATIAL SCALES

As SAVSKILL currently stands and its future development is expected to proceed, derived knowledge of savanna biodiversity will remain limited to the spatial scales on which data collection is focused (less than 1 km). Yet, many macroprocesses in ecosystems, especially water cycles, extend across watersheds through adjacent habitats. These habitats differ strikingly in their biological and physical properties.

It is unclear how many intensive study sites are needed to accurately and representatively characterize biodiversity at large spatial scales. SAVSKILL's Study Sites (with embedded ISA's) must be replicated within a larger landscape to generate an overview of properties at regional scale. Extrapolating the results to predict changes in biodiversity and effects of human impacts at spatial scales over 1 km and beyond is very challenging. Additional knowledge is required:

1 Detailed mapping of landscape composition and geometry, to incorporate different habitats and objectively describe their distribution, such that assemblages of interlinked habitats can be zoned as ecoregions. Depending on management requirements, landscapes will be mapped at various scales (ranging from 1:50 000 and 1:250 000). These reviews depend heavily on remotely sensed data, especially satellite and aerial photographs. If this interpretation is to be of scientific relevance, it must be validated by expert "ground-proofing". Final maps should be compiled in a geo-referenced GIS to allow incorporation and comparison of other spatial information (including cadastral, geology, socio-economic and independently derived biological datasets). Conversion of spatial data to electronic format requires very thoughtful planning (Montgomery & Schuch, 1993).

2 Expansion of the SAVSKILL methodology to wetlands and other vegetation types (especially mopane woodlands and dry forests on Kalahari Sands). Monitoring of aquatic systems will have to incorporate additional target taxa, including Ephemenoptera, Odonata and fishes.

3 Maximum use should be made of available historical data to build a descriptive knowledge of landscapes extending to regional scales. For example, the ecology of mopane woodland is comparatively well understood (Timberlake, 1994), and available knowledge on monospecific stands could tentatively support realistic predictions for management decisions.

4 Landscape ecology has been dominated by descriptive studies, at the expense of mechanistic and experimental approaches (Wiens, 1992, 1995). More rigorous experiments at these larger scales are very necessary, particularly to interpret the consequences of rapid and widespread habitat alteration, and especially those of habitat fragmentation (Janzen, 1986).

5 Holling (1992) suggests that population dynamics of multiple species assemblages be monitored across a range of spatial scales. This is a challenging task. Nevertheless, SAVSKILL could analyze certain data sets, especially from permanent vegetation plots (if they cover sufficiently extensive areas) and use internested "spatial windows" to test hypotheses on spatially-linked variation in plant dynamics.

6 A more encompassing strategy is to rely on an ATBI dataset, whereby exhaustive inventories of 100 000 Ha of terrestrial habitat will generate presently unavailable information, and allow many of the analyses discussed in preceding paragraphs. An ATBI is obviously expensive and time consuming, but not excessively so, considering the considerable economic and scientific benefits of the knowledge it will produce (Janzen & Hallwachs, 1993).

8.4 FURTHER CONSIDERATIONS FOR THE SAVSKILL PROGRAMME

Logistical Support for Field Work

It is essential that the spectrum of allied inputs required in multidisciplinary research is effectively managed and planned. Carefully planned logistical support of field work is crucial. Sustained monitoring of ecosystems, and most importantly the scientific relevance of generated results, relies on sustained management of monitoring activities to maintain the quality of all data.

Environmental Awareness

Ulfstrand (1992) maintained that a priority in biodiversity conservation is to raise awareness of the relevance of biodiversity within society. An integral policy of Phase One exposed students (high school pupils - aged 15 to 18) to these issues. Experiential education, of all participants in SAVSKILL operations, especially in the theory and practice of biodiversity sampling, is a most valuable exercise. Benefits accrue to all high school pupils, technical and research personnel in the value of multidisciplinary biology, and the importance and relevance of ecology and biosystematics.

Training and Education

This aspect of SAVSKILL needs to be developed and further integrated into the programme. Training activities need to be formalised: a useful development would be to provide SAVSKILL fieldwork activities as complementary modules and activities to formal courses for all involved, whether participants are undergraduates, technical staff, or post graduate students.

Technical Skills

In Phase One, BFA's experiential training focused on improving technical skills, especially from natural history museums and herbaria in African countries. The Kalomo study confirmed that many of the participants involved in fieldwork possessed a great wealth of practicable experience, especially in collecting and processing biological specimens. They have great potential to provide sorely needed training to new recruits in this threatened discipline.

Professional Biologists

Most importantly, the focus on the diversity of entire organisms (and not just on their macromolecules or tissues) is of significance in training current and future biologists to appreciate the properties of the living world. The widespread disregard for ecology, biosystematics, and natural history, and the biased support for reductionist subdisciplines (namely molecular and medical biology) has created distorted perceptions of the environment and biology. The scope of molecular biology to solving environmental problems is, at best, exceedingly limited. This is simply not its theatre of investigation. Much reductionistic biological research, for example characterizing macromolecules yet ignoring their phylogenetic interpretation or relevance (see Lubec, *et al.*, 1994 for a notorious example, Cotterill, *in press*), provides no contribution to scientific understanding of a complex natural world. Many molecular biologists appear ignorant of the historical imperatives of biology (Gould, 1986; Cotterill, 1995), which is the substance of systematics and ecology, and is a central challenge to these biologists. More scientists, both potential and active, need to be exposed to these issues and tensions in biology.

Systematics is the most essential but most neglected science (Cotterill, 1995; Wheeler, 1995). Of all continents, Africa has the most inadequate infrastructure and support for the biodiversity sciences, and especially lacks experienced and qualified scientists to do this research (Cracraft, 1995). Future operations in SAVSKILL should devote a major commitment to direct training of advanced undergraduates and postgraduates in biodiversity measuring and monitoring. Furthermore, the skills to accurately and efficiently name organisms are exceedingly scarce, especially for tropical regions. BFA considers the development of these skills a priority. SAVSKILL provides an ideal framework and abundant opportunities for experiential training of young taxonomists. Self motivated undergraduate and postgraduate students should become actively involved in field work, and increasingly participate in analyses of biodiversity information generated by SAVSKILL. This will obviously reduce what Janzen (1993) terms "taxonomic roadblocks.

8.5 CRITICAL DEVELOPMENTS NEEDED IF BIODIVERSITY MANAGEMENT IS TO SUCCEED

This final section of Part I endorses the need for a regional expansion of an ecological monitoring programme for central Africa. Data collection and consolidation should incorporate existing herbaria and natural history museums, which will require tremendous corporate restructuring to perform professionally.

The prevailing focus on monitoring protected and only comparatively intact, ecological landscapes is insufficient. Modified (human created) ecosystems (agroecolandscapes and wetlands) must be managed to maintain their integrity, within a framework of larger, interconnected landscapes (Lovejoy, 1994). This need is prescribed by the Convention on Biological Diversity - which many African nations, notably those dominated by savanna landscapes, have ratified. The following developments are seen as important to scientific support of biodiversity management at a regional scale:

- An infrastructure is needed to survey and monitor ecosystems with the requisite scientific thoroughness. To avoid unwanted mistakes and wasted time, we must borrow ideas and solutions from around the world: including the National Biological Service in the USA (NRC, 1993); ERIN in Australia (Richardson, 1994); and INBio in Costa Rica (Gamez, *et al.*, 1993).
- Ecological landscapes must become thoroughly known and understood. Successful ecosystem management - and thus biodiversity conservation, maintaining ecological integrity - requires recognition and maintenance of biogeophysical processes, occurring across a range of scales in space and time. Practicable acknowledgement of this state of affairs requires a substantial philosophical shift in thinking: many people (including many involved in environmental affairs) may need to explore unfamiliar mental territory. The focus on elucidating hotspots of biodiversity at a global scale, with highly inadequate datasets (Section 8.8) typifies a central theme of the biodiversity paradigm. This fervent search for biodiversity hotspots may be important, but it has obfuscated attempts to know and maintain biodiversity in all habitats across a range of spatial scales.
- The premise is that professional environmental management, founded in rigorous science, must extend across all ecological landscapes, regardless of their form of land use. The overriding objective is to maintain the ecological integrity of these systems. All management and consumptive uses of biodiversity must be based on an objective knowledge of its dynamic properties (their composition, structure and dynamics of ecosystems). Most importantly, we must understand how different ecosystems respond to stresses and disturbances, which demands a scientific knowledge of their properties of resistance, persistence and resilience, as based on the elucidation of principal ecological mechanisms.
- Ultimately, land owners and users of biodiversity will have to pay for knowledge generated from monitoring biodiversity. This being the information to support environmentally sound decisions and maintain the basis

and sources of their wealth and livelihood. Governments cannot continue to shirk responsibilities and commitments for professional management of the ecosystems on which citizens' well being, and ultimately, national and regional economic security depends.

Raising the perceived value of biodiversity is of quintessential importance. This requires that knowledge, and most especially, biological information and products derived from "wild" organisms, be marketed to society in a diversity of ways. These enterprises require considerable investment in biodiversity prospecting (Janzen, 1991, 1994). The creation of a vibrant biodiversity industry is an urgent priority in tropical countries, especially in Africa. SAVSKILL's datasets will contribute an injection of valuable knowledge into such an enterprise.

PART II

8.6 KEY REQUIREMENTS FOR BIODIVERSITY RESEARCH

- Efficient and successful biological research depends on a spectrum of human skills; including experienced technicians, skilled biologists and information managers in both field and laboratory. Before field work can even begin, thorough attention to research strategy, and the careful design of sampling protocols, is vital.
- An important determinant of success in any scientific study of biodiversity is the availability of human skills to sample biodiversity. An equal challenge is managing and interpreting the deluge of complex information rapidly generated by biodiversity inventories. The ultimate filter, governing the quality of information produced in all inventories and ecology, and thus the quality of knowledge produced by any biodiversity research, are taxonomic skills. Expert taxonomists are essential to accurately and efficiently identify, and classify target organisms.
- Overall, scientific studies of biodiversity centres on collating, analyzing and disseminating complex information. Characterization of biodiversity must be accurate and objective, and rely on clearly defined biological concepts. Any such enquiry requires the collation, analysis and storage of biological information, and equally importantly - to be scientific - these original data must be open to refutation. All biologists should understand the framework of protocols and minimum standards which are prerequisites for successful biodiversity research.

8.7 MANAGEMENT OF BIODIVERSITY INFORMATION

Biodiversity research orientates around the characterization of a diverse assemblage of objects. Each described object (organism) is inherently complex. In absolute terms, objective characterization and thus thorough description of just one organism would require processing a very large quantity of information. Furthermore, requirements to collate, process and store information - its management - increases exponentially as the scope of an investigation into biodiversity expands; to describe individual properties of a greater variety (and numbers) of organisms and their ecological interactions.

In a hypothetical situation, a complete characterization of all biodiversity, occurring in one sampled portion of the biosphere, would entail collating, processing and disseminating awesome amounts of information. Total characterization of all biodiversity in even a small sample (say a few cubic metres of savanna habitat, especially the soil) is impossible under present circumstances. So, biologists have to be selective in their investigations

of biological phenomena. Only subsets of information can be measured and recorded. These constraints dictate that any characterization of biodiversity can only sample selected portions of ecological complexes. Furthermore, descriptions of target organisms must also record only limited information on their properties. These choices must also consider the additional costs of repeated samples. A common objective is to compare different properties of biodiversity in space and time, and so obviously measurements must be repeated. The crucial decisions are choosing which subsets of the biotic assemblage, occurring in an ecological landscape, to sample. This introduces the challenging problem of representation (discussed in detail in Section 8.8).

Three Categories of Information

Collection and management of biodiversity information follows a system of procedures and processes. For any Biodiversity Information System (BIS), the research objective is to generate and disseminate scientific knowledge. The biological information collected to characterize biodiversity falls into three categories:

- Specimens - of preserved organisms; stored in collections for future reference and refutation. The entire organism is not always preserved. And portions of an entire organism (skeleton, genitalia, nucleic acids, epidermis, and other tissues) may be preserved separately.
- Inventory Data - associated with specimen collection (attributes of their occurrence in space and time at collection), and any environmental, ecological and behavioural data on sampled (not collected) organisms. All other biological data (including images and sound) in magnetic or optical media are included in this category.
- Summarized Information, the collated, analyzed summaries of biological information. In their final form, analyzed information (summaries of specimen and inventory data) is typically disseminated as peer reviewed publications of scientific knowledge.

Storage of the three different types of information differs. The most representative way of storing specimens (information in preserved organisms) is to preserve organisms for future reference in an environment which minimizes degradation of biological tissues. Maintaining the integrity of natural science specimens is a mammoth challenge to museologists (Duckworth, *et al.*, 1993). Collectively, natural science collections preserve a tremendous diversity of historical information. Worldwide, these collections are dwindling, and are very poorly preserved. This global crisis is extirpating irreplaceable biological information (Cotterill, *in press*). SAVSKILL must evaluate conditions under which its collections of biological specimens are preserved, with the goal of guaranteeing their integrity.

Biological information is nearly always integrated with fields of physical information (meteorological, spatial, geological, cadastral, etc) in printed and electronic media. Physical data may be collected in the same situation with biological investigations, or derived from independent sources for analysis.

Inventory data and scientific knowledge are traditionally stored and disseminated by mechanical means. The printed medium of information management is being increasingly complemented by electronic technology. Managing biological information in electronic media considerably facilitates its storage, analysis and dissemination. Nevertheless, efficient and reliable management of biological information in electronic media requires very careful design and management of biodiversity information systems. Their operation depends on professionally assembled equipment and especially human skills. Some aspects of a Biodiversity Information System, to support BFA's corporate objectives and activities, have been outlined (Cotterill, 1994).

A Biodiversity Information System

As noted in Chapter 2, and as the individual summaries of results clearly show, the most valuable attributes of SAVSKILL's dataset from Kalomo, lies in its simultaneous description of a spectrum of biodiversity. Any such biological information is inherently historical and thus irreplaceable. Most importantly, the relevance of this

information will increase as monitoring studies are repeated through time at the same localities. It is, therefore, crucial that the integrity of these data be securely maintained in an electronic medium (secured by hard-copy backups) for efficient retrieval. Efficient access to, and analysis of, biodiversity information is crucial to future comparisons.

Professional processing of biodiversity information, from its field collection to dissemination into the sphere of scientific publishing, is vital. The singular objective of professional management of biodiversity information should be to maintain its integrity and maximize the efficiency and accuracy of operations producing scientific knowledge, now and into the future. These requirements apply equally to specimens, inventory data, and scientific publishing. The following operations are essential to achieve professional standards and efficiency in information management:

1 Objective and thorough description of existing methodology by which biodiversity information, on each target group in ecological landscapes, is collected and managed: initial processing; field storage; processing in laboratory; storage in laboratory; analysis and comparison by researchers; publishing and dissemination. These different descriptions will produce different records, and their nested fields, constructed for each specimen and the attributes of each field.

2 An encompassing requirement in all biodiversity research, and information management, is the spatial attribute (including the specific scale) of all collated records. This geo-reference is a primary data field, which is invariably a focus of all analyses of biodiversity information and its use in management.

3 The procedures, whereby target components of biodiversity are sampled and collated information managed (as elucidated in 1), must be professionally described in terms of the structures and data flows in information models. Commonalities and incompatible data structures of each record type must be recognized and accommodated in an integrated BIS. Standardization and sharing of common fields (especially geographical locality) is critical, if comparisons among and between target organisms are to remain possible.

4 Generate a set of data standards describing essential properties of the attributes (fields) for collected data, and define methods used to sample target groups. These standards must be maintained for to all future inventories. Their adoption will require that these standards are gazetted, with adherence to them enforced through the contracts binding BFA operatives. Dangerfield (Chapter 4) recommends publication of "cookbooks" to detail sampling methodologies. These are ideal vehicles to communicate data standards, and should include these protocols as a central component of individual methodologies. These guidelines should illustrate commonalities among existing datasets for different target taxa, as part of the overall SAVSKILL methodology.

With the exception of the permanent vegetation plot and insect sampling, existing management of **electronic** information in Phase I of SAVSKILL has been based on idiosyncratic methods with scant consideration to the integration of individual datasets. This state of affairs considerably obfuscated, and thus delayed, the production of this final report. Although most data were available in electronic format (Word processed files, and spreadsheets), integration was still tedious and in some cases required that raw data be entirely recompiled. Not all operators fully appreciate the imperative requirements for standardized protocols for data collation and storage, especially in electronic formats. These problems will constrain efficient and reliable management and dissemination of integrated datasets. The problem will exacerbate as databases increase in size, and especially in complexity. Solutions to this problem will require implementation of the operations detailed above.

Principles of Biodiversity Information Management

These exceedingly demanding challenges and sacrifices required in the scientific characterization of biodiversity dictates that all research, pertaining to the assessment, experimentation on, and monitoring of, biodiversity must:

1 Sample biodiversity using, when they are already available, standardized methodologies (sampling designs, protocols, techniques) for target taxa. Studies which ignore these requirements generate data of scant scientific relevance. For example, scientific characterization of arboreal biodiversity of large trees, using canopy fogging (not yet attempted in miombo savanna) would adhere to the above guidelines, and furthermore adopt the minimum sampling standards used by Stork (1991). The Natural History Museum in London has already carried out over 70% of all canopy fogging worldwide (N. E. Stork, *pers comm.*).

2 Important inputs, essential to the ultimate quality, and scientific relevance, of published information, are: efficient and accurate sampling; professional collection and preservation of voucher specimens, accurate and verifiable identifications of these specimens. Most importantly, all voucher specimens must be professionally stored in recognized collections for future needs.

3 Scientific collection of biological information requires that reported findings (especially organisms' identifications) be open to refutation (supporting the axiom of the scientific method). This requires that collected organisms be preserved into perpetuity.

To conclude this topic, professional management of all biodiversity information collected during SAVSKILL's research is vital. Storage of information, whether this be in the form of specimens, inventory data and analyzed results, in a stable, secure, and accessible format is of paramount importance to the scientific quality of the programme - namely the relevance of the knowledge it produces.

8.8 REPRESENTATIVENESS OF BIODIVERSITY KNOWLEDGE

SAVSKILL's focus on a spectrum of target taxa - representing a range of functional groups - improves on single group approaches (on Families or Orders of vertebrates, or invertebrates). The representation of ecological macro-processes by these focal groups, and representative samples of the indicators themselves, requires closer examination. Discussion of this complicated topic focuses on 50 Ha of ISA, in miombo landscape, within the larger Study Site.

Characterization of biodiversity is organized into three levels, from the genetic to the ecological, with most biodiversity research focused on properties of organisms (Harper & Hawkesworth, 1994). The accommodation and representative characterization This problem applies to any biological study carried out a landscape scale, and representation of microorganisms which have disproportionate contributions to ecological processes, is especially challenging (Chapter 2; Golley, 1993; Brown, 1994).

The complexity of ecosystems, whose organismal biodiversity is so diverse and very poorly known, dictates a compromise in any biodiversity study. Biologists need reliable indicators of total biodiversity - its composition, structure and dynamics - and seek practical solutions to collate this information (Pearson, 1994; Stork, 1994). Representation of biodiversity requires appropriate indicators. Characterizations of sampled organisms indicate the complex properties of biological assemblages, and must allow for comparisons between localities. The protocols to select suitable indicators have to consider a variety of criteria (Pearson, 1994). Indicators are site and phenomena specific, and their suitability as indicators appears to vary widely. It appears impossible to find and develop a set of indicators which universally estimate biodiversity throughout the biosphere (Huston, 1994). Focal taxa indicate the properties of biodiversity: either its taxonomic, and/or ecological attributes, which are both complex and interrelated issues. Taxonomic indicators summarize the phylogenetic properties of organismal biodiversity, whilst ecological indicators quantify the processes operating at larger scales in landscapes.

TABLE 8.1 Overview of different problems involved in the objective and adequate representation of the properties of biodiversity.

CATEGORY :	ecological	organismal / taxonomic
OBJECTIVE :	Quantify relationship between organismal biodiversity and macroprocesses in ecological landscape	Adequately assess composition of biodiversity in sampled portion of ecological landscape
EXAMPLE :	Reliable and encompassing understanding of water cycling in savanna soils	Objective characterization of biotic assemblage in chosen study area.
PRINCIPLE PROBLEM :	Representative sampling, at sufficiently large scales, of organisms involved in ecological macro-process (in this case water flux) and organisms living in soils, ground water and aquatic habitats.	Representative sampling and description of 100 000+ (or even millions) of undescribed taxa

Indices of Organismal (Taxonomic) and Ecological Biodiversity

Target groups of organisms have been used in attempts to summarise what biodiversity occupies local landscapes, nations, entire continents, and the biosphere. Many of these groups of taxa are chosen rather for convenient analysis, or aesthetic appeal, than for their reliable estimation of the properties of biodiversity - whether these properties are its phylogenetic diversity measures, biotic integrity or assessments of ecological macro-processes. As argued throughout this report, indicators of biodiversity cannot be chosen haphazardly, yet many groups (notably avifauna, e.g. Bibby, *et al.*, 1992) have been press ganged into this newfound role. The scientific relevance of such taxa needs to be critically reviewed, especially for studies which aim to objectively measure biodiversity.

