Proceedings of the Workshop on Ecological Monitoring for Biodiversity in the East Usambaras, from 8 - 13 July, 1996

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Summary

The Departments of Zoology and Marine Biology, and Botany of the University of Dar es Salaam and the East Usambara Catchment Forest Project organized and jointly sponsored a workshop from July 8 - 13, 1996 on ecological monitoring in the East Usambaras. Representatives attended this workshop from the Departments of Zoology and Marine Biology, Botany, and the Faculty of Science of the University of Dar es Salaam, the East Usambara Catchment Forest Project, the Division of Forestry, the Catchment Forestry Project, GEF Biodiversity Project, Sokoine University of Agriculture, University of Utah, USA, and the University of Cape Town, South Africa. Support for this workshop was provided by the John D. and Catherine T. MacArthur Foundation and the East Usambara Catchment Forest Project.

The first two days of the workshop were held in Tanga. During this period, invited speakers presented papers on monitoring biodiversity. Additionally, general discussion took place on the utility and value of ecological monitoring in relationship to identified forest management problems. Participants concluded that important insights and vital feedback necessary to address many of the most challenging forest management problems in the East Usambaras can be gained through the establishment of an ecological monitoring program.

Participants at the workshop recommended that a comprehensive biodiversity monitoring program be established in the East Usambaras in order to evaluate the impact of human activities on biological diversity and to gain a greater understanding of the ecological dynamics of these forests. Implementing such a program (Table 1) will entail monitoring (1) both selected biotic and abiotic components of the environment; (2) various functional levels of biodiversity (primary producers, primary consumers, secondary consumers, detrivores); and (3) the major organizational scales of biodiversity (genetic, population, species, community, ecosystem, and landscape).

Given that many ecological processes and patterns in the East Usambaras are known to change along elevational gradients as well as the logistical and monetary constraints facing the monitoring project, participants recommended that initially a geographically-restricted monitoring program be established. It was recommended that a pilot ecological monitoring program should be established in the Amani region of the East Usambaras because of the presence of the Amani Nature Reserve and the existence in this region of baseline data for many of the proposed indicator species.

Following the "classroom" activities in Tanga, the workshop moved to Amani in the East Usambaras. From the 10 - 14 July, monitoring techniques were demonstrated and/or field tested for proposed indicator species and communities. During the course of the field work, a reference collection of dung beetles was developed.

During both the classroom and field portions of the workshop, considerable discussion was focused upon examining and evaluating monitoring methodology for indicator species for the East Usambaras. The proposed indicator species and communities are listed in Table 1. These species and communities were chosen because they have been shown in other studies in tropical forests to be quite sensitive to forest disturbance (see attached papers), and nearly all of these indicator species and communities can be monitored by local technicians who will be gathering and recording ecological data on a daily basis. Additionally it was noted that if collections are necessary as part of the sampling protocol, identifications can be made in-country for most of the indicator species.

The scientific validity of the monitoring activities as well as the potential utility of the monitoring activities to address problems of forest management can be greatly enhanced by having explicit hypotheses and adequate replicated treatments and controls. Participants recommended that several sites which are currently undisturbed but will most likely experience human exploitation in the near future be selected as treatments. The most likely location of such sites in the Amani region are on public lands adjacent to the nature reserve. Additionally, the participants recommended that several sites be identified within the Amani Nature Reserve that can serve as a controls and which can be simultaneously monitored.

Finally, the participants emphasized the importance of forest managers developing explicit objectives for the monitoring program. Specifically, managers need to identify the level of change in indicator populations and communities (e.g., 5%, 10%, 20% increase or decrease) over a given time frame (5 years, 10 years, 20 years, 50 years) that they would like the monitoring program to be able to detect. This is critical in determining the frequency of sampling as well as the number of sites that need monitored.

The participants of the workshop recognized that many important procedural and administrative matters still need to be resolved before an ecological monitoring program can be fully implemented. Among the more important issues that need to be addressed are: (1) the identification of the location of the treatment and control sites; (2) the development of sampling and recording protocols for local technicians; (3) specification by forest managers of the desired "resolution" of the monitoring program; (4) the establishment of a data storage and retrieval system; and (5) the clarification and/or formalization of activities and responsibilities of the various institutions involved in ecological research, inventory, monitoring and forest management in the East Usambaras.

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Table 1. Proposed pilot biodiversity monitoring program for the East Usambaras.

Ecosystem Component	Organizational Scale	Functional Group	Ecological Indicators/ Parameters	Methods	Experimental Design
Biotic	Landscape		forest cover;	satellite/	entire forest
			fragmentation; gaps	aerial imagery	every 5 years
Biotic	Community	primary producers	plants	permanent plots with controls monitored annually	replicate plots
Biotic					
	Community	primary & secondary consumers	understory birds	permanent plots with controls monitored	replicate plots
Biotic	Community	detrivores	dung beetles	annually	
Biotic	Population	primary producer	epiphytes	permanent plots	replicate plots
Biotic	Population	primary producer	fruit	with controls	
Biotic	Population	primary consumer	hornbills	monitored	
Biotic	Population	primary consumer	primates	bimonthly	
Biotic	Population	secondary consumer	frogs		
Abiotic			temperature	forest edge	replicate plots
Abiotic			light	to interior	
Abiotic			relative humidity	gradients monitored daily	
Abiotic			pH of water	monitored weekly	replicate plots

Ecological Monitoring: Its Importance for the Conservation of Biological Diversity in the Eastern Arc Forests

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Introduction

The Eastern Arc forests of Tanzania have been classified as one of the 14 most threatened tropical forest hotspots worldwide because of their unusual concentrations of endemic species and the significant threats facing them (Myers 1990, 1991). The Eastern Arc Mountains are for their size the richest site biologically in Tanzania. Although the closed forests of the Eastern Arc Mountains cover less than .2% (1,800 km^2) of the land surface of mainland Tanzania, these forests contain approximately 18% of all plants, 43% of all butterflies, 22% of all amphibians and reptiles, 26% of all birds, and 24% of all mammals found in mainland Tanzania (Newmark in prep.). Possibly even more importantly, these forests contain one of the highest proportions of endemic species of any region in Africa. Approximately 25% of plant species, 82% of linyphiid spider species, 39% of butterflies species, 66% of herpetofauna species, 28% of montane bird species, and 7% of mammals species are endemic to the Eastern Arc mountains (Newmark in prep.). Furthermore, the Eastern Arc forests contain the majority of the globally endangered, vulnerable, and rare mammal and bird species and subspecies found in mainland Tanzania (Newmark in prep.).

As a result of their unusual diversity and endemism, there has been considerable interest both nationally and internationally in conserving the biological diversity of the Eastern Arc Mountains. A number of projects have been implemented (e.g., East Usambara Forest Catchment Project, East Usambara Agriculture and Conservation Projects, and proposed Ambangulu Conservation Project) and protected areas established (e.g., Udzungwa National Park and proposed Amani Nature Reserve) in the last 10 years to conserve biological diversity in the Eastern Arc forests. The long-term success of these projects and protected areas is dependent upon reducing human pressures upon the forests, increasing the effectiveness of forest management, and developing a more complete understanding of the ecological dynamics of these forests. Ecological monitoring is central to particularly these latter two requirements.

The purpose of this paper is to briefly highlight the useful role that ecological monitoring can play as part of a broader program of activities to conserve biological diversity and to discuss current and planned ecological monitoring activities in the East Usambaras.

Broad-scale Strategies for Conserving Biological Diversity

Biological diversity is the natural variation in genes, populations, species, communities, ecosystems, and landscapes (Wilson 1988). This variation changes both through space and time. In addition, this variation is a result of the interaction of organisms with their environment of which such ecological and evolutionary processes as predation, competition, nutrient cycling, energy flows, succession, pollination, disturbance, dispersal, and movement are particularly important. Thus the conservation of biological diversity requires not only conserving the spatial and temporal dimensions of biological diversity but also maintaining the ecological and evolutionary processes upon which this natural variation is dependent.

In principle, information and activities required to conserve biological diversity does not differ from that required to conserve most other resources. That is one must know: (1) the location of the resource; (2) the abundance of the resource; (3) changes in the abundance of the resource over time; and (4) factors responsible for changes in abundance in the resource over time.

The process of documenting the location and relative abundance of biological diversity may be thought of as inventorying, while that of identifying the temporal variation in biological diversity and factors responsible for this variation can be considered as ecological monitoring.

Importance of Ecological Monitoring for Forest Management

Ecological monitoring is important for forest management for a variety of reasons. First, ecological monitoring can provide advanced warning of undesirable ecological change and thus permit managers to adopt an adaptive management approach to conserving biological diversity. Given the complexity of tropical forest ecosystems, following an adaptive management approach is essential. Secondly, ecological monitoring is a necessity in order to objectively evaluate whether project or protected area objectives of conserving biological diversity are being achieved. One of the major short-comings of most of the early integrated conservation and development projects has been the absence of a comprehensive ecological monitoring program (Kremen et al. 1994). Thirdly, ecological monitoring is a necessity in order to evaluate the long-term impacts of human activities and disturbance on biological diversity. This is particularly true because there is often a lag between a disturbance event and a subsequent response. Fourthly, ecological monitoring can provide important insights into the functioning of complex ecosystems. Understanding the ecological dynamics of a forest is a perquisite to developing sustainable forest practices.

