AN INVESTIGATION INTO THE FEASIBILITY OF USING BIRDS AS INDICATORS OF DISTURBANCE AT DE HOOP NATURE RESERVE

By

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"James gave the huffle of a snail in danger.
And nobody heard him at all"

The Four Friends. A.A. Milne.

ABSTRACT

The origins of this study are found in the perceived conflict of land uses that arose with the announcement in 1983 that the South African Armaments Development Corporation (Armscor) intended building a missile test range on the southern Cape coast. The issues of conflict resolution and multiple land-use management, therefore, bear importantly on this investigation. Both are encapsulated in the functions of ecological monitoring.

The primary objective of this study was to assess the feasibility of developing an ecological monitoring programme for the terrestrial ecosystems of this subregion. Towards this end a number of subsidiary objectives were formulated, namely :

1) To introduce the concept of ecological monitoring and provide an understanding of its potential and limitations;

2) To test the sensitivity of birds to disturbance and assess the feasibility of their incorporation into a full-scale monitoring programme;

3) To address some of the problems associated with a diverse and dynamic environment that limit the wider applicability of ecological monitoring;

4) To test a range of analytical techniques for their ability to detect ecosystem stress from ecological data.

A 12 month, side-by-side comparative study of control and experimental plots was conducted in Milkwood Thicket, Southcoast Strandveld and Lowland Limestone Fynbos. Experimental plots were subjected to existing disturbances within the De Hoop Nature Reserve, the severity and nature of which approximated those anticipated at the Overberg Missile Range. Bird populations in each plot were censused four times per month throughout the study period and assessed for their ability to discriminate between disturbed and undisturbed plots.

It was found that birds as a community were able to discriminate between disturbed and undisturbed plots in Milkwood Thicket, but not in Strandveld or Fynbos habitats. Stemming from this finding a number of conclusions were drawn :

1) Vegetation has an overriding effect on the abundance and distribution of bird populations. Disturbances which do not affect the resources on which birds depend are less likely to be detected. The use of two or more categories of indicator organism, therefore, may broaden the applicability of ecological monitoring;

2) Richer and more abundant bird communities provide greater opportunities for detecting disturbance and overcoming background noise;

3) Ecological monitoring is limited by factors which produce variable data.

With respect to the latter conclusion, measures which addressed the variable nature of natural systems would greatly enhance the power and applicability of ecological monitoring. Towards this end, this study determined the range within which bird populations are likely to fluctuate, in the absence of disturbance. It also identified the most favourable conditions for censusing birds and the optimum number of times a community needs to be censused in order to produce data that is sufficiently complete and uniform.

Regarding the analytical techniques used, this study found that by selecting those components of an ecosystem that were likely to respond to opportunities and stress in similar ways, background noise could be reduced and patterns in the data set enhanced. Techniques which provide a more focused approach to data analysis facilitate this process amd are favoured in any future ecological monitoring programme.

Recommendations regarding the establishment of such a programme are made at the end of this report.

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INTRODUCTION

1.1 BACKGROUND TO STUDY

This study arose out of two topical issues in the field of environmental resource management : conflict resolution and multiple land-use management. Its origins are to be found in the perceived conflict of land uses that arose with the announcement in 1983 that the South African Armaments Development Corporation (Armscor) intended building a missile test range on the southern Cape coast. Such an enterprise entailed the expropriation of a large tract of land, part of which included the ecologically valuable provincial nature reserve, De Hoop. The conflicting land-uses in question were, therefore, military research on the one hand and environmental conservation and education on the other.

The apparent incompatibility of these two activities lead to a large and vigorous public protest being conducted against Armscor's unilateral decision. This campaign was aimed mainly at halting the proposed project or at least insisting that it be built elsewhere. Much of the anger and rhetoric vented during this period, however, was a result of the secrecy with which Armscor had gone about its activities. The campaign, therefore, was also a demand for greater public participation in matters concerning the continued well-being of communal resources.

In this respect the widespread public protest may be said to have achieved one of its aims. Armscor agreed to allow an independent commission to be established in which all concerned parties were invited to voice their opposition and suggestions. The commission, chaired by Dr Hey, began its deliberations in June 1983 and published its findings in November of the same year, after having conducted a wide ranging study of the implications of weapons testing at De Hoop. In its concluding comment the report stated that "... multiple use of this diverse and natural area as both a proclaimed nature reserve and a weapons test range, will be possible without undue prejudice to either cause, provided the conditions stipulated in this report are met and honoured" (Hey,1983).

The conditions agreed to by Armscor (Hey,1983) included the following :

- The existing De Hoop/Potberg Nature Reserve and all associated conservation and educational facilities and recreational areas will not be directly affected in any way.
- The De Hoop vlei and adjoining wetlands will be left undisturbed.
- The eastern area between Potberg Estates and Cape Infanta will be under dual management of Armscor and the CPA.
- The fire fighting team and resources would be made available to the CPA and other parties in the vicinity of the weapons test range.
- Armscor will actively assist ... in the promotion of nature conservation, for example, in fighting the intrusion of alien vegetation such as Australian Acacias.
- All low flying over the existing De Hoop Reserve will be prohibited.
- No other form of military exercises will take place in the range area, specifically no vehicle testing, troop manouvers, tracking, parachuting, marine landings, etc.

* A thorough botanical and zoological survey of the entire area acquired for weapons test range and including the present De Hoop Nature Reserve, must be undertaken immediately and repeated at 10 year intervals to monitor any changes that might result from the multiple use of this area.

By having a commission consisting of respected individuals appointed by the minister of Environment Affairs, it was hoped to resolve the conflict between the proponents of arms manufacture and those of environmental conservation. While the commission did much to defuse the controversy and to reduce the rampant rumour-mongering that had proliferated in the prevailing atmosphere of secrecy, it could nevertheless not hope to please everyone. There were many who were bitterly disappointed at the commission's decision, believing that the decision to allow the missile test range to be built was an irreversible one and one which would alter the various ecosystems and unique character of the area forever. It was a signal for large-scale development to take place, the momentum of which would demand further development. In addition, public mistrust of Armscor would continue in the absence of any guarantees ensuring that conditions laid down in the commission's report were fully met.

For these reasons the commission insisted that the area be monitored over time in order to detect any changes that may occur in the environment as a result of human impact. Monitoring was to be undertaken by the Cape Department of Nature and Environmental Conservation and was to take the form of a thorough botanical and zoological survey of the entire area acquired for the weapons test range. This was to be undertaken before Armscor began operations in earnest and repeated at ten year intervals (Hey,1983).

1.2 NEED FOR MONITORING

Besides fulfilling the political functions of allaying public fear and mistrust and apportioning blame in the event of habitat degradation occurring, a monitoring programme is needed for a number of other reasons.

Because of the complexity of natural systems, prediction of impacts can never be made with absolute certainty. So too, large-scale developments and multiple-usage of land may result in unforseen impacts or changes that occur slowly and with cumulative effect. A sensitive and integrated monitoring system would, however, be able to detect such disturbances should they occur and in so doing provide some warning that the vigor and integrity of the ecosystem was being threatened.

Multiple usage of land is justified only insofar as it does not undermine the ability of the environment to support one or other of the activities for which it is being used. Monitoring may thus be used to confirm compliance of each party to the standards and practices agreed upon, to check that predictions of impact made are correct and that mitigating measures are in fact succeeding.

Finally, a monitoring programme fulfills the very important function of providing feedback to management, thus enabling management to improve its understanding of the ecosystems under its jurisdiction and to assess periodically the degree to which management goals have been successful.

The need for monitoring nevertheless needs to be seen in the light of its cost, particularly in terms of human resources. Monitoring undertaken merely for the sake of monitoring, is wasteful and of little benefit to anyone. It needs to have a focus, selecting those components of the ecosystem which have been shown to be sensitive to disturbance and which are meaningful to management objectives. As Gerard (1965) has said, "before measurements can be meaningful they must be directed at the right things and, even in science, finding these things is the major achievement; entitation is more important than quantitation." (Quoted in Mcintosh,1967.) Herein lies the major difficulty of monitoring: choosing an entity that is meaningful and focused in an environment of which there is only a rudimentary understanding.

Unfortunately, not enough mention was made by the Hey commission of the need for monitoring, or of the costs and difficulties involved. There was no suggestion as to how it should take place, nor any reference as to the importance of a monitoring programme, or of the need to initiate it as expeditiously as possible. The commission did not articulate any clear conception of the nature of the monitoring programme it was insisting upon, nor give any indication of the purposes of such a programme. In short, the Department of Nature and Environmental Conservation was charged with the responsibility of fulfilling something about which it had no clear brief and little conception as to its importance or purpose. The responsibility for initiating such a programme, therefore, became a millstone to the department. Little enthusiasm was shown towards monitoring, which was seen by many as an exercise in futility, drawing valuable personnel away from ongoing projects merely to satisfy the requirements of a commission (Burgers, pers.comm.). In addition, it is suggested that the many difficulties and pitfalls associated with meaningful monitoring have further retarded the department from establishing an ongoing and functioning programme.

It must be stated, however, that regular counting of waterfowl, oystercatchers and small antelope is diligently carried out by management staff at De Hoop. Such data, while valuable in increasing our understanding of the individual species involved and in providing baseline data, is nevertheless not designed for the detection of ecosystem change resulting from human disturbances.

The Hey Commission's insistence on a monitoring programme has thus only fulfilled part of its purpose - that of allaying immediate public ire - but has done little towards detecting disturbances within the environment.

1.3 OBJECTIVES

The present project hopes to contribute towards the process of developing an integrated, reliable and workable monitoring programme, the underlying purpose of which is to further the aims of sound land management. First it introduces and provides a theoretical framework for the concept of ecological monitoring. In so doing it provides a perspective on the nature, scope, potential and limitations of this concept.

The study then examines the feasibility of using biological measures as one way of improving the accuracy, predictability and usability of monitoring in as cost effective and meaningful manner as possible.

Towards this latter goal the study focuses on birds as one class of organism that, in theory, holds promise as an indicator of disturbance. In this it must be emphasised that the study is more concerned with impacts to an ecosystem as a whole rather than with changes in the bird populations themselves. For this reason, the study is less concerned with specific species as it is with monitoring of groups or whole communities of birds. Such an approach, which follows Steele et al (1984), integrates information from many ecosystem components and is therefore less sensitive to unexplained population fluctuations of a single species.

In evaluating birds as monitoring tools, their sensitivity to disturbances is tested. In so doing, a number of analytical techniques are used, and their ability to depict patterns and elicit features of a community that point to the occurrence of change, and perhaps stress in the ecosystem, is assessed.