Perhaps because humans are visually orientated primates, we tend to bias our attentions towards the conspicuous organisms, with subjective choices of study organisms dominating biodiversity measurements. Our gross neglect of organisms of more diverse and abundant taxa (especially in the microscopic realm) is extreme (Embley, *et al.*, 1994; May, 1994). Biodiversity researchers typically select tangible taxa (which are assumed to indicate the properties of biodiversity, *sensu lato*). This is undoubtedly based on the feasibility of sampling, identifying and classifying these organisms. This does not mean that this is a sound sampling strategy to reliably estimate the properties of the biosphere.

Two other problems can be identified in the choice and uses of biodiversity indicators. Firstly, selection may not clearly distinguish between indexes of the organismal and ecological components of biodiversity, yet this dichotomy may be critically important. For example, Bibby, *et al.*, (1993) attempted to use avifauna to identify hotspots of biodiversity *sensu lato* (as biodiversity is defined by the Biodiversity Convention, UNEP, 1992). The scope of vertebrates to represent, let alone allow scientific comparisons of phylogenetic, or ecological properties of biodiversity (especially across continents) is limited at best. Pearson & Cassola (1992) advocated the use of tiger beetles as a more encompassing index of terrestrial biodiversity to evaluate conservation priorities, and also do not specify whether estimates of organismal or ecological biodiversity had priority. Halffter (1993) suggested using scarab beetles to assess "ecosystem function" in terrestrial landscapes. Secondly, it

is rarely stated at what spatial scales a focal taxon is suitable as reliable indicators of certain properties of biodiversity.

TABLE 8.2 Some examples of Taxa used as indicators of biodiversity

TAXA	INDEX	CATEGORY	REFERENCE
Birds	Conservation Priorities	Organismal	Bibby, *et al.*, 1992
Fish	Biotic Integrity	Ecological	Lyons, *et al.*, 1995
Butterflies	Biotic Integrity	Ecological	Kremen, 1994
Scarab Beetles	Ecological Processes	Ecological	Di Castri, *et al.*, 1992
Angiosperms	Conservation Priorities	Organismal	Gentry, 1990
Angiosperms	Ecological processes	Ecological	Dallmeier, 1992

Characterization of Organismal (Taxonomic) Biodiversity

Taxonomic characterization of biodiversity centres on assays of species richness (Forey, *et al.*, 1994). Total taxonomic representation would describe all types of organisms in a studied portion of ecological landscape. Selected indicators provide indexes of overall species richness, for which using a single taxon is very unreliable. Nevertheless, though practically feasible to measure, such subjective choices are not taxonomically representative (Hammond, 1994). Adequate taxonomic representation of biodiversity, especially to identify geographical "hotspots", is a serious challenge to modern biology. Use of indicator groups, such as vertebrates, to characterize biodiversity for decisions on conservation priorities (at global and continental scales) is fraught with problems of taxonomic representation. These studies have virtually no relevance to ecological properties of the biodiversity they attempt to characterize. Furthermore, attempts to map any taxon of Afrotropical organisms at a continental scale invariably produces indexes of sampling effort and not summaries of biogeographical patterns (Fig. 8.1). Similarly, reviews of Amazonian biodiversity identified hotspots around intensely studied biological field stations (Pearson, 1994).

Biology's entrenched approach is to work at the bottom, or middle of phylogenies - ideally on well known Orders, Families and Genera of related taxa. It is instructive to turn this approach upside down, and assess biodiversity from the top down; to ask how many Kingdoms of each Domain are represented in a prescribed area of ecological landscape. To give realistic descriptions of biodiversity, the focus of analysis would be on organisms, or their genetic signatures (Harper & Hawkesworth, 1994). We would then have to review how many Kingdoms of bacteria are represented in the divergent Domains of the Archaea and Eubacteria (Woese, 1994), before beginning to examine the diversity of Eucarya. In turn, objective description of Fungi or eukaryotic organisms would require comparative representation of Phyla - measuring relative abundances of Arthropoda, Mollusca and Nematoda, for example. This surely is a more objective strategy, but also engages a more humbling perspective, as the traditional focus on Orders lies four levels below the encompassing characterizations of Domains (Embley, *et al.*, 1994).

Top-down characterization is technically demanding - especially if microbial fauna are to be adequately measured (Embley, *et al.*, 1994; Woese, 1994). Molecular methods to directly compare nucleic acids are

PAUCITY AND PATCHINESS OF SCIENTIFIC DATA

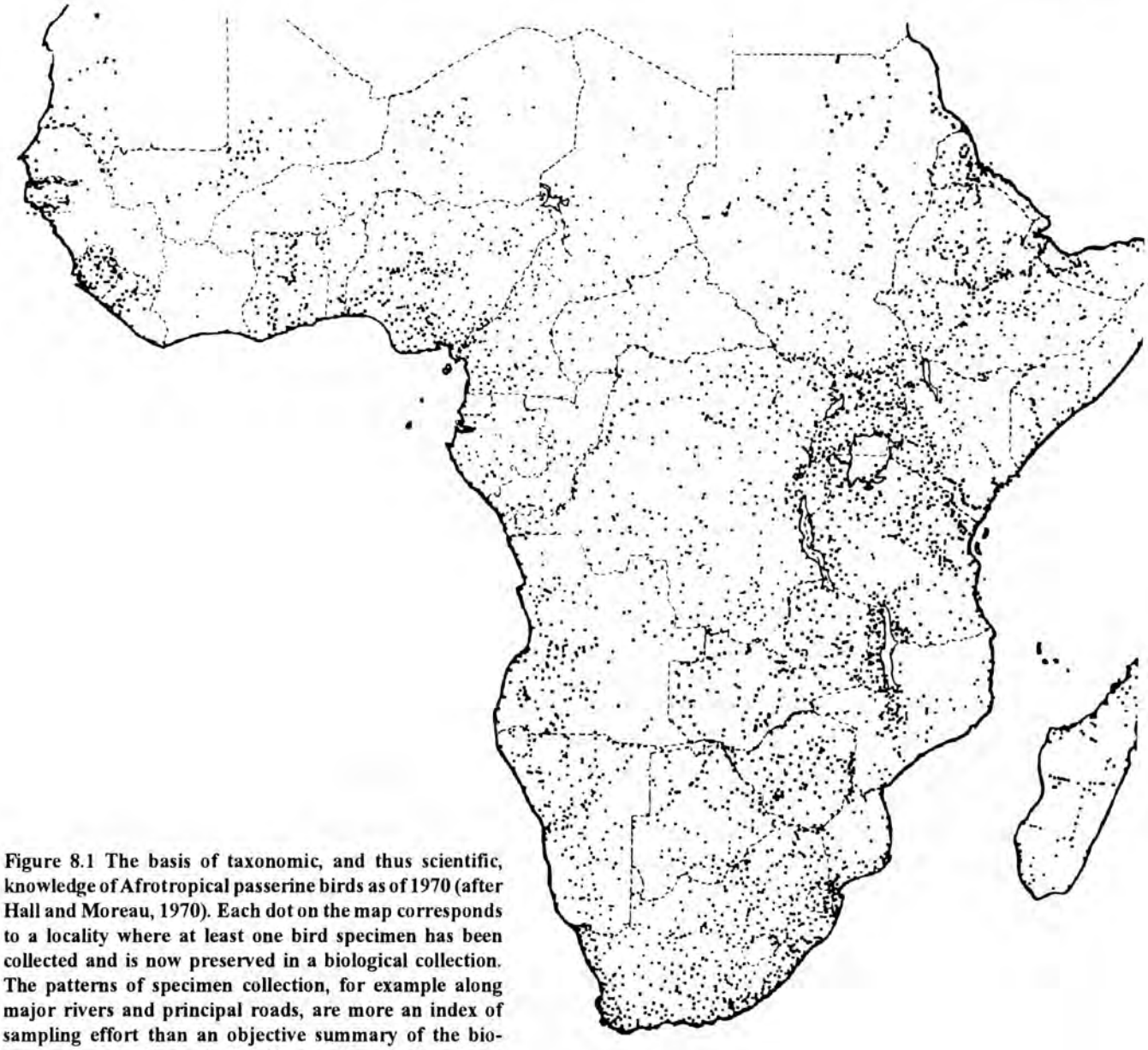

Figure 8.1 The basis of taxonomic, and thus scientific, knowledge of Afrotropical passerine birds as of 1970 (after Hall and Moreau, 1970). Each dot on the map corresponds to a locality where at least one bird specimen has been collected and is now preserved in a biological collection. The patterns of specimen collection, for example along major rivers and principal roads, are more an index of sampling effort than an objective summary of the biogeography of Afrotropical avifauna. Nonetheless, birds are widely considered to be the best known group of organisms.

essential to objectively describe microbial diversity, but representative descriptions of microbial faunas (to produce indexes of their ecological activity) in SAVSKILL would raise costs exorbitantly.

As noted by Hammond (1994), reliable taxonomic representation (for any study including an ATBI, All Taxa Biological Inventory) requires extrapolations from robust datasets to generate indexes of total species richness for prescribed areas of habitat. SAVSKILL is not attempting to compare conservation priorities of different habitats or landscapes, but it is primarily concerned with adequately representing ecological biodiversity. Evaluation of reliable indexes of ecological aims at total assays of species richness (sample the majority of taxa) in the functional group. Here, aspects of taxonomic representation are most relevant to SAVSKILL.

Characterization of Ecological Biodiversity

As only single measurements, the data collected in Phase I of SAVSKILL provide limited insights into ecological processes. Repeated inventories of a target group such as Lepidoptera (generating profiles of total and relative abundance) would produce an index of these organisms' roles in herbivory. In the same way, monitoring soil macrofauna provides an index of decomposition and thus nutrient cycling.

Ideal indicators of ecological biodiversity are functional groups which significantly contribute to ecological macro-processes, and can also be efficiently sampled and characterized. Biologists may have to reconcile with a state of affairs where such panaceas simply do not exist; and in the real world, this appears to be so. Prodigious effort is required to collect very large quantities of biodiversity information in order to reliably describe biodiversity. If this situation applies, realizing encompassing objectives of biodiversity research appears very daunting. To provide representative ecological knowledge; the following phenomena need to be monitored:

1 Macro-processes in the domain of investigation (typically an Intensive Study Area), including: primary production; decomposition; water and nutrient cycles. Interactions among target organisms in a different functional groups should reliably indicate the properties of macro-processes in the studied ecosystem. The available knowledge of tropical savannas (Lamotte, 1978; Menaut, *et al.*, 1985; Walker, 1987; Scholes & Walker, 1993) and terrestrial ecosystems generally (Holling, 1992) circumstantially suggests that existing targets of SAVSKILL (such as Lepidoptera, scarabs, soil macrofauna and vascular plants) are partially representative of these principal ecological processes.

2 To be realistic, monitoring programmes need to measure phenomena with more intermittent frequencies of occurrence. Such processes, such as mechanical disturbance (where large mammals are important), and ecological interactions, particularly pollination and predation, which influence the regeneration and reproduction of other organisms of functional significance, such as vascular plants.

3 Over longer time scales, knowledge of intermittent meteorological processes and stochastic events (especially fire) is vital. The serious frost, with extensive geographical impacts on south-central Africa in June/July 1994, is a pertinent example of an important disturbance event. (The incidence of killing frost is intermittent and erratic, typically occurring once in three to four decades, Scholes & Walker, 1993) These insights, intrinsically historical, provide crucial knowledge of the determinants of ecosystems' properties.

The contribution of a population to macro-processes in the landscape is inherently asymmetrical when compared to other species, which as discussed in Chapter 2, varies tremendously among species. A population's representation is determined by its functional traits and its more localized distribution in the domain where a macro-process (such as nitrogen cycling) occur. At proximal scales, patterns of organisms' abundances in space and time determines their relative contributions to macroprocesses. Influenced by both physical environments and species-dependent properties, individual organisms vary in their distribution and abundance in time and space. The ultimate determinants of an organism's ecological contribution lies in its activities - its different adaptations to obtain energy and modify its ecological neighbourhood, under prevailing

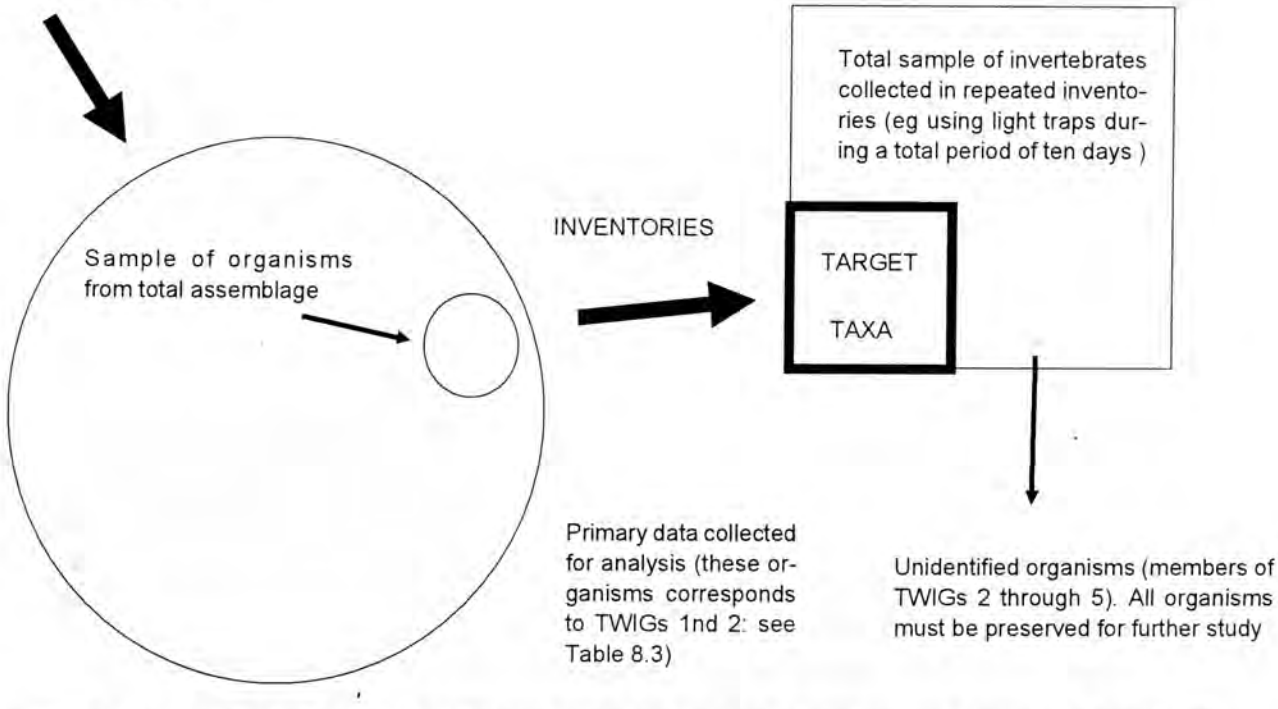

Figure 8.2 Schematic depiction of the representativeness of samples of target taxa as an index of overall ecological processes within the domain of an Intensive Study Area (ISA). (A TWIG is a Taxonomic Working Inventory Group, see Table 8.3 for further details)

environmental conditions. These specific differences (unique to individual populations) determines the role of an organism in an interaction web (see Chapter 2).

Representative ecological characterization should adequately represent the determinants (organisms' interactions) of major macro-processes occurring in the ecological landscape. Repeated assessments of this biodiversity should give an index of macro-processes. A schematic outline of the problem is shown in Figs 8.2 and 8.3. Faced with biological complexity it is most difficult to determine the functional groups on which one should focus sampling efforts, such that contributions of organismal biodiversity to the propagation and regulation of macro-processes are reliably measured. Application of control theory (Schulze, 1995) to the flux of energy and matter through ecosystems may be useful. Nevertheless, controls on energy flux through trophic webs involves alternating shunts and regulators, which perform in different ways under different conditions. Given this complexity, it is suggested that to be representative, characterizations of ecological biodiversity must satisfy the following criteria:

1 Monitor organisms at higher trophic levels, namely predators, where transfers of energy and matter through ecosystems are magnified. This focus on secondary consumers is insensitive to specific changes at lower trophic levels.

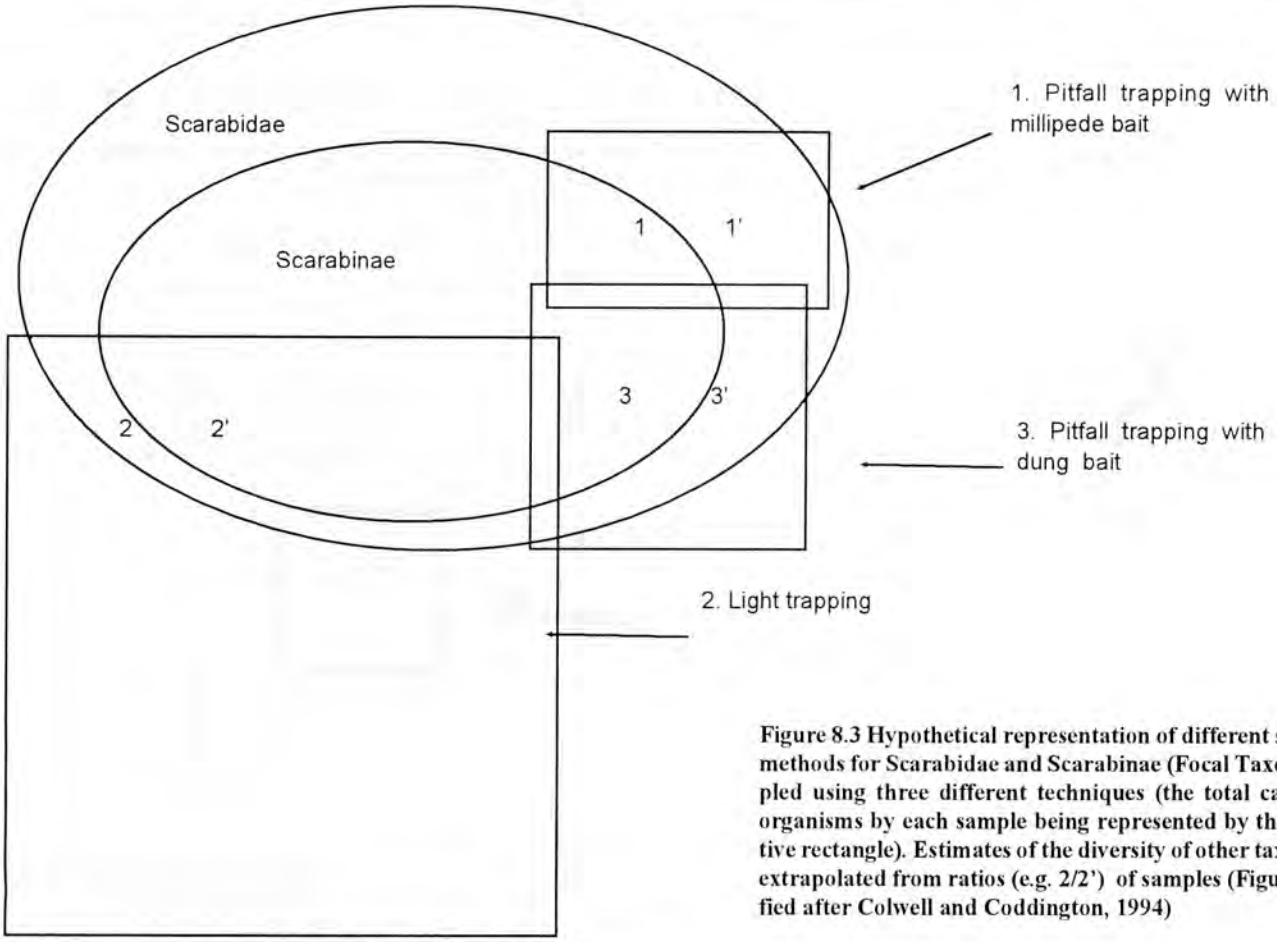

Figure 8.3 Hypothetical representation of different sampling methods for Scarabidae and Scarabinae (Focal Taxon), sampled using three different techniques (the total capture of organisms by each sample being represented by the respective rectangle). Estimates of the diversity of other taxa can be extrapolated from ratios (e.g. 2/2') of samples (Figure modified after Colwell and Coddington, 1994)

2 Monitor dynamics of autogenic ecosystem engineers (*sensu*, Jones, *et al.*, 1993). Monitoring vascular plants in savannas contributes significant data, not only of microhabitat availability and habitat structure, but provides an index of primary productivity, and energy and matter transfer through the ecosystem.

3 Monitor allogenic ecosystem engineers, including antbears, termites and other soil macrofauna (including beetle larvae, and scarab beetles). This provides an index of mechanical and chemical engineering in savanna soils.

4 Monitor highly diverse monophyletic clades. Beetle families (especially Scarabidae and Carabidae), in their occupation of many trophic levels and other ecological activities (e.g. ecological engineering and pollination), are ideal targets, but demanding of taxonomic resources. Statistical estimates (*sensu*, Colwell & Coddington, 1994; Fig. 8.3) of representation are of special importance to test these samples.