Important Considerations in Designing an Ecological Monitoring Program

Prior to implementing any ecological monitoring program, there must be clear objectives and hypotheses. For the Eastern Arc forests, two obvious objectives of an ecological monitoring program are: (1) to enhance the understanding of the ecological dynamics of the forests; and (2) to evaluate the impact of human activities and disturbance on populations, species, communities, and landscapes. In relationship to the latter objective, a null hypothesis is that human activities do not adversely affect biological diversity while the alternative hypothesis is that human activities do adversely affect biological diversity.

Ecological Indicators

Identifying what to monitor can be simplified if indicators of various functional and organizational levels can be identified (Noss 1990, Hellawell 1991). Identifying species and suites of species which are representative of various functional groups (primary producers, primary consumers, secondary consumers, tertiary consumers) is a strategy which has been frequently advocated (Kremen et al. 1993, 1994). In many cases, the suitability of species or suites of species as indicators of change may need to be pretested. In many tropical forests epiphytes and orchids (Turner et al. 1994), butterflies (Hill et al. 1995), termites (Collins 1980), and dung beetles (Klein 1989), understory birds (Johns 1986, Newmark 1991, Thiollay 1992) and primates (Skorupa 1986; Weisenseel et. al 1993) have been found to be particularly sensitive to human disturbance and thus are useful indicators of ecological change.

Current and Proposed Ecological Monitoring in the Usambaras

Since 1987, I have been monitoring annually understory bird populations on an archipelago of nine forest fragments and an adjacent control site in the East Usambaras. In 1989, I initiated a parallel study on a second archipelago of four forest fragments and an adjacent control site in the West Usambaras. The broad objectives this research are to evaluate the impact of forest fragmentation on understory bird communities; and to gain a greater understanding of the population dynamics of tropical forest birds. Specific objectives of this research are to examine (1) the metapopulation dynamics of understory bird communities on two archipelagoes of forest fragments whose total size are near identical but whose fragments differ in average size and distance from a control site; (2) variation in understory bird survivorship, natality, and movement within the two archipelagoes and across individual forest fragments; (3) how temperature, humidity, luminescence, and vegetation structure varies from forest edge to the interior and its relationship to the distance that understory birds species are encountered from the forest edge; and (4) the impact of past selective logging upon understory bird communities.

Understory birds in the Usambara Mountains are quite sensitive to forest disturbance and thus appear to be good indicators of ecological change. However our understanding of the dynamics of forest ecosystems and the impact of human disturbance on biological diversity could be enhanced if additional suites of species which are representative of other functional groups are also simultaneously monitored. Efforts are currently under way through the support of the MacArthur Foundation to develop a more comprehensive ecological monitoring program in the East Usambaras which will include additional functional groups and organizational scales.

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MEASURING AND MONITORING CHANGES IN PLANT COMMUNITIES AND RELATED HUMAN IMPACTS

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Introduction

Measuring and monitoring changes in plant communities entails quantifying the variety and variability among the community, and the ecological complexes in which this community exists. This may also reflect measurements of plant diversity patterns within the community, habitat, or ecosystem. Biological diversity includes genetic diversity, species diversity, and community level diversity at multiple, spatial and temporal scales in a highly stochastic and ever changing state (Primack 1993; Stohlgren 1995). Discussions of biological diversity or plant diversity often centers on world or regional diversity and includes such issues as how many species there are in tropical rain forests (Dallmeire et al. 1992). Other concerns may center on threatened or endangered species, endemic species, or even special types of habitats (most of these cover a small component of the total biological diversity).

Measuring and monitoring plant communities and their diversity is inseparable from measuring and monitoring human impacts. Human actions are a major cause of change in plant communities. Human use of plant communities have diverse impacts and may result in modification or even complete alteration of vegetation communities. Thus monitoring vegetation changes always should go hand in hand with monitoring the causes of the changes, i.e., human impacts.

Measuring and monitoring plant communities is central to quantitative plant ecology, a subdiscipline of ecology and biogeography; and it is also related to vegetation sciences, which in turn encompasses plant population ecology and vegetation dynamics (succession and vegetation change)(van der Maarel 1984). Vegetation is an integral part of an ecosystem (Tansley 1935; Waring 1989) and can only be studied by fully exploring its role within the ecosystem. Vegetation cannot be isolated as a separate entity from the ecosystem within which it exists. Individual plants normally belong to several species which in turn form plant communities. In this respect the absence or presence of particular species is of primary importance.

In this paper, I focus on some of the methods of measuring and monitoring changes in plant communities and related human impacts, emphasizing the sampling units and design. The permanent sample plot methodology (PSP) is discussed as a special technique for measuring and monitoring plant communities and biodiversity in general.

Measuring and monitoring plant communities

Why?

Many situations exist where plant communities merit study. Examples include:-

- Phytoecology, i.e., the description and definition of different vegetation types.
- Mapping of vegetation communities.
- Studying the relationships between plant species distribution and environmental controls.

- Studying vegetation as habitat for other organisms (e.g., mammals, birds, and insects).
- Determining change in vegetation over time - succession and climax.
- Assessing human induced impacts on plant communities.

The information obtained from monitoring plant communities may be required to help solve ecological problems related to environmental conservation and ecosystem management including such areas as conservation of endangered species, input to environmental impact statements, the monitoring of management practices, and predicting possible future changes.

The presence or absence, or marked changes in the relative abundance of certain species which have known environmental tolerance and preference have been used as indicators of habitat conditions (Westman 1985). Species may be of indicator value either because they are very intolerant of degraded conditions, and therefore first to disappear following disturbances, or because they are usually tolerant of degraded conditions and survive where others will not. Examples of such indicator plants include: lichens whose abundance at a site are frequently used to indicate SO_2 pollution; the presence/absence of rare species such as orchids to indicate human disturbance; and increased abundance of certain spiny or unpalatable shrubs as indicators of past grazing intensity. Generally indications of changing environmental conditions are conveyed more subtly by changes in overall plant community composition.

Vegetation measuring and monitoring programs may serve at least three basic functions. First, it can forewarn of impending biological problems and provide a baseline to evaluate the effectiveness of conservation activities. Secondly, monitoring programs can provide the scientific basis for management action. And, thirdly, the presence of a monitoring team act as a deterrent to illegal activities (Munishi and Struhsaker 1995).

Renewable natural resources especially forests (plant communities) are normally conserved for three major purposes: (1) the maintenance of ecological processes and life support systems; (2) the sustained use of resources for consumptive and social benefits; and (3) the conservation of biodiversity for ethical, moral, aesthetic, and evolutionary reasons (Burley and Gauld 1995). Only if all three of these purposes are met can sustainable development be achieved, and this in turn requires quantification of the current status and identification of change in the resource. To ensure political and public support for conservation and wise use of resources may also require economic evaluation of the various values and benefits of preserving biodiversity (see Flint 1991; Pitelka 1993).

Monitoring human impacts is important because human activities are the major agent of vegetation change. The impact of man upon a plant community will vary among plant communities and by intensity of use. This means that monitoring programs for plant communities are inseparable from monitoring human impacts on plant communities.

Long-term monitoring programs

There are three levels of long term monitoring. The first level is to conduct periodic surveys and inventories to provide basic information on abundance and distribution of species. This level of monitoring gathers the baseline biological and environmental data that allows the prediction of change by defining, creating, and testing models of environmental change; and by laying the ground work for the development of a global monitoring network.

The second level should entail work on the population dynamics of selected species and provide a reference for the health of the population in relation to environmental factors. Some parameters that are frequently measured include rates of growth, and mortality, age/stand structure, reproduction and phenology. Indicator species would be the best to be monitored at this level.

The third level should describe and check ecosystem diversity in target areas. This may be accomplished using ecological assessment programs that incorporate technologies ranging from GIS to on the ground verification.

Considerations in vegetation/plant community monitoring

To monitor plant communities precisely is not an easy task due to some inherent constraints in the monitoring process. One of the most frequently asked question in ecology is how many plots are needed to have a representative sample of the area to be monitored for reasonable conclusions and generalizations? The ultimate decision in this case is linked to plot shape and size, the pattern and placement of plots, and the variance/heterogeneity of the plant community (usually data obtained from preliminary sampling).

Normally less than one percent of the landscape is typically surveyed, and placing too few samples may cause one to miss important vegetation patches. Too many samples (rarely a problem in vegetation studies) on the other hand could increase the redundancy (Stohlgren 1995; Stohlgren et al. 1995). In homogeneous environment the pattern of sampling is irrelevant (Stohlgren 1994). However, in complex natural landscapes, the pattern of sampling greatly influences the observed vegetation patterns. For example, Fortins et al. (1989) found that a clustered systematic sampling design was superior to either a random design or uniform sampling grid to describe patterns of sugar maple Acer saccharum density. However, rare landscape features remain difficult to detect with almost any sampling design. This would mean that the pattern and design of sampling technique should be a function of the complexity of the landscape.