Many of the factors limiting the wider applicability of ecological monitoring relate to the difficulties of making predictions in a very variable environment. Measures which, to some extent, overcome these difficulties may, therefore, add greatly to the power and applicability of ecological monitoring. This study addresses the problems of a variable environment in three ways:

1) The range of natural variation experienced by the system is determined, so that situations of abnormality may be more confidently detected, when they occur;

2) Fluctuations in atmospheric conditions produce data which is often incomplete, and widely divergent from one day to the next. This study identifies the most favourable conditions for data collection, so as to maximise the information content of each census;

3) The optimum number of times a bird community needs to be censused, in order to produce a sufficiently complete set of data, is identified.

Finally, from the experience gained during this study, it is intended to offer suggestions regarding the establishment of a full-scale monitoring system. Such suggestions pertain particularly to the problems of site selection, data collection and data analysis.

1.4 APPROACH

The approach of this project takes the form of a 12 month comparative study between bird populations of disturbed and undisturbed areas in three different habitat types. The study makes use of disturbances already occurring within De Hoop Nature Reserve and does not venture beyond its borders.

Data collected during the study period are analysed using a variety of techniques. Differences between control and experimental data are then tentatively attributed to the effects of disturbance and evaluated for their potential as indicators of disturbance.

Recommendations regarding the feasibility of ecological monitoring and the establishment of a monitoring system are made on the basis of the above analyses, the literature reviewed and the experience gained during the course of this study.

CHAPTER 2

A FRAMEWORK FOR ECOLOGICAL MONITORING

2.1 INTRODUCTION

This chapter clarifies what is meant by ecological monitoring. It reviews environmental impact assessment in relation to environmental monitoring before dealing with ecological monitoring in some detail. The practice of ecological monitoring is placed within the framework of ecosystem development and the statistical design of ecological monitoring systems is addressed briefly.

2.2 THE TERMS USED

In preparation for the 1972 United Nations Conference on the Human Environment in Stockholm, an intergovernmental meeting defined environmental monitoring as, "a system of continued observation measurement and evaluation for defined purposes". (Sors, 1984). The "defined purposes", for which monitoring is to be carried out, are to be seen, according to Sors, within the context of environmental management. Monitoring is not an end in itself but an essential step in the process of environmental management. Its purpose, according to Beanlands and Duinker (1983), is to test impact hypotheses and test mitigative measures. Holdgate (in Hinds, 1984) sums it up saying, "an accurate judgement of environmental consequences resulting from technological development requires that appropriate designs for the collection of environmental data be available and consistently followed." Like the Stockholm definition it assumed that this judgement would be made for the purposes of "corrective action".

Much of the environmental monitoring carried out since 1972 has, nevertheless, been largely fruitless as it has confined itself to the measurement of air and water quality, without considering the biotic component of the environment (Hinds, 1984). Hirsch's(1980) question, "are our ecosystems healthy or are we altering them however subtly?" cannot be answered by referring merely to the physical quality of the environment. In addition, "biotic assemblages of one sort or another" must be examined (Hinds, 1984). This he termed, "ecological monitoring" and defined it as the "purposeful and repeated examination of the state or condition of specifically defined biotic groups in relation to external stress."

Ecological monitoring is distinguished from environmental monitoring in that it emphasises changes in living organisms and not changes in the physical environment. Hinds also distinguished it from biological monitoring which, he says, "use the biota as a surrogate 'filter' to be analysed to indicate environmental quality." In contrast, ecological monitoring has its focus in the biotic community itself: the emphasis is on the living organisms themselves, rather than on the abiotic components that make up that environment.

Mentis (1984), in his report Monitoring in South African Grasslands, also distances himself from the narrow confines of the traditional air and water quality monitoring practices (that were designed for the detection of specific pollution agents). Monitoring, he says, functions to test the null hypothesis of no change in predefined properties of a system which is vulnerable to impacts, "the nature, timing and location of which are not necessarily known." If these details are known, Mentis explains, then so is the cause of the impact and the study becomes an environmental investigation rather than ecological monitoring. According to Mentis's definition, therefore, monitoring may be used to check for a number of diverse and perhaps unforeseen impacts,the magnitude and cause of which may not be self-evident.

Ecological monitoring, therefore, is systematic, repeated, goal-directed and management oriented. It has its specific focus in the biotic community of the environment being studied and may be used in the detection of a wide and perhaps diffuse range of impacts, the cause of which may not be known.

2.3 OBJECTIVES AND CONSTRAINTS

Munn was instrumental in the establishment of the Global Environmental Monitoring System (GEMS) for the International Council of Scientific Unions. He states (Munn,1973) that the objective of monitoring is, "to provide information necessary to ensure present and future protection of human health and safety and the wise management of the environment and its resources."

This to be achieved, according to Munn, by :

a) (i) Increasing our quantitative knowledge of natural and man-made changes in the environment;

(ii) Increasing our understanding of the environment.

b) Providing early warning of significant environmental change in order to take corrective measures.

c) Developing means to check the effectiveness of establishing regulatory mechanisms.

For such a programme to be effective, and for all programmes in which an holistic understanding is sought, an inter-disciplinary approach is needed.

Such goals, must always be sought within the demanding constraints of time and resource limitations. Monitoring, therefore, must be justified in part by its efficiency. The ease of data collection and analysis is of great importance to the future usage of any system. Of no less importance, is the quality of the data itself. Data must be reliable over time and its content must be valid to the problems at hand.

The choice of components to be measured is important. The complexity of the environment is far too large to allow anything but a small sample of the whole to be measured. This sample must, therefore, be representative so that the data will provide wide and relevant information. Components to be measured must also be sensitive to environmental change and should be easy to measure.

The procedures devised to ensure that the above requirements are met must be systematised and documented and an adequate storage system for collected data established.

2.4 MONITORING AND ENVIRONMENTAL IMPACT ASSESSMENT

In beginning his discussion on the future and importance of biological monitoring, Cairns (1980) states, "for those who desire both the advantages of a technological society and the amenities of natural systems (including our dependence on them as a life support system), it is mandatory that the interface between the two systems be as harmonius as possible". This requires that a continual supply of reliable and meaningful data be obtained - from an environment that is notorious for the noisiness of the information that it yields. Beanlands and Duinker (1984), for example, state that "most scientific and technical problems associated with environmental impact assessment can ultimately be traced back to the natural variability inherent in many physical and biological phenomena." So great was this variability that "... the time normally available for impact assessment studies precludes anything but an approximation of the natural variability of the important environmental components."

This inherent variability is found, in part, in the highly dynamic nature of natural systems. It is found spatially in the patchwork distribution of its components and temporarily in the seasonal and cyclic fluctuations to which any natural system is subjected.

In addition to the variability of the natural environment, a number of other factors may contribute to diminish the confidence with which a researcher is able to make predictions. According to Dickert and Tuttle (1985) the many interactions between the biotic and abiotic components of the environment, compensatory responses, and problems of field measurement, may also serve to mask the true impact that a development may have on a system.

Much uncertainty therefore exists in making environmental predictions. The magnitude and nature of impacts that result from a particular development may thus be seriously divergent from those that were forecast. Such a possibility argues strongly for the need to undertake regular and objective monitoring during both construction and operational phases of development as well as in the abandonment phase of certain activities.

There are two other compelling reasons why monitoring ought to be seen as an integral part of the overall environmental planning process. Firstly, monitoring is an information tool in the sound management of natural resources and secondly, it is of great use in detecting environmental change resulting from the cumulative effect of many small impacts over time. Each of these facets will be discussed below :

2.4.1. Sound Management

Natural resources are under increasing pressure as people seek to meet their needs and aspirations. More intensive and often multiple use of resources have strained the tolerance limits of natural systems. Yet little is understood of the carrying capacity of natural systems and the difficulties that environmental variability pose for the impact researcher are no less taxing for the environmental manager. Clearly, the exploitation of natural resources needs to be managed as scientifically and sensitively as possible.

There is a need, therefore,for the practice of resource management to be founded on a sound scientific base. Management practices thus founded will be able to refine and modify mitigative measures, take steps to increase the vigor of ecosystems and make use of information feedback on the degree to which their predictions were accurate and practices successful.

Cairns (1980) called the process of developing feedback "biological monitoring". According to him, no system can be properly managed without a continual feedback of information about its condition. Both Mentis (1984) who termed this process "scientific management" and Holling (1978) who called it "adaptive management" strongly endorse this claim.

A system for the sound management of natural resources is incomplete if it does not continually seek to evaluate and correct current practices in the light of information generated by a system of monitoring that is fully integrated into the framework of the management process.

2.4.2 Cumulative Impact

Most environmental impact assessments are directed at the large immediate and direct impacts of proposed developments and seldom at the insidious nature of small, often overlooked and unintended, cumulative impacts of development (Dickert and Tuttle, 1985). An environmental impact assessment is often deemed successful if it is able to account for, and ameliorate obvious large impacts. Yet small cumulative impacts may over time bring about pronounced and permanent changes to the environment.

Cumulative impacts are those that result from interactions of many incremental activities, each of which may have an insignificant effect when viewed alone, but which become cumulatively significant when seen in the aggregate. Cumulative impacts may interact in an additive or synergistic way, they may occur on-site or off- site, may have short-term or long-term effects and may appear soon after disturbance or be delayed (Dickert and Tuttle, 1985).

The notion of cumulative impacts is closely linked to the threshold concept which states that significant environmental damage may occur when the combined effects of several impacts exceed a certain threshold. In order to maintain cumulative effects below this threshold, two approaches are suggested by Dickert and Tuttle.

2.4.2.1. *The comprehensive approach.*

Here extensive fieldwork is done in order to establish the carrying capacity of the system before development is approved. Standards can then be set to maintain impacts below the threshold level. Attractive as such an approach sounds, it is nevertheless limited by our inability to determine system thresholds.

2.4.2.2 *The incremental approach.*

In this approach, each case is treated separately and without a priori knowledge of the system's capacity. The approach makes use instead of ongoing monitoring of the environment, and thus depends on the ability of the monitoring system to detect when an ecosystem is under stress (before the point at which damage becomes irreversible). Unfortunately such monitoring is costly and is seldom seen as a priority. The potential for cumulative impacts occurring, must not be overlooked. This method of monitoring, that is ongoing, cost effective, and which has the ability to reflect the cumulative damage of numerous insignificant impacts over time would be of much value. The use of living organisms in a system of ecological monitoring may therefore hold much promise in dealing with the problem of cumulative impact detection.

2.5 ECOLOGICAL MONITORING

"The purposeful and repeated examination of the state or condition of specifically defined biotic groups in relation to external stress" was how Hinds (1984) defined ecological monitoring. This he distinguished from environmental and biological monitoring as was made clear in section 2.2.

In this section an ecological framework within which to view monitoring and impact assessments will be developed. The potential and limitations of ecological monitoring will be made clear and the numerous techniques for measuring ecological change will be reviewed. Ecological monitoring will then be placed within the framework of ecosystem development theory.