5 BFA should carry out a validation study to evaluate the relative contributions of target taxa to macro-processes within study areas. This is mostly efficiently determined by calculating the relative biomass of functional groups.

6 More revealing measurements would investigate carbon and nutrient (P, K and N) budgets and fluxes within the ISA, together with direct measurements of target organisms' roles in these processes. These characterizations of nutrient and energy cycles would be a major undertaking and require substantial commitments of time and resources. Such a study might be feasibly carried out by at least one parallel PhD study in concert with monitoring. The role of the microbial fauna needs to be investigated.

Colwell and Coddington (1994) review the options available to extrapolate from data collated in inventory samples. Statistical extrapolations from relative abundances of sampled species can estimate the diversity and composition of total assemblages. The statistical methods include the use of ratios (of known taxa to unknown), catch per/unit effort of sampling, and comparing complementary sampling strategies (Fig. 8.3). Gardiner (Chapter 5) demonstrated how sampling of bomacid moths versus butterflies differed in their representation of taxa, as based on catch per unit effort. It is extrapolations such as these which are vital to quantify the scientific relevance of SAVSKILL's datasets. It is essential to calculate confident estimates of the total diversity of target taxa.

The greatest challenge and barrier to understanding ecosystems is their inherent dynamics - their properties are always changing, in irreversible ways (see Brown, 1994). Ultimately, unambiguous understanding of representation (both ecological and taxonomic attributes) of biodiversity must be limited to stratified samples of the biosphere. Here, a carefully designed and exhaustive ATBI, allied with comprehensive descriptions of energy/matter flux through some 50 000 Ha of biodiverse landscape, will be essential.

8.9 SELECTION OF TARGET GROUPS FOR BIODIVERSITY ASSESSMENT AND MONITORING:

Relevance And Additional Requirements

This section discusses methodological details specific to sampling of target taxa. For SAVSKILL, consensus on which components of biodiversity to monitor was drawn from theoretical discussions and fieldwork (in July/August and December), complemented by the BFA workshop in November 1994. The considerable inputs and insights gained from the SI/MAB course at the Smithsonian, in May 1994, were also invaluable in identifying weaknesses, establishing priorities, and moving towards consensus. Whilst the data collected on the abundance of any taxon are inherently biased (Southwood, 1978; Kremen, *et al.*, 1993) successive inventories, with repeated use of standardized methodologies, delivers comparable and thus valuable insights into organismal and ecological biodiversity (Stork, 1994).

The results presented in this report were collected a toolkit of methods: which firstly; assess a spectrum of the organisms in an ecosystem; and secondly, allow accurate comparisons between independent results. Strengths, and weaknesses (requiring remedy), of the overall methodology of SAVSKILL's research are discussed:

Vascular Plants

SAVSKILL's characterization of the major structural components of savanna landscapes - trees - provides insights into availability of the arboreal habitat used by a large diversity of interstitial organisms. Knowledge of the structure and dynamics of vegetation is also vital to understand nutrient and water cycling, and their central role in the ecosystem as primary producers.

Assessment of trees is comparatively straightforward, although establishment of permanent plots is initially demanding in human resources and materials. It is suggested that permanent plots must be larger if they are to realistically assess the dynamics of plant communities in miombo savannas. Rarer tree species, occurring in Kalomo miombo woodlands, are not represented in the 1 Ha plot (Chapter 3). Larger plot areas will account for these rare species, which are often of ethnobotanical significance and harvested for such purposes.

Selection of plot sites, and sizes, is a biological exercise. The survey and physical establishment of permanent plots (and the larger ISA) is a logistical exercise. For efficiency, particularly to maximize return on expenditure,

these complementary activities should be performed independently. Mapping and marking plant stems should employ separate teams (at least three teams of five people each to establish a 10 Ha plot). Ideally, a team of technicians with a team leader (with museum or herbarium experience) to coordinate all data collection by the team: additional members would measure, tag and mark stems. The overall operation must be coordinated by a project leader (biologist) with the support of at least one information manager. This strategy would make plot establishment a far more efficient exercise.

The diversity and relative abundance of the plants comprising the herbaceous layer within permanent plots also requires assessment. Inventories of the herbaceous layer (grasses and small dicotyledons) are restricted to certain seasons, so logistical plans must accommodate this requirement. The botanical surveys, of all vascular plants, could ideally take place in late summer; when contracted taxonomists can carry out all identifications and necessary taxonomic work (including the collection of voucher specimens). Studies of the herbaceous layer must avoid artificial disturbances from sampling of other disciplines - especially trampling. Perhaps the best strategy is to set aside 20 x 20 m quadrants (within permanent plots), in a random design; exclusively for monitoring the herbaceous layer.

Macrofungi and Mycorrhizae

This important group was not assessed in any way in the Kalomo Study, as the late rains adversely affected the emergence of macrofungi. Assessments of macrofungi provide an index of mycorrhizal activity in the soil. Mycorrhizae, through their symbiotic relationships with plants' roots, with essential roles in supplying phosphorus and other elements to the plant (Read, 1993). Mycorrhizal research requires specialized microscopic techniques. Nevertheless, knowledge of their contributions to nutrient cycling appears crucial to assessing human impacts on terrestrial ecosystems. It is suggested that a direct index of their presence be developed.

Soil Fauna

Soil macrofauna, including scarab beetles, millipedes and termites, are important players in decomposer webs, recycling carbon and nutrients in the soil. As already emphasized, a representative knowledge of the properties of their relative abundance and contribution to decomposition is obviously valuable (Dangerfield, 1990; Stork & Eggleton, 1992; Chapter 4). Soil macrofauna can be directly monitored, although measuring the relative abundances of termites is very difficult, so an estimation of foraging activity of termites is the pragmatic option.

Representative taxonomic assessments of soil fauna, especially meso- and microfauna, are very difficult. Recent evidence strongly suggests that soils constitute the most diverse, and poorly known biological frontier (Andre, *et al.*, 1994). It is suggested that complete samples of soil fauna be taken, using a suitable extractive technique (see Andre, *et al.*, 1994) and preserved, as historical benchmarks, to complement immediate assessments of target organisms. The eventual characterization of these samples will prove, through time, to be most valuable to further research. They will be of immense value, once methods and taxonomic resources become available to characterize their composition. This would eventually evaluate the relevance, and biases, of SAVSKILL's inventories of target groups. These benefits will outweigh the additional work required to preserve these complete samples.

Terrestrial Arthropods

There are important groups of arthropods (herbivorous Insecta are a good example) whose species diversity is immense, and patterns of their abundance are extremely variable. A representative assessment of their relative abundance is too daunting a task to be comprehensively and repeatedly performed.

It is recommended that all invertebrate specimens be collected from all traps. To date, this has not been a clearly articulated policy. To maximize the scope and returns from sampling efforts, all invertebrates collected, for example in pitfall arrays and scarab traps must be routinely collected and stored for further analysis.

A technique suitable for a highly detailed (and apparently taxonomically representative) assessment of arboreal arthropods is canopy fogging (Stork, 1991). An abundant, widely distributed tree species (such as *Brachystegia spiciformis*) should be selected for intensive study in miombo. This could be carried out as a complementary exercise; as a PhD study, perhaps. Insights from canopy fogging would provide valuable insights into the arthropod fauna, especially if measurements are replicated.

Vertebrates

Relative abundances of both large mammals and birds need to be recorded in intensive SAVSKILL monitoring. An index of their abundance would be adequate and practicable. For example, recording large mammal sign would be a useful technique to compare relative abundance of nocturnal and large mammals between study sites. Such assessments of the avifauna could usefully compare SAVSKILL data with historical data (reviewed by Winterbottom, 1978).

8.10 TOWARD A COMPLETE CHARACTERIZATION OF BIODIVERSITY SAMPLES

SAVSKILL should develop and refine sampling methodologies which are complementary (*sensu*, Colwell & Coddington, 1994). The suite of methods - SAVSKILL's toolkit - circumstantially appears to be representative. In absence of an exhaustive validation study, this section provides suggestions to improve on the representativeness of samples at collecting diverse samples of target taxa. The postulated validation studies of SAVSKILL and suggestions in this section should increase representation of a spectrum of organismal biodiversity in savannas.

It has already been recommended that all organisms collected in arthropod samples be preserved, in addition to target organisms, with samples ("historical benchmarks") of soil being preserved. Archiving representative and complete samples should underpin SAVSKILL's research strategy. It is suggested that these preserved samples will realize considerable scientific benefits, especially of pitfalls and soil samples. The intensive study of a west African savanna (Lamto in Ivory Coast) strongly suggested that ecological activities of fungi and microorganisms (bacteria and unicellular Eucarya) dominated over those of all other animals in Guinean savannas (Lamotte, 1978). This state of affairs quite possibly applies to other savannas (including miombo). SAVSKILL needs to consider and account for this phenomenon in its on going biodiversity surveys.

The processing of taxa would benefit from the information processing strategy of an ATBI, where Taxonomic Working Inventory Groups (TWIGs) are established. Each taxonomic group (typically a Family) forms a separate TWIG. TWIGs are grouped according to the relative feasibility of characterizing different taxa. Feasibility of taxonomic characterization is primarily determined by the availability of taxonomic resources and the relative efficiency of taxonomists' research. TWIGs include both non-target and target groups (Table 8.3, Janzen & Hallwachs, 1993). A TWIG comprises the integrated set of sampling methodologies, collected specimens, and taxonomic experts to process and manage biodiversity information on focal taxa. As outlined above, information orientated around specimens and derived information, is essential. Each TWIG will require a Principal Coordinator to maintain and archive all information and direct research on focal taxa.

An example of the benefits of thorough inventories (with complete preservation of all specimens) and meticulous information management is the Swartkrans study in South Africa; the collecting site of famous hominid fossils (Brain, 1994). Sampling of cave deposits involved their precise mapping in 3 dimensional space, and a complete inventory and preservation of all the fossil objects recovered (no matter how inconsequential they appeared in the sieves). The eventual identification and classification of these artifacts yielded unprecedented insights into the palaeo-assemblage - especially its evolutionary origins. The final, and incomparably thorough, charac-

terization of Swartkrans subsequently required radical reappraisals of the stratigraphy of the complex cave deposit. A most significant benefit of painstaking data collection at Swartkrans was the discovery that hominids living in the cave had manipulated fire one million years ago.

Successful scientific characterization of Swartkrans' palaeofauna was made possible by meticulous inventory (with subsequent multidisciplinary research performed by many investigators throughout the world) of the diversity of fossils recovered (Brain, 1994). An equivalent example in ecology is the permanent vegetation plot on Barro Colorado Island in Panama. The detailed data (on over 300 000 stems in a 50Ha plot) collected on all plant stems has permitted robust extrapolations (founded in exhaustive datasets) to understand vegetation dynamics at larger landscape scales (Hubbell, 1994; Condit, 1995).

The Curse Of Inadequate Taxonomies

A considerable bottleneck limiting comparison of biodiversity information, especially at global scales, are inadequate taxonomies. For many Arachnida Families in the Zambesiaca region, there are no taxonomies whatsoever. This seriously weakens the relevance and comparison of datasets, especially between sites. Processing information on such poorly known groups is exceedingly difficult.

Producing universal taxonomies for target taxa should be a priority activity - in the continued SAVSKILL programme - which should proceed in parallel with inventories. Obviously, resources are required to generate sound taxonomic classifications. The principal costs are researchers' time, travel and communication. These are essential for taxonomists to review all relevant museum material and scientific literature. The alternative, for BFA to do nothing about inadequate taxonomies for SAVSKILL's important target taxa (especially in TWIGs 2 and 3) will create serious bottlenecks in information processing, which will in turn weaken the multidisciplinary dataset. A suggested route is to support PhD revisions of these target groups in partnership with relevant natural history museums [AMNH, CalaCAD, NHMB (Bulawayo), NHM (London), ROM, Smithsonian] and university institutions such as Rhodes University (South Africa) and the Durrell Institute in Canterbury, UK. For such major taxonomic revisions, access to Global Master Species Databases (see, Bisby, 1994) is essential.

Seasonal Effects

Seasonal variation greatly effects all properties of savannas varies considerably between seasons. A large number of studies and considerable natural history data demonstrate the majority of organisms to be most abundant and active during the hot, wet season (November to April). Consensus within BFA is that this is when inventories of target taxa occur. Such timing coincides with the pulse in primary productivity typical of savanna ecosystems (Rutherford, 1982). Nevertheless, with logistical problems, fieldwork during wet seasons is often problematic, with sampling interfered with by wet weather. Establishment of permanent vegetation plots, and other surveying activities should ideally occur during the dry season, when it is logistically feasible.

Inventories of target taxa to encompass seasonal variation and annual cycles would be of limited value in terms of SAVSKILL's objectives gained at considerable cost. A principal site, proposed by BFA, will be crucial for monthly monitoring of target taxa. Sampling of arthropods (and their biomass) using standardized light traps, would provide a baseline against which to gauge results of intensive inventories performed in hot, wet seasons. This would be of considerably greater value in detecting episodic emergences of invertebrates (especially herbivores) with significant ecological impacts. A sustained monitoring exercise would benefit greatly from maintained records of outbreaks of larvae, and similar episodic phenomena of ecological significance. Two parataxonomists (*sensu* Janzen, 1991) could perform such sustained monitoring, under professional direction, at the principal site. Equally importantly, meteorological data should be recorded.

Table 8.3 Hierarchial arrangement of Taxonomic Working Inventory Groups (TWIGs) in priority for taxonomic refinement. Feasibility is determined by the availability of taxonomic resources and the efficiency with which taxa can be characterized to species level. This classification for SAVSKILL adapted from Janzen & Hallwachs (1993)

TWIG / FEASIBILITY OF CHARACTERIZATION	TAXA	ATTRIBUTES
1 / FEASIBLE	Vertebrates, Butterflies, Vascular Plants, Scorpions, Bombycoidea, Macrofungi, Sphingidae	Taxonomic keys and experts easily available
2 / ACHIEVABLE	Selected Aranae, Formicidae, Cetioniinae, Scarabinae, Few Acari	Taxonomic Keys (accurate to species) incomplete; and experts limited and non-resident
3 / PROBLEMATIC	Millipedes, Fungi, Some Soil Macrofauna, Most Aranae and Acari	Taxonomic keys for identifications to genera unavailable. Too few experts at global scales
4 / VERY COSTLY	Millipedes,, Some Soil Macrofauna, Meso- and Micro-fauna in soil, Fungi	Taxonomies very limited. No experts resident in the Afrotropics
5 / YEARS TO DECADES OF WORK	Microbial fauna, Protists, Many parasites	No taxonomies. Practicably no experts. Sampling and preservation highly technical and problematic

A Final Word

In small but positive ways, the framework of SAVSKILL - together with practicable results presented in this report - points in the direction of pluralistic biology, focused on studies of organisms and their properties. This "whole-organism biology" relies heavily on museum-based taxonomy . The overall objective is to understand ecological biodiversity in order to support its management. Common currencies and requirements for realistic monitoring of biodiversity are a synergy and pluralism of theory and activity. This need applies to research designs, implementation and the scope and relevance of generated knowledge. To succeed, biodiversity research has to be pluralistic. Not only does the representative characterization of ecological assemblages require multidisciplinary investigations (to be representative) but the theoretical basis of this research depends on a synthesis between evolutionary biology and ecology. This requires teamwork and professional human resource management.

Without realistic support and action, endorsements and action plans, alone, are practicably useless. Biologists, the private sector, and especially governments, need to come to terms with the tightly interwoven requirements for monitoring ecosystems, managing the landscapes where ecological complexes occur, and for rigorous scientific enquiry into their properties. Further procrastination and indecisiveness will only compound existing environmental problems and severely hinder their solution. The consequences of continued apathy and disinterest, especially amongst policy makers, will be negative impacts on economies worldwide, especially on agriculture and human health. It is up to governments, and the private sector, to support integrated taxonomic and ecological research on biodiversity with the level of funding it deserves. They owe this requirement to their shareholders.

"The worst thing that can happen during the 1980s is not energy depletion, economic collapse, limited nuclear war, or conquest by a totalitarian government. As terrible as these catastrophes would be for us, they can be repaired within a few generations. The one process ongoing in the 1980s that will take millions of years to correct is the loss of genetic and species diversity by the destruction of natural habitats. This is the folly that our descendants are least likely to forgive us."

E. O. Wilson. 1988.

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Chapter 9

APPENDICES : PRIMARY BIODIVERSITY DATA FROM THE KALOMO STUDY SITE

Appendix 8.1 Georeferences for Permanent Plot (BFA01) and Sampling Stations at Kalomo Intensive Study Site

GPS coordinates for middle and each corner of the main vegetation plot.

16°58'37"S : 26°36'05"E 16°58'33"S : 26°36'03"E : 1464m a.s.l.

Middle of Plot 16°58'34"S : 26°36'06"E

16°58'36"S : 26°36'11"E 16°58'31"S : 26°36'09"E

Soil Fauna Monoliths

Arable Plot 1: 16°58'44"S : 26°36'37"E : 1 300m a.s.l.

Arable Plot 2: 16°58'59"S : 26°36'37"E

"Sandy" Plot : 16°58'50"S : 26°37'36"E

Butterfly Traps

101	16°58'38"S : 26°36'09"E
102	16°58'42"S : 26°36'10"E
103	16°58'45"S : 26°36'08"E
104	16°58'48"S : 26°36'09'E
105	16°58'51"S : 26°36'06"E
106	16°58'56"S : 26°36'11"E
107	16°58'59"S : 26°36'07"E
108	16°59'01"S : 26°36'10"E

Reptile Pitfall Array near Camp
16°58'59"S : 26°37'01"E

Appendix 8.2 Mensural data for 1 Hectare permanent vegetation plot (within 6 Hectare plot) collected July/August 1994, Kalomo, Zambia

BFA 01 HECTARE TREE PLOT, KALOMO, ZAMBIA, AUGUST 1994
TREE DATA AND POSITION

Plot	Quad.	No.	Species	DBH (cm)	X	Y	HT (m)	Notes	Basal Area (m^2)	Volume (m^3)
1	1	1	BRAC SPIC	33.6	0.15	20.80	15.5		0.0887	0.4124
1	1	2	PSEU MAPR	3.1	9.48	11.37	2.5		0.0008	0.0006
1	1	3	COMB MOLL	4.5	13.19	8.81	4.5		0.0016	0.0021
1	1	4	PSEU MAPR	3.2	14.19	7.28	2.0		0.0008	0.0005
1	1	5	BRAC XLON	43.0	14.13	8.30	13.5		0.1452	0.5882
1	1	6	BRAC XLON	43.2	14.38	8.55	13.5		0.1466	0.5937
1	1	7	LANN DISC	5.8	22.32	15.15	3.0		0.0026	0.0024
1	1	8	BRAC XLON	4.2	27.91	19.22	2.0		0.0014	0.0008
1	1	9	BRAC XLON	4.7	23.55	20.73	3.5		0.0017	0.0018
1	1	10	OCHN SCHW	4.3	18.60	26.41	3.0		0.0015	0.0013
1	2	1	BRAC XLON	4.2	0.57	19.50	3.0		0.0014	0.0012
1	2	2	MONO GLAB	3.2	2.49	19.20	3.5		0.0008	0.0008
1	2	3	BRAC XLON	3.3	6.15	15.00	3.0		0.0009	0.0008
1	2	4	BRAC XLON	3.5	6.31	15.67	3.0		0.0010	0.0009
1	2	5	BRAC XLON	3.0	6.69	15.00	2.5		0.0007	0.0005
1	2	6	BRAC XLON	3.5	9.48	11.28	2.5		0.0010	0.0007
1	2	7	BRAC XLON	4.4	10.90	13.01	3.0		0.0015	0.0014
1	2	8	BRAC XLON	5.2	13.57	7.39	4.0		0.0021	0.0025
1	2	9	RHUS	4.3	13.74	6.55	3.5	*	0.0015	0.0015
1	2	10	RHUS	3.5	13.72	6.55	3.0	*	0.0010	0.0009
1	2	11	BRAC XLON	4.6	18.63	4.06	4.0		0.0017	0.0020
1	2	12	BRAC XLON	3.2	19.32	1.10	3.0	*	0.0008	0.0007
1	2	13	BRAC XLON	4.6	19.37	0.85	3.5	*	0.0017	0.0017
1	2	14	BRAC XLON	4.6	16.65	8.86	4.0		0.0017	0.0020
1	2	15	BRID CATH	3.8	20.21	11.55	3.0		0.0011	0.0010
1	2	16	BRAC XLON	32.6	21.90	12.29	14.5		0.0835	0.3631
1	2	17	BRAC XLON	41.8	23.95	19.83	15.0		0.1372	0.6176
1	2	18	BRAC XLON	6.6	15.48	11.51	4.5		0.0034	0.0046
1	2	19	BRAC XLON	3.5	15.50	13.42	3.0		0.0010	0.0009
1	2	20	BRAC XLON	3.4	20.36	20.94	3.0		0.0009	0.0008
1	2	21	BRAC XLON	3.5	10.88	16.20	2.5		0.0010	0.0007
1	2	22	OCHN SCHW	3.5	15.52	22.46	2.5	*	0.0010	0.0007
1	2	23	OCHN SCHW	3.3	16.02	22.46	2.5	*	0.0009	0.0006
1	2	24	BRAC XLON	3.5	15.44	23.76	2.5		0.0010	0.0007
1	2	25	OCHN SCHW	3.6	18.78	27.25	2.5		0.0010	0.0008
1	3	1	BRAC XLON	29.8	6.65	13.61	11.5	*	0.0698	0.2407
1	3	2	BRAC XLON	23.4	7.00	13.61	10.5	*	0.0430	0.1355
1	3	3	BRAC XLON	3.0	9.89	14.66	2.5		0.0007	0.0005
1	3	4	JULB GLOB	20.7	18.32	4.36	9.0		0.0337	0.0909
1	3	5	COMB MOLL	4.1	20.97	15.45	4.0		0.0013	0.0016
1	3	6	JULB GLOB	44.2	21.24	15.70	14.5		0.1535	0.6675
1	3	7	BRAC XLON	4.0	16.00	16.12	3.5		0.0013	0.0013
1	3	8	BRAC XLON	3.1	14.48	16.11	2.0		0.0008	0.0005
1	3	9	BRAC XLON	3.2	15.27	17.55	2.0		0.0008	0.0005
1	3	10	BRAC XLON	3.3	9.28	20.65	2.0		0.0009	0.0005
1	4	1	BRAC XLON	25.0	9.24	21.35	11.0		0.0491	0.1620
1	4	2	BRAC XLON	3.9	8.70	14.60	3.0		0.0012	0.0011
1	4	3	BRAC XLON	4.0	12.83	8.09	4.0		0.0013	0.0015
1	4	4	BRAC XLON	56.9	23.24	14.50	16.5		0.2543	1.2589
1	4	5	OCHN SCHW	3.4	13.36	17.64	2.5		0.0009	0.0007
1	4	6	BRAC XLON	42.7	12.14	17.30	10.5		0.1432	0.4511
1	5	1	BRAC XLON	20.4	13.02	8.04	8.0	*	0.0327	0.0785
1	5	2	BRAC XLON	19.0	12.60	7.66	8.5	*	0.0284	0.0723
1	5	3	MONO GLAB	15.1	20.42	12.41	8.0		0.0179	0.0430
1	5	4	BURK AFRI	9.1	24.36	14.90	5.5		0.0065	0.0107