Methods for measuring and monitoring plant communities

Forest inventory plots provide one approach to documenting and monitoring plant community diversity, and are one means for obtaining long term data on the growth, mortality, regeneration, and dynamics of forest trees and plant communities. Monitoring of plant communities entails a number of repeated inventories over time. A system of permanent and temporary sample plots in forests have been developed and used widely in the field of forestry (see Adlard 1990; Husch 1971). Other work to expand the traditional forest inventory plots into plant community/vegetation/biodiversity monitoring plots have been conducted by different international organizations e.g CSIRO, UNESCO, MAB-SI, and FAO.

Sampling Units

Sampling units may be permanent or temporary. In either case sampling units have generally two characteristics: size, and shape. Other aspects to consider in addition to these include: the effectiveness of the unit in representing the variation in the population, the case of boundary definition, the convenience, and costs. Large sampling units are usually more effective in representing the variation than smaller units but are more expensive to identify and measure. In contrast, for a given sampling fraction a larger number of smaller units will provide a more precise estimate than fewer larger units (see Dallmeier 1992; Phillip 1993).

Plot shapes may be circular, square or rectangular, and each one has its own biases, advantages and disadvantages. Normally different vegetation types will require different plot shapes. Circular plots are best used to describe the condition of a relatively homogeneous unit. Its minimal perimeter to surface area ratio limits its usefulness in studies of plant diversity and species richness pattern however. A rectangular plot with a greater perimeter to area ratio will cover more efficiently a more heterogeneous area (Stohlgren 1995).

Sampling Design

Sampling designs may be classified into:

- Subjective sampling design where the sampling units are allocated at the description of the individual.
- Objective sampling which can be (a) systematic sampling either stratified or unstratified, (b) random sampling which can be (i) one stage sampling subdivided into unrestricted random sampling or stratified random sampling; or (ii) multistage sampling which can be either two stage sampling or more than two stages in the sample selection

Systematic Sampling

The sampling units are arranged in such a way that each one has a common relationship with its neighbors, and the selection of the first or any one of the units automatically selects the remainder. Examples include sampling every 10th tree in every 6th row, or sampling units lie at the intersection of a rectangular grid, i.e., sampling units are located at regular or systematic intervals. Care should be taken in systematic sampling that the sampling interval does not coincide with any pattern in the vegetation owing either to the properties of plants themselves or to some regularly distributed environmental control.

Random Sampling

The choice of each sampling unit selected is made independently of that of any other, i.e., the selection of one unit gives no identity of any other selected unit. Each point within the survey area should have an equal chance of being chosen on each sampling occasion. Examples include random walk procedure where by a sample point is located taking a random number between 0^o and 360^o to give the compass bearing. Most descriptive vegetation work does not require random sampling, rather stratified sampling is used. However where a hypothesis is to be tested random sampling is essential.

Commonly Used Designs in Ecological Monitoring

Stratified Sampling

The method is common in vegetation measurements and plant community ecology. The principle of stratification is that the vegetation is divided up before sampling on the basis of major and usually very obvious variations within it. The object is to divide the study area into more or less homogeneous strata. The samples are then allocated in these strata, either randomly or systematically. This system also allows a flexible systematic sampling ("flexible systematic model") whereby more samples are taken where variation in floristic composition is high and less where it is low. It is here assumed that where the diversity and rate of change is high, the vegetation should be sampled more intensively (see Smartt 1978). Stratified random sampling should allow for better estimates of species composition and richness by increasing the homogeneity within strata. However a worker may not afford to sample proportionately in all vegetation types.

Transects

This is an approach which is very popular in vegetation work. A transect is a line along which samples of vegetation are taken. Transects are usually set up deliberately across areas where there are rapid changes in vegetation and marked environmental gradients. Most transects are biased in location but the end and start can be located randomly and samples taken along the line connecting the points. Examples include placing transects uphill where slope angle, drainage and altitude combine; across major changes in geology; or through ecotones (Kent and Coker 1992).

Plotless sampling

In areas where vegetation is sparsely distributed and require very large transects/plots, plotless sampling designs can be used. The simplest of these is the nearest individual method (Wenger 1984; Kent and Coker 1992; Hetts 1994). It involves locating random sampling points within the area and measuring the distance to the nearest individuals of each point. The density of each species is then given by the following equation: density for a species = $(\text{mean area}/2)^{0.5}$, where mean area = $(\text{mean distance to nearest n individuals})^2$ (see Mueller-Dombois and Ellenbeg 1974).

Quadrats

This a sampling frame for recording plant species. It is the usual means of sampling vegetation for floristic description, the purpose of which is to establish a standard area for examining the vegetation. The shape is traditionally square, although rectangular or even circular quadrats have been used. Quadrat size is very important and will vary from one type of vegetation to another (see Cain 1938; Kent and Coker 1992). Table 1 shows some suggested quadrat sizes for certain vegetation types.

The Permanent Plot Methodology

The permanent plot methodology may be used in different ways to monitor vegetation communities and forests. It can be used to document species diversity and tree composition in protected forest areas (Dallmeier et al. 1992). It can also be used to monitor growth and yield of a forest community and biomass production. It can as well be used to simultaneously monitor other ecological processes and aspects within a forested ecosystem such as nutrient dynamics, invertebrate diversity, and forest regeneration.

The plot is designed as a zone encompassing 25 ha divided into 25 plots of 1 ha. The shape of the 1 ha plot may be rectangular or square although the latter shape is being used increasingly more frequently with such programs as the MAB-Smithsonian Institution permanent plot program.

Each 1 ha plot is in turn subdivided into 25 quadrats 20 m x 20 m in size with the quadrats permanently marked. Each tree with DBH equal or greater than 10 cm is mapped (in relation to two adjacent corner stakes), tagged, and identified.

The minimum diameter recorded may differ depending on the vegetation type and desired size of plants to be measured. However in inventorying tree species, the lower limit for DBH permits

Figure 1. The nearest-individual method of plotless sampling (Source: Kent and Coker 1992).

distinguishing between trees and shrubs or saplings
in a given vegetation (Wenger 1984; Hetts 1994).
be covered and the patterns of variability in these features as well as the objective of establishing the permanent plot.

Locating and Describing the Permanent Plot

Site location should be based on cartographic information, aerial photographs, and field verification. At least one permanent geological marker (locatable) for each plot is recommended.
Description of the plot should include:

- Detailed data on location, access and how the plot was demarcated to help subsequent researchers find the area.
- Careful recording of slope, aspect, soil types, geology, and local climate.
- History of past land use in the area
- General information about the sites flora and fauna.

Within the 1 ha plot, individual quadrats may vary in orientation. For

Information obtainable from Permanent Sample Plots

Measurements and information from permanent sample plots include breast height diameter, height, number of species, families, and number of stems. From these measurements the following can be computed (Dallmeier 1992):

- The density, hence relative density for each species, i.e., number of individuals of a species as a proportion of the total number of individuals of all species.

Table 1. Suggested quadrat sizes for certain vegetation types (Source: Kent and Coker 1992).

Vegetation type	Quadrat size
- Bryophyte and lichen communities	0.5 m x 0.5 m
- Grasslands, dwarf heaths	1 m x 1 m - 2 m x 2 m
- Shrubby heath, tall herbs and grassland communities	2 m x 2 m - 4 m x 4 m
- Scrub, woodlands shrubs	10 m x 10 m
- Woodland canopies	20 m x 20 m - 50 m x 50 m (or plotless sampling)

- Basal area for each species, i.e., basal area (m^2) of a particular species as a proportion of the totalbasal areas of all species.
- Relative dominance, i.e., the combined basal area of a single species as a proportion of the total basal area of all species.
- Relative frequency, i.e., the frequency of a given species as a proportion of the sum of frequencies for all species.
- Relative diversity, i.e., number of species in one family as a proportion of all species.
- Importance Value Index (IVI), i.e., the sum of relative density, relative dominance, and relative frequency for species.
- Family Importance Value (FIV), i.e., the sum of relative density, relative dominance, and relative frequency, for a family.

In addition to the above information recruitment and mortality in the ecosystem can be assessed. Recruitment here may be defined as the number of individuals which reach/qualify for the specified minimum diameter (DBH) while mortality refer to the number of individuals/species which are lost or die out and disappear from the area. From the same plots one can monitor plants other than trees, whether they are present or absent and their relative abundance as well as changes in their populations.

Monitoring Human Impacts

Human impact in this paper is defined as any human activity (legal or illegal) that influences vegetation communities and their components. The impacts may arise from human interactions with the resources (vegetation) or from use of the resource, which includes both timber and non-timber products. Uses may also be either consumptive or non-consumptive, each which may have their own impact.

Methods of Monitoring

These methods are often indirect. The most direct method in this case would be quantifying in the field the amount of product removed (which may be compared to the allowable removal) which is often difficult to estimate due to inadequate data or information in most cases. However, less direct methods are available and may include consumption surveys of various biological resources from the forest or plant community. In this method, one would look at such things as type of resources used, their location, frequency of use/removal, and whether uses are commercial or domestic. Such information if carefully obtained and analyzed can highlight greatly the extent of impact upon a plant community.

Other indirect assessments can be made by field observations of indicators of human interaction with a forest or plant community. Random walks in the forest looking at the extent of damage to trees can detect, for example, which size class of trees or tree species are being exploited. The network or intensity of foot paths can also provide insights as to the extent of use of a plant community. The distance to the source of the product can also provide useful information as to the intensity of impact of a given plant community. This also can give a way to another method, i.e, a measure of the effort used in obtaining a product from a given vegetation community. If less effort is required to obtain the resource it is most likely the impact on the resource will be less than if more effort is used to obtain the same amount of the resource. Although some of these methods are not easy to quantify they can provide some insights into the use of a plant communities.