Ecological monitoring is, to all intents and purposes, untried in South Africa. The numerous methodological, statistical and ecological problems with which it is faced appear to have intimidated most researchers in the field of impact assessment. The intriguing possibilities that ecological monitoring offers should these problems be overcome justifies further research in this field. In determining the health of a natural system ecological monitoring makes use of the living material itself. Measurement is therefore direct. Instead of predicting a biological response from physical or chemical measures the actual response of organisms or populations to environmental disturbance is measured. Living organisms act as " convenient full-time monitors" of environmental stresses (Thomas, 1972). The particular individuals, populations or communities of organisms chosen to fulfill this function are known as indicators.

The response of living organisms to environmental stress is not a measure of the current level of a particular disturbance, but is a response to the collective set of all accumulated stresses over time. The measure, therefore, is able to account for the effect of cumulative impacts as well as the effect of any brief extreme disturbances that may occur. The effects of unforeseen and unknown impacts will be registered, as will cumulative impacts whose effects may be felt exponentially by the system.

Ecological monitoring does not account for the set of impacts in an additive way. It reflects antagonistic and synergistic interactions between different impacts. That is, the interaction between two different impacts may serve to lessen the overall impact to the system or it may, in certain cases, exacerbate the situation in a multiplicative way. Ecological monitoring, by looking at the response of living material itself, is thus able to account for such interactions.

Ecological monitoring may be employed on a continuous basis to detect a broad range of disturbances. Such monitoring may have particular application in large development projects whose environmental effects are many, diffuse, and cover a wide area. The surveillance of the many different potential impacts that such a development may cause is likely to be tedious, expensive and very cumbersome. Ecological monitoring is well suited to long term monitoring in which the well-being or integrity of the whole system is assessed. Ecological monitoring does not usually consider specific impacts. But if specific disturbances are detected in the environment, additional resources may be diverted towards establishing their cause, bringing about their amelioration, and closer monitoring of that particular disturbance.

The use of indicators in ecological monitoring function as an ecological litmus paper. They are one means of keeping a finger on the pulse of a natural system; an irregular beat may be the sign of a disturbance (naturally or anthropogenically caused) and must be investigated.

The unique contribution of ecological monitoring is well summarised by Thomas (1972). "Because ability to support life is a prime characteristic of any environment, the general vigor of natural populations provides a readily accessible gauge of habitability which will be used more frequently as our ability to interpret population fluctuations increases."

The measurement of population changes is central to the practise of ecological monitoring. How these population changes are measured and expressed will be discussed in 2.6

2.5.1 Constraints and Limitations of Ecological Monitoring

In the 15 years since environmental monitoring was promoted as a promising tool of environmental management little progress appears to have been made. Sors (1984) says that in spite of the many resources devoted to the design and operation of monitoring systems since the 1972 Stockholm Conference, a widespread feeling has developed that monitoring has failed to live up to expectations. Its perceived failure, according to Sors, may be attributed to two factors.

a) In spite of the resources used, many of the early monitoring programmes were too ambitious and were designed without clear objectives and therefore were of limited usefulness.

b) Only recently have researchers come to realise the scientific and technical complexity of deciding what, where, when and how to monitor.

Despite these difficulties Sors indicates that there has been a recent renewed interest in monitoring, and that some progress in the design, operation and utilization of monitoring systems has been made. Such attempts are nevertheless being made with greater respect for the limitations inherent in environmental and ecological monitoring.

Before an ecological monitoring programme can be considered worthy of use, it has to satisfy three stringent criteria. This "tripartite requirement" is summed up by Hinds (1984) as being a need for, "ecologically relevant, statistically credible and cost-effective monitoring methods." He goes on to say that failure to meet any one of these characteristics "is at the root of many problems that are found in ecological monitoring". These three requirements, which are dealt with in detail by Hinds, are considered briefly below followed by two further considerations.

2.5.1.1. Ecologically relevant.

The major difficulty in this respect is to choose and quantify, from the highly complex and dynamic nature of an ecosystem, "specific biotic conditions or activities" that are sensitive to the programme's objective. Thus, for a particular species of organism to be chosen as an indicator, it must be shown to respond to stress in a detectable way.

The choice of level of scale that is most relevant is also an important consideration. Ideally, one should consider the whole system. This, however, is probably impossible to replicate and is likely to be unwieldy and very expensive. The ecosystem level, too, has been very little explored on account of the sophistication required in the modelling of such a system. Subsystem levels of organization may be useful. Selected species, functional groups such as guilds, or trophically linked species are three such sub-system levels that hold much promise as tools of ecological monitoring.

Hinds concludes by saying that current ecological science cannot predict the long term usefulness of these different approaches.

2.5.1.2. *Statistically credible.*

Having chosen pertinent ecological material to be measured, the quantitative aspects of measuring environmental change must then be considered. A major requirement for ecological monitoring is the specification of appropriate replication standards. Yet no two parts of an environment are identical. The credibility of conclusions based on statistical analysis rests largely on the degree to which independent replication is built into the study design. Yet there appears to be little consensus as to which of the numerous available methods of establishing replication standards is the most appropriate. Furthermore, it should be borne in mind that while replication determines to a large extent the statistical power of a monitoring design, it also adds greatly to the cost of such a programme.

2.5.1.3. *Cost-effective.*

Demands on time and resources are a most important consideration in any monitoring effort. Statistically credible and ecologically appropriate monitoring designs are rendered useless if cost is prohibitive. The emphasis in designing monitoring programmes therefore ought to be on selecting that which is adequate and not necessarily maximal in meeting the project's objectives and the level of resolution required. An optimal solution, therefore, is one which allows for compromise in each of the three requirements.

2.5.1.4 Interpretation.

In addition to the above constraints on monitoring design are the problems of interpreting a complex and highly dynamic environment. The environment is constantly responding to opportunities and stresses that face it. Data are therefore noisy and the difficulties of separating natural background variations from human induced effects are immense. This is compounded by the fact that naturally occurring stresses may further mask the effects of human actions. Thus, even when significant ecosystem changes are detected, it is not always easy to link them to causal mechanisms. Added to this is the difficulty of establishing stable data baselines in an environment that is in a constant state of flux.

To crown this litany of difficulties is the fact that the landscape mosaic is often overlayed by a variety of land uses, each of which produce an array of impacts. The problem of establishing the source of environmental disturbance is therefore extremely difficult.

Out of this complexity, indicators that are sensitive to the problem at hand, easily measurable, and reliable over time, must be drawn. Such a task is not only difficult but also seldom perfected.

A further problem is pointed out by Hirsch (1980) who says that there are many compensatory mechanisms in ecosystems and that ecosystems exhibit varying degrees of resiliency. So even when impacts are detected, it is often hard to define their real importance.

2.5.1.5 Institutional Problems

Finally, these very real scientific difficulties are compounded by a number of institutional problems (Hirsch, 1980). There is a need to maintain some basic long-term ecosystem studies in order to distinguish from among long-term ecosystem changes, "those which are cyclic, those which are unidirectional, those which are natural, and those which are human induced" (Hirsch, 1980). Lack of funding for such research is seen by Hirsch as a serious limitation to furthering understanding of mounting monitoring programmes.

The attractiveness of a monitoring system that is able to reflect the ability of an environment to sustain life must therefore be weighed against the numerous and serious difficulties that must be overcome.

2.6 INDICATORS OF ENVIRONMENTAL DISTURBANCE

2.6.1 Introduction

Indicators are used both in our language and in our everyday lives. They are signs that give clues to the state or condition of a larger and more complex whole. They are an easy, quick means of simplifying, condensing and communicating information about an aspect of the environment that is pertinent to our needs. The number of cars sold in a month is used as an indicator of the health and future trend of an economy, and the arrival of migrating swallows is a hint that spring will not be long in coming.

Environmental indicators are used to provide information on the state of the environment, particularly where a part of that environment is faced with some form of human disturbance. From the complexity of the environment selected, indicators provide summarised and understandable data that can be used by decision-makers for the sound management and exploitation of natural resources. For example, the sediment load that is recorded in a river may be used as a measure of the amount of accelerated erosion taking place in a particular drainage basin. A further example is that of Zimbabwe where prospecting for copper was greatly facilitated by the discovery that the distribution of the plant Basil Ocimum homblei was limited to areas where the concentration of copper in the soil exceeded 100 p.p.m. (Thomas, 1972).

Almost any characteristic of living material may be used as a biological measure. According to Cairns and Dickson (1980) most ecological monitoring techniques may be divided into those that employ single species as indicators and those that study the response of aggregations of organisms. Since one of the best measures of the health of an ecosystem is the condition of both the individual species and the communities of indigenous biota (Cairns, 1980) both methods may be used in the same monitoring system. These are described separately in the paragraphs that follow.

2.6.2 Indicator Organisms

The idea that certain species may be used to indicate certain types of environmental conditions is well established. The term 'indicator organism' refers to plants, animals or microbes which are indicators ecological conditions. That is, by their presence or absence or specific characteristics they give clues to various ecologic conditions (Southwick,1976). At De Hoop for example, Leucadendron meridianum is indicative of high limestone content in the substrate. Organisms with relatively narrow tolerance levels to specific environmental factors make the best indicator organisms. The narrower the tolerance the greater the accuracy in indicating specific ecologic conditions.

The introduction of the concept of indicator organisms may largely be attributed to the development of the "Saprobien System" by Kolkowitz and Marrson in 1909 (Lenat et al 1980),. This was a system of using river benthos to provide information on water quality. Lists of organisms which were associated with various zones of pollution were developed. These zones ranged from highly polluted water with low dissolved oxygen concentrations to clean water with high dissolved oxygen concentrations. These saprobic-system zones were considered to be "centres of optimum growth and development" for the organisms associated with them. Organisms collected and identified at a particular location would then be compared with established lists in order to determine what degree of organic pollution was exhibited at that location. For example, an aquatic community dominated by certain tubificids or by midge larvae of the genus Chironomus may reflect an area characterised by low dissolved oxygen concentrations and high organic enrichment (Lenat et al, 1980). In this instance, species presence is used as an indicator of certain environmental conditions. Species absence, however, may also be used as an indicator.

According to Whittaker (1967) "populations of species along continuous environmental gradients typically form bell-shaped curves with densities declining to scarcity and absence." In the saprobic system described above, indicator species would be those whose distribution curves were at their peak. It may at times, however, be useful to choose indicator species that are distributed at the edge of their centres of optimum growth. (That is, in the 'tail' of their distribution curve). Such species would be living in an environment to which they are not wholly suited and will therefore be less able to withstand changes in the environment. Their absence may therefore signify the presence of stressful influences in the environment.