1	5	5	BRAC SPIC	14.6	16.46	11.85	9.0		0.0167	0.0452
1	5	6	FAUR SPEC	8.0	13.70	11.85	4.0		0.0050	0.0060
1	5	7	JULB GLOB	29.2	10.99	20.72	14.5		0.0670	0.2913
1	5	8	BURK AFRI	7.4	20.47	24.55	6.0		0.0043	0.0077
1	6	1	BRAC XLON	18.9	14.62	7.50	9.5		0.0281	0.0800
1	6	2	BRAC SPIC	24.6	9.30	12.96	14.0		0.0475	0.1996
1	6	3	OCHN SCHW	5.1	2.70	19.00	4.0	*	0.0020	0.0025
1	6	4	OCHN SCHW	6.2	2.70	19.00	5.0	*	0.0030	0.0045
1	6	5	OCHN SCHW	6.8	2.70	19.00	4.5	*	0.0036	0.0049
1	6	6	OCHN SCHW	5.1	2.70	19.00	4.0	*	0.0020	0.0025
1	6	7	OCHN SCHW	3.9	2.70	19.00	3.5	*	0.0012	0.0013
1	6	8	BRAC SPIC	24.6	10.05	21.70	12.0		0.0475	0.1711
1	6	9	XIME	4.2	10.55	15.70	3.5		0.0014	0.0015
1	6	10	BRAC SPIC	30.0	16.13	13.30	10.5		0.0707	0.2227
1	6	11	BRAC SPIC	40.0	18.56	14.55	12.5		0.1257	0.4713
1	6	12	ALBI AMAR	44.0	19.45	19.65	10.0		0.1521	0.4562
1	6	13	TERM STEN	6.6	19.98	21.83	6.0		0.0034	0.0062
1	6	14	ZIZI MUCR	5.3	18.00	25.70	5.0	*	0.0022	0.0033
1	6	15	ZIZI MUCR	3.4	17.85	25.70	2.0	*	0.0009	0.0005
1	6	16	ZIZI MUCR	3.5	17.85	25.70	2.0	*	0.0010	0.0006
1	7	1	LANN DISC	5.3	18.40	2.97	3.5		0.0022	0.0023
1	7	2	BRAC XLON	37.9	16.64	4.18	15.0		0.1128	0.5077
1	7	3	BRID CATH	5.7	11.90	14.27	3.5		0.0026	0.0027
1	7	4	TERM SERI	4.2	11.90	16.06	4.0		0.0014	0.0017
1	7	5	LANN DISC	5.6	13.32	16.12	3.5	*	0.0025	0.0026
1	7	6	LANN DISC	3.9	12.96	16.00	3.5	*	0.0012	0.0013
1	7	7	BRAC XLON	4.1	23.02	20.43	3.0		0.0013	0.0012
1	7	8	PELT AFRI	23.9	23.80	18.18	11.0	*	0.0449	0.1481
1	7	9	PELT AFRI	19.8	23.80	18.18	8.0	*	0.0308	0.0739
1	7	10	PELT AFRI	22.1	23.80	18.18	10.0	*	0.0384	0.1151
1	7	11	STER QUIN	12.3	25.00	19.04	7.0		0.0119	0.0250
1	7	12	FLAC INDI	9.8	26.10	19.60	6.0		0.0075	0.0136
1	7	13	TERM SERI	4.2	20.63	13.73	4.5		0.0014	0.0019
1	8	1	MONO GLAB	4.7	14.87	14.10	3.0		0.0017	0.0016
1	8	2	PERI ANGO	36.8	18.40	9.90	14.5		0.1064	0.4627
1	8	3	ALBI ANTU	29.8	19.54	12.32	8.5		0.0698	0.1779
1	8	4	BRAC XLON	31.6	25.50	20.60	9.0		0.0784	0.2118
1	8	5	TERM SERI	4.8	24.98	20.69	5.0		0.0018	0.0027
1	8	6	MONO GLAB	4.0	17.17	23.50	2.5	*	0.0013	0.0009
1	8	7	MONO GLAB	3.1	17.17	23.50	2.0	*	0.0008	0.0005
1	9	1	BRAC XLON	47.6	17.55	7.37	15.5		0.1780	0.8276
1	9	2	MONO GLAB	4.5	10.27	9.84	4.0		0.0016	0.0019
1	9	3	BRAC XLON	3.1	8.06	12.16	3.0		0.0008	0.0007
1	9	4	BRAC XLON	3.2	7.70	12.40	3.0		0.0008	0.0007
1	9	5	BRAC XLON	4.6	5.00	16.85	3.5		0.0017	0.0017
1	9	6	JULB GLOB	16.5	12.70	22.04	7.0		0.0214	0.0449
1	9	7	BRAC SPIC	16.7	17.05	19.56	7.0		0.0219	0.0460
1	9	8	JULB GLOB	32.6	19.85	25.00	12.0		0.0835	0.3005
1	10	1	BRAC XLON	5.2	19.20	5.72	4.0		0.0021	0.0025
1	10	2	BURK AFRI	20.3	7.00	13.19	9.0		0.0324	0.0874
1	10	3	BRAC XLON	24.5	20.10	23.83	13.5	*	0.0471	0.1910
1	10	4	BRAC XLON	22.6	20.10	23.83	9.0	*	0.0401	0.1083
1	10	5	MONO GLAB	3.3	24.30	15.00	2.5		0.0009	0.0006
1	11	1	BRAC XLON	22.9	4.65	17.00	10.0		0.0412	0.1236
1	11	2	BRAC XLON	39.2	6.90	16.20	16.5		0.1207	0.5975
1	11	3	PILI THON	22.5	8.94	16.85	5.5		0.0398	0.0656
1	11	4	PTER ANGO	5.2	9.90	20.51	5.0		0.0021	0.0032
1	11	5	OCHN SCHW	6.1	20.70	9.50	4.0		0.0029	0.0035
1	11	6	OCHN SCHW	4.1	22.55	10.08	2.5	*	0.0013	0.0010
1	11	7	OCHN SCHW	5.2	22.55	10.08	3.0	*	0.0021	0.0019

1	11	8	TERM SERI	11.2	20.70	8.50	7.0		0.0099	0.0207
1	11	9	BURK AFRI	19.4	20.95	8.00	7.5	*	0.0296	0.0665
1	11	10	BURK AFRI	13.4	20.95	8.00	10.0	*	0.0141	0.0423
1	11	11	LANN DISC	4.9	19.19	5.02	3.0		0.0019	0.0017
1	11	12	BRAC XLON	23.8	19.14	4.33	12.0	*	0.0445	0.1602
1	11	13	BRAC XLON	4.7	19.14	4.33	5.5	*	0.0017	0.0029
1	11	14	BRAC XLON	30.4	28.25	19.67	12.5		0.0726	0.2722
1	11	15	BRAC XLON	3.6	24.95	19.23	2.5		0.0010	0.0008
1	11	16	JULB GLOB	21.8	16.40	16.50	12.5		0.0373	0.1400
1	11	17	LANN DISC	7.1	17.80	22.33	4.5		0.0040	0.0053
1	11	18	AZAN GARK	11.9	16.27	22.36	5.0		0.0111	0.0167
1	12	1	BRAC XLON	36.0	1.55	19.85	15.5		0.1018	0.4734
1	12	2	JULB GLOB	26.3	10.37	14.40	11.0		0.0543	0.1793
1	12	3	MONO GLAB	4.1	15.64	9.00	3.5		0.0013	0.0014
1	12	4	BRAC XLON	29.8	21.13	11.93	14.5		0.0698	0.3034
1	12	5	BRAC XLON	25.3	21.84	17.96	10.5	*	0.0503	0.1584
1	12	6	BRAC XLON	8.2	21.84	17.96	6.0	*	0.0053	0.0095
1	12	7	BRAC SPIC	27.1	21.35	19.70	11.0		0.0577	0.1904
1	12	8	BRAC SPIC	15.5	18.00	17.32	11.0		0.0189	0.0623
1	12	9	MONO GLAB	3.8	20.26	22.15	2.5		0.0011	0.0009
1	13	1	BRAC XLON	7.4	7.70	12.60	5.5	*	0.0043	0.0071
1	13	2	BRAC XLON	8.4	7.70	12.60	5.5	*	0.0055	0.0091
1	13	3	BRAC XLON	4.4	6.50	14.54	2.5		0.0015	0.0011
1	13	4	BRAC XLON	3.3	7.80	16.40	2.0		0.0009	0.0005
1	13	5	BRAC XLON	5.6	24.25	15.40	4.5		0.0025	0.0033
1	13	6	BRAC XLON	6.4	25.07	16.28	4.5		0.0032	0.0043
1	13	7	LANN DISC	10.9	18.85	12.66	4.5		0.0093	0.0126
1	13	8	BRAC XLON	5.8	24.83	20.12	5.0		0.0026	0.0040
1	13	9	MONO GLAB	3.1	24.10	20.30	2.0	*	0.0008	0.0005
1	13	10	MONO GLAB	4.2	24.10	20.30	4.0	*	0.0014	0.0017
1	13	11	BRAC XLON	7.5	17.95	15.50	5.5		0.0044	0.0073
1	13	12	BRAC XLON	5.0	17.55	16.13	4.5		0.0020	0.0027
1	14	1	BRAC SPIC	24.7	5.95	18.10	11.5		0.0479	0.1653
1	14	2	BURK AFRI	19.6	9.63	19.40	9.0		0.0303	0.0817
1	14	3	TERM SERI	4.2	9.30	11.19	3.0		0.0014	0.0012
1	14	4	BRAC SPIC	28.4	12.98	11.24	12.5		0.0634	0.2376
1	14	5	BOSC SALI	24.4	18.55	1.69	6.5	T	0.0468	0.0912
1	14	6	DIOS MESP	27.3	19.30	7.97	8.0	T	0.0585	0.1405
1	14	7	LANN DISC	4.0	18.53	10.18	2.5	*	0.0013	0.0009
1	14	8	LANN DISC	3.2	18.53	10.18	2.0	*	0.0008	0.0005
1	14	9	LANN DISC	5.6	22.86	12.17	3.5	** T	0.0025	0.0026
1	14	10	LANN DISC	4.7	22.86	12.17	3.0	** T	0.0017	0.0016
1	14	11	LANN DISC	4.9	23.25	12.30	3.0	T	0.0019	0.0017
1	14	12	BRAC XLON	3.6	22.25	14.32	3.0		0.0010	0.0009
1	14	13	OCHN SCHW	3.2	23.53	20.75	2.0		0.0008	0.0005
1	14	14	COMM MOLL	3.0	21.35	20.50	3.0		0.0007	0.0006
1	15	1	XIME AMER	3.7	4.50	20.26	4.0	T	0.0011	0.0013
1	15	2	ACAC NILO	13.7	7.13	16.80	7.5	*T	0.0147	0.0332
1	15	3	ACAC NILO	11.9	7.13	16.80	7.5	*T	0.0111	0.0250
1	15	4	ACAC NILO	13.7	7.13	16.80	7.5	*T	0.0147	0.0332
1	15	5	EUCL DIVI	10.2	6.70	17.07	6.5	T	0.0082	0.0159
1	15	6	DIOS SENE	3.2	10.51	15.95	3.0	T	0.0008	0.0007
1	15	7	COMM sp.	8.8	10.77	15.70	6.0	T	0.0061	0.0109
1	15	8	COMM sp.	3.4	10.73	15.38	6.0	T	0.0009	0.0016
1	15	9	ALBI AMAR	33.9	10.90	14.45	12.5	* T	0.0903	0.3385
1	15	10	ALBI AMAR	26.5	10.90	14.45	11.0	* T	0.0552	0.1820
1	15	11	ALBI AMAR	9.6	10.90	14.45	6.5	* T	0.0072	0.0141
1	15	12	ALBI AMAR	14.2	10.90	14.45	8.0	* T	0.0158	0.0380
1	15	13	ALBI AMAR	4.4	10.90	14.45	5.0	* T	0.0015	0.0023
1	15	14	GREW MONT	5.1	11.46	12.99	5.5	* T	0.0020	0.0034
1	15	15	GREW MONT	4.3	11.46	12.99	4.0	* T	0.0015	0.0017

1	15	16	GARD VOLK	4.5	10.40	10.54	4.0	* T	0.0016	0.0019
1	15	17	GARD VOLK	3.8	10.40	10.54	4.0	* T	0.0011	0.0014
1	15	18	GARD VOLK	4.5	10.40	10.54	4.0	* T	0.0016	0.0019
1	15	19	GARD VOLK	4.9	10.40	10.54	4.0	* T	0.0019	0.0023
1	15	20	FLAC INDI	3.2	15.45	5.16	3.0	T	0.0008	0.0007
1	15	21	AZAN GARK	3.5	18.15	8.21	3.0	T	0.0010	0.0009
1	15	22	LANN DISC	16.5	14.03	9.56	4.5	T	0.0214	0.0289
1	15	23	LANN DISC	6.0	13.39	11.91	4.0	T	0.0028	0.0034
1	15	24	STER QUIN	10.3	26.29	18.06	5.5	*	0.0083	0.0138
1	15	25	STER QUIN	6.8	26.29	18.06	4.0	*	0.0036	0.0044
1	15	26	BRAC SPIC	32.8	25.20	18.31	12.0		0.0845	0.3042
1	15	27	LANN DISC	5.7	24.70	17.58	4.5		0.0026	0.0034
1	15	28	DIOS MESP	35.7	23.38	17.01	12.0	T	0.1001	0.3604
1	15	29	XIME AMER	5.5	16.41	12.92	3.0	T	0.0024	0.0021
1	15	30	PELT AFRI	28.3	22.16	20.45	10.0	* T	0.0629	0.1887
1	15	31	PELT AFRI	24.6	22.16	20.45	9.0	* T	0.0475	0.1283
1	15	32	BOSC SALI	11.7	16.99	17.65	4.5	T	0.0108	0.0145
1	15	33	EUPH INGE	9.5	12.96	14.74	3.0	* T	0.0071	0.0064
1	15	34	EUPH INGE	9.0	12.96	14.74	3.0	* T	0.0064	0.0057
1	15	35	EUPH INGE	8.6	12.96	14.74	3.0	* T	0.0058	0.0052
1	15	36	EUPH INGE	9.1	12.96	14.74	2.0	* T	0.0065	0.0039
1	15	37	COMB MOLL	7.0	14.31	19.84	4.5	T	0.0038	0.0052
1	15	38	COMM 5.8	12.83	19.26	4.5		T	0.0026	0.0036
1	15	39	CORD GOET	5.0	11.78	18.95	3.5	* T	0.0020	0.0021
1	15	40	CORD GOET	3.7	11.78	18.95	3.5	* T	0.0011	0.0011
1	15	41	CORD GOET	7.1	11.78	18.95	5.5	* T	0.0040	0.0065
1	15	42	CORD GOET	4.4	11.78	18.95	3.5	* T	0.0015	0.0016
1	15	43	CORD GOET	4.9	11.78	18.95	3.5	* T	0.0019	0.0020
1	15	44	CORD GOET	5.7	11.78	18.95	3.5	* T	0.0026	0.0027
1	15	45	CORD GOET	3.0	11.78	18.95	3.5	* T	0.0007	0.0007
1	15	46	LANN DISC	5.0	14.86	22.07	3.5	T	0.0020	0.0021
1	15	47	LANN DISC	5.2	15.24	23.32	3.0	T	0.0021	0.0019
1	15	48	COMM MOLL	8.2	11.87	20.76	6.0	T	0.0053	0.0095
1	15	49	COMM MOLL	10.8	10.20	20.22	6.5	* T	0.0092	0.0179
1	15	50	COMM MOLL	10.3	10.20	20.22	6.5	* T	0.0083	0.0163
1	15	51	COMM MOLL	5.6	10.20	20.22	6.5	* T	0.0025	0.0048
1	15	52	COMM MOLL	8.5	10.20	20.22	6.5	* T	0.0057	0.0111
1	15	53	LANN DISC	3.1	10.23	20.74	3.0	T	0.0008	0.0007
1	15	54	LANN DISC	7.5	11.40	22.73	4.5	T	0.0044	0.0060
1	16	1	BRAC SPIC	28.8	8.38	18.15	9.5		0.0652	0.1857
1	16	2	BRAC SPIC	33.3	10.22	19.63	12.0		0.0871	0.3136
1	16	3	BRAC SPIC	17.9	8.30	20.84	6.0		0.0252	0.0453
1	16	4	BRID CATH	3.0	8.50	21.02	2.0		0.0007	0.0004
1	16	5	BURK AFRI	14.1	3.07	17.90	10.5		0.0156	0.0492
1	16	6	BRAC SPIC	38.2	13.50	15.60	10.5		0.1146	0.3611
1	16	7	BRAC SPIC	33.9	25.54	16.50	12.0		0.0903	0.3250
1	17	1	BRAC SPIC	13.9	17.33	8.50	9.0		0.0152	0.0410
1	17	2	BRAC SPIC	16.9	11.07	10.16	7.5		0.0224	0.0505
1	17	3	LANN DISC	6.2	10.70	11.50	2.0		0.0030	0.0018
1	17	4	BRAC XLON	32.7	11.45	11.63	13.5		0.0840	0.3402
1	17	5	MONO GLAB	16.3	4.13	16.32	5.0		0.0209	0.0313
1	17	6	BURK AFRI	16.6	6.03	18.24	7.5	*	0.0216	0.0487
1	17	7	BURK AFRI	5.7	6.03	18.24	3.0	*	0.0026	0.0023
1	17	8	MONO GLAB	3.1	12.83	23.10	3.0		0.0008	0.0007
1	17	9	JULB GLOB	40.0	18.00	22.73	12.5		0.1257	0.4713
1	17	10	SWAR MADA	4.2	23.70	13.87	3.0	*	0.0014	0.0012
1	17	11	SWAR MADA	5.3	23.70	13.87	3.0	*	0.0022	0.0020
1	17	12	SWAR MADA	5.9	23.70	13.87	2.5	*	0.0027	0.0021
1	18	1	BRAC XLON	3.2	20.63	8.62	3.5		0.0008	0.0008
1	18	2	BRAC SPIC	32.8	11.16	11.48	16.5		0.0845	0.4183