Conclusion

Monitoring changes in plant communities and related human impacts is not an easy task due to methodological and theoretical limitations. The choice of methods and representative sample sizes especially in a wide variety and heterogenous vegetation types may have many constraints. The major question is how much area to sample to adequately represent a given site. This question has both logistical and financial implications which are often not easy to resolve. Therefore, long-term measuring and monitoring plant communities require secure long-term funding and commitment with appropriate design of monitoring techniques to comply with the available human, physical, and financial resources. Monitoring programs should therefore aim at obtaining high quality data at a minimum cost.

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Techniques for long-term monitoring of amphibians in the East Usambaras, Tanzania

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Introduction

Amphibians are important indicators of environmental health. The complex life histories of most species span both terrestrial and aquatic microhabitats. All amphibian life stages are relatively unprotected, and are sensitive to changes in temperature, humidity, water and air quality. Amphibians have limited capacity for long distance dispersal, and their populations may depend upon small habitat patches during seasonal breeding periods. Furthermore, amphibians are important intermediate members in many communities, serving key roles both as predators and prey (Duellman and Trueb 1986). Because of these characteristics, amphibians often are among the first organisms to respond to unfavorable environmental changes and therefore represent a critical "early warning system".

There is increasing evidence that amphibian populations are declining or fluctuating in many regions of the world, often in areas that are not directly disturbed by people (Blaustein et al. 1994). This may be particularly true of species in tropical montane habitats (Blaustein and Wake 1990; Pounds and Crump 1994). Possible causes for these declines include air and water pollution, increased ultraviolet radiation, unusual weather patterns, global warming, and habitat fragmentation (Blaustein and Wake 1990; Wyman 1990). The general characteristics of amphibians would tend to make them more sensitive to all of these factors.

The Usambaras and other Eastern Arc mountains of Tanzania support a rich biota that includes a remarkable proportion of endemic species (Wasser and Lovett 1993; Newmark 1995). This general pattern is reflected in the unique amphibian faunas of the region (Howell 1993). Because of the factors outlined above, amphibians are a particularly important group for long-term monitoring of environmental health.

Amphibians of the East Usambaras

Howell (1993) lists a total of 20 forest-dependant amphibians from the East Usambaras (**Table 1**), including 18 species of anurans representing five families (Arthroleptidae, Bufonidae, Hyperoliidae, Microhylidae, and Ranidae) and two caecilians (families Caeciliidae and Scolecomorphidae). This list is not exhaustive. The East Usambaras may support other amphibians that are not obligate forest inhabitants. Furthermore, there may be additional forest-dependent species in this region that remain to be discovered (Howell 1993).

Although specific information on the amphibians of the East Usambaras is limited, the known fauna includes members of groups that show great diversity in life history and habits (Schiøtz 1975; Duellman and Trueb 1986; Heyer et al. 1994). Some groups have classic biphasic development with fully aquatic larvae and terrestrial or semi-aquatic adults. These may lay eggs in standing water (bufonids, ranids), in soil or on vegetation near water (hyperoliids), or in water-filled plant cavities (at least one microhylid). Other species do not have aquatic larvae, and may be viviparous or ovoviviparous (caecilians) or oviparous with direct development from egg to a terrestrial stage (arthroleptids). As adults, many species are principally arboreal whereas others are semi-aquatic, terrestrial or fossorial.

Table 1. -- Forest-dependent amphibians of the East Usambara region, from Howell (1993). Life history information from Schiøtz (1975); Duellman and Trueb (1986); Heyer et al. (1994).

ANURA (frogs)

Arthroleptidae -- Terrestrial or semi-aquatic adults -- small clutch of large terrestrial eggs -- direct development
- Arthroleptis adolfifriderici
- Arthroleptis affinis
- Schoutedenella xenodactyla

Bufonidae -- Terrestrial adults -- aquatic eggs and larvae
- Bufo brauni
- Nectophrynoides tornieri -- ovoviviparous

Hyperoliidae -- Arboreal adults
- Leptopelis -- medium-sized to large (s-v length 33-70 mm) -- eggs buried in soil near water -- aquatic larvae with long tails and reduced fins.
  - L. barbouri
  - L. parkeri
  - L. flavomaculatus
  - L. uluguruensis
  - L. vermiculatus
- Afrixalus -- small (s-v 23-28 mm) -- unpigmented eggs within thick jelly in folded leaf above or below surface of still water -- aquatic larvae "shark-like" with long tail and reduced mouthparts.
  - A. uluguruensis
- Hyperolius -- small (s-v 18-30 mm) -- unpigmented or pale green eggs in jelly mass on vegetation above water, aquatic larvae.
  - H. mitchelli
  - H. puncticulatus
  - H. spinigularis

Microhylidae -- adults arboreal, terrestrial, or fossorial -- eggs in water or in soil near water -- aquatic larvae.
- Hoplophryne rogersi -- breeds in water-filled cavities
- Callulina kreffti
- Probreviceps macrodactylus

Ranidae -- Adults terrestrial or arboreal -- eggs in water or in soil near water -- aquatic larvae
- Arthroleptides martiensseni
- Phrynobatrachus kreffti

GYMNOPHIONA (caecilians) -- adults fossorial -- viviparous

Caeciliidae
- Boulengerula boulengeri

Scolecomorphidae
- Scolecomorphus vittatus

Figure 1. Randomized selection of sampling quadrats. (A) Numbered grid system covering study area, and (B)

small sampling quadrat within a larger map grid.

Figure 2. Sample data sheet for quadrat surveys.

Figure 3. Portable enclosure for sampling aquatic amphibian larvae (from Heyer et al. 1994).

Inventory/monitoring methods

Methods used to inventory and monitor amphibians for a long-term project should be relatively simple, quantitative, easily standardized, and should have little or no impact on animal populations. Various techniques target different microhabitats and life stages or rely on different behavioral traits for detection, and a monitoring program that uses several methods will produce results that are more thorough. This is particularly important given our limited knowledge of the amphibians of the East Usambaras and their potential ecological diversity. The methods outlined here are derived from Heyer et al. (1994).

Terrestrial quadrat sampling -- This method can be used to determine species richness, relative abundance, and densities, and is most effective for species that are ground dwelling, fossorial, or that spend time on low vegetation. It involves thorough searching of small, randomly selected quadrats. A map of the study area is divided into a numbered grid system of large (e.g., 100 x 100 m) square units (Fig. 1). A standard number of quadrats to be searched during each monitoring period is determined beforehand (between 50 and 100), and this number of map grid squares is chosen randomly at the start of each monitoring period. A small (e.g., 8 x 8 m) quadrat is them located randomly within each chosen grid square and outlined with stakes and twine. The area enclosed within each small quadrat is carefully and systematically searched for amphibians, and the number of individuals of each species recorded on a standard data sheet (Fig. 2).

Patch sampling -- This approach can be used to determine relative abundance and densities of species that are confined to particular microhabitats (for example, those that breed in plant cavities or that are fossorial). It involves identifying all discrete patches in a particular area (for example, patches beneath logs on a section of forest floor or cavities in tree buttresses). All patches, or a predetermined number selected randomly, are thoroughly searched for amphibians, and the number of individuals of each species recorded. Areas between patches are ignored.

Aquatic sampling -- This approach can be used to determine species richness, relative abundance, and densities of aquatic larvae. By using enclosures, relatively large bodies of standing or flowing water can be sampled quantitatively in a manner analogous to quadrat sampling. The area of aquatic habitat is mapped with a grid, and a predetermined number of sampling points chosen randomly at the start of each monitoring period. A portable sampling enclosure (Fig. 3) is used to trap larvae occurring within a standard area. All larvae are collected and the number of individuals of each species is recorded on a standard data sheet (Fig. 4) prior to release.

Drift fence/pitfall trapping -- This method can be used to determine species richness, relative abundance, and species activity patterns. It is an effective method for monitoring terrestrial amphibians, as well as small mammals and other ground-dwelling animals. Several drift fence/pitfall arrays are established at fixed sites within the study area. Arrays consist of standard-sized cans or buckets buried in a line with a low fence bisecting the open top of each trap (Fig. 5) to direct and capture animals moving along the ground. Trap arrays are run for a standard time period during each monitoring session. They should be checked as often as possible to avoid trap deaths and to obtain information on species activity patterns (a minimum of twice daily, immediately after dawn and just before dusk). Released animals can be marked by toe clipping (Fig. 6) for recapture data. Data should be recorded on standard sheets (Fig. 7). Between monitoring sessions, fences should be removed and traps should be closed with secure lids to prevent accidental captures.

Acoustic monitoring -- This approach uses a tape recording system to monitor frog vocalizations at fixed sites. It can provide information on local species richness and relative abundance, and breeding periodicity. In addition, it can provide information on primates, birds, and other vocal animals. For effective long-term monitoring, methods must be standardized with respect to place and time of recording.

Data analysis and interpretation

An effective inventory/monitoring program should 1) establish good baseline information on populations and communities, 2) provide data that can reveal any major changes, and 3) help determine the underlying causes of these changes.