One such indicator which has been well tried and tested is the lichen. It is used as an indicator of atmospheric pollution by sulphur dioxide. A lichen is a dual organism; it is composed of fungus and algae living in a close, mutually dependent relationship. Most species of lichen, according to Hawksworth (1974) are adapted to precise ecological niches and can tolerate relatively narrow limits of ecological amplitude. Their sensitive physiological system plus the fact that they derive their nutrients principally from atmospheric moisture and dust, rather than from the substrate on which they grow, make lichens particularly suitable as monitors of environmental change. It is their absence which is used to indicate change.

The idea of using presence or absence of indicator species is very narrow and absolute. Although the presence of a species gives the assurance that certain minimum conditions have been met, determining the significance of the absence of a species is rather more risky (Lenat <u>et al</u>, 1980). The absent species, for example, may have been displaced by another species or the species in question may not have had an opportunity of colonising the area. In addition, a major limitation is that a large number of factors unrelated to the health of the local ecosystem may influence populations of individual species, for example, disease, parasites and predation (Steele, <u>et al</u>, 1984).

The absence of an entire <u>group</u> of species with similar environmental requirements provides considerably more assurance that that group has been excluded. It is much more informative, therefore, to investigate the presence, absence and characteristics of indicator communities (Cairns and Dickson, 1980).

2.6.3 Community Indicators

A community is an interlocking, interdependent system of species in which an effect on one part will ultimately affect the whole (Lenat _et al_, 1980). The idea, therefore, that the response of an assemblage of organisms could collectively be used to assess stress in a community is appealing and has, in recent years, gained much credibility (Lenat _et al_, 1980). According to Steele _et al_ (1984), monitoring communities integrates information from many ecosystem components and is less sensitive to unexplained population fluctuations of single species. Assemblages of organisms such as birds or small mammals are suitable communities to use for monitoring because they are ecologically diverse in that they use a wide variety of food and other resources. They thus reflect the condition of many aspects of an ecosystem (Steele _et al_, 1984).

For an understanding of the many characteristics of a community and of the underlying processes at work, a knowledge of both the structure and function of the community is necessary. Our ability to do this is severely limited and the present discussion is limited to methods of analysing the structure of communities.

A number of important community characteristics may be of particular benefit in assessing the carrying capacity and general vigor of an ecosystem. They are species richness, abundance and relative abundance, each of which are elements of the unifying concept of diversity, itself a potential indicator of environmental disturbance. Each will briefly be considered below.

2.6.3.1 Species Richness

This term refers to the total number of species recorded in a given area or ecosystem and is usually confined ,in the animal kingdom, to a particular class of organism, such as birds or insects. Such a measure is clearly dependent upon ,amongst other things, the diversity of the habitat and the extent of the area under consideration.

In very general terms it is assumed that in natural systems a decrease in the number of species present is an indication that the system is under some form of stress. This assumption is based on the idea that certain species will be less tolerant than others of particular disturbances and will either leave the area or die off. It should be remembered, however, that in certain cases low level disturbances to a system may lead to an increase in the number of species being present.

While species richness is a characteristic that is easy to measure, it is limited in its usefulness in that it does not take into account the particular composition of the species recorded. For example, species richness will remain unchanged if the demise of one species is matched by the entry of another one into the community - even though such an occurrence may result from disturbances that are seriously affecting the integrity of the system.

A further limitation is found in its inability to account for the relative abundance of individual organisms within each species. For example, a disturbance may merely reduce the size of a particular population without affecting the total number of species present.

2.6.3.2 *Abundance*

Abundance, or density, refers to the number of individuals (of all species of a particular class) living within a specified area. It is a function of the carrying capacity of the ecosystem and therefore may be used to reflect changes in the ability of that system to support all its constituent components. Like species richness, it is a crude measure which when viewed in isolation, is unlikely to reveal anything beyond the broad picture.

2.6.3.3 *Relative Abundance*

Unlike species richness or abundance, relative abundance is not expressed as a single figure. It is a list of all species occurring in the area, together with the respective numerical contribution made by each species to the total abundance of that system.

In most natural systems it is usual to find that different species vary greatly in terms of their relative contribution to the total population. A few species are likely to be very abundant while a relatively large number of species will only account for a small proportion of the total abundance.

Relative abundance, therefore, is able to account for the numerical importance of each species. In order to understand the ecological importance of each species, however, the contribution of each species to the biomass of the system must be calculated. Both measures of 'importance' may be valuable in interpreting changes in the richness or abundance of an area.

Ecologically or numerically important species do not necessarily make the best indicator species. To be of value as an indicator, a species must be sensitive to environmental change. Such a characteristic is less likely to be found amongst abundant species which, because of their adaptation to the particular surroundings and perhaps their generalist nature, are able to cope with a fairly wide range of environmental change. Less common species, on the other hand, may be specialist in their relationship to the environment or may also be living at the extremity of their distributional range and thus in a habitat which is not wholly hospitable to their particular needs. Such a species, it is suggested, will be less tolerant of environmental changes and will quickly respond to perturbations. Because their vulnerability may stem from their specialized nature, a change in their population characteristics may provide a clue as to the nature of the perturbation causing the change.

Summarising, 'species richness' and 'density' are measures which attempt to describe the community in a single figure. As such, they are simple and communicate easily, but are greatly lacking in information content. 'Relative abundance', on the other hand, is able to account for species richness and abundance but with a consequent loss of simplicity and clarity.

2.6.3.4 Diversity

Species diversity is basically a measure of variety in ecological communities (Southwick, 1976). It is a function of the number of species present (richness) and the distribution of individual organisms amoung the species (termed equitability by Lloyd and Ghelardi, 1964). Diversity, therefore, is a composite of two structural properties of a community.

The concept of diversity is important because it is commonly considered an attribute of a natural community (Hairston, 1959) and is said to relate to important ecological processes (McIntosh, 1967). It has been claimed to enhance community stability and to play a role in the "productivity, integration, evolution, niche structure and competition of the community" (McIntosh, 1967). According to Gause (1936), the relationship between abundant and rare species (which diversity attempts to define) is the single most important structural property of a community. Hairston (1959) supports this claim, saying that "... numerical abundance and spatial distribution of all species must be taken into account before an understanding of community organisation can be achieved." Diversity, therefore, is a promising conceptual tool in the understanding of ecological relationships and it is little wonder so much time and effort has been spent in devising ways to meaningfully quantify it.

2.6.3.5 Diversity Indices

Indices are an important subset of the universe of indicators and are able to greatly extend their power and applicability. When a measure or quantity (of a particular parameter) is compared to a scientific or arbitrary standard, it is known as an index. The use of the centigrade scale on a thermometer is an example of an index that is commonly used (Inhaber, 1976). By creating a standard against which to anchor our measurements, quantification becomes a more meaningful exercise. Comparisons can be made in space or time and trends and changes more meaningfully plotted.

Diversity indices are "mathematical expressions which express the ratio between species and individuals in a biotic community" (Wilhm, 1968). Besides being of ecological interest they also serve an important communication function (Ott, 1978). They provide a single figure describing the community in terms of both density and the number of species present (Dicks, 1976). They therefore permit the summarisation of large amounts of information about numbers and kinds of organisms (Wilhm, 1968) and are particularly useful to people who are not immediately familiar with specific biota (Godfrey, 1978). Ideally they reduce a large quantity of data down to its simplest form while retaining essential meaning for the questions being asked of the data. Indices, therefore, have an important role to play in meeting the needs of the general public to determine the impact of developments on the world around them (Ott, 1978).Diversity indices are most reliable when describing changes in one type of community at one site over a period of time and are thus particulary applicable to monitoring studies (Dicks,1976).

Because of the difficulties involved in measuring diversity in ecology, many different diversity indices have been devised. Of these, the best known are based on concepts of information theory, such as that which was introduced by Shannon in 1948. In the language of information theory, diversity is the measure of uncertainty of the specific identity of the next individual in a census (MacArthur, 1965). Thus, "the more species there are and the more nearly even their distribution, the greater the uncertainty and hence greater diversity" (Pielou, 1966).

In addition to numerous other factors, species diversity is affected by environmental quality. It may be possible, therefore, to use diversity as an indicator of environmental disturbance. According to Wilhm and Doris (1968) in aquatic communities, "water pollution results in a depression in the diversity of the biotic community". This hypothesis has gained wide acceptance and has resulted in many attempts to use diversity indices as an indicator of environmental stress. Very generally the hypothesis rests on the idea that man-induced environmental stress will alter conditions and so affect sensitive species. As these species reduce in numbers or disappear, so the patterns of resource allocation and competition are changed, enabling the species capable of withstanding these altered conditions to increase in number. The resulting new relative abundance of the community is reflected in the diversity index.

Attempts to use diversity indices as indicators of environmental disturbance have been largely confined to water and air pollution studies where the nature of the stress is reasonably well understood. Little work, if any, has been done to determine human induced stress in terrestrial ecosystems.

2.6.3.6 *Limitations of Diversity Indices*

In spite of their wide use, diversity indices are not without their limitations. Both their biological relevance and their ability to communicate unambiguously have been seriously questioned. The greatest criticism of diversity indices appear to revolve around their theoretical validity. Hurlbert (1971) has pointed out that although species diversity and species richness are often positively correlated, such positive correlation is neither a biological nor a mathematical necessity. For example, it is possible to have a community with few species of low abundance equal in diversity to a many species community with only a few species in great abundance (Godfrey, 1978). Similarly, diversity indices do not consider the taxonomic composition of the community. Thus, it may not be possible to discriminate between two very different communities (or even one which has changed over time) on the basis of the index itself.

One of the most distinctive failures of diversity indices concerns their inability to distinguish between 'abundance' and 'importance' (Smith, 1966). The more abundant species are not necessarily the most important or influential in the community. For example, fewer but larger individuals may be of considerable importance to a community - a fact which would be underestimated by their relatively minor contribution to the overall abundance.

To overcome the difficulties created by the "pyramid of numbers", Wilhm (1968) has proposed a system of calculating diversity indices in which each species is weighted according to its respective biomass. In this way, the "geometric factor is eliminated and the quantitative relations of the standing crop are well shown" (Wilhm, 1968). Such a system would help to account more realistically for important species.

A further criticism concerns the influence of rare species which often serve as sampling artefacts. Structually, rare species are minor components of their communities and yet their effect on diversity is variable. For depauperate communities rare species have a significant effect on diversity and yet for populous communities their effect is marginal.

Another area of concern relates to the "striking non-concordance" between the many different diversity indices" (Hurlbert, 1971). For example, Peet (1974) has shown that Simpson's index is most sensitive to small percentage changes in abundance of dominant species and relatively unresponsive to change in abundance of rare species. The Shannon-Weiner index, on the other hand, responded most strongly to changes in abundance of the rarest species. Different diversity indices, therefore, may indicate quite different magnitudes and directions of change in diversity, using the same data set (Westman, 1985).