1	18	3	MONO GLAB	3.5	8.64	17.84	2.0		0.0010	0.0006
1	18	4	JULB GLOB	32.7	11.63	19.86	15.0		0.0840	0.3780
1	18	5	SWAR MADA	3.6	10.70	14.07	3.0		0.0010	0.0009
1	18	6	MONO GLAB	10.5	13.50	15.35	4.5		0.0087	0.0117
1	18	7	BRAC XLON	4.9	17.95	14.34	4.5		0.0019	0.0025
1	18	8	JULB GLOB	4.3	22.32	19.14	3.0		0.0015	0.0013
1	18	9	BRAC XLON	3.8	24.04	20.74	4.0		0.0011	0.0014
1	18	10	MONO GLAB	3.7	17.96	11.83	3.5		0.0011	0.0011
1	18	11	BRAC XLON	4.8	24.47	18.32	3.0		0.0018	0.0016
1	18	12	BRAC XLON	5.7	25.70	19.09	4.0		0.0026	0.0031
1	19	1	SWAR MADA	13.0	20.54	7.35	4.5	*	0.0133	0.0179
1	19	2	SWAR MADA	13.6	20.54	7.35	5.0	*	0.0145	0.0218
1	19	3	MONO GLAB	4.1	19.87	9.46	3.0		0.0013	0.0012
1	19	4	LANN DISC	5.5	15.93	4.28	4.0	*	0.0024	0.0029
1	19	5	LANN DISC	4.8	15.93	4.28	3.5	*	0.0018	0.0019
1	19	6	LANN DISC	5.3	13.28	6.93	3.5		0.0022	0.0023
1	19	7	BRAC XLON	3.6	9.18	15.42	2.5		0.0010	0.0008
1	19	8	BRAC XLON	7.0	9.38	21.15	5.0		0.0038	0.0058
1	19	9	BRAC XLON	5.1	11.55	22.23	4.5		0.0020	0.0028
1	19	10	BRAC XLON	3.7	11.86	21.72	3.5		0.0011	0.0011
1	19	11	MONO GLAB	3.2	12.73	22.84	3.5		0.0008	0.0008
1	19	12	BURK AFRI	5.6	14.67	19.36	4.0		0.0025	0.0030
1	19	13	BRAC XLON	3.5	20.56	22.69	3.0		0.0010	0.0009
1	19	14	BRAC XLON	3.0	17.66	17.67	3.0		0.0007	0.0006
1	19	15	BURK AFRI	14.7	15.60	15.96	6.5		0.0170	0.0331
1	19	16	MONO GLAB	24.0	13.33	13.86	8.0		0.0452	0.1086
1	19	17	BRAC XLON	28.5	21.55	18.10	10.0	*	0.0638	0.1914
1	19	18	BRAC XLON	46.8	21.55	18.10	10.5	*	0.1720	0.5419
1	19	19	BRAC XLON	3.1	22.23	10.47	2.0		0.0008	0.0005
1	20	1	ALBI ANTU	15.0	17.07	2.91	6.0		0.0177	0.0318
1	20	2	BRAC XLON	4.0	16.15	11.53	3.5		0.0013	0.0013
1	20	3	BRAC XLON	21.5	6.87	16.13	8.0		0.0363	0.0871
1	20	4	JULB GLOB	44.6	11.58	22.58	16.0		0.1562	0.7500
1	20	5	BRAC XLON	17.5	14.08	22.69	10.0		0.0241	0.0722
1	20	6	BRID CATH	5.4	14.69	23.82	4.0		0.0023	0.0027
1	20	7	BURK AFRI	10.0	20.70	22.76	4.5		0.0079	0.0106
1	20	8	BRAC XLON	5.0	17.90	17.27	5.0	*	0.0020	0.0029
1	20	9	BRAC XLON	3.4	17.90	17.27	3.5	*	0.0009	0.0010
1	20	10	BRAC XLON	9.0	17.90	17.27	7.0	*	0.0064	0.0134
1	20	11	BRAC XLON	3.3	17.90	17.27	3.0	*	0.0009	0.0008
1	20	12	BRAC XLON	5.8	21.95	19.03	5.0	**	0.0026	0.0040
1	20	13	BRAC XLON	9.0	21.95	19.03	6.0	**	0.0064	0.0115
1	20	14	BRAC XLON	6.5	21.95	19.03	5.5	**	0.0033	0.0055
1	20	15	TERM SERI	6.2	22.91	19.68	5.0		0.0030	0.0045
1	20	16	MONO GLAB	3.3	22.45	11.88	3.0		0.0009	0.0008
1	20	17	BRAC XLON	5.8	23.77	14.13	4.0		0.0026	0.0032
1	20	18	BRAC XLON	3.9	25.85	16.43	3.0		0.0012	0.0011
1	21	1	BRAC XLON	29.5	5.25	15.00	13.5		0.0684	0.2769
1	21	2	BRAC XLON	22.4	18.18	16.17	11.0		0.0394	0.1301
1	21	3	LANN DISC	4.9	14.87	5.79	3.0		0.0019	0.0017
1	21	4	BRAC XLON	41.3	20.53	12.75	13.5		0.1340	0.5426
1	21	5	LANN DISC	9.3	20.67	13.26	4.0	*	0.0068	0.0082
1	21	6	LANN DISC	6.4	20.67	13.26	4.0	*	0.0032	0.0039
1	21	7	MONO GLAB	3.1	25.45	19.05	3.0	*	0.0008	0.0007
1	21	8	MONO GLAB	3.3	25.45	19.05	3.0	*	0.0009	0.0008
1	21	9	BRAC XLON	5.4	21.31	13.55	4.5		0.0023	0.0031
1	21	10	BRAC XLON	3.3	20.09	19.12	3.0		0.0009	0.0008
1	21	11	ALBI ANTU	17.0	18.34	19.10	5.0		0.0227	0.0341
1	21	12	LANN DISC	9.2	17.86	19.23	4.0		0.0066	0.0080
1	21	13	LANN DISC	8.2	17.58	17.52	5.0		0.0053	0.0079
1	21	14	LANN DISC	4.5	16.18	18.40	3.5		0.0016	0.0017

1	21	15	BRAC XLON	4.0	16.09	19.75	3.5	*	0.0013	0.0013
1	21	16	BRAC XLON	3.4	16.09	19.75	3.0	*	0.0009	0.0008
1	21	17	BRAC XLON	5.8	17.66	21.94	4.5		0.0026	0.0036
1	21	18	BRAC XLON	12.5	19.56	22.94	7.0		0.0123	0.0258
1	21	19	BRAC XLON	5.8	16.52	23.32	4.5		0.0026	0.0036
1	21	20	FLAC INDI	3.2	15.42	18.14	3.5		0.0008	0.0008
1	22	1	BRAC XLON	5.0	4.50	18.46	4.5		0.0020	0.0027
1	22	2	MONO GLAB	11.1	6.28	17.40	5.5		0.0097	0.0160
1	22	3	MONO GLAB	5.3	8.96	18.45	3.5		0.0022	0.0023
1	22	4	BURK AFRI	7.6	12.80	14.90	3.5		0.0045	0.0048
1	22	5	BURK AFRI	18.6	8.17	13.05	8.5		0.0272	0.0693
1	22	6	FAUR SALI	7.7	7.00	12.98	5.0		0.0047	0.0070
1	22	7	OCHN SCHW	6.1	7.55	12.50	4.0	*	0.0029	0.0035
1	22	8	OCHN SCHW	6.2	7.55	12.50	4.0	*	0.0030	0.0036
1	22	9	BRAC XLON	3.9	15.42	12.79	2.5		0.0012	0.0009
1	22	10	BRAC SPIC	33.9	18.63	17.45	15.5		0.0903	0.4198
1	22	11	BRAC XLON	3.5	17.24	20.97	2.0		0.0010	0.0006
1	22	12	LANN DISC	8.7	14.45	20.14	4.5		0.0059	0.0080
1	22	13	JULB GLOB	20.1	13.19	22.50	11.0		0.0317	0.1047
1	23	1	BRAC XLON	3.5	4.38	19.45	2.0	*	0.0010	0.0006
1	23	2	BRAC XLON	5.1	4.38	19.45	2.5	*	0.0020	0.0015
1	23	3	BRAC XLON	31.8	7.50	16.10	12.5		0.0794	0.2979
1	23	4	BRAC SPIC	8.6	15.16	9.10	6.5	*	0.0058	0.0113
1	23	5	BRAC SPIC	4.5	15.16	9.10	4.0	*	0.0016	0.0019
1	23	6	JULB GLOB	20.0	17.80	2.58	10.5		0.0314	0.0990
1	23	7	JULB GLOB	21.9	21.80	11.88	8.5		0.0377	0.0961
1	23	8	PTER ANGO	19.3	27.56	19.40	9.0		0.0293	0.0790
1	23	9	SWAR MADA	11.7	19.27	18.73	3.5		0.0108	0.0113
1	23	10	BRAC XLON	32.2	20.45	21.55	13.0		0.0814	0.3176
1	23	11	MONO GLAB	7.8	18.70	22.80	4.0	*	0.0048	0.0057
1	23	12	MONO GLAB	6.7	18.70	22.80	2.0	*	0.0035	0.0021
1	23	13	JULB GLOB	24.8	14.05	17.67	9.5		0.0483	0.1377
1	23	14	MONO GLAB	4.5	15.58	25.18	5.0		0.0016	0.0024
1	24	1	BRAC XLON	3.1	4.00	20.04	2.5		0.0008	0.0006
1	24	2	BRAC XLON	4.7	7.48	19.60	4.0		0.0017	0.0021
1	24	3	SWAR MADA	7.5	11.28	18.10	5.0	*	0.0044	0.0066
1	24	4	SWAR MADA	4.1	11.28	18.10	4.5	*	0.0013	0.0018
1	24	5	SWAR MADA	8.1	11.28	18.10	5.0	*	0.0052	0.0077
1	24	6	SWAR MADA	5.0	11.28	18.10	5.0	*	0.0020	0.0029
1	24	7	MONO GLAB	5.1	13.10	10.49	4.5	*	0.0020	0.0028
1	24	8	MONO GLAB	4.5	13.10	10.49	4.0	*	0.0016	0.0019
1	24	9	BRAC XLON	27.4	14.90	13.55	14.0		0.0590	0.2477
1	24	10	FAUR SPEC	16.0	15.85	10.10	9.5		0.0201	0.0573
1	24	11	OCHN SCHW	3.4	18.54	1.80	3.0		0.0009	0.0008
1	24	12	BRAC SPIC	17.3	19.50	14.27	9.5	*	0.0235	0.0670
1	24	13	BRAC SPIC	14.4	19.50	14.27	6.0	*	0.0163	0.0293
1	24	14	JULB GLOB	19.6	25.20	19.85	12.0		0.0302	0.1086
1	24	15	BRAC XLON	5.1	22.10	17.49	3.0		0.0020	0.0018
1	24	16	BRAC XLON	3.1	22.18	17.90	2.5		0.0008	0.0006
1	24	17	JULB GLOB	24.8	21.82	20.24	12.5		0.0483	0.1812
1	25	1	SWAR MADA	13.9	6.03	19.65	4.5		0.0152	0.0205
1	25	2	JULB GLOB	3.4	7.24	12.83	3.5		0.0009	0.0010
1	25	3	JULB GLOB	26.6	9.93	10.45	12.5		0.0556	0.2084
1	25	4	BRAC XLON	4.3	13.62	13.82	4.0		0.0015	0.0017
1	25	5	JULB GLOB	22.0	15.95	9.10	8.5		0.0380	0.0969
1	25	6	BURK AFRI	15.8	17.75	6.25	8.5		0.0196	0.0500
1	25	7	BRAC XLON	4.8	19.04	6.44	4.0		0.0018	0.0022
1	25	8	BURK AFRI	11.5	19.38	4.58	5.5		0.0104	0.0171
1	25	9	BRAC XLON	5.5	25.96	17.23	4.5		0.0024	0.0032
1	25	10	JULB GLOB	3.8	20.53	12.65	3.5		0.0011	0.0012

1	25	11	BRAC XLON	3.6	20.30	14.10	3.0		0.0010	0.0009
1	25	12	BRAC XLON	6.0	17.26	11.12	4.0		0.0028	0.0034
1	25	13	BRAC XLON	4.3	18.32	14.77	3.0		0.0015	0.0013
1	25	14	MONO GLAB	19.1	23.20	20.06	5.5		0.0287	0.0473
1	25	15	BURK AFRI	6.0	17.40	23.70	4.5	*	0.0028	0.0038
1	25	16	BURK AFRI	9.1	17.40	23.70	5.0	*	0.0065	0.0098
						TOTAL	7.5495	25.7365		

Appendix 8.2 cont. **Mensural data for 7 termitaria in 6 Hectare Plot collected in 1994, Kalomo, Zambia**

BFA TREE PLOT, KALOMO, ZAMBIA, AUGUST 1994 VASCULAR PLANTS ON TERMITARIA

Plot	Quad	No.	Species	DBH (cm)	Notes	Basal Area (m^2)
1	T1	1	COMB MOLL	32.0		0.0804
1	T1	2	COMB MOLL	4.9		0.0019
1	T1	3	ALBI AMAR	46.2		0.1677
1	T1	4	COMB MOLL	3.2		0.0008
1	T1	5	ZIZI MUCR	4.9		0.0019
1	T1	6	ALBI AMAR	23.6	*	0.0437
1	T1	7	ALBI AMAR	38.1	*	0.1140
1	T1	8	ALBI AMAR	22.6	**	0.0401
1	T1	9	ALBI AMAR	28.3	**	0.0629
1	T1	10	CARI EDUL	5.0	*	0.0020
1	T1	11	CARI EDUL	4.6	*	0.0017
1	T1	12	EUPH INGE	10.0	*	0.0079
1	T1	13	EUPH INGE	7.4	*	0.0043
1	T1	14	EUPH INGE	7.0	*	0.0038
1	T1	15	EUPH INGE	8.2	*	0.0053
1	T1	16	RHUS	3.0		0.0007
1	T1	17	COMB MOLL	3.1		0.0008
1	T1	18	DICH CINE	4.6	*	0.0017
1	T1	19	DICH CINE	3.2	*	0.0008
1	T1	20	DICH CINE	3.0	*	0.0007
1	T1	21	EUPH INGE	7.1		0.0040
1	T1	22	CAPP TOME	3.5	*	0.0010
1	T1	23	CAPP TOME	4.5	*	0.0016
1	T1	24	CORD GOET	3.0		0.0007
1	T1	25	CORD GOET	7.0		0.0038
1	T1	26	CORD GOET	4.2		0.0014
1	T1	27	ZIZI MUCR	3.8		0.0011
1	T1	28	LANN DISC	5.0	*	0.0020
1	T1	29	LANN DISC	6.2	*	0.0030
1	T1	30	LANN DISC	4.5		0.0016
1	T1	31	LANN DISC	5.9		0.0027
1	T1	32	LANN DISC	4.0	*	0.0013
1	T1	33	LANN DISC	7.4	*	0.0043
1	T1	34	LANN DISC	4.3	*	0.0015
1	T1	35	DICH CINE	3.9		0.0012
1	T1	36	ALBI AMAR	5.6		0.0025
1	T1	37	LANN DISC	8.5		0.0057
1	T1	38	COMM MOLL	15.0	*	0.0177
1	T1	39	COMM MOLL	14.1	*	0.0156
1	T1	40	COMM MOLL	6.5	*	0.0033
1	T1	41	COMM MOLL	3.6	*	0.0010
1	T1	42	COMM MOLL	5.8	*	0.0026
1	T1	43	COMM MOLL	9.6	*	0.0072
1	T1	44	COMM MOLL	4.5	*	0.0016
1	T1	45	COMM MOLL	5.2	*	0.0021
1	T1	46	COMB MOLL	3.5		0.0010
1	T1	47	CASS ABBR	13.9		0.0152
1	T1	48	LANN DISC	7.3		0.0042
1	T1	49	CASS ABBR	4.0		0.0013
1	T1	50	COMB MOLL	7.6		0.0045
1	T1	51	COMB MOLL	4.6		0.0017
1	T1	52	COMB MOLL	9.6		0.0072
1	T1	53	DICH CINE	3.4	*	0.0009
1	T1	54	DICH CINE	3.1	*	0.0008
1	T1	55	COMB MOLL	5.0		0.0020
1	T1	56	CASS ABBR	4.2		0.0014
1	T1	57	CORD GOET	3.1		0.0008
1	T1	58	CORD GOET	7.0	*	0.0038
1	T1	59	CORD GOET	5.1	*	0.0020
1	T1	60	CORD GOET	4.5	*	0.0016
1	T1	61	CORD GOET	3.4	*	0.0009
1	T1	62	CORD GOET	3.0	*	0.0007
1	T1	63	CORD GOET	3.6	*	0.0010
1	T1	64	CORD GOET	4.2	*	0.0014
1	T1	65	COMB MOLL	4.9		0.0019
1	T1	66	LANN DISC	4.2	*	0.0014
1	T1	67	LANN DISC	7.2	*	0.0041
1	T1	68	LANN DISC	7.8	*	0.0048
1	T1	69	LANN DISC	9.4	*	0.0069
1	T1	70	LANN DISC	3.4	*	0.0009
1	T1	71	XIME AMER	3.1	*	0.0008
1	T1	72	XIME AMER	4.4	*	0.0015
1	T1	73	XIME AMER	3.3	*	0.0009
1	T1	74	PSEU MAPR	3.5		0.0010
1	T1	75	PSEU MAPR	3.1		0.0008
1	T1	76	COMB MOLL	5.3		0.0022
1	T1	77	LANN DISC	3.3		0.0009
1	T1	78	LANN DISC	5.6	*	0.0025
1	T1	79	LANN DISC	4.7	*	0.0017
1	T1	80	LANN DISC	7.2	*	0.0041
1	T2	1	COMM MOLL	8.4		0.0055
1	T2	2	DICH CINE	5.5	*	0.0024
1	T2	3	DICH CINE	4.8	*	0.0018
1	T2	4	DICH CINE	4.2	*	0.0014
1	T2	5	COMM MOLL	6.1		0.0029
1	T2	6	COMM MOLL	3.2	*	0.0008
1	T2	7	COMM MOLL	4.0	*	0.0013
1	T2	8	COMM MOLL	4.4	*	0.0015
1	T2	9	COMM MOLL	4.4	*	0.0015
1	T2	10	COMM MOLL	6.6		0.0034
1	T2	11	ALBI ANTU	19.4		0.0296
1	T2	12	LANN DISC	6.2		0.0030
1	T2	13	LANN DISC	5.7		0.0026
1	T2	14	LANN DISC	3.3		0.0009
1	T2	15	ALBI ANTU	23.9		0.0449
1	T2	16	LANN DISC	5.3		0.0022
1	T2	17	ZIZI MUCR	10.6	*	0.0088
1	T2	18	ZIZI MUCR	16.8	*	0.0222