Species richness -- Counts of numbers of species are the most basic measurements that can be taken from biological survey data. Species richness can

Figure 4. Sample data sheet for quantitative surveys of aquatic amphibian larvae.

Figure 5. Design for drift fence/pitfall trap array. (A) Trap consisting of two No. 10 cans and an opening funnel made from a plastic container (from Heyer et al. 1994). (B) Drift fence construction and arrangement of pitfalls in a linear array.

Figure 6. Toe-clipping scheme for marking frogs, and a table showing the unique numbers possible from clipping

1, 2, and 3 toes on an individual (from Heyer et al. 1994).

Figure 7. Sample data sheet for pitfall trapping.

Figure 8. Examples of species-effort curves. (A) Cumulative number of species recorded with repeated quadrat sampling. (B) Long-term accumulation of species for a single study area (from Heyer et al. 1994).

be determined for specific sites or habitat types or for an entire study region. It is useful to plot changes in the cumulative number of species as a function of sampling effort. This produces a species-effort curve that provides a simple measure of sampling thoroughness (Fig. 8a).
As samples are taken, the number of species increases rapidly and eventually approaches an asymptote indicating that sampling is fairly complete. However, sampling over very long time periods continues to add some species slowly (Fig. 8b). These tend to be species that are rare or are otherwise difficult to sample. More importantly, long-term changes in species richness may reveal changes in community structure. For example, repeated monitoring at a site during the course of disturbance might reveal the local extinction of a forest-dependent species or the addition of a generalist species.

Relative abundance -- This is a comparative measure of proportional representation of a species in a sample or group of samples. Patterns of relative abundance can be assessed across sampling sites to determine habitat preferences, and may be correlated with other ecological or life history traits. Repeated sampling at standard intervals may reveal changes in relative abundance that can be associated with environmental change.

Density -- Several survey methods provide data that can produce quantitative estimates of number of species (species density) or number of individuals of a given species (population density) per unit area. Measures of density are most sensitive in assessing spatial and temporal changes in both species richness and abundance.

Species identification -- The accurate association of data with a particular species requires the collection of voucher specimens. These specimens permanently document the actual source of data, and represent the only actual proof that results have been interpreted accurately. Vouchers should be obtained for adults of every species encountered during sampling. If positive identification to species is not possible, animals should be placed in obvious morphological groups (frog "species" A, B, etc.) and identified later from vouchers. Aquatic larvae should be collected and reared to adulthood in order to associate developmental stages, and a developmental series of specimens should be preserved for each species. Calls of some hyperoliid frogs have been described by Schiøtz (1975). Call of other species need to be identified by collecting voucher specimens of calling males, or by comparison to calls made by identified individuals in captivity.

Standardization -- The primary goal of a long-term monitoring program is to assess actual patterns of change in population or community structure through time. This requires that sampling procedures be standardized as much as possible. Standardization also allows results to be compared to those from other studies. Standard methods should be set beforehand and, if necessary, modified during an initial trial period. Any subsequent changes should be made only if they provide additional data and do not restrict comparisons with earlier results.

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Monitoring Understory Birds

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Introduction

Most ecological monitoring programs are established to evaluate the ecological impacts of human activities and/or to gain insights into the structure and function of populations, communities, and ecosystems. Trying to predict a priori in tropical forests which species to monitor can be daunting task given the diversity of species as well as the complexity of species interactions However, results from a wide variety of studies conducted over the last 20 years indicate that understory birds are a particularly good group of organisms to monitor because of their sensitivity to forest fragmentation and logging, two of the most common forms of forest disturbance. Research from South and Central America (Kattan et al. 1994; Karr 1982; Thiollay 1992), Asia (Wong 1985; Johns 1986, 1987, 1989; Lambert 1992), and Africa (Newmark 1991) has shown that understory bird species, birds which are active predominantly within two meters of the forest floor, are particularly sensitive to forest disturbance in comparison to bird species which are active at higher heights within the forest.

Techniques

Techniques to monitor understory birds can be grouped into four categories: Point counts, line transects, territory mapping, and mist netting. Each of these techniques has its advances and disadvantages, and thus selecting a method(s) to monitor understory bird populations depends largely upon the objectives and resources available for monitoring.

Point Counts

In a point count survey, a worker records all birds seen or heard within a given distance from a series of random or fixed points located within the forest. The primary advantage of the point count method is that an area can be surveyed quickly, and thus it is a rapid means to continuously monitor a site. The disadvantage of the point count method is that many tropical understory bird species are cryptic, i.e., difficult to observe or do not or very rarely sing (Karr 1981a). Additionally, differences among observers can lead to widely different estimates of relative abundance or density and thus spatial or temporal comparisons can be problematic.

Furthermore, if estimates of species density are made using this technique, difficulties associated with detection of species can violate important underlying assumptions that: (1) all birds which occur within a plot are recorded; and (2) all birds are correctly classified as falling within or outside of a plot.

Line Transects

In a line transect survey, a researcher records all birds seen or heard at fixed or variable distances along a transect in the forest. As with the point count technique, the important assumptions underlying estimates of species density are that (1) all birds which occur within the strip transect are recorded; and (2) all birds are correctly classified as falling within or outside of the strip transect.

The primary advantage of the line transect method, as with the point survey method, is the speed with which an area can be monitored while its disadvantage is the difficulty monitoring cryptic or silent species. Additionally differences between observers can be extremely problematic in evaluating changes in trends of species through space and time (Karr 1981a).

Territory Mapping

Territory mapping relies upon mapping the location of counter-singing males (Terborgh et al. 1990). Territory mapping is usually conducted along a grid system of trails (e.g., Moyer 1993). For bird species which hold territories and in which males counter-sing, it is almost certainly the most accurate technique for estimating population density. The disadvantage of this method, however, is that many tropical bird species do not have territories and/or males do not or rarely sing. Additionally, this technique is more labor intensive than either the point count or line transect because a site needs to be repeatedly visited until territories are entirely mapped.

Mist Netting

Mist nets are fine-mesh, low visibility nets that are widely used to capture understory birds. Mist nets are placed along cleared trails within the forest. Birds which are captured can be ringed and released and thus, at least in theory, population density can be estimated. In practice, however, an important assumption underlying most mark-recapture models, that individuals are equally catchable, is frequently violated (Krebs 1989). The primary advantages of mist netting is that this technique is much less affected by observer differences then those described above. Thus, it is easier to compare relative abundances of species across space and time with different observers (Karr 1981b). The disadvantages of mist-netting are that it is labor intensive and capture rates reflect both activity patterns as well as population density.

I personally feel that mist-netting is the preferable method for monitoring understory birds because this method can effectively sample cryptic species and observer differences are minimal. Mist nets do provide a random unbiased sample of the relative abundance of birds in the space in which the nets are placed. However, it is important to exercise caution in interpreting results since capture rates are an index of population density rather than a direct measurement of density (Karr 1981b).

Mist-netting Protocol

During the last 10 years, I have employed the following protocol to monitor understory bird populations. I operate nets at each site for 36 hours or three consecutive days from dawn to dusk, unless heavy rains forces their early closure. In case of rains, I operate nets during a fourth day until I have accumulated 36 hours of sampling.

Although mist nets may be deployed in a variety of patterns, I prefer to erect mists in a long line, end to end, and perpendicular to the edge of the forest because distance from forest edge is a critical factor affecting both abundance and distribution of understory bird species in the Usambaras (Newmark 1991).

I prefer to leave nets up over night so as to minimize net handling time. I do check, however, during the first half hour after dark the mist nets for bats during the first two nights it which the nets are up. I have found that by the third night, bats have normally learned the location of the nets and thus can avoid them.

I use 12 m X 2 m nets with 36 mm mesh. Mesh size does influence capture rates. Larger mesh size is more effective at capturing large-bodied birds while small mesh size is more effective at capturing small-bodied birds. 36 mm mesh appears to be effective at capturing virtually all understory bird species in the Usambaras with the exception of those weighing more than 75 g. These latter species, such as large doves and raptors will frequently bounce off of the nets instead of becoming entangled.

I check nets every 10 to 20 minutes, which is a higher frequency of monitoring than in many studies, and thus my capture rates may be slightly lower than in studies in which nets are checked less frequently. I prefer to check nets frequently because birds are placed under less stress which in turn will reduce overall net mortalities. In addition, it is easier to remove captured birds if nets are frequently checked because the longer a bird is in a net the more entangled it will become.

I place on all captured birds an uniquely numbered aluminum band and record standard morphometric measurements (body weight, culmen, tarsus, wing, and tail length). In recent years, I have banded a subset of this population with color rings so as to be able to be able to follow known individuals from a distance.

General Considerations in Monitoring Understory Birds

In any long-term monitoring project, it is critical that methods remain constant over time. Given the difficulty in measuring directly understory bird species density, it is particularly important if an index of population density is being monitored, that methodologies are standardized and are consistently followed over time.

Local technicians can gather much important ecological data. If local technicians are used to monitor understory birds, considerable effort needs to be placed upon training them to correctly identify and handle birds. In most situations, particularly when birds are being mist-netted, it will be necessary to have an university trained biologist on-site to supervise and assist in the handling and identification of captured birds.