As a result, Westman says, they cannot be recommended to measure overall changes in diversity.

Since only relative abundance is considered in diversity indices, the great effort involved in developing indices is out of proportion to the information they yield (Godfrey, 1978). While the collection of data on richness, density and relative abundance is extremely helpful in following community changes, diversity indices have added little except the potential for confusion (Westman, 1985).

In spite of claims to the contrary, Godfrey (1978) believes that diversity indices are not ecologically meaningless. While it may not be possible to use them as direct measures of disturbance, they may be usefully employed as descriptive parameters which may or may not aid in interpreting the community response to a changed environment. Interpretation, however, should always be done in conjunction with other parameters.

2.6.4 Guild Theory

Rather different from the more traditional approaches to understanding community ecology is the theory of guilds. The guild was originally proposed and defined by Root (1967) as, "a group of species that exploit the same class of environmental resources in a similar way". Birds, for example, that are foilage-gleaning insectivores, may be grouped into a guild. While these species need not be taxonomically related they nevertheless use "a similar foraging manoeuvre to obtain similar food resources from similar substrates in a shared environment" (Verner, 1984).

While the idea of guilds is not new, its use as a mechanism for assessing environmental impact is rather more recent. It is an innovation, first proposed by Severinghaus in 1981, which may hold promise in overcoming some of the limitations inherent in the various indicators discussed above.

Severinghaus (1981) suggests that guilds can be used as an analytical and predictive tool in environmental decision-making procedures. He claims that relatively accurate quantifiable predictions of environmental impact can be made and cause-effect relationships determined. Importantly, such a system is significantly more cost-effective.

The use of guild theory as a mechanism for assessing environmental impact is founded on the assumption that, if organisms can be grouped by how they similarly use environmental resources, then "actions that affect environmental resources will similarly affect the members of the guilds using those resources" (Severinghaus, 1981). An insecticide therefore, which reduced the number of insects living among the foliage, would be reflected in the altered abundance or composition of members of the foliage-gleaning insectivore guild.

Because guild members utilize similar resources, Severinghaus makes the bold claim that once the impact on one species in a guild is determined, the impact on every other species in that guild is known. A single species may therefore be chosen to represent (or indicate) that guild. This has important cost-saving implications since only one, or a few species per guild need be studied in order to establish the resulting impacts on all members of that guild.

A further advantage suggested by both Severinghaus (1981) and Steele _et al_ (1984) is that such a method may help to delineate cause - effect relationships between human actions and the natural environment. A change, for example, in the relative composition of a particular guild may necessitate an investigation into the status of the resource upon which the guild is dependent. This may, in turn, reveal community changes that are coincident with impact events.

A major obstacle in the use of guild theory in applied science is encountered in the practical delineation of guilds. The validity and reliability of delineation is dependent on the appropriate allocation of species into predefined and meaningful categories - a process which lacks a systematic methodology and often relies on subjective judgement.

Severinghaus's optimistic proposals on the use of guilds was tempered to some extent by Verner (1984) who rejected the notion that indicator species could be selected to represent a whole guild. Instead, Verner put forward alternative ways in which to apply the guild concept. He suggests the use of whole guilds as a useful means of indicating the capability of habitat zones to support populations of the natural biota and sets out a systematic methodology for the delineation of guilds and the allocation of species to them.

Verner puts forward the idea of the "management guild". He defines it as "a group of species that respond in a similar way to a variety of changes likely to affect their environment". That is, species are grouped according to how they respond to <u>disturbance</u> or changes in the environment, and not according to the particular resources they utilize. Such a classification of species no longer bears any relation to the evolutionary interrelationships of the species. Root's (1967) original definition is operationalised so that it has immediate relevance to the <u>management</u> of the ecosystem.

The harvesting of timber, for example, is an action which removes tree canopies and negatively affects all species that feed there, regardless of what they eat. Consequently, all species that depend upon tree canopies for their food supply (whether it be fruit, buds, leaves or insects taken from the foliage) may be placed into a single management guild.

The intriguing aspect of this idea is that it suggests that the detection of environmental stress may be achieved at a finer level of resolution. Species within each management guild are more likely to respond in unison to stresses experienced by that zone of the ecosystem. Background 'noise' is reduced and emerging trends are more likely to be enhanced and highlighted, thus enabling the manager to 'pick up' environmental change at an earlier stage.

Guilds, in a number of ways, occupy the middle ground between indicator species and indicator communities and in theory are able to display the merits of each. They are more stable than the erratic nature of indicator species and allow greater scope for analysis than that offered by the limited measures of presence and absence. Guilds have the advantage over indicator communities of being more focused and likely to suffer less from the neutralising effects of 'averaging' which have so limited the blanket measures of species richness, density and diversity.

Promising as guilds may appear to be they are nevertheless largely untried and are a long way from becoming widely accepted as tools of environmental management. It must be remembered that they are artificial measures, their classification being dependent upon the assumptions and objectives of the person delineating the guilds.

2.6.5 Summary

Just as the health of people is determined by indicators such as blood pressure, pulse rate and temperature and the health of societies by the rates of infant mortality, crime, unemployment and housing backlog, so the ecological integrity of natural systems can be gauged using biological indicators.

Biological indicators may be divided into those that employ single species and those that study the response of assemblages of organisms. In general, the use of indicator communities is a more reliable measure than indicator organisms.

There are a number of structural characteristics of a community that may be measured and which may be of use in detecting environmental stress. All, however, have their limitations and are best employed in conjunction with other community characteristics.

2.7 ECOLOGICAL MONITORING AND THE THEORY OF ECOSYSTEM DEVELOPMENT

In beginning his paper entitled "The Strategy of Ecosystem Development", Odum (1969) states that an understanding of ecological sciences provides a basis for resolving people's conflict with nature. He goes on to say that the principles of ecological succession bear importantly on the relationships between humankind and nature.

The variety of ecosystems found on the earth is enormous. Each of these systems is dynamic in nature and constantly responding to the environmental flux in which it is set. Yet, despite this complexity, the theory of succession makes the claim that the process of change conforms to a basic pattern in every system and is therefore broadly predictable. Such an assertion has profound management implications and demands that the principles by which ecosystem development is said to occur be examined.

According to Odum (1975) ecosystem development may be defined in terms of three parameters :

a) It is an orderly process of community change which is directional and therefore predictable.

b) It results from the modification of the physical environment and population structure by the community. That is, ecological change is community controlled.

c) It culminates in the establishment of a stable ecosystem known as the climax stage.

Succession may be seen as a process of community evolution in which the ecosystem seeks to increase its control of the physical environment and achieve a steady state that provides maximum protection from environmental perturbations. It does this through changes in its functional and structural organisation, thus enabling it to better utilize the resources available to it.

Two of the most striking trends in succession are: a decrease in net community production; and a corresponding increase in community respiration. Associated with this is an increase in biomass and the standing crop of organic matter. From a structural standpoint there is a change both in the composition and diversity of species in a community. Those species that are important in the pioneer stages are not likely to be important in the final stage.

The end point in this theoretically predictable, directional sequence of changes is a mature, complex, apparently stable and persistent ecosystem whose constituent species have developed a highly interdependent and complex network of interactions between themselves and the environment. This stage, where the community has achieved its greatest emancipation from the environment, is known as the climax stage.

A feature of succession common to almost all texts on the subject is that it is directional and predictable. That is, an ecosystem whose 'clock' has been set back by some disturbance would regroup and proceed along the same path it had come so that its endpoint or climax, and all the stages in between, would match those of the previous successional sequence.

It is suggested that should the nature or frequency of the disturbance exceed a certain tolerance level peculiar to that ecosystem, then it may be possible that a qualitatively new ecosystem will develop - the old successional blueprint disappearing forever and a new stable equilibrium being established.

The process whereby a successional sequence of stages is reversed when a community is subjected to chronic stress has been termed "retrogression" by Whittaker (1973). Such communities are characterised by a more simplified structure, the loss of specialist species, a reduction of species diversity, a loosening of nutrient cycles and a decrease in stability (Woodwell, 1970). Thus retrogression is, in many respects, a reversal of the successional sequence. In principle, therefore, a knowledge of the successional patterns of a community may be used in the measurement and detection of retrogression. For example, the reduction of any community characteristic that should increase through succession (such as species diversity or richness) may be used as an indicator of environmental disturbance. Likewise, species that are characteristic of a particular successional stage may be used to indicate the condition of the environment and perhaps the direction in which the successional process is taking it. In this respect, it is interesting to note that the Dictionary of Biology (Steen, 1971) defines an indicator as, "a plant or animal species which is characteristic of a particular seral stage".

The concept of retrogression must be used with circumspection. While it may be regarded as a general probability that species richness and equitability increase during succession, there are other community changes that may work against these trends (Odum, 1975). Thus, an increase in the size of organisms, an increase in the length or complexity of their life histories or an increase in interspecific competition may <u>reduce</u> the number of species that can live in a given area. Trends that appear to be retrogressive, therefore, should be seen in the light of all other evidence.

Applications of ecological theory provide useful insights to conservation planning and management. Concepts such as Pleistocene refugia and island biogeography have profitably been used to determine the minimum critical size of reserves (Lovejoy, 1984), and the theory of ecosystem development is a useful framework within which to place ecological monitoring, and from which detected changes in biological indicators can be better understood.

This chapter has introduced the concept of ecological monitoring, described its potential and limitations, and placed it within the contexts of environmental impact assessment and the theory of ecosystem development. In so doing it has provided a framework in which to understand the methods and results of this study. Before the methodology is spelled out however the physical characteristics, vegetation and history of land use of the study area are described in the following chapter.

CHAPTER 3

STUDY AREA

3.1 LOCATION, TOPOGRAPHY AND CLIMATE

3.1.1 Location

The area proposed for the weapons test range is situated near the southern tip of Africa in the Bredasdorp district, south of the Ruens area. It extends along the southern Cape coast from Waenhuiskrans in the west to Cape Infanta in the east. Within this area lies the De Hoop Nature Reserve in which the present study is conducted. The reserve is bordered by a range of limestone hills in the north and by the Indian ocean in the south. The De Hoop vlei and the Potberg mountains are found on its respective western and eastern boundaries as indicated on Figures 3.1 and 3.2 below.