1	T2	19	LANN DISC	5.3		0.0022
1	T2	20	XIME AMER	4.0	*	0.0013
1	T2	21	ROUR ORIE	3.5		0.0010
1	T2	22	XIME AMER	4.4	*	0.0015
1	T2	23	XIME AMER	3.3	*	0.0009
1	T2	24	XIME AMER	4.7	*	0.0017
1	T2	25	ALBI AMAR	4.2		0.0014
1	T2	26	BRAC SPIC	4.0		0.0013
1	T2	27	STER QUIN	9.6	*	0.0072
1	T2	28	STER QUIN	15.4	*	0.0186
1	T2	29	GREW MONT	7.2	*	0.0041
1	T2	30	GREW MONT	5.0	*	0.0020
1	T2	31	GREW MONT	7.7	*	0.0047
1	T2	32	GREW MONT	4.5	*	0.0016
1	T2	33	GREW MONT	4.6	*	0.0017
1	T2	33.1	GREW MONT	4.6	*	0.0017
1	T2	34	CAPP TOME	5.4		0.0023
1	T2	35	CASS ABBR	19.0		0.0284
1	T2	36	LANN DISC	5.6		0.0025
1	T2	37	BRAC SPIC	9.2		0.0066
1	T2	38	BRAC SPIC	6.1		0.0029
1	T2	39	ZIZI MUCR	4.2		0.0014
1	T2	40	DICH CINE	4.7		0.0017
1	T2	41	DICH CINE	3.9	*	0.0012
1	T2	42	DICH CINE	3.9	*	0.0012
1	T2	43	DICH CINE	4.6	**	0.0017
1	T2	44	DICH CINE	3.2	**	0.0008
1	T2	45	DICH CINE	3.5	*	0.0010
1	T2	46	DICH CINE	3.6	*	0.0010
1	T2	47	BOSC SALI	13.6	*	0.0145
1	T2	48	BOSC SALI	16.2	*	0.0206
1	T2	49	COMM MOLL	8.1	*	0.0052
1	T2	50	COMM MOLL	7.8	*	0.0048
1	T2	51	ZIZI MUCR	4.5	*	0.0016
1	T2	52	ZIZI MUCR	3.2	*	0.0008
1	T2	53	ZIZI MUCR	7.5	*	0.0044
1	T2	54	ZIZI MUCR	4.7	*	0.0017
1	T2	55	CAPP TOME	6.1		0.0029
1	T2	56	BOSC ANGU	17.0		0.0227
1	T2	57	LANN SCHW	15.7	*	0.0194
1	T2	58	LANN SCHW	11.0	*	0.0095
1	T2	59	LANN SCHW	14.5	*	0.0165
1	T2	60	LANN SCHW	4.0	*	0.0013
1	T2	61	LANN SCHW	5.1	*	0.0020
1	T2	62	LANN SCHW	4.1	*	0.0013
1	T2	63	COMM MOLL	5.6		0.0025
1	T2	64	COMM MOLL	8.0	*	0.0050
1	T2	65	COMM MOLL	7.6	*	0.0045
1	T2	66	COMM MOLL	5.5	**	0.0024
1	T2	67	COMM MOLL	3.2	**	0.0008
1	T2	68	JULB GLOB	4.0		0.0013
1	T2	69	MAYT HETE	4.0		0.0013
1	T2	70	MAYT HETE	4.0	*	0.0013
1	T2	71	MAYT HETE	3.8	*	0.0011
1	T2	72	DICH CINE	5.0	*	0.0020
1	T2	73	DICH CINE	3.8	*	0.0011
1	T2	74	EUCL DIVI	4.1	*	0.0013
1	T2	75	EUCL DIVI	4.4	*	0.0015
1	T2	76	EUCL DIVI	4.6	*	0.0017
1	T2	77	EUCL DIVI	7.2	*	0.0041
1	T2	78	EUCL DIVI	6.1		0.0029
1	T2	79	EUCL DIVI	7.9		0.0049
1	T2	80	EUCL DIVI	6.0		0.0028
1	T2	81	EUCL DIVI	4.9	*	0.0019
1	T2	82	EUCL DIVI	6.0	*	0.0028
1	T2	83	LANN DISC	7.6	*	0.0045
1	T2	84	LANN DISC	8.7	*	0.0059
1	T2	85	COMM MOLL	5.6	*	0.0025
1	T2	86	DICH CINE	3.2		0.0008
1	T2	87	COMM MOLL	5.7	*	0.0026
1	T2	88	LANN DISC	5.3		0.0022
1	T2	89	COMB MOLL	3.6		0.0010
1	T2	90	GREW MONT	4.6		0.0017
1	T2	91	FLAC INDI	4.6		0.0017
1	T2	92	FLAC INDI	3.5		0.0010
1	T3	1	BOSC SALI	22.4		0.0394
1	T3	2	LANN DISC	4.6		0.0017
1	T3	3	COMM MOLL	5.1		0.0020
1	T3	4	COMM MOLL	3.4		0.0009
1	T3	5	COMM MOLL	7.0		0.0038
1	T3	6	GREW FLAV	4.0		0.0013
1	T3	7	GREW FLAV	3.4		0.0009
1	T3	8	LANN SCHW	30.0	*	0.0707
1	T3	9	LANN SCHW	17.1	*	0.0230
1	T3	10	ZIZI MUCR	4.3	*	0.0015
1	T3	11	ZIZI MUCR	4.7	*	0.0017
1	T3	12	ZIZI MUCR	5.6	*	0.0025
1	T3	13	ZIZI MUCR	5.0	*	0.0020
1	T3	14	ZIZI MUCR	13.2	*	0.0137
1	T3	15	ZIZI MUCR	14.9	*	0.0174
1	T3	16	DICH CINE	3.4	*	0.0009
1	T3	17	DICH CINE	4.0	*	0.0013
1	T3	18	DICH CINE	3.3		0.0009
1	T3	19	GREW MONT	4.3	*	0.0015
1	T3	20	GREW MONT	4.8	*	0.0018
1	T3	21	COMM MOLL	6.3	*	0.0031
1	T3	22	COMM MOLL	6.6	*	0.0034
1	T3	23	LANN SCHW	7.3	*	0.0042
1	T3	24	LANN SCHW	8.5	*	0.0057
1	T3	25	LANN SCHW	26.0	*	0.0531
1	T3	26	LANN SCHW	6.8	*	0.0036
1	T3	27	LANN SCHW	7.5	*	0.0044
1	T3	28	LANN SCHW	9.4	*	0.0069
1	T3	29	LANN SCHW	9.7	*	0.0074
1	T3	30	LANN SCHW	28.8	*	0.0652
1	T3	31	EUCL DIVI	5.0	*	0.0020
1	T3	32	EUCL DIVI	4.7	*	0.0017
1	T3	33	EUCL DIVI	4.5	*	0.0016

1	T3	34	ALBI AMAR	43.3		0.1473
1	T3	35	STRY SPIN	14.7		0.0170
1	T3	36	COMM MOLL	10.1		0.0080
1	T3	37	BOSC SALI	25.4		0.0507
1	T3	38	COMM MOLL	16.6		0.0216
1	T3	39	ZIZI MUCR	7.5	*	0.0044
1	T3	40	ZIZI MUCR	3.6	*	0.0010
1	T3	41	FLUE VIRO	3.2		0.0008
1	T3	42	FLUE VIRO	3.5		0.0010
1	T3	43	FLUE VIRO	3.7		0.0011
1	T3	44	FLUE VIRO	4.0		0.0013
1	T3	45	FLUE VIRO	3.7		0.0011
1	T3	46	FLUE VIRO	3.0		0.0007
1	T3	47	COMM MOLL	15.9	**	0.0199
1	T3	48	COMM MOLL	9.3	**	0.0068
1	T3	49	COMM MOLL	6.6	**	0.0034
1	T3	50	DICH CINE	3.3	*	0.0009
1	T3	51	DICH CINE	3.9	*	0.0012
1	T3	52	COMM MOLL	14.3	**	0.0161
1	T3	53	DICH CINE	3.3	*	0.0009
1	T3	54	DICH CINE	3.4	*	0.0009
1	T3	55	DICH CINE	3.8	*	0.0011
1	T3	56	ZIZI MUCR	9.5	*	0.0071
1	T3	57	ZIZI MUCR	8.8	*	0.0061
1	T3	58	ZIZI MUCR	9.8	*	0.0075
1	T3	59	BOSC SALI	17.2		0.0232
1	T3	60	ZIZI MUCR	7.6	*	0.0045
1	T3	61	ZIZI MUCR	5.5	*	0.0024
1	T3	62	ZIZI MUCR	5.8	*	0.0026
1	T3	63	ZIZI MUCR	5.4		0.0023
1	T3	64	DICH CINE	3.2		0.0008
1	T3	65	FLUE VIRO	3.2	*	0.0008
1	T3	66	FLUE VIRO	3.0	*	0.0007
1	T3	67	FLUE VIRO	3.2	*	0.0008
1	T3	68	FLUE VIRO	3.0		0.0007
1	T3	69	COMM MOLL	4.9		0.0019
1	T3	70	FLUE VIRO	4.5		0.0016
1	T3	71	COMM MOLL	13.3	*	0.0139
1	T3	72	COMM MOLL	9.1	*	0.0065
1	T3	73	COMM MOLL	10.8	*	0.0092
1	T3	74	COMM MOLL	12.1	*	0.0115
1	T3	75	COMM MOLL	6.5	*	0.0033
1	T3	76	BOSC SALI	23.5		0.0434
1	T3	77	CASS ABBR	4.9	*	0.0019
1	T3	78	CASS ABBR	6.2	*	0.0030
1	T3	79	COMB MOLL	5.8		0.0026
1	T3	80	ZIZI MUCR	7.3		0.0042
1	T3	81	ZIZI MUCR	7.6		0.0045
1	T3	82	ZIZI MUCR	5.5	*	0.0024
1	T3	83	ZIZI MUCR	4.9	*	0.0019
1	T3	84	ZIZI MUCR	6.4		0.0032
1	T3	85	ZIZI MUCR	3.9		0.0012
1	T3	86	ZIZI MUCR	3.5		0.0010
1	T3	87	COMM MOLL	15.0	*	0.0177
1	T3	88	COMM MOLL	7.7	*	0.0047
1	T3	89	COMM MOLL	16.2	*	0.0206
1	T3	90	COMM MOLL	4.2	**	0.0014
1	T3	91	COMM MOLL	3.6	**	0.0010
1	T3	92	COMM MOLL	5.7	**	0.0026
1	T3	93	COMM MOLL	3.0	**	0.0007
1	T3	94	COMM MOLL	4.5	**	0.0016
1	T3	95	COMM MOLL	3.6	**	0.0010
1	T3	96	COMM MOLL	4.1	**	0.0013
1	T3	97	COMM MOLL	5.5	**	0.0024
1	T3	98	COMM MOLL	3.2	**	0.0008
1	T3	99	ALBI AMAR	5.1		0.0020
1	T3	100	BOSC SALI	17.8		0.0249
1	T4	1	XIME CAFF	16.6		0.0216
1	T4	2	LANN DISC	14.1		0.0156
1	T4	3	LANN DISC	6.5		0.0033
1	T4	4	LANN DISC	4.1		0.0013
1	T4	5	XIME AMER	10.1		0.0080
1	T4	6	COMM MOLL	8.3		0.0054
1	T4	7	XIME AMER	3.9		0.0012
1	T4	8	XIME AMER	6.9	*	0.0037
1	T4	9	XIME AMER	3.1	*	0.0008
1	T4	10	XIME AMER	4.7	*	0.0017
1	T4	11	ZIZI MUCR	4.8		0.0018
1	T4	12	FLAC INDI	6.3		0.0031
1	T4	13	CASS ABBR	6.6		0.0034
1	T4	14	PILI THON	14.7		0.0170
1	T4	15	DIOS MESP	36.4	*	0.1041
1	T4	16	DIOS MESP	6.0	*	0.0028
1	T4	17	LANN DISC	8.5		0.0057
1	T5	1	LANN DISC	8.2		0.0053
1	T5	2	PTER ROTU	6.2		0.0030
1	T5	3	RHUS TENU	3.9		0.0012
1	T5	4	RHUS TENU	5.4	*	0.0023
1	T5	5	RHUS TENU	5.4	*	0.0023
1	T5	6	RHUS TENU	4.0		0.0013
1	T5	7	PTER ROTU	3.4	*	0.0009
1	T5	8	PTER ROTU	3.5	*	0.0010
1	T5	9	PTER ROTU	3.4	*	0.0009
1	T5	10	PTER ROTU	6.1		0.0029
1	T5	11	PTER ROTU	3.4		0.0009
1	T5	12	LANN DISC	8.8		0.0061
1	T5	13	FLUE VIRO	3.2	*	0.0008
1	T5	14	FLUE VIRO	3.5	*	0.0010
1	T5	15	FLUE VIRO	3.5	*	0.0010
1	T5	16	LANN DISC	8.1		0.0052
1	T5	17	PTER ROTU	6.2		0.0030
1	T5	18	DICH CINE	3.3		0.0009
1	T5	19	PTER ROTU	10.8		0.0092
1	T5	20	PTER ROTU	7.2		0.0041
1	T5	21	BRID CATH	6.6		0.0034
1	T5	22	BRID CATH	3.8		0.0011

1	T5	23	BRID CATH	4.2		0.0014	1	T6	11	ZIZI MUCR	11.9	*	0.0111
1	T5	24	PTER ROTU	5.3		0.0022	1	T6	12	ZIZI MUCR	7.3	*	0.0042
1	T5	25	COMM MOLL	10.3		0.0083	1	T6	13	ZIZI MUCR	3.6	**	0.0010
1	T5	26	COMM MOLL	10.3		0.0083	1	T6	14	ZIZI MUCR	11.8	**	0.0109
1	T5	27	COMM MOLL	8.2		0.0053	1	T6	15	LANN DISC	5.4		0.0023
1	T5	28	COMM MOLL	9.4	*	0.0069	1	T6	16	CASS ABBR	5.1		0.0020
1	T5	29	COMM MOLL	9.3	*	0.0068	1	T6	17	CASS ABBR	3.3		0.0009
1	T5	30	ZIZI MUCR	11.3		0.0100	1	T6	18	BOSC SALI	16.5	*	0.0214
1	T5	31	ZIZI MUCR	13.9	*	0.0152	1	T6	19	BOSC SALI	17.5	*	0.0241
1	T5	32	ZIZI MUCR	14.1	*	0.0156	1	T6	20	EUCL DIVI	4.3		0.0015
1	T5	33	ZIZI MUCR	8.1	*	0.0052	1	T6	21	LANN DISC	4.0		0.0013
1	T5	34	ZIZI MUCR	13.3		0.0139	1	T6	22	ZIZI MUCR	21.0		0.0346
1	T5	35	ZIZI MUCR	3.0		0.0007	1	T6	23	LANN DISC	3.0		0.0007
1	T5	36	DICH CINE	3.5	*	0.0010	1	T6	24	BRID CATH	7.5	*	0.0044
1	T5	37	DICH CINE	3.3	*	0.0009	1	T6	25	BRID CATH	4.7	*	0.0017
1	T5	38	FERE AERU	3.1		0.0008	1	T6	26	STRY POTA	3.8		0.0011
1	T5	39	EUCL DIVI	4.1		0.0013	1	T6	27	STRY POTA	3.8		0.0011
1	T5	40	MAYT HETE	3.2		0.0008	1	T6	28	LANN DISC	8.3		0.0054
1	T5	41	EUCL DIVI	6.2	*	0.0030	1	T6	29	FLUE VIRO	3.0	*	0.0007
1	T5	42	EUCL DIVI	3.6	*	0.0010	1	T6	30	FLUE VIRO	3.0	*	0.0007
1	T5	43	LANN DISC	8.0		0.0050	1	T6	31	BOSC SALI	13.1		0.0135
1	T5	44	EUCL DIVI	6.0		0.0028	1	T6	32	ALBI AMAR	56.2		0.2481
1	T5	45	EUCL DIVI	3.3		0.0009	1	T6	33	GREW MONT	3.2		0.0008
1	T5	46	COMM MOLL	6.7		0.0035	1	T6	34	GREW MONT	3.5	*	0.0010
1	T5	47	LANN DISC	5.4		0.0023	1	T6	35	GREW MONT	3.0	*	0.0007
1	T5	48	PTER ROTU	3.4		0.0009	1	T6	36	GREW MONT	3.0		0.0007
1	T5	49	PTER ROTU	4.7		0.0017	1	T6	37	LANN DISC	3.3		0.0009
1	T5	50	LANN DISC	7.7		0.0047	1	T7	1	XIME AMER	3.7		0.0011
1	T5	51	PTER ROTU	9.0		0.0064	1	T7	2	ACAC NILO	13.7		0.0147
1	T5	52	DICH CINE	3.2	*	0.0008	1	T7	3	ACAC NILO	11.9		0.0111
1	T5	53	DICH CINE	3.6	*	0.0010	1	T7	4	ACAC NILO	13.7		0.0147
1	T5	54	LANN DISC	4.6		0.0017	1	T7	5	EUCL DIVI	10.2		0.0082
1	T5	55	EUCL DIVI	6.1		0.0029	1	T7	6	DIOS SENE	3.2		0.0008
1	T5	56	EUCL DIVI	4.0		0.0013	1	T7	7	COMM MOLL	8.8		0.0061
1	T5	57	COMM MOLL	9.8	**	0.0075	1	T7	8	COMM MOLL	3.4		0.0009
1	T5	58	EUCL DIVI	4.5		0.0016	1	T7	9	ALBI AMAR	33.9	*	0.0903
1	T5	59	PTER ROTU	3.5		0.0010	1	T7	10	ALBI AMAR	26.5	*	0.0552
1	T5		PTER ROTU	5.3	1/11/04	0.0022	1	T7	11	ALBI AMAR	9.6	*	0.0072
1	T5	60	COMM MOLL	7.8	**	0.0048	1	T7	12	ALBI AMAR	14.2	*	0.0158
1	T5	61	EUCL DIVI	5.4		0.0023	1	T7	13	ALBI AMAR	4.4	*	0.0015
1	T5	62	PTER ROTU	3.7		0.0011	1	T7	14	GREW MONT	5.1		0.0020
1	T5	63	PTER ROTU	6.4		0.0032	1	T7	15	GREW MONT	4.3		0.0015
1	T5	64	ZIZI MUCR	10.2		0.0082	1	T7	16	GARD VOLK	4.5		0.0016
1	T5	65	ALBI AMAR	8.3		0.0054	1	T7	17	GARD VOLK	3.8		0.0011
1	T6	1	LANN DISC	4.0		0.0013	1	T7	18	GARD VOLK	4.5		0.0016
1	T6	2	COMM MOLL	53.5		0.2248	1	T7	19	GARD VOLK	4.9		0.0019
1	T6	3	ZIZI MUCR	4.9		0.0019	1	T7	20	FLAC INDI	3.2		0.0008
1	T6	4	BOSC SALI	12.5		0.0123	1	T7	21	AZAN GARK	3.5		0.0010
1	T6	5	BRAC XLON	6.8	*	0.0036	1	T7	22	LANN DISC	16.5		0.0214
1	T6	6	BRAC XLON	3.1	*	0.0008	1	T7	23	LANN DISC	6.0		0.0028
1	T6	7	COMB MOLL	7.1		0.0040	1	T7	24	STER QUIN	10.3		0.0083
1	T6	8	LANN DISC	8.4	*	0.0055	1	T7	25	STER QUIN	6.8		0.0036
1	T6	9	LANN DISC	5.0	*	0.0020	1	T7	26	BRAC SPIC	32.8		0.0845
1	T6	10	LANN DISC	3.9		0.0012	1	T7	27	LANN DISC	5.7		0.0026

1	T7	28	DIOS MESP	35.7			0.1001
1	T7	29	XIME CAFF	5.5			0.0024
1	T7	30	PELT AFRI	28.3	*		0.0629
1	T7	31	PELT AFRI	24.6	*		0.0475
1	T7	32	BOSC SALI	11.7			0.0108
1	T7	33	EUPH INGE	9.5	*		0.0071
1	T7	34	EUPH INGE	9.0	*		0.0064
1	T7	35	EUPH INGE	8.6	*		0.0058
1	T7	36	EUPH INGE	9.1	*		0.0065
1	T7	37	COMB MOLL	7.0			0.0038
1	T7	38	COMM MOLL	5.8			0.0026
1	T7	39	CORD GOET	5.0	*		0.0020
1	T7	40	CORD GOET	3.7	*		0.0011
1	T7	41	CORD GOET	7.1	*		0.0040
1	T7	42	CORD GOET	4.4	*		0.0015
1	T7	43	CORD GOET	4.9	*		0.0019
1	T7	44	CORD GOET	5.7	*	Q15	0.0026
1	T7	45	CORD GOET	3.0	*	Q15	0.0007
1	T7	46	LANN DISC	5.0		Q15	0.0020
1	T7	47	LANN DISC	5.2		Q15	0.0021
1	T7	48	COMM MOLL	8.2	*	Q15	0.0053
1	T7	49	COMM MOLL	10.8	*	Q15	0.0092
1	T7	50	COMM MOLL	10.3	*	Q15	0.0083
1	T7	51	COMM MOLL	5.6	*	Q15	0.0025
1	T7	52	COMM MOLL	8.5	*	Q15	0.0057
1	T7	53	LANN DISC	3.1		Q15	0.0008
1	T7	54	LANN DISC	7.5		Q15	0.0044
1	T7	55	BOSC SALI	24.4		1/14/05	0.0468
1	T7	56	DIOS MESP	27.3		1/14/06	0.0585
1	T7	57	LANN DISC	5.6	*	1/14/09	0.0025
1	T7	58	LANN DISC	4.7	*	1/14/10	0.0017
1	T7	59	LANN DISC	3.0		1/14/11	0.0007

Appendix 8.4a Butterflies caught in the Kalomo Intensive Study Area.