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Techniques for Long-term Monitoring of Key Mammal Groups in the East Usambaras, Tanzania

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Introduction

The long history of isolation of the Eastern Arc mountains of Tanzania has produced a rich and unique assemblage of forest mammals (Kingdon and Howell 1993). The forest mammal fauna of the East Usambara region is ecologically diverse, including small to moderately large species belonging to 18 families in 8 orders (Table 1). Many of these species are local or regional endemics (Kingdon 1971-1977; Kingdon and Howell 1993; Newmark 1995).

Some of the mammal groups in the East Usambaras are known to be affected adversely by major habitat disturbances such as extensive logging, or are subject to direct exploitation from hunting. These include the diurnal and nocturnal primates and small ungulates (Marsh and Mittermeier 1987; Newmark 1995). Effects of habitat disturbance on indigenous small mammals (shrews, bats and rodents) are not as well documented. However, these groups include a large proportion of endemic species that may be sensitive. In tropical forests elsewhere, endemic small mammals generally are restricted to areas with little or no disturbance, whereas more widely distributed non-endemic species predominate in disturbed habitats (Rickart 1994). The same pattern is seen for some small mammals in the Eastern Arc forests (W. Stanley, personal communication).

Inventory/monitoring methods for key groups

The mammal fauna of the East Usambaras includes species with extreme differences in basic ecology and behavior (Table 1). With respect to monitoring methods, the fauna can be divided into four main target groups based on ecological traits or conservation priority: (1) diurnal primates, (2) nocturnal primates, (3) small, non-flying mammals, and (4) bats. Different approaches are required to monitor each group.

<u>Transect surveys</u> -- This approach can be used to determine relative abundance and estimate population densities, and to provide basic information on ecology and behavior of target species. It involves visual surveys conducted along straight-line transects or established trails (National Research Council 1981; Marsh and Mittermeier 1987). This is an effective census method for diurnal, arboreal primates (Cercopithecidae), and can be used simultaneously for other diurnal groups such as tree squirrels (Sciuridae). For nocturnal primates (Galagonidae) and other nocturnal groups, transect surveys can be made using head lamps to locate animals by reflected eye-shine. Several transects should be established throughout the study area. Transect lines or trails are marked with regular position indicators so that animal positions can be located and mapped along the transect. During each census period, observers walk slowly and quietly along the transects and record the size and composition of animal groups. The position of a sighting along the transect is determined by estimating the distance between the observer and the animal or group, measuring the angle of observation with a compass or protractor, and then estimating the perpendicular distance of the subject from the transect line (Fig. 1). Data should be recorded on standard census forms (Fig. 2).

Visual monitoring at fixed sites -- This approach involves monitoring activity at feeding sites or other places where animals concentrate, or surveying broad areas of tree-top habitat from a high vantage point. It can be used to determine relative abundance and can provide information on the ecology and behavior of target species. It may be used during the day to supplement information on monkeys and other diurnal species. Galagos may be observed at night at close range under red light, and tracked to nest sites where they may be monitored more closely (Charles-Dominique 1977). Observation under red light may be used for other nocturnal mammals as well (e.g., fruit bats, anomalures, small carnivores).

Acoustic surveys -- The loud morning and evening chorus vocalizations of diurnal primates can be monitored from fixed sites. Data on direction and distance to calling groups, and estimates of group size can be used to determine relative abundance. Simultaneous paired observation allows more accurate measurement of distances by triangulation for estimating density (Fig. 3). Certain species may be monitored by recording vocalizations at fixed sites such as established feeding locations.

Drift fence/pitfall trapping -- This method can be used to determine species richness, relative abundance, and activity patterns of small, non-flying mammals (insectivores and murid rodents). It has proved to be particularly effective for sampling the diverse shrew faunas of the Usambaras and other Eastern Arc mountain (Stanley and Goodman 1994). The system can be used to simultaneously monitor terrestrial amphibians and other ground-dwelling animals.

Mist netting -- This is one of the best methods for censusing forest-dwelling bats (Kunz 1988). It is very effective for determining species richness and relative abundance of most pteropodid fruit bats. Relative abundance of insectivorous bats is more difficult to determine because they are less easily captured in nets. Bat surveys can be run in conjunction with bird census work, although nets need to be set somewhat differently. The best net sites for bats are along ridge tops, across streams and established trails, and at the margins of forest openings. Nets should be monitored constantly during the period of peak activity (the two hours after dusk), and should be closed when unattended.

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Table 1. -- List of families of forest-dependent mammals from the East Usambara region. From Kingdon (1971-1977) and Kingdon and Howell (1993).

Insectivora -- mainly nocturnal, ground-dwelling
  Soricidae -- shrews

Macroscelidea -- diurnal, ground-dwelling
  Macroscelididae -- elephant shrews

Chiroptera -- nocturnal, flying
  Pteropodidae -- fruit bats
  Emballonuridae -- sheath-tailed bats
  Nycteridae -- slit-faced bats
  Megadermatidae -- ghost bats
  Rhinolophidae -- horseshoe bats
  Vespertilionidae -- evening bats
  Molossidae -- free-tailed bats

Primates
  Galagonidae -- bush babies -- nocturnal, arboreal
  Cercopithecidae -- monkeys -- diurnal, arboreal-scansorial

Rodentia
  Sciuridae -- tree squirrels -- diurnal, arboreal
  Anomaluridae -- anomalures -- nocturnal, arboreal
  Muridae -- rats and mice -- mainly nocturnal, ground-dwelling or scansorial

Hyracoidea -- mainly nocturnal, arboreal
  Procaviidae -- hyraxes

Artiodactyla -- mainly nocturnal
  Bovidae -- antelope

Carnivora
  Herpestidae -- mongooses -- diurnal, climbing
  Viverridae -- civets -- nocturnal, climbing

Methods for the inventory and ecological monitoring of dung beetles, butterflies and termites in the East Usambaras

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Introduction

The use of insects as indicators of habitat degradation is a comparatively recent trend in ecological monitoring programs. Several insect taxa have been recommended including dung-burying beetles (Halffter and Favila 1993), butterflies (Kremen 1992; Sparrow et al. 1993) and termites. All of these groups comprise many species showing specialist spatial distributions which are sensitive to habitat disturbance. This paper discusses trapping methods which are appropriate for inventory and ecological monitoring of these taxa. As a specialist in dung beetles, I will deal with this group in greater detail than with the butterflies and termites.

Dung beetles (Coleoptera: Scarabaeidae: Scarabaeinae, Coprinae)

Trapping methods

Dung-burying beetles are a particularly useful group for ecological monitoring since the alpha taxonomy is relatively advanced and species rich assemblages are attracted to a universal dung bait. Therefore, the use of dung-baited pitfall traps facilitates the collection of large quantitative data sets with a minimum of effort. Comparison between data from pitfall traps and natural dung pads indicates that both methods record similar numbers of most species (Doube and Giller 1990).

For my work on dung beetles, I have been using a standard pitfall trap (Davis 1990) which assists comparison between different studies. As shown in Figure 1, each trap comprises a square, galvanized, metal plate with a large hole machined from its center by a local engineering works. This is rested over a hole dug into the ground and is sprinkled with earth to reduce heat absorption. A large funnel is suspended by its rim from the center of this plate over. This funnel comprises an enamelled, metal lampshade with its apex machined out. Two stiff wires are balanced across the top of the funnel to support a dung bait at ground level so emulating a natural dung pad. The bait is wrapped in a square of thin cloth, drawn together and fastened using a pipe cleaner. This allows dissemination of dung volatiles whilst excluding dung beetles. The attracted beetles fall into a receptacle at the base of the trap containing a little water and detergent to immobilize the catch. If the trap is to be left in the field for any length of time, it is useful to also dig in a bucket or a flowerpot to retain the soil at the sides of the pitfall. On each successive trapping occasion, it takes only 30-60 seconds to reset the trap with a new receptacle and a fresh pre-prepared bait. When the trap is not in use, the funnel should be inverted over the hole to exclude the ground fauna. The basic design of the trap may be modified according to the availability of local materials.

As designed, the trap is suitable only for destructive sampling since small beetles, especially, are able to fly out if not immobilized. The trap may be modified for live-sampling by using a funnel with a long basal tube. This tube should be fed through a hole in the lid of a screw-top receptacle with moist soil at its base. This design should prevent most beetles from escaping. However, there is a disadvantage to live sampling if large insect predators are also captured, e.g., burrowing scaratine carabids or shrews.

Figure 1. Transverse section through a standardized baited pitfall trap (from Davis 1990).

Figure 2. Associations of Afrotropical Coleoptera with decaying matter (from Davis 1994).

Receptacles for both the destructive and live-sample traps should be both sufficiently large to accommodate a day's catch and equipped with a screw-top and lid to prevent spillage or escape of the catch during transportation.