3.1.2 Topography

From the sandy coastline west of Koppie Alleen rises an area of high, mobile sand dunes. East of this point, calcified dunes follow the coastline. Extending inland from these two features is a coastal plain. This low-lying and flat land type, which constitutes the largest portion of the reserve, is underlain by a continuous bed of calcrete. The sandy alkaline soil-cover is usually no more than a veneer over this bed. In the slacks between the old dune ridges, deeper wind-blown sands have collected, producing soils which are less alkaline and less fertile. From the plain rises a line of limestone hills running parallel to the sea

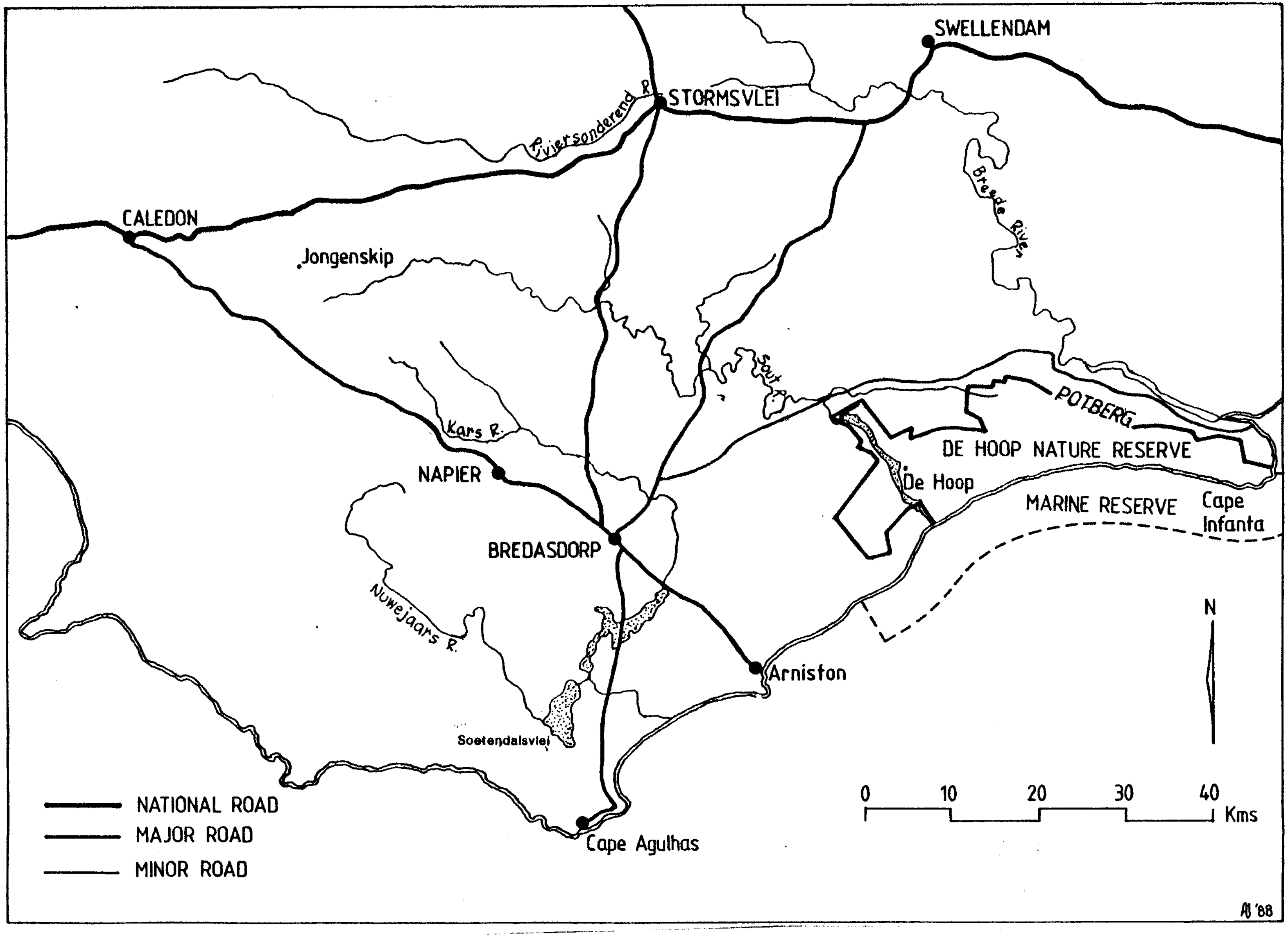


Figure 3.1 Bredasdorp district showing the location of the De Hoop Nature Reserve..

The Potberg range is an inselberg of sandstone and quartzite rock and forms an isolated part of the Cape folded belt. The De Hoop vlei, formed by the damming action of the mobile dune field, is another important topographic feature of the reserve. The present study, however, is confined to the coastal plain and the stabilized dunes that line the coast.

3.1.3 Climate

The region is characterised by dry, hot summers and cold, wet winters. Between 1958 and 1980 annual rainfall averaged 368 mm (Butcher, 1983) and average maximum and minimum temperatures during the study period ranged from 26°C to 6.5°C. Light frost may occur during the winter months. The area is subjected to strong easterly and westerly winds, though northerly 'berg' winds are not unknown.

3.2 VEGETATION

According to Acocks (1975) three veld types are represented in the coastal region between Bredasdorp and Cape Infanta. They are Coastal Renosterveld, Mountain Fynbos and Coastal Fynbos.

<u>Coastal Renosterveld</u> grows on shales of the Bokkeveld formation. Today only remnants of this once widespread vegetation type survive, more than 90% having been destroyed by cultivation (Burgers, 1983). In the De Hoop Nature Reserve only small remnants occur at Windhoek and near the Potberg Education Centre.

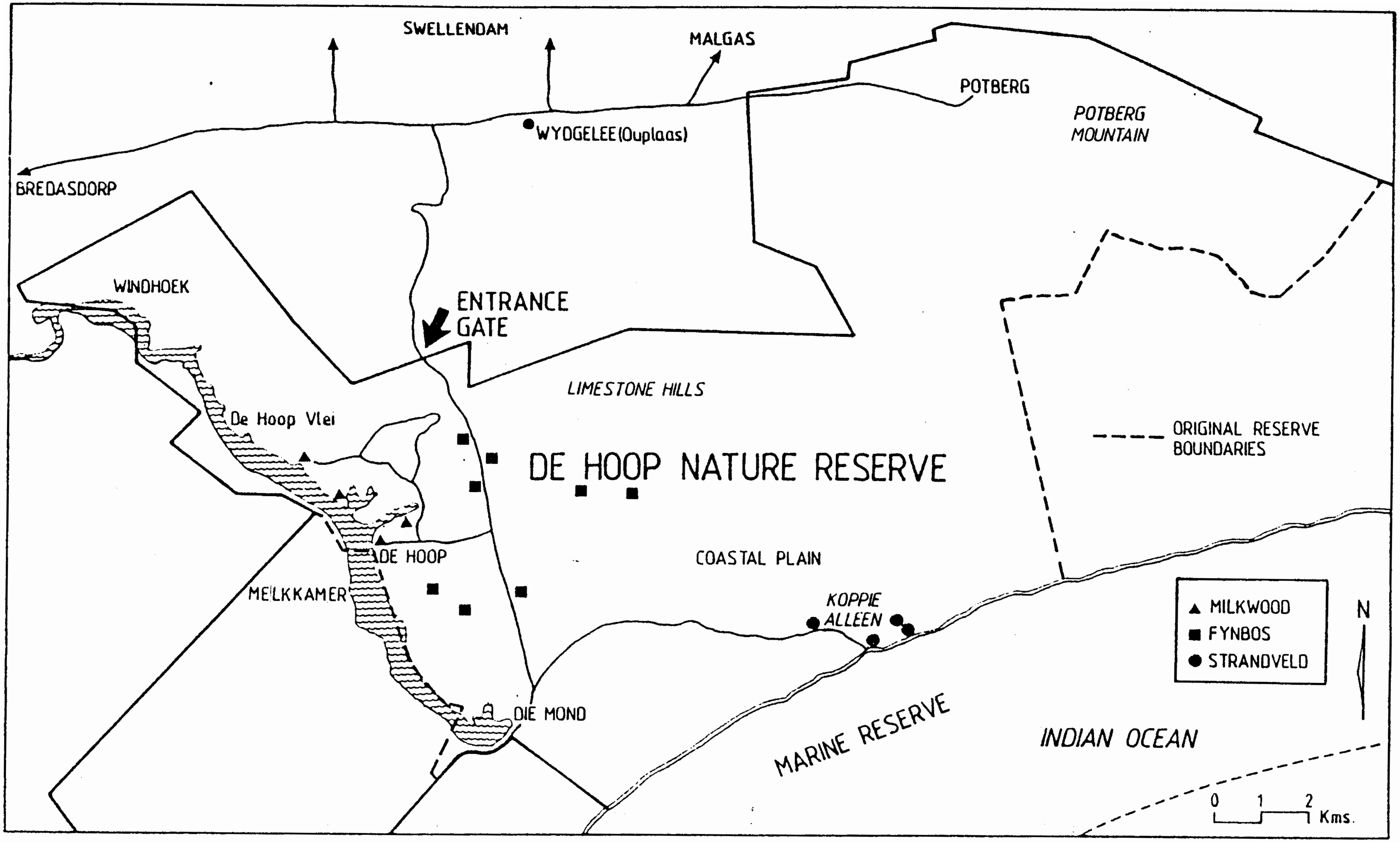


Figure 3.2 De Hoop Nature Reserve showing the distribution of plots in the different vegetation types.

Mountain Fynbos occurs on the Potberg range, which is an inselberg of sandstone and quartzite rocks of the Table Mountain Group (Cape Supergroup). A number of locally endemic plant species are found in this isolated community of Mountain Fynbos vegetation. Neither Mountain Fynbos nor Coastal Renosterveld are considered in this investigation.

Coastal Fynbos is found on sands and limestones of the Bredasdorp Formation. According to Burgers (1983) Coastal Fynbos in this region is of great conservation significance and scientific interest, since it occurs predominantly on calcereous and non-calcareous eutrophic soils as opposed to the dystrophic, acid leached soils of Mountain Fynbos environments. Rapid speciation has taken place in this area - possibly as a result of new habitats created by alternating marine transgressions and regressions of the Tertiary and Pleistocene - and numerous ecological vicariads (i.e. species closely related yet geographically separate) which have adapted to different geological formations, have developed as a result.

Coastal Fynbos is a broad term and one which does not do justice to the numerous vegetation complexes found in the De Hoop Nature Reserve.

Acocks himself said that with closer scrutiny the vegetation of the southern Cape coast would probably be deserving of a more detailed classification. For the purposes of this study, the vegetation subsumed under the label 'Coastal Fynbos' will be described and classified according to the broad geologic features in which it is found. This classification follows that of Burgers (1983).

3.2.1 Mobile Sand Dunes.

Along the coast west of Koppie Alleen exists an extensive area of unconsolidated, alkaline sands on which low, small-leaved shrubs such as Metalasia muricata and Passerina are found. In the protected areas a mid-high, broad-leaved coastal scrub has developed with Sideroxylon inerme as climax (Burgers, 1983).