Species	Abun	Date	ANo	No. spec
JULY DATA				
Acraea acrita		1	7	9
Acraea anemosa		1	8	19
Acraea atolmis		1	9	28
Acraea caldarena		1	10	28
Anthene lunulata		18	11	32
Axiocerses bambana		14	12	32
Belenois aurota		9	13	33
Belenois gidica		6	14	33
Byblia acheloia		1		
Castalius hintza		4		
Catopsilia florella		9		
Charaxes achaemenes		2		
Charaxes guderiana		27		
Charaxes jasius saturnus		3		
Colotis antevippe		12		
Colotis celimene amina		1		
Colotis danae annae		1		
Colotis eris		5		
Colotis euippe		1		
Colotis evagore		1		
Colotis evenina		4		
Colotis pallene		2		
Colotis regina		1		
Crudaria leroma		3		
Danaus chrysippus	7			
Euchrysops malathana		5		
Euchrysops osiris		1		
Hamanumida daedalus		1		
Mylothris chloris		1		
Phalanta phalantha		2		
Platylesches robustus		1		
Syntarucus sp.		4		
Teniorhinus harona		4		

DECEMBER DATASET

Plot	Trans	Date	Spec. No.	Species
1	A	7	1	Belenois gidica
1	A	7	2	Colotis euippe
1	A	7	3	Euchrysops osiris
1	B	7	4	Axiocerses bambana
1	B	7	5	Anthene lunulata
1	B	7	6	Belenois gidica
1	B	7	7	Danaus chrysippus
1	B	7	8	Axiocerses bambana
1	B	7	9	Acraea caldarena
1	B1	7	10	Charaxes guderiana
1	C	7	11	Danaus chrysippus
1	C3	7	12	Charaxes achaemenes
1	B	8	13	Belenois aurota
1	A	8	14	Acraea acrita
1	A	8	15	Belenois aurota
1	A	8	16	Anthene lunulata
1	A	8	17	Anthene lunulata
1	A	8	18	Acraea anemosa
1	A	8	19	Catopsilia florella
1	A	8	20	Colotis antevippe
1	A	8	21	Teniorhinus harona
1	B	8	22	Danaus chrysippus
1	B	8	23	Danaus chrysippus
1	B	8	24	Catopsilia florella
1	B	8	25	Colotis evenina
1	B	8	26	Colotis pallene
1	B	8	27	Axiocerses bambana
1	B	8	28	Catopsilia florella
1	B	8	29	Colotis antevippe
1	B	8	30	Euchrysops malathana
1	C	8	31	Colotis antevippe
1	C	8	32	Axiocerses bambana
1	C	8	33	Belenois gidica
1	C	8	34	Anthene lunulata
1	C1	8	35	Charaxes guderiana
1	C1	8	36	Charaxes guderiana
1	C2	8	37	Byblia acheloia
1	C3	8	38	Charaxes guderiana
1	A	9	39	Anthene lunulata
1	A	9	40	Anthene lunulata
1	A	9	41	Castalius hintza
1	A	9	42	Axiocerses bambana
1	B	9	43	Euchrysops malathana
1	B	9	44	Euchrysops malathana
1	B	9	45	Syntarucus sp.
1	B	9	46	Syntarucus sp.
1	B	9	47	Colotis eris
1	B	9	48	Anthene lunulata
1	C2	9	49	Charaxes guderiana
1	C	9	50	Syntarucus sp.
1	C	9	51	Crudaria leroma
1	C	9	52	Belenois gidica
1	C	9	53	Castalius hintza
1	C	9	54	Colotis antevippe
1	A	9	55	Colotis regina
1	A	9	56	Colotis antevippe
1	A	9	57	Belenois aurota
1	A	9	58	Euchrysops malathana
1	A	9	59	Teniorhinus harona
1	B	9	60	Anthene lunulata
1	B	9	61	Mylothris chloris
1	B	9	62	Colotis evagore
1	B	9	63	Acraea atolmis
1	C	9	64	Catopsilia florella
1	C	9	65	Catopsilia florella
1	C	9	66	Axiocerses bambana
1	C	9	67	Belenois aurota
1	C	9	68	Colotis celimene amina
1	A	10	69	Colotis eris
1	A	10	70	Anthene lunulata
1	A	10	71	Catopsilia florella
1	A	10	72	Catopsilia florella
1	C	10	73	Belenois gidica
1	B	10	74	Castalius hintza
1	B	10	75	Crudaria leroma
1	A3	10	76	Charaxes guderiana

Plot	Trans	Date	Spec. No.	Species
1	B1	10	77	Charaxes guderiana
1	B2	10	78	Charaxes guderiana

1	B3	10	79	Charaxes guderiana
1	C1	10	80	Charaxes guderiana
1	C3	10	81	Charaxes guderiana
1	C3	10	82	Charaxes guderiana
1	A	11	83	Platylesches robustus
1	A	11	84	Colotis antevippe
1	A	11	85	Belenois aurota
1	A	11	86	Syntarucus sp.
1	B	11	87	Castalius hintza
1	B	11	88	Phalanta phalantha
1	B	11	89	Crudaria leroma
1	B	11	90	Colotis antevippe
1	B	11	91	Colotis eris
1	B	11	92	Danaus chrysippus
1	C	11	93	Axiocerses bambana
1	A	11	94	Colotis danae annae
1	A	11	95	Anthene lunulata
1	B	11	96	Phalanta phalantha
1	C	11	97	Belenois gidica
1	A1	11	98	Charaxes guderiana
1	A2	11	99	Charaxes guderiana
1	A3	11	100	Charaxes guderiana
1	B1	11	101	Charaxes guderiana
1	B2	11	102	Charaxes guderiana
1	B2	11	103	Charaxes j. saturnus
1	C2	11	104	Charaxes guderiana
1	A	12	105	Colotis eris
1	A	12	106	Anthene lunulata
1	A	12	107	Anthene lunulata
1	A	12	108	Colotis pallene
1	A	12	109	Axiocerses bambana
1	B	12	110	Axiocerses bambana
1	B	12	111	Axiocerses bambana
1	B	12	112	Belenois aurota
1	B	12	113	Catopsilia florella
1	C	12	114	Belenois aurota
1	C	12	115	Colotis antevippe
1	C	12	116	Colotis antevippe
1	C	12	117	Anthene lunulata
1	C	12	118	Anthene lunulata
1	C	12	119	Colotis evenina
1	A2	12	120	Charaxes j. saturnus
1	A2	12	121	Charaxes achaemenes
1	B2	12	122	Charaxes guderiana
1	A	13	123	Belenois aurota
1	A	13	124	Colotis evenina
1	A	13	125	Axiocerses bambana
1	A	13	126	Hamanumida daedalus
1	A	13	127	Danaus chrysippus
1	A	13	128	Anthene lunulata
1	B	13	129	Colotis antevippe
1	B	13	130	Colotis antevippe
1	B	13	131	Colotis antevippe
1	B	13	132	Colotis evenina
1	B	13	133	Euchrysops malathana
1	C	13	134	Colotis eris
1	C	13	135	Catopsilia florella
1	C	13	136	Axiocerses bambana
1	C	13	137	Axiocerses bambana
1	C	13	138	Teniorhinus harona
1	A2	13	139	Charaxes guderiana
1	B1	13	140	Charaxes guderiana
1	C3	13	141	Charaxes guderiana
1	B3	13	142	Charaxes j. saturnus
1	B	14	143	Belenois aurota
1	B	14	144	Axiocerses bambana
1	B	14	145	Teniorhinus harona
1	B	14	146	Danaus chrysippus
1	C	14	147	Anthene lunulata
1	C	14	148	Anthene lunulata
1	C	14	149	Anthene lunulata
1	C1	14	150	Charaxes guderiana
1	C2	14	151	Charaxes guderiana
1	C2	14	152	Charaxes guderiana
1	A1	14	153	Charaxes guderiana
1	B3	14	154	Charaxes guderiana

Appendix 8.4b. Cetoniini beetles collected in the Kalomo Intensive Study Area.

Plot/ Trans/Trap No.		Date	Spec. No.	Species
1A 2	7	1		Porphyronota ?hebreae
1C 3	8	137		Tephraea morosa
1C 1	15	5661		Porphyronota ?hebreae
1A 1	11	5662		P. ?hebreae
1B 3	9	5663		P. ?hebreae
1A 1	11	5664		P. ?hebreae
1B 3	11	5665		P. ?hebreae
1C 2	11	5666		P. ?hebreae
1C 3	9	5667		P. ?maculatissima
1B 3	9	5668		P. ?maculatissima
1B 3	11	5669		P. ?maculatissima
1B 2	9	5670		P. ?maculatissima
1C 1	13	5671		Pachnoda sinuata flaviventris
1A 1	15	5672		Pachnoda sinuata flaviventris
1A 3	16	5673		Pachnoda sinuata flaviventris
1A 3	16	5674		Pachnoda sinuata flaviventris
1B 1	11	5675		Tephraea morosa
1B 3	13	5676		Tephraea morosa
1C 3	8	5677		Tephraea morosa
1B 3	11	5678		Plaesiorrhinella trivittata
1C 3	13	5679		Plaesiorrhinella trivittata
1C 1	9	5680		Plaesiorrhinella trivittata
1C 1	9	5681		Plaesiorrhinella trivittata
1C 1	9	5682		Plaesiorrhinella trivittata
1A 3	11	5683		Polystalactica conspergata
1A 3	11	5684		Polystalactica conspergata
1C 1	12	5685		Polystalactica conspergata
1C 1	9	5686		Tephraea dichroa
1A 1	10	5687		Polystalactica perroudi
1B 1	8	5688		Polystalactica perroudi
1A 3	11	5689		Chlorocala africana subsuturalis
1A 1	11	5690		Caelorrhina barthi mashunal
1B 3	14	5691		Eudicella quadrimaculata
1A 3	9	5692		Anisorrhina flavomaculata
1C 2	16	5693		Anisorrhina flavomaculata

Appendix 8.5a Daily catches of Spiders caught in the Drift Fence Pitfall trap placed in the plot.

DATE	FAMILY	GENUS/SPECIES	NO.	SEX
8.12.94	Oxyopidae	Oxyopes "A"	1	♂
8.12.94	Corinnidae	Graptartia "A"	1	♂
8.12.94	Corinnidae	Graptartia "B"	1	♂
8.12.94	Zodariidae	H. loricatus	1	♂
8.12.94	Zodariidae	Cydrela "A" ?	1	♂
8.12.94	Heteropodidae	A	2	♂
8.12.94	Gnaphosidae	Asemesthes "A"	1	juv
8.12.94	Lycosidae	C	1	♂
8.12.94	Zodariidae	Capheris	1	♂
9.12.94	Gnaphosidae	Setaphis "A"	3	3♀,1♂
9.12.94	Gnaphosidae	Asemesthes "A"	2	♂, ♀
9.12.94	Zodariidae	Diores "A"	2	juv
9.12.94	Lycosidae	C	1	♂
9.12.94	Lycosidae	I	1	♂
9.12.94	Heteropodidae	B	3	♂
10.12.94	Pisauridae	A	2	♂
10.12.94	Zodariidae	Capheris	1	♂
10.12.94	Lycosidae	F	2	♂
10.12.94	Lycosidae	C	6	♂
10.12.94	Thomisidae	Simorcus	2	♂
10.12.94	Gnaphosidae	Setaphis "A"	3	♂
10.12.94	Zodariidae	Diores "A"	1	♂
10.12.94	Gnaphosidae	Camillina cordifera?	1	♀
10.12.94	Gnaphosidae	Asemesthes "A"	1	juv
11.12.94	Theraphosidae	Pterinochilus	1	♂
11.12.94	Thomisidae	Simorcus	2	♂
11.12.94	Thomisidae	Synema "A"	1	♂
11.12.94	Heteropodidae	A	1	♂
11.12.94	Lycosidae	C	7	6♂,1♀
11.12.94	Gnaphosidae	Setaphis "A"	2	♂
11.12.94	Lycosidae	F	1	♂
12.12.94	Dipluridae	Thelechoris karschi?		1♂
12.12.94	Pisauridae	A	1	♂
12.12.94	Palpimanidae	Palpimanus	1	juv
12.12.94	Zodariidae	Diores "A"	2	♂,juv
12.12.94	Zodariidae	Hermippus loricatus	1	♂
12.12.94	Zodariidae	Capheris	1	♂
12.12.94	Lycosidae	F	1	♂
12.12.94	Lycosidae	C	1	♂
12.12.94	Gnaphosidae	Setaphis "A"	11	4♀,3♂,4juv
12.12.94	Lycosidae	A	2	♂
12.12.94	Gnaphosidae	Asemesthes "A"	1	♀
12.12.94	Salticidae	B	1	♂
12.12.94	Zodariidae	Palfuria	1	♀
12.12.94	Heteropodidae	A	1	♂
13.12.94	Zodariidae	Capheris	1	♂
13.12.94	Zodariidae	Hermippus loricatus	2	♂
13.12.94	Lycosidae	A	1	♂
13.12.94	Lycosidae	C	1	♀
13.12.94	Zodariidae	Cydrela "A" ?	1	♂
13.12.94	Salticidae	C	1	♂
13.12.94	Zodariidae	Diores "A"	1	♀
13.12.94	Heteropodidae	B	1	♂
13.12.94	Heteropodidae	A	1	♂
13.12.94	Gnaphosidae	Asemesthes "A"	1	♀
13.12.94	Gnaphosidae	Xerophaeus "B"	1	♂
13.12.94	Gnaphosidae	Setaphis "A"	15	6♂,6♀,3juv
14.12.94	Gnaphosidae	Asemesthes "A"	1	♀
14.12.94	Zodariidae	Diores "A"	1	♀
14.12.94	Lycosidae	C	1	juv
14.12.94	Heteropodidae	A	1	♂
OTHER				
Solifugae	Solpuga predatrix ?		9	4♂, ♀, 4juv
	Diplopoda		4	
	Pseudoscorpionida		1	
Acari	Mite		1	
9.12.94	Lycosidae	C	2	♂
9.12.94	Zodariidae	Diores "B"	3	♂,♀,j
9.12.94	Gnaphosidae	Asemesthes "A"	1	♂
10.12.94	Theraphosidae	Pterinochilus	1	♂
10.12.94	Gnaphosidae	Asemesthes "A"	1	♂
10.12.94	Gnaphosidae	Setaphis 'C"	1	♂
10.12.94	Gnaphosidae	Camillina" lutea	1	♀
10.12.94	Lycosidae	C	5	♂
10.12.94	Lycosidae	F	1	♂
10.12.94	Zodariidae	Cydrela "A" ?	2	♂
10.12.94	Zodariidae	Diores "B"	1	♀
10.12.94	Thomisidae	A	1	juv
10.12.94	Gnaphosidae	Camillina "A"	1	♂
11.12.94	Dipluridae	Thelechoris karschi?		1 ♂
11.12.94	Corinnidae	Graptartia "B"	2	♂,♀
11.12.94	Zodariidae	Hermippus loricatus		2 ♂
11.12.94	Gnaphosidae	Setaphis "A"	3	2♂ ♀
11.12.94	Gnaphosidae	Asemesthes "A"	1	♂
11.12.94	Zodariidae	Diores "B"	1	juv
11.12.94	Pisauridae	A	1	♂
11.12.94	Lycosidae	???	10	♂
11.12.94	Lycosidae	N	1	♂
11.12.94	Araneidae	A	1	♂
12.12.94	Scytodidae	Scytodes "B"	1	♂
12.12.94	Oxyopidae	Oxyopes "C"	1	juv
12.12.94	Gnaphosidae	Setaphis "A"	1	♂
12.12.94	Gnaphosidae	Asemesthes "A"	1	♂
12.12.94	Gnaphosidae	Zelotes	1	♂
12.12.94	Zodariidae	Capheris	1	♂
12.12.94	Salticidae	B	2	♂
12.12.94	Lycosidae	C	4	♂
12.12.94	Gnaphosidae	Xerophaeus "A"	1	♂
13.12.94	Lycosidae	C	3	♂
13.12.94	Salticidae	F	1	♀
13.12.94	Gnaphosidae	Setaphis "A"	1	♂
13.12.94	Gnaphosidae	Asemesthes "A"	1	♂
13.12.94	Zodariidae	Cydrela "A" ?	1	♂
14.12.94	Zodariidae	Hermippus loricatus	1	♂
14.12.94	Lycosidae	C	1	♂
OTHER				
	Solifugae	Solpuga	2	♀
	Diplopoda		17	
	Chilopoda		2	
9.12.94	Scytodidae	Scytodes "B"	2	♂♀
9.12.94	Thomisidae	Runcinia depressa?	1	♂
9.12.94	Pisauridae	A	2	♂

DATE	FAMILY	GENUS/SPECIES	NO.	SEX
9.12.94	Gnaphosidae	Asemesthes "A"	1	♂
9.12.94	Gnaphosidae	Setaphis "C"	1	♂
9.12.94	Heteropodidae	B	3	1 ♀2 ♀
9.12.94	Lycosidae	J	3	♂
9.12.94	Lycosidae	K	7	♂
9.12.94	Zodariidae	C	2	♀
10.12.94	Oxyopidae	Oxyopes "A"	1	♂
10.12.94	Thomisidae	Runcinia depressa?	1	♂
10.12.94	Zodariidae	Diores "A"	1	♀
10.12.94	Lycosidae	K	1	♂
10.12.94	Lycosidae	A	1	♂
10.12.94	Lycosidae	L	1	♂
10.12.94	Lycosidae	E	1	♂
10.12.94	Gnaphosidae	Setaphis "A"	5	3 ♀2 ♂
10.12.94	Gnaphosidae	Asemesthes "A"	1	♀
11.12.94	Pisauridae	A	2	♂
11.12.94	Palpimanidae	Palpimanus	1	♀
11.12.94	Thomisidae	Simorcus	1	♂
11.12.94	Araneidae	A	1	♂
11.12.94	Lycosidae	J	6	3 ♂3j
11.12.94	Lycosidae	K	9	8 ♂♀
12.12.94	Pisauridae	B	1	♂
12.12.94	Pisauridae	A	2	♂
12.12.94	Zodariidae	Hermippus loricatus	1	♂
12.12.94	Heteropodidae	A	1	juv
12.12.94	Lycosidae	E	1	♂
12.12.94	Lycosidae	K	6	♂
13.12.94	Salticidae	B	1	♂
13.12.94	Lycosidae	E	1	♂
13.12.94	Gnaphosidae	Camillina" lutea	1	♀
13.12.94	Caponidae	Caponia	2	j
14.12.94	Lycosidae	C	5	2 ♂ ♀2j
14.12.94	Zodariidae	Diores "A"	1	♂
14.12.94	Heteropodidae	A	1	♂
OTHER				
	Diplopoda		7	
	Acari Mite		2	
	Chilopoda		2	

Appendix 8.5b Daily catches of spiders caught by beating 20 trees along each transect

DATE		FAMILY	GENUS/SPECIES	NO.	SEX
9.12.95	A	Heteropodidae	C	2	juv
9.12.95	A	Philodromidae	Philodromus sp	1	♀
9.12.95	A	Clubionidae	Cheiracanthium "A"	1	juv
9.12.95	A	Thomisidae	Tmarus cameliformis	1	juv
9.12.95	A	Araneidae	B	1	juv
9.12.95	A	Salticidae	B	2	juv
9.12.95	B	Oxyopidae	Oxyopes "E"	1	♀
9.12.95	B	Araneidae	B	1	juv
9.12.95	B	Heteropodidae	C	1	juv
9.12.95	B	Araneidae	7	1	juv
9.12.95	B	Salticidae	F	1	juv
9.12.95	B	Oxyopidae	Oxyopes "D"	1	♂
9.12.95	B	Salticidae	B	1	juv
9.12.95	B	Araneidae	D	1	juv
9.12.95	B	Thomisidae	Synema "F"	1	juv
9.12.95	C	Oxyopidae	Oxyopes "E"	1	♀
9.12.95	C	Oxyopidae	Oxyopes "D"	1	juv
9.12.95	C	Thomisidae	Tmarus cameliformis	1	juv
9.12.95	C	Thomisidae	Synema "C"	2	♀,juv
10.12.94	A	Thomisidae	Tmarus cameliformis	1	juv
10.12.94	A	Heteropodidae	C	1	juv
10.12.94	A	Clubionidae	Cheiracanthium "A"	1	juv
10.12.94	A	Salticidae	E	1	juv
10.12.94	A	Salticidae	F	3	juv
10.12.94	A	Thomisidae	Synema "D"	1	juv
10.12.94	A	Thomisidae	Synema "E"	1	♀
10.12.94	A	Araneidae	I	1	juv
10.12.94	B	Araneidae	F	1	♂
10.12.94	B	Clubionidae	Cheiracanthium "A"	5	juv
10.12.94	B	Thomisidae	Synema "C"	1	juv
10.12.94	B	Salticidae	G	1	♀
10.12.94	B	Salticidae	F	1	juv
10.12.94	B	Salticidae	B	1	juv
10.12.94	B	Salticidae	H	1	juv
10.12.94	C	Thomisidae	Tmarus cameliformis	4	juv
10.12.94	C	Oxyopidae	Oxyopes "E"	1	juv
10.12.94	C	Oxyopidae	Oxyopes "D"	2	juv
10.12.94	C	Thomisidae	Synema "C"	1	juv
11.12.94	A	Araneidae	B	1	juv
11.12.94	A	Araneidae	D	1	♂
11.12.94	A	Clubionidae	Cheiracanthium "A"	1	juv
11.12.94	B	Thomisidae	Tmarus africanus 1	♂	
11.12.94	B	Salticidae	F	3	♀, 2juv
11.12.94	B	Oxyopidae	Oxyopes "D"	1	juv
11.12.94	B	Oxyopidae	Oxyopes "E"	1	♀
11.12.94	B	Clubionidae	Cheiracanthium "A"	2	♂, juv
11.12.94	B	Thomisidae	Tmarus cameliformis	1	juv

DATE	FAMILY		GENUS/SPECIES	NO.	SEX
11.12.94	B	Philodromidae	Tibellus gerhardi 1	juv	
11.12.94	B	Scytodidae	Scytodes "A"	1	juv
11.12.94	C	Thomisidae	Tmarus cameliformis	15	♂,14j
11.12.94	C	Oxyopidae	Oxyopes "E"	4	juv
11.12.94	C	Salticidae	F	3	juv
11.12.94	C	Araneidae	H	1	juv
11.12.94	C	Oxyopidae	Oxyopes "D"	1	♀