Distribution of dung beetles across space, food, and time

Dung beetle species show distinct partitioning of the three principal resources of food, space and time. Dung specialists partition food according to dung type (Davis 1994) and size of the dropping (Peck and Howden 1984). However, food specializations also include, carrion (Walter 1983), fungi (Bornemissza 1971), even rotten wood (Cambefort and Walter 1985), leaf litter (Monteith and Storey 1981), fruit, and the gut contents of dead millipedes. Space is partitioned according to soil and vegetation type (Howden and Nealis 1975, Cambefort 1982; Doube 1983, 1991), altitude and rainfall regime (Davis and Dewhurst 1993). Time is partitioned according to weather conditions (Davis 1995) and season (Cambefort 1982). An inventory of species and their distribution across the range of local resources in the Usambaras, particularly different vegetation types, will enable the prediction of the faunal changes which may be expected to occur with habitat disturbance. It will also identify the potentially most sensitive indicator groups on which to concentrate attention and assist in the interpretation of any spatial changes in occurrence and relative abundance of species detected during ecological monitoring.

Trophic distribution

In South Africa, dung beetles are principally associated with either omnivore or herbivore dung although specialists also occur on each herbivore dung type either ruminant or non-ruminant (Davis 1994). In southern Africa, dung-burying scarabaeids specialized on non-ruminant dung are now largely restricted to game reserves which reflects the fragmentation in range of large, indigenous, non-ruminant herbivores. The non-ruminant dung specialists shown in Figure 2 (Davis 1994) comprise members of non-scarabaeid, dung beetle families, the coprophagous Aphodiidae and the predatory Staphylinidae, Histeridae and Hydrophilidae. Scarabaeid carrion specialists were recorded in the South African study but were not included in the analysis due to low abundance. Thus, specialization to carrion was not prominent in eastern South Africa nor in a West African study (Cambefort 1982). However, in Zaïre, more than 40% of species showed a bias to necrophagy, particularly in forests (Walter 1983).

These empirical data will assist in design of methods for inventory and ecological monitoring in the Usambaras. Table 1 (Davis 1994) shows that the use of any type of dung bait will record most of the abundant species but in different relative abundances. A combined bait of three equal parts ruminant/non-ruminant/omnivore dung may be used if it is desired to reduce trophic bias in results. Size of the bait also needs to be standardized as it influenced scarabaeid species composition and relative abundance in a South American study (Peck and Howden 1984).

As the mammal faunas and their dynamics are likely to differ between forest and disturbed areas, availability of different dung types and carrion may also vary between vegetation types. Such differences could lead to the asymmetrical distribution of specialization between dung beetle faunas from cleared areas to forest as reported for Zaïre (Walter 1983). This could be tested by placing traps baited with a similar range of different dung types and carrion in each vegetation type. As any radical change in the mammal fauna of one vegetation type could influence the dung beetle fauna independently of vegetational status, perhaps relative abundance and relative distribution of specialization between species in forest and disturbed areas should be tested at regular intervals.

Spatial distribution

Soil type is an important determinant of both species distribution (Davis 1996a) and functional composition (Doube 1990, 1991) of dung-burying beetle communities. Comparison between South African communities on soil-type extremes (Table 2) shows that, on a logarithmic scale, the largest sand specialists occur in the fourth magnitude of size whereas the largest clay specialists are restricted to the third magnitude of size (Davis 1996b). The largest sand specialists are numerically dominated by very large ball rollers and very large, fast-burying tunnellers. The next largest size class is numerically dominated by large fast-burying tunnellers on sand and by ball rollers on clay. At the opposite end of the body-size scale, sand specialist kleptocoprids, which use dung buried by other scarabs, are prominent whereas clay kleptocoprids are drawn from the pool of soil generalist species which are mostly concentrated

Table 1. Associations of Afrotropical Coleoptera with decaying matter. Abundance and trophic/microhabitat association of beetle species from five families trapped in numbers of 20 or >20 (associations: B, overripe banana; G, rotting grass clippings; C, cattle dung; H, horse dung; P, pig dung; O, rotting offal) (from Davis 1994).

Table 2. Community organization of Gauteng dung beetle assemblage (91 spp.) in terms of abundance, body size, functional group and soil association (from Davis 1996b).

into the two smallest size classes. A number of other community differences also occur. Table 3 (Davis 1996b) shows that right across the range in body size, there is often extreme species bias to either clay or sand. Therefore, in any trapping program in which soil is not a test factor, the trapping grid needs to be standardized as regards soil type.

Vegetation type influences dung beetle distribution primarily by its effect on light intensity and insolation (Doube 1983) which affects radiant heat and surface temperature. Both light intensity and ambient temperature are important in the initiation of flight by dung beetles (Houston and McIntyre 1985). Trapping from shaded forest mainland across partially shaded, degraded shrub/woodland to unshaded pasture, will provide data on the relative vegetation specialization of species and will identify indicator species whose disappearance (shade specialists) or appearance (sunlight specialists) in forest will indicate ongoing forest degradation. Because there is a large pool of non-shade specialists in East Africa, it may be assumed that a process of replacement of shade specialists by sunlight specialists will occur in the Usambaras as opposed to a process of decline in species richness which has been recorded from forest across a clear-cut margin to cleared areas in Mexico (Halffter *et al*. 1992) and South America (Klein 1983). Over the same spatial axis, alpha diversity changes from lognormal through logseries to geometric series in Central and South America.

Decreasing size of forest fragments also causes a decline in species richness and diversity of dung beetles in South America (Klein 1989). It would be worthwhile duplicating such a study in the Usambaras to determine whether there are differences in dung beetle responses to forest fragmentation in Africa. However, the South American study was conducted in well-defined, clear-cut fragments resulting from a commercial logging operation. Any fragments resulting from population pressure are likely to be less clearly isolated and/or less clearly defined.

Apart from clearance at the margins, degradation in forests may commence around pathways and gaps. Therefore, should gaps be present, the appearance of open area dung beetle elements in small, natural gaps or, especially, in larger anthropogenic gaps, will be indicative of ongoing forest degradation. Pathways, in particular, should be studied as they are notorious as invasion routes from disturbed into natural vegetation. If any pathways are developed informally for foraging, or for purposes of generating ecotourism revenue through hiking trails, then monitoring for the relative penetration of open area invasive elements should be conducted. As a variation on the theme, and should such exploitation exist, the dung beetle fauna of forest areas where a network of pathways has been established should be compared with forest areas where few paths occur.

Regional data on the effect of climate show how species richness and changes in species composition occur with cooler temperatures at altitude and higher rainfall regimes (Davis and Dewhurst 1993). Altitudinal and rainfall gradients will be important in conservation planning. Three main peaks in high rainfall occur in the Usambaras which are presumably related to altitude. Known distribution data for a dung beetle tribe with ancient Gondwanaland affiliations, the Canthonini, suggest that these peaks should be managed as core conservation areas with least disturbance. The Afrotropical Canthonini show a South African center of distribution with montane and forest relicts extending up the east coast to Tanzania (Scholtz and Howden 1987). The South African to Tanzanian, coastal forest genus, *Gyronotus*, is one of these east coast relicts whereas the genus, *Anachalcos*, is exceptional in showing a widespread, predominantly intertropical distribution. Two *Anachalcos* and one *Gyronotus* species have been recorded at relatively low altitude in the Usambara region whereas three canthonine genera which are endemic to the Uluguru and Usambara Mountains have been recorded at 1450 m and above. Trapping across an altitudinal and rainfall gradient might provide further evidence of increasing endemism with altitude which would strengthen the present data and the case for conservation of core catchment areas.

Temporal distribution

A problem in evaluating ecological monitoring data for dung beetles results from the short-term variation in activity shown in response to weather, particularly incidence of rainfall (Davis 1995). Over 10 days in South Africa, species richness in open situations (grassland, open woodland) declined by 50% from 40+ species immediately after heavy rainfall to ±20 species with increasing dryness. In shaded thickets, fluctuations in species richness were much less pronounced. However, in groups of dung beetles defined according to whether they showed greater activity under wet or drier conditions, daily fluctuations in relative abundance of the groups occurred in all habitats and were pronounced in thickets. Whereas many component species of these groups were trapped in greater abundance in response to rainfall, some showed

Table 3. Dry body weight, functional group and total abundance of 91 species present in numbers of > 10 in a Gauteng dung beetle assemblage (see Table 2 for key to functional groups) (from Davis 1996b).

stronger responses than others resulting in changes in rank abundance from dry to wet conditions. Thus, short-term variation in trap catches has little predictive value. Even over the long-term, reliable trends are likely to emerge only after the collection of several years' data and these will be useful only if the effects of short-term variation are evened out by meaning the data for several months or the entire season. However, the data remains meaningful as a monitor of forest degradation if sustained decline in the abundance of all selected, specialist, forest indicator species is accompanied by the increasing abundance of open area elements in the forest traps.

As in all insects, dung beetle activity varies seasonally with high numbers recorded in the warm, rainy season and low numbers in the cool, dry season (Davis 1996c). There is also a certain amount of month to month variation in species composition and relative abundance. Therefore, comparison of ecological monitoring data for forest will only be valid between the same months in different years or between entire years' data. If the activity is particularly low in the Usambaras during the short dry season, it might be worthwhile reducing the workload by restricting trapping to the rainy season.

Year to year variation in rank abundance of dung beetles has been recorded in South Africa (Doube 1987). This may be related to climatic variation in that wet years will raise the probability of recording rainfall specialists whereas in drier years, the dry-tolerant species will be recorded more frequently. A simple impression of the relative yearly bias to wet-adapted or dry-tolerant species may be gained by examining the percentage deviation of each year's rainfall from the long-term average. Classification of indicator species according to their response to incidence of rainfall or dry periods would assist the interpretation of long-term results of monitoring.

Trapping frequency should be tailored to the requirements of the monitoring program. If the intention is to monitor a few indicator species, then results may be standardized by trapping at irregular intervals according to similar weather conditions. Ideal weather for trapping would be the warm, moist conditions immediately after rainfall when beetle activity is maximal. Alternatively, one may settle for a regular trapping frequency and rely upon meaning out of the data to smooth the effects of short-term variation. If species richness is a concern, it should be noted that trap catches are influenced both by trapping frequency and by the number of traps. In a South African study, three traps in open woodland were baited once a week. As a result of weather variation, overall numbers of species during two month periods were from 40% - 66.6% greater than the mean number per trapping occasion which were, in turn, somewhat greater than the mean number per trap (Davis 1996c). Different treatments of 18 days continuous trap data from three traps in thickets in South Africa, show that a trapping frequency of about once or twice per week will record, respectively, ±58% or ±70% of the species present.

Butterflies (Lepidoptera: Papilionidae, Hesperiidae, Acraeidae, Lycaenidae, Nymphalidae, Pieridae, Danaiidae, Libythaeidae, Satyridae)

The alpha taxonomy of butterflies is even more advanced than that of dung beetles and they are widely recognized as useful ecological indicators. However, there is no universal quantitative method for monitoring the group. Monitoring methods described in a recent paper (Sparrow *et al*. 1993) are similar to the collecting methods recommended in my old handbook of Southern African butterflies which was published 30 years ago (Pinhey 1965). Relatively qualitative and time-consuming methods comprise walking transects either netting as many butterflies as possible or identifying them on the wing which, of course, requires a measure of familiarity with the local fauna. Easily duplicated and well-defined walk lines comprise pathways, roads and forest edges. Most species present were recorded by monitoring twice weekly in a South American study (Sparrow *et al*. 1993). A quantitative method comprises attracting species to van Someren-Rydon, or similar, traps baited with rotting fruit, particularly overripe banana or pineapple. However, only some species fly to fruit. In Africa, these include some Satyridae and, particularly, the nymphalid genus, *Charaxes*, which comprises a number of distinctive bushveld and forest species (Pinhey 1965). In a recent study in South Africa, colored cups were used to make a quantitative study of monkey beetles (Hoplidae) which are attracted to flowers (Picker and Midgeley 1996). As many butterflies are also attracted to flowers, it would be worthwhile to design and test a trap using colored discs which might act as a more universal method for monitoring butterflies.

Being plant-associated insects, rather than members of the ground fauna, some of the ecological factors influencing butterfly occurrence differ from those affecting dung beetles. In particular, butterflies are not only influenced by vegetative structure through its effect on light and temperature, but also by vegetative species composition owing to larval dependence on one or more, specific, host plants. Limited but selective removal of particular plants species from the forest could, therefore, influence the butterfly fauna. Host plant distribution in relation to soil type will also influence butterfly distribution. As a number of species show dry-season forms, butterflies are, presumably, less influenced by incidence of rainfall than fossorial insects.

Termites (Isoptera)

Termites are less well known as an indicator group of forest degradation. Monitoring of the raised nests of certain species would be the best and least labor-intensive method of study. Pitfall traps are probably not useful other than to provide a qualitative record of species presence. In South Africa, termites were captured sporadically in large numbers but were otherwise uncommon in pitfalls (A.L.V. Davis, personal observation). Raised nest structures are characteristic of soils with a sizeable clay fraction. On sand, completely subterranean nests are the rule. Shifting colonies of termites sometimes colonized dung pads on sandveld in South Africa. The type of vegetative cover is also important as termites are primarily consumers of plant material. Additionally, the effect of vegetative cover on insolation will be important for thermo-regulation within nests.

As regards methods of study, unit areas of similar size (perhaps along pathways) should be selected in forest, degraded shrub/woodland and pasture. The numbers of nests and the sizes (basal circumference, height, diameter etc.) should be recorded. A sample of the occupants of as many nests as possible should be extracted whilst attempting to record as many castes as possible. This may be done by drawing occupants to a small hole in the nest, by recording exiting individuals, or by placing pitfalls close to identified entrances, particularly if the diel activity period of the species is unknown. Such methods will provide a quantitative inventory of the spatial distribution of raised nesting structures and spatial differences in nest architecture and species occurrence.

For monitoring of termites in forests, nests should be marked and any increase in the numbers of nests should be recorded together with the species of the occupants. Increase in the size of nests should be monitored by repeatedly measuring dimensions or by driving nails into the sides of nests to see if, and to what degree, the protruding graduated section is covered with time. Small holes may be driven through the sides to see if they draw the occupants. Holes should be monitored on successive occasions to see if they have been cemented over. Alternatively, pitfalls may be set by entrances to detect occupation. Interpretation of data may be complicated by the fact that abandoned nests are sometimes recolonized (V.M. Uys, personal communication). Also, more than one species and, sometimes, more than one genus have been found in the same nest (V.M. Uys, personal communication). Such a study program will monitor possible invasion of open area elements into forest and the possible status of pre-existing nests.

Summary of some proposed methods

(1) Ecological monitoring should be conducted at fixed points along pathways, at forest edges (perhaps 10-20 m into forest) and at greater distance into forest from pathways and edges. Such an arrangement should provide a dual warning of changes.

(2) Dung beetles. A inventory should to be made of the dung beetle fauna in forest and in cleared areas to select indicator species. Owing to some seasonal species turnover, it will be necessary to repeat the inventory at several times of the year. Ecological monitoring should be conducted in forest and along forest pathways to test for long-term decline in forest specialists and increase in open area elements.

(3) Butterflies. Both netting along walk lines and trapping to fruit should be conducted in forest and open areas to inventory butterfly species. Ecological monitoring will be conducted in the forest using fruit-baited traps to detect changes in forest specialists versus open area elements. Butterflies should be netted on walk lines along pathways to detect relative penetration of open area elements.

(4) Termites. Unit areas should be selected in forest and open areas. Numbers of raised termites nests should be counted and an inventory made of the species distribution. Increase in number and size of nests should be monitored in forests and along forest pathways. Status of nests (occupied or unoccupied) and species of the occupants should be monitored to detect decline in forest specialists and increase in open area elements. Should there be few specialist forest elements, then monitoring will merely test for the invasion of termites from open areas.

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Time Table for Workshop, July 8 - 9

Ecological Monitoring for Biodiversity in the East Usambaras

Day 1

8:00 Registration

8:30 Opening Remarks -- Prof. A. Nikundiwe

8:40 Welcoming Remarks -- Mr. M.I.L. Katigula

8:50 Ecological Monitoring for Biodiversity -- Dr. W. Newmark

9:50 Discussion of Forest Reserve Objectives -- FD personnel

10:30 Tea Break

11:00 Discussion of Problems facing Forest Reserves in Tanzania -- FD personnel

12:30 Lunch Break

13:30 Discussion of Ecological Monitoring in Relationship to Identified Problems -- all workshop participants

14:30 Discussion of Hypotheses, Experimental Design, and Detection of Significant Trends in Populations -- Dr. W. Newmark

15:30 Tea Break

16:00 Administrative Structure of Monitoring Project -- Dr. W. Newmark and M.I.L. Katigula

Day 2

8:30 Monitoring Human Disturbance in Plant Communities -- P.K.T. Munishi

10:00 Monitoring Epiphytes and Fruit Abundance -- Dr. W. Newmark

10:30 Tea Break

11:00 Monitoring Amphibians -- Dr. E. Rickart, Prof. A. Nikundiwe, and Prof. K.Howell

12:30 Lunch Break

13:30 Monitoring Understory Birds -- Dr. W. Newmark

14:00 Monitoring Mammals -- Dr. E. Rickart and Prof. K. Howell

15:00 Monitoring Dung Beetles, Butterflies, and Termites -- Dr. A. Davis

15:30 Tea Break

16:00 Monitoring Dung Beetles, Butterflies, and Termites -- Dr. A. Davis

156:30 Monitoring Microclimatic Conditions -- Dr. W. Newmark

17:00 End of Day 2

Time Table for Workshop Field Activities, July 10 - 14

Ecological Monitoring for Biodiversity in the East Usambaras

July 10

morning: travel from Tanga to Amani; check into IUCN and Malaria Research guest houses.

afternoon: field demonstration of monitoring techniques for assessing pole and timber cutting, and monitoring plant communities.

night: frog survey.

July 11

morning: placement of dung beetle traps in moderately disturbed forested site.

afternoon: continue with the placement of dung beetle traps.

night: frog survey.

July 12

morning: collect dung beetle traps at moderately disturbed site and reset traps at slightly disturbed site.

afternoon: monitoring primates;

monitoring understory birds and hornbills (the latter from Mbomole Hill).

night: frog survey.

July 13

morning: estimation of statistical power to detect significant trends in populations (sample size and sample frequency);

monitoring epiphytes and fruit abundance.

afternoon:monitoring light, humidity, and temperature along edge to interior gradients;

collect dung beetle traps at slightly disturbed site and reset traps at undisturbed site.

July 14

morning:departure of most workshop participants.

continuation of the development of a dung beetle reference collection.

Important Supporting Publications