3.2.2 Calcified Dunes.

Inland of the mobile dune field and following the coastline east of Koppie Alleen, a line of consolidated hummocky dunes is found. It consists of exposed calcrete outcrops and leached sandy soils and supports a number of plant communities.

3.2.2.1 Zygophyllum suffruticosum - Euclea racemosa *thicket.*

This vegetation is found on coastal calcareous sands in protected areas. It is a distinctly non-fynbos vegetation, being an evergreen, broad-leafed and dense shrub-thicket with a woody overstory up to four meters in height. It's understory is low and sparse. It is best described by the term 'Low Thicket' (Edwards, 1983). Most conspicuous species present are Zygophyllum suffruticosum, Euclea racemosa, Chrysanthemoides monilifera, Rhus glauca, Eriocephalus africanus, Sideroxylon inerme, Cassine peragua and Carissa bispinosa.

This vegetation is found in isolated pockets which appear to be associated with areas that are protected from sea spray and which enjoy a relatively high amount of moisture.

Soil in these communities is sandy, deep, calcareous and slightly humic stained.

3.2.2.2 Agathosma collina - *Ericaceae shrubland.*

This community is also found on coastal calcareous sands, and is fairly extensive in its distribution. In protected areas, this community formed almost homogenous stands of only a few species, while in other more exposed areas, the vegetation displayed a much greater diversity of species. In general, it may be described as a low, mid-dense, woody shrub community (Campbell et al, 1981). It is strongly represented by Rutaceae, Ericaceae and Restionaceae. Leaf size is mostly picophyllous.

The soil that supports this community is sandy, structureless, deep and calcareous. Unlike soil in the Xygophyllum shrub-thicket, very little humic staining was evident.

In terms of the vegetation categories proposed by Moll et al (1984), the Zygophyllum and Agathosma communities probably correspond to the category 'South Coast Strandveld'. In the vegetation described above, however, 'succulence' was often not a distinguishing feature of the vegetation, as is the case in 'true' Strandveld communities. For the purposes of this report, these two communities will be collectively referred to as 'Strandveld'.

3.2.2.3 Thamnocortus erectus *herbland.*

Further inland, in slacks between limestone ridges, is found a community growing in deep, wind-blown, reddish leached sands. This community, which is visually very distinctive, is notable by its exceptionally low diversity of species. It is wholly dominated by the 2 meter tall, tussocky Thamnocortus erectus. It is, using the system of Campbell et al (1981), a 'Tall Closed Herbland' and corresponds to the 'Sandplain Fynbos' category of Moll et al (1984). This vegetation is not considered in this study.

3.2.3 Coastal Plain.

Inland from the calcified dune system stretches the marine-planed coastal plain. It is underlain by an almost continuous pavement of calcrete which is either exposed at the surface or covered by a veneer of shallow, alkaline, sandy soil. Two very different communities occurring on these surface calcretes are described.

3.2.3.1 Protea obtusifolia - Aspalathus calcaria *shrubland.*

This is the most extensive vegetation type within the reserve, being found across the entire coastal plain and onto the limestone hills that border the reserve. In general, the vegetation may be described as a mid-high open proteoid shrubland. Due to the old farming practice of bush-cutting, where larger woody shrubs were systematically eliminated because of their low forage utility, large areas of this vegetation lack a proteoid overstory.

The most conspicuous taxa present are Protea obtusifolia, Leucadendron murii, Aspalathus calcaria and several ericaceous species.

Following Moll et al (1984), this community corresponds to the category 'Lowland Limestone Fynbos'. It is found wherever surface calcrete deposits are located, such as in the limestone hills and in calcrete outcrops of the calcified dunes.

Throughout most of this area, rock cover was high and soil cover seldom amounted to more than a veneer over a solid and continuous limestone pavement.

In places where soil depth was greater, however, an entirely different community emerged. This broad-leafed scrub community was characterised by species such as Solanum sodomaeum, Lycium tetrandrum, Rhus glauca, Euclea racemosa, Carissa bispinosa, Tarchonanthus camphoratus, Olea europaea var. africana and O. exasperata. Communities such as this occurred in numerous, small, isolated pockets throughout the limestone fynbos.

3.2.3.2 Sideroxylon inerme *thicket.*

This community, which is similar to Zygophyllum thicket described above, is distributed along the eastern shores of De Hoop vlei and in kloofs in the limestone hills. It is a broad-leafed, evergreen sclerophyllous vegetation which, according to Van der Merwe (unpublished report), is composed of both forest and scrub elements.

This vegetation, referred to as Milkwood Thicket, grows on exceptionally shallow, limestone derived soils, little different to that which supports the Limestone Fynbos over the remainder of the coastal plain. It is a relatively lush and fast-growing community, which is able to survive in this harsh environment by the softening effect of an altered microclimate resulting from its proximity to the vlei.

Sideroxylon inerme as the dominant species forms the canopy and reaches a height of about seven meters. It's middle story is a woody scrub consisting of species such as Rhus longispina, R. glauca, Carissa bispinosa, Pterocelastrus tricuspidatus, Euclea racemosa, Olea africana and Tarchonanthus camphoratus. It reaches a height of about four meters. The understory consists of various herbs, grasses, and geophytes. Succulents such as Zygophyllum suffruticosum and Tetragonia fruticosa are found in open areas of the thicket along the edge of the vlei.

3.2.4 Limestone Hills.

These hills, forming the northern boundary of the reserve, represent the oldest sequence of calcified aeolian sands of the Bredasdorp formation. Exposed calcrete with minimal soil cover is present over more than 60% of this area (Burgers, 1983). Vegetation here is similar to the Lowland Limestone Fynbos on the plain, consisting of mid-high proteoid shrublands with Leucadendron meridianum and Protea obtusifolia as dominants.

Four of the above communities are considered in the present study. They are : Lowland Limestone Fynbos (referred to as Fynbos); Milkwood Thicket; Zygophyllum suffruticosum thicket; and Agathosma collina shrubland. The latter two communities will be considered collectively and are referred to as Strandveld in this report.

3.3 HISTORY OF LAND USAGE AT DE HOOP

While De Hoop Nature Reserve serves as a preserve for remnants of ecotypes typical of the South Western Cape, and may generally be considered to be in a 'natural' state, it nevertheless has a long history of occupation, during which time considerable change may have taken place. An understanding of the nature of this association is important in a monitoring context, because the detection of change is relative to present day conditions, and may involve positive as well as negative change from past conditions.

The following brief history of land ownership and usage at De Hoop makes extensive use of the account given on the subject by Butcher (1983) to whom the author is indebted.

3.3.1 Ownership Record

While the area was undoubtedly used by people before the arrival of European settlers, little is known of the nature of these relations and the effect they had on the ecosystems of the region. For this reason, the following account of land usage is taken from the time that the land came to be permanently occupied and subject to rights of ownership.

According to local history, the area first came to be permanently occupied in the early 18th century, with De Hoop being one of the earliest settlements in the Bredasdorp district. According to records filed in the office of the Surveyor General in Cape Town, ownership of the De Hoop farm was first registered in the name of Pieter Lourens Cloete. In 1850 this piece of land, together with a number of other parcels of land, was constituted and registered as Bredasdorp farm number 74. This farm, with the exception of two portions, then passed through the hands of a succession of owners, until it was transferred to the Cape Department of Nature Conservation in August 1956. The two portions excluded from this transfer have since been incorporated into the De Hoop Nature Reserve.

In 1983 the entire area, extending from Waenhuiskrans to Cape Infanta, was expropriated by the South African Department of Defence, for the purposes of weapon testing. Control of the De Hoop reserve and portions of land on its eastern and western boundaries, however, remained in the hands of the local nature conservation authorities.

3.3.2 Agriculture at De Hoop

"The practice of agriculture at De Hoop has not been easy" (Butcher, 1983). Low mean annual rainfall, strong desicating winds, rocky terrain, and very shallow soil on a pavement of limestone, makes the area unsuited to grain farming as practised in the surrounding districts.

In contrast, agriculture has always been centered on livestock (despite the low carrying capacity of the veld and the scarcity of readily available, potable water). The most important landmark in this respect, was the establishment of the Spanish horse stud by the Cloete family, which was apparently widely renowned, even before the turn of the 19th Century.

Because of environmental constraints in the environs of De Hoop, it would appear that the region is not currently capable of sustaining economically viable agricultural development. It has been suggested that these constraints are in part due to a reduced carrying capacity of the area as a result of overgrazing, and the unwise and too frequent use of fire.

While unsubstantiated, anecdotal accounts of the area point to rapid environmental change, from a predominance of grassland vegetation to that of shrub or "bushy" vegetation. The appearance and spread of alien invasive plants such as <u>Acacia cyclops</u>, and to a lesser extent <u>A. saligna</u>, has altered the appearance of the landscape in areas such as Melkkamer and is a sign that the land has become degraded. Overgrazing and frequent burning are two common culprits in this process. In the present case, however, the spread of alien <u>Acacia</u> species may also be attributed to the 1957 flood. Large areas to the west of De Hoop vlei were inundated for a considerable length of time so that the natural vegetation died, thus allowing alien <u>Acacia</u> species to gain a foothold (Burgers, pers. comm.).

3.3.3 Nature Conservation at De Hoop

The acquisition of De Hoop by the Cape Department of Nature Conservation in 1956, saw the continuation of the practice of livestock farming. The objective in this case, however, was the experimental breeding of rare and endangered wildlife species, especially antelope. For this purpose grasses and fodder crops were sown in many of the pans and low-lying areas.

In pursuing this objective, land management at De Hoop until 1971 involved the planting of crops, bushcutting, application of fertilizers and trace elements to certain areas, provision of drinking troughs and burning the veld to encourage grasses.

Since 1972, however, management policy has placed a greater emphasis on the concept of ecosystem conservation. Animal species not considered indigenous to the area, such as Springbok, Antidorcas marsupialis and Black Wildebeest, Connochaetes gnou were removed, the cultivation of fodder crops ceased, and management plans focussed on the rehabilitation of a natural coastal fynbos community. To this end, the eradication of alien invasive plants and the controlled burning of selected plots, was carried out. During this time, increasing emphasis has also been placed on the importance of environmental education.

Much of the reserve, however, has only benefitted from these more enlightened policies since 1978, when extensive areas of private farmland became incorporated into the reserve. As it is, the fence demarcating the pre-1978 boundary has only recently been removed.

In this chapter a description of the location, topography and climate of the area provided the setting for an understanding of the vegetation and the history of the land usage of the area and, paved the way for a description of the methods used in the study in the following chapter.

A survey of the vegetation provided some measure of its variability, and helped to categorise and map the flora into different communities, and thereby providing the basis on which sampling of the study area was carried out.

An understanding of the history of land usage of the area, gave a broader perspective of monitoring and the management goal of "no change", and made the point that the measurement of change is relative to present day conditions and may therefore be positive as well as negative.

In the folllowing chapter, the methodology for testing the feasibility of using birds as instruments in the measurement of change, is described.

CHAPTER 4

METHODS

4.1 STATEMENT OF PROBLEM

In view of the widely acknowledged ecological and educational value of the Overberg Missile Test Range area, its recent expropriation has generated widespread public interest, and a strong call for the integrity of all of the ecosystems that it represents to be maintained. Large scale developments and greater human usage, however, may result in disturbances of which a number may be unknown or have unknown effects. The consequent need to manage the land more closely demands that it be regularly surveyed in order to detect any changes that may occur. The need to monitor became mandatory once insisted upon by the Hey Commission (Hey,1983).

4.2 GENERAL APPROACH

An effective monitoring programme must be sensitive to changes in all the many facets of the environment. It must be relatively easy to use and implement and must be cost effective.

This study begins the process of developing a monitoring programme by looking at one aspect of the environment, that of terrestrial birds. It seeks to determine both the sensitivity of this class of organism to environmental change, and the feasibiilty of incorporating it into a monitoring programme. In so doing, a number of analytical techniques will be tested and assessed for their ability to indicate environmental change. Possible methods of data collection and site selection will also be suggested.

Ideally, in order to understand how disturbances affect a habitat or a particular class of organism within that habitat, a longitudinal study should to be conducted, in which baseline measurements are taken before the onset of disturbances, and repeated during or after such disturbances have taken place. Such a procedure, however, is far too lengthy and although it has the advantage of using the same sampling site, it is still unable to control for changing conditions over time.

An alternative approach, and that employed in the present study, is to use a side-by-side comparative design in which experimental sampling sites that have been exposed to some suitable disturbance are compared to similar undisturbed control sites. Differences detected between the two may then be attributed to the effects of the disturbance.

A problem arises as to the type of disturbances to be applied to the experimental sampling sites. Obviously, they ought to accord with the type of disturbances anticipated by future developments in the Overberg Missile Test Range. Clearly, these disturbances are not restricted to impacts associated with the testing of missiles. On the contrary, the diverse and numerous impacts that are to be expected with the increased human presence and activity in the area are probably of greater concern - at least to the terrestrial ecosystems associated with this investigation.

Similarly, activities and future developments proposed for De Hoop will also have impacts on the environment and ought to be considered as well. In this respect, it is suggested that the activities and developments at De Hoop may not be dissimilar in nature or intensity from those anticipated for the Missile Test Range, once the basic infrastructural developments have been completed, and assuming that the assurances given by

Armscor to the Hey Commission are all met. Relatively few people will occupy the area and all movements and activities will be well controlled, with disturbances resulting mainly from the day to day activities of personnel living and working in the area, rather than from the more obvious military activities.

For this reason, and for the reason that access to areas outside the reserve would not have been easy to achieve on a regular basis, it was decided to conduct the study entirely within the borders of the reserve. Experimental plots would make use of areas within the reserve that had already been disturbed.

A limitation of the use of such areas, however, is that the disturbances found within them are, on the whole, very mild. Differences between disturbed and undisturbed areas, therefore, are likely to be more difficult to detect, particularly with the large amount of variation associated with natural systems.

On the other hand, once the infrastructural developments have been completed, the nature of disturbances to be expected in the Missile Test Range are likely to be similar to those found in De Hoop. In addition, it should also be pointed out that future developments are also planned for the reserve, and that an understanding of the effect of disturbances in these areas may be of importance in the location and construction of such developments.

A further limitation of using ongoing, existing activities as one's treatment effect, is that it is not easy to quantify these activities or effects. It is therefore not possible to develop a gradient of disturbance against which community characteristics or tolerance limits of individual species may be measured.

What then are the disturbances to be employed within each experimental plot?

In the De Hoop Nature Reserve, three types of disturbance may be immediately identified. Each is found in a separate and distinctive vegetation type. The main road that carries all traffic to and from the reserve cuts through the Lowland Fynbos found on the limestone plain. Traffic flow is not high. Over 12 months an average of 427 vehicle movements occurred each month. This represents an average of 14 vehicles per day or roughly 1.2 vehicles per hour during daylight hours. Lining this route are telephone poles and a game-fence which provide convenient perches for birds which perhaps are not normally associated with this treeless environment.

In the Southcoast Strandveld which is found on the recent sands along the coast, the main disturbances are centered around the Koppie Alleen Environmental Education Centre and its access road. Vehicles and groups of people (who may remain in and around the Centre for as little as an hour to as many as three days) constitute the main disturbances. Koppie Alleen is a focal point for the environmental education programmes that are conducted in the reserve. It is also a popular destination for most visitors to the reserve. Nevertheless, disturbances here are also relatively mild, with little or no damage being done to the habitat. Recently, the road to the centre has been upgraded by Armscor and an observation station created. These developments, however, did not form part of the study.

Unlike the Fynbos or Strandveld, the Milkwood Thicket that lines the eastern shores of De Hoop vlei is subjected, in certain areas, to more severe disturbances. These disturbances are associated mainly with human habitation, they are diverse in nature and are more pernicious in their effect than those found in either of the other two vegetation types.

Besides a constant human presence, impacts such as paths, roads and vehicles, livestock, poultry, litter and organic waste have all contributed to the overall impact on Milkwood Thicket. These disturbances may have short-term, immediate effects, such as those caused by passing vehicles or groups of people, or may have longer term effects such as those caused by paths and poultry which both contribute to opening up the otherwise dense habitat.

Disturbances such as the latter two, affect not only the fauna living in that habitat, but also the ease with which bird censusing is carried out. In comparing results between disturbed and undisturbed plots of this vegetation type, therefore, the possibility of exaggerated abundance and species richness figures in disturbed Milkwood Thicket should be borne in mind.

4.3 SAMPLING DESIGN

Decisions regarding the sampling of the avifauna within the three vegetation types must begin with the very important question regarding the type of census method to be used. Many techniques have been employed to count birds but few analyses have compared efficiencies of different methods and the variability of the results (Steele et al, 1984). Those studies that have been made are mostly contained in a volume edited by Ralph and Scott (1981) and it is largely from this source that the following discussion is drawn.

No census method is applicable in every instance or without its drawbacks. The particular technique chosen ultimately depends on the particular set of circumstances displayed by the environment and the needs and resources of the researcher. Each method ought to be judged by its ability to estimate accurately and reliably the bird density and richness of a particular habitat in the most efficient manner.

Accuracy, reproducibility and efficiency are, in turn, dependent on the nature of the habitat and its avifauna and the particular resources available to the researcher. The structure of the habitat and the detectability of the birds within it, for example, have an important effect on the estimation of population characteristics. In addition, much disagreement between methods exists for the estimation of numbers of the same species, suggesting that different methods favour different populations of birds (Jolly,1981). Many of the problems imposed by the particular circumstances, however, may be overcome by carefully choosing a suitable method. Whatever method is chosen, an understanding and appreciation of its limitations is essential.

A review of Ralph and Scott (1981) identified three candidate methods for use in the present study. The line-transect method is a popular technique which is best used in open terrain such as savanna or scrub. It involves the observer walking along a transect within the study area for a given distance, and recording all birds observed within a certain distance from him or her, as well as an estimation of the lateral distance from the line to each bird. This estimate is incorporated into a co-efficient of detectability which is used in calculating density estimates. It unfortunately exposes the method to observer error and places its reliability between different observers in some doubt.

Logistically it is a very suitable method and is useful in surveying large areas. It is also well suited to censusing bird populations along linearly shaped habitats such as river courses or in the present instance, along roadsides.

The line-transect method, is nevertheless limited in diverse habitats in that it is particularly vulnerable to many influences along its extensive perimeter. It therefore would not be suitable in the Fynbos or Strandveld, and is precluded from being used in Milkwood by the density of that habitat.

The variable circular plot method enables the observer to concentrate more on the birds than on pushing through the vegetation (Edwards, et al, 1981) making it an attractive method for the Fynbos and Milkwood habitats. It makes use of timed counts at a number of stations located along a transect line through the habitat.

According to Scott el al, (1981) it is useful in surveying large geographical areas, comparing different habitats and working in rugged and remote terrain. According to DeSante (1981) it is best used in the breeding season, outside of which its accuracy and reproducibility is not known. It is also said to over-estimate species that are sparsely populated and underestimate commonly occurring species. Like the transect method, it is sensitive to observer error in distance estimation, though is not as efficient as the latter.

The sample plot method uses a fixed area of land through which the observer moves , recording all birds seen or heard within it. Density estimates from structurally different habitats may not be comparable because species detectability in each habitat may differ. This method does not require distance estimates to be made at each observation and, therefore, is much more efficient with respect to time required for training observers. Estimation of density is also simpler to calculate.

A sample plot is easier to define in terms of its vegetational composition and may therefore be more readily compared to other plots. Additionally, it suffers less from 'edge effect' than does the line-transect method and consequently is more suitable in diverse habitats. This method has been successfully employed in Mountain Fynbos and Milkwood Scrub in the Cape of Good Hope Nature Reserve (Fraser, pers comm.). It is a simple method and one which appears to be usable in all three vegetation types at De Hoop and was consequently chosen for the present study.

4.4 SITE SELECTION

Experimental plots were sited within each of the three identified habitat types near existing disturbances. Control plots were also located in each of the three vegetation types , but distant from disturbances. In the Strandveld and Milkwood Thicket, treatment and control plots were replicated twice, while plots in the fynbos, to reflect the greater area of this vegetation type, were replicated four times: a total of 16 plots in all.

In view of the limited number of areas in which experimental plots could be sited, and the difficulties involved in finding comparable control sites in vegetation that is very variable, the distribution of plots was determined by decisions based on a vegetation survey (in which the structure of the vegetation and the dominant taxa were recorded) rather than on the statistically preferable means of random selection. The location of plots used in this study is shown on figure 3.2

In view of the variability of the landscape in the Fynbos and Strandveld, creation of small, apparently homogenous plots would have been meaningless. Instead, it was decided to treat the patchwork nature of the vegetation as an integral part of the landscape by establishing larger plots. In these habitats, plots of 4 hectares each were used . These were either square (200 metres x 200 metres) or, when located along a road, rectangular (100 metres x 400 metres). The larger sized plots, it was felt, would also prove to be more efficient sampling units in view of the relatively low bird densities associated with these two habitats.

In the Milkwood Thickets, plots were 1.5 hectares in area, reflecting the much smaller size of this habitat and the considerably greater densities of birds living within it.

4.5 DATA COLLECTION

4.5.1 Frequency

Each plot was censused four times per month for twelve months. Censusing was conducted throughout the day, though the time at which each plot was censused was rotated, so that the more favourable times of the day for censusing (