11.12.94	C	Clubionidae	Cheiracanthium "A"	2	♀,juv
11.12.94	C	Salticidae	E	1	juv
11.12.94	C	Araneidae	K	1	juv
12.12.94	A	Salticidae	F	2	juv
12.12.94	A	Salticidae	E	1	♀
12.12.94	A	Oxyopidae	Oxyopes "D"	1	♂
12.12.94	A	Salticidae	B	1	juv
12.12.94	A	Thomisidae	Synema "G"	1	♀
12.12.94	A	Araneidae	C	1	juv
12.12.94	A	Araneidae	B	1	juv
12.12.94	B	Thomisidae	Tmarus cameliformis	2	juv
12.12.94	B	Thomisidae	Synema "F"	1	juv
12.12.94	B	Salticidae	F	2	♀,juv
12.12.94	B	Salticidae	E	1	♀
12.12.94	C	Oxyopidae	Oxyopes "E"	4	2♂,1♀,j
12.12.94	C	Oxyopidae	Oxyopes "D"	2	j
12.12.94	C	Thomisidae	Tmarus cameliformis	1	♀
12.12.94	C	Thomisidae	B	1	♀
13.12.94	A	Araneidae	E	1	♀
13.12.94	A	Thomisidae	Tmarus cameliformis	2	♀,j
13.12.94	A	Salticidae	B	1	juv
13.12.94	A	Araneidae	J	1	juv
13.12.94	B	Clubionidae	Cheiracanthium "B"	1	♂
13.12.94	B	Thomisidae	Tmarus cameliformis	4	♀,3j
13.12.94	B	Araneidae	B	3	juv
13.12.94	B	Salticidae	F	1	juv
13.12.94	B	Gnaphosidae	Asemesthes "A"	1	juv
13.12.94	B	Oxyopidae	Oxyopes "D"	2	♀, j
13.12.94	B	Oxyopidae	Oxyopes "E"	1	♀
13.12.94	C	Thomisidae	Tmarus cameliformis	14	3♂,11j
13.12.94	C	Thomisidae	B	1	♀
13.12.94	C	Araneidae	Caerostris sp	1	juv
13.12.94	C	Oxyopidae	Oxyopes "D"	5	1♀,4j
13.12.94	C	Oxyopidae	Oxyopes "E"	3	♀,2j
13.12.94	C	Araneidae	B	3	juv
13.12.94	C	Salticidae	B	3	juv
14.12.94	A	Araneidae	B	1	juv
14.12.94	A	Araneidae	I	1	juv
14.12.94	B	Gnaphosidae	Asemesthes "A"	1	juv
14.12.94	B	Salticidae	F	1	juv

DATE	FAMILY	GENUS/SPECIES		NO.	SEX
14.12.94	B	Salticidae	H	2	juv
14.12.94	B	Salticidae	G	1	♀
14.12.94	B	Thomisidae	Tmarus cameliformis	3	juv
14.12.94	B	Clubionidae	Cheiracanthium "A"	1	juv
14.12.94	B	Oxyopidae	Oxyopes "E"	1	♀
14.12.94	B	Oxyopidae	Oxyopes "D"	2	juv
14.12.94	B	Araneidae	I	1	juv
14.12.94	C	Oxyopidae	Oxyopes "E"	1	juv
14.12.94	C	Thomisidae	Tmarus cameliformis	3	juv
14.12.94	C	Salticidae	F	1	juv
OTHER					
		Acari	Mite	1	
			Tick	1	
8.12.94	A	Araneidae	H	1	juv

8.12.94	A	Zodariidae	B	1	♂
8.12.94	A	Scytodidae	Scytodes "A"	1	juv
8.12.94	A	Salticidae	H	1	♀
8.12.94	A	Salticidae	K	2	juv
8.12.94	A	Thomisidae	Monaeses quadrituberculatus	1	♀
8.12.94	A	Thomisidae	Monaeses gibbus 1	♀	
8.12.94	A	Thomisidae	Runcinia flavida	1	♀
8.12.94	A	Philodromidae	Tibellus gerhardi 4	1♀, 3juv	
8.12.94	A	Thomisidae	Monaeses austrinus	2	♂
8.12.94	A	Oxyopidae	Oxyopes "D"	1	juv
8.12.94	A	Lycosidae	O	1	juv
8.12.94	A	Araneidae	L	1	♂
8.12.94	A	Araneidae	P	1	juv
8.12.94	A	Araneidae	M	1	juv
8.12.94	A	Araneidae	B	1	juv
8.12.94	A	Araneidae	N	1	♂
8.12.94	A	Lycosidae	B	1	juv
8.12.94	B	Araneidae	B	1	juv
8.12.94	B	Araneidae	O	3	2♂, 1♀
8.12.94	B	Araneidae	P	2	♀
8.12.94	B	Salticidae	F	1	♀
8.12.94	B	Salticidae	B	1	juv
8.12.94	B	Oxyopidae	Oxyopes "D"	1	juv
8.12.94	B	Thomisidae	Synema "A"	1	♂
8.12.94	B	Thomisidae	Monaeses austrinus	2	♂
8.12.94	B	Philodromidae	Tibellus gerhardi 2	juv	
8.12.94	B	Araneidae	H	1	juv
8.12.94	C	Salticidae	J	2	♂
8.12.94	C	Salticidae	B	1	juv
8.12.94	C	Salticidae	H	2	juv
8.12.94	C	Lycosidae	B	1	juv
8.12.94	C	Araneidae	B	3	juv
8.12.94	C	Araneidae	N	1	♀

DATE	FAMILY	GENUS/SPECIES		NO.	SEX
8.12.94	C	Araneidae	Q	1	juv
8.12.94	C	Araneidae	K	1	juv
8.12.94	C	Thomisidae	Monaeses austrinus	1	♂
8.12.94	C	Philodromidae	Tibellus gerhardi 1	juv	
8.12.94	C	Thomisidae	Avelis	1	♂
9.12.94	A	Araneidae	R	1	♂
9.12.94	A	Araneidae	G	2	♀, juv
9.12.94	A	Araneidae	S	1	♂
9.12.94	A	Oxyopidae	Oxyopes "D"	1	♀
9.12.94	A	Scytodidae	Scytodes "A"	1	juv
9.12.94	A	Salticidae	B	1	juv
9.12.94	A	Salticidae	F	1	♂
9.12.94	A	Salticidae	E	2	♀, juv
9.12.94	A	Lycosidae	B	1	juv
9.12.94	A	Heteropodidae	C	1	juv
9.12.94	A	Philodromus	Tibellus gerhardi 4	juv	
9.12.94	A	Thomisidae	Tmarus	3	juv
9.12.94	A	Thomisidae	Monaeses austrinus	2	♂,♀
9.12.94	A	Thomisidae	Runcinia flavida	1	♀
9.12.94	B	Araneidae	B	1	juv
9.12.94	B	Oxyopidae	Oxyopes "C"	1	juv

9.12.94	B	Salticidae	H	1	juv
9.12.94	B	Philodromidae	Tibellus gerhardi 1	juv	
9.12.94	B	Lycosidae	O	1	juv
9.12.94	C	Araneidae	B	1	juv
9.12.94	C	Araneidae	O	1	♂
9.12.94	C	Araneidae	H	2	♂,j
9.12.94	C	Araneidae	G	1	♀
9.12.94	C	Theridiidae	A	1	juv
9.12.94	C	Lycosidae	O	1	juv
9.12.94	C	Philodromidae	Tibellus gerhardi 6	juv	
9.12.94	C	Thomisidae	Monaeses austrinus	2	♂, ♀
9.12.94	C	Salticidae	B	2	♀,j
9.12.94	C	Salticidae	F	3	juv
9.12.94	C	Salticidae	I	2	juv
10.12.94	A	Oxyopidae	Oxyopes "D"	1	juv
10.12.94	A	Scytodidae	Scytodes 1	juv	
10.12.94	A	Araneidae	N	1	♀
10.12.94	A	Araneidae	B	3	juv
10.12.94	A	Salticidae	I	1	juv
10.12.94	A	Salticidae	J	3	2♂,j
10.12.94	A	Salticidae	K	1	♀
10.12.94	A	Salticidae	F	2	♂
10.12.94	A	Thomisidae	Monaeses austrinus	3	2♂,1♀
10.12.94	A	Thomisidae	Runcinia flavida	1	♀
10.12.94	A	Philodromidae	Tibellus gerhardi 3	♀, 2j	
10.12.94	A	Araneidae	H	1	juv

DATE	FAMILY	GENUS/SPECIES		NO.	SEX
10.12.94	A	Thomisidae	Tmarus	1	juv
10.12.94	A	Thomisidae	Synema "C"	1	juv
10.12.94	B	Araneidae	B	1	juv
10.12.94	B	Araneidae	N	1	♀
10.12.94	B	Araneidae	T	1	juv
10.12.94	B	Theridiidae	A	2	♀
10.12.94	B	Araneidae	H	1	juv
10.12.94	B	Clubionidae	Cheiracanthium "A"	1	♀
10.12.94	B	Oxyopidae	Oxyopes "D"	1	juv
10.12.94	B	Oxyopidae	Oxyopes "C"	1	juv
10.12.94	B	Salticidae	H	3	1♀,2j
10.12.94	B	Salticidae	B	1	♀
10.12.94	B	Thomisidae	Synema "A"	1	♂
10.12.94	B	Philodromidae	Tibellus gerhardi 2	juv	
10.12.94	B	Thomisidae	Monaeses austrinus	1	♂
10.12.94	B	Lycosidae	B	1	juv
10.12.94	B	Araneidae	B	1	juv
10.12.94	C	Araneidae	N	1	♀
10.12.94	C	Araneidae	B	1	juv
10.12.94	C	Araneidae	T	1	juv
10.12.94	C	Theridiidae	A	1	♀
10.12.94	C	Salticidae	I	1	juv
10.12.94	C	Araneidae	H	3	juv
10.12.94	C	Thomisidae	Monaeses austrinus	2	♂, ♀
10.12.94	C	Lycosidae	B	1	juv
11.12.94	A	Lycosidae	B	1	juv
11.12.94	A	Oxyopidae	Oxyopes "D"	1	♀
11.12.94	A	Oxyopidae	Oxyopes "C"	1	juv

11.12.94	A	Oxyopidae	Oxyopes "A"	1	♂
11.12.94	A	Theridiidae	A	1	♀
11.12.94	A	Araneidae	B	2	juv
11.12.94	A	Araneidae	P	1	♀
11.12.94	A	Salticidae	I	2	♀, juv
11.12.94	A	Salticidae	H	1	juv
11.12.94	A	Salticidae	F	1	♂
11.12.94	A	Thomisidae	Monaeses austrinus	2	♂, ♀
11.12.94	A	Philodromidae	Tibellus gerhardi 2	juv	

DATE	FAMILY	GENUS/SPECIES	NO.	SEX
11.12.94	A	Thomisidae	Runcinia flavida	2	♀
11.12.94	A	Araneidae	H	1	juv
11.12.94	B	Oxyopidae	Oxyopes "D"	1	juv
11.12.94	B	Theridiidae	A	1	♀
11.12.94	B	Araneidae	I	1	♂
11.12.94	B	Theridiidae	Latrodectus renivulatus	1	♂
11.12.94	B	Thomisidae	Pherecydes lucinae	2	♀
11.12.94	B	Philodromidae	Tibellus gerhardi 4	juv	

DATE	FAMILY	GENUS/SPECIES	NO.	SEX
11.12.94	B	Thomisidae	Runcinia depressa 1	juv	
11.12.94	C	Araneidae	B	3	juv
11.12.94	C	Araneidae	N	1	juv
11.12.94	C	Salticidae	H	2	juv
11.12.94	C	Salticidae	F	2	juv
11.12.94	C	Salticidae	I	1	♀
11.12.94	C	Heteropodidae	B	1	♀
11.12.94	C	Philodromidae	Tibellus gerhardi 1	juv	
11.12.94	C	Araneidae	H	4	1♂, 3 juv
11.12.94	C	Thomisidae	Synema "B"	1	j,
MORNING SAMPLES					
12.12.94	A	Thomisidae	Monaeses austrinus	2	♂
12.12.94	A	Thomisidae	Monaeses quadrituberculatus 1	♂	
12.12.94	A	Thomisidae	Tmarus	1	juv
12.12.94	A	Araneidae	B	1	juv
12.12.94	A	Oxyopidae	Oxyopes "B"	1	♀
12.12.94	B	Lycosidae	B	1	juv
12.12.94	B	Araneidae	B	1	juv
12.12.94	B	Salticidae	J	1	♂
12.12.94	B	Salticidae	F	2	juv
12.12.94	B	Oxyopidae	Oxyopes "D"	1	juv
12.12.94	B	Philodromidae	Tibellus gerhardi 2	juv	
12.12.94	C	Araneidae	B	2	♀, juv
12.12.94	C	Araneidae	N	3	1♀, 2j
12.12.94	C	Araneidae	P	1	♀
12.12.94	C	Lycosidae	B	1	juv
12.12.94	C	Salticidae	B	2	♀, ♂
12.12.94	C	Philodromidae	Tibellus gerhardi	1	juv
12.12.94	C	Thomisidae	Monaeses austrinus	1	♂
AFTERNOON SAMPLES					
12.12.94	A	Lycosidae	B	3	juv
12.12.94	A	Scytodidae	Scytodes "A"	1	juv
12.12.94	A	Salticidae	I	1	juv
12.12.94	A	Salticidae	H	2	juv
12.12.94	A	Araneidae	B	6	juv

12.12.94	A	Araneidae	O	1	♀
12.12.94	A	Araneidae	U	1	♂
12.12.94	A	Araneidae	V	1	♀
12.12.94	A	Araneidae	W	1	♀
12.12.94	A	Araneidae	N	1	♀
12.12.94	A	Araneidae	X	1	juv
12.12.94	A	Thomisidae	Synema "A"	1	♂
12.12.94	A	Araneidae	H	4	1♂, 3 juv
12.12.94	A	Thomisidae	Monaeses austrinus	2	♂, j
12.12.94	A	Philodromidae	Tibellus gerhardi 5	juv	
12.12.94	B	Lycosidae	B	1	juv

DATE	FAMILY	GENUS/SPECIES	NO.	SEX
12.12.94	B	Araneidae H	1	juv
12.12.94	B	Philodromidae	Tibellus gerhardi 2	juv	
12.12.94	B	Oxyopidae	Oxyopes "C"	1	juv
12.12.94	B	Oxyopidae	Oxyopes "E"	1	juv
12.12.94	B	Oxyopidae	Oxyopes "D"	1	juv
12.12.94	B	Araneidae	T	1	♂
12.12.94	B	Araneidae	B	2	juv
12.12.94	B	Araneidae	P	1	juv
12.12.94	B	Araneidae	K	1	juv
12.12.94	B	Araneidae	I	2	juv
12.12.94	B	Salticidae	H	1	juv
12.12.94	B	Salticidae	F	1	♂
12.12.94	B	Salticidae	J	1	♂
12.12.94	C	Philodromidae	Tibellus gerhardi 5	juv	
12.12.94	C	Thomisidae	Synema "A"	2	♂, j
12.12.94	C	Thomisidae	Tmarus	2	juv
12.12.94	C	Theridiidae	Latrodectus renivulatus	1	♂
12.12.94	C	Araneidae	K	2	juv
12.12.94	C	Oxyopidae	Oxyopes "D"	1	juv
12.12.94	C	Lycosidae	B	1	juv
12.12.94	C	Salticidae	B	1	juv
12.12.94	C	Salticidae	H	1	juv
13.12.94	A	Thomisidae	B	1	♀
13.12.94	A	Thomisidae	Heriaeus 1	juv	
13.12.94	A	Philodromidae	Tibellus gerhardi 3	juv	
13.12.94	A	Thomisidae	Monaeses austrinus	1	♀
13.12.94	A	Thomisidae	Runcinia flavida	1	♀
13.12.94	A	Lycosidae	B	2	juv
13.12.94	A	Salticidae	I	1	juv
13.12.94	A	Salticidae	H	1	♀
13.12.94	A	Salticidae	F	1	juv
13.12.94	A	Salticidae	B	2	juv
13.12.94	A	Araneidae	B	7	juv
13.12.94	A	Araneidae	P	1	♀
13.12.94	A	Araneidae	I	1	juv
13.12.94	A	Araneidae	K	4	juv
13.12.94	A	Theridiidae	A	1	♀
13.12.94	B	Lycosidae	B	3	juv
13.12.94	B	Salticidae	I	2	♀, j
13.12.94	B	Salticidae	H	2	juv
13.12.94	B	Salticidae	B	1	juv
13.12.94	B	Araneidae	B	4	juv
13.12.94	B	Araneidae	Q	1	juv

13.12.94	B	Theridiidae	A	1	♀
13.12.94	B	Thomisidae	B	1	♂
13.12.94	B	Philodromidae	Tibellus gerhardi 3	juv	
13.12.94	B	Thomisidae	Monaeses austrinus	1	♂
13.12.94	C	Lycosidae	B	2	juv

DATE	FAMILY	GENUS/SPECIES	NO.	SEX
13.12.94	C	Salticidae	J	1	♂
13.12.94	C	Salticidae	B	1	juv
13.12.94	C	Salticidae	H	1	juv
13.12.94	C	Oxyopidae	Oxyopes "D"	1	juv
13.12.94	C	Araneidae	P	2	♀, j
13.12.94	C	Araneidae	B	4	♀
13.12.94	C	Araneidae	G	1	♀
13.12.94	C	Araneidae	X	1	juv
13.12.94	C	Araneidae	K	1	juv
13.12.94	C	Araneidae	I	4	juv
13.12.94	C	Philodromidae	Tibellus gerhardi 3	juv	
13.12.94	C	Araneidae	H	1	♂
13.12.94	C	Thomisidae	Runcinia flavida	1	♀
13.12.94	C	Thomisidae	Tmarus	1	juv
14.12.94	A	Thomisidae	Monaeses austrinus	4	2♂,2♀
14.12.94	A	Philodromidae	Tibellus gerhardi 3	juv	
14.12.94	A	Uloboridae	Miagrammops	1	♂
14.12.94	A	Lycosidae	B	5	juv
14.12.94	A	Salticidae	H	1	juv
14.12.94	A	Salticidae	I	1	♀
14.12.94	A	Salticidae	F	2	♂, juv
14.12.94	A	Oxyopidae	Oxyopes "D"	1	♀
14.12.94	A	Araneidae	X	1	juv
14.12.94	A	Theridiidae	A	1	♀
14.12.94	B	Philodromidae	Tibellus gerhardi 6	juv	
14.12.94	B	Thomisidae	Simorcus	1	juv
14.12.94	B	Araneidae	H	2	juv
14.12.94	B	Thomisidae	Runcinia flavida	2	♂, ♀
14.12.94	B	Lycosidae	B	2	juv
14.12.94	B	Oxyopidae	Oxyopes "D"	2	♀, juv
14.12.94	B	Oxyopidae	Oxyopes "C"	1	juv
14.12.94	B	Salticidae	H	1	juv
14.12.94	B	Salticidae	F	1	juv
14.12.94	B	Araneidae	B	2	juv
14.12.94	B	Araneidae	P	2	juv
14.12.94	C	Scytodidae	Scytodes 1	♀	
14.12.94	C	Lycosidae	B	4	juv
14.12.94	C	Salticidae	H	2	♀, juv
14.12.94	C	Salticidae	I	1	♀
14.12.94	C	Salticidae	B	1	juv
14.12.94	C	Salticidae	F	1	juv
14.12.94	C	Araneidae	B	1	juv
14.12.94	C	Araneidae	X	1	juv
14.12.94	C	Araneidae	Y	1	♂
14.12.94	C	Araneidae	T	1	juv
14.12.94	C	Araneidae	G	1	♀
14.12.94	C	Araneidae	K	2	juv
14.12.94	C	Araneidae	Q	1	juv
14.12.94	C	Thomisidae	Misumenops rubrodecorata	1	♀

14.12.94	C	Philodromidae	Tibellus gerhardi 1	juv	
14.12.94	C	Thomisidae	Monaeses austrinus	2	♀,♂
14.12.94	C	Araneidae	H	2	juv
14.12.94	C	Thomisidae	Runcinia flavida	1	♀
14.12.94	C	Thomisidae	Synema "C"	2	juv
14.12.94	C	Thomisidae	Tmarus	1	juv
OTHER					
		Acari	Mite	15	
		Acari	Tick	6	

SAVSKILL

A Methodology to Measure and Monitor

Biodiversity in Central African Savannas

- This publication is the report of multi-disciplinary survey of biodiversity in the savanna woodlands in south-central Africa.

- The experience gained in this exercise subsequently supported more recent projects executed by the Biodiversity Foundation for Africa in partnership with the Zambezi Society. These include an assessment of the biodiversity of Zambezi Basin wetlands.

- In 1998 a partnership was formed between BFA, the Zambezi Society, and Flora and Fauna International (FFI) to initiate the Zambezi Basin Initiative (ZBI). The ZBI has benefitted greatly from BFA's earlier experiences in the SAVSKILL project in 1994.

- The ZBI aims to support and coordinate an improvement in knowledge of the biodiversity and ecology of the Zambezi Basin. A core objective of the ZBI is to make this information available to society toward the support and implementation of conservation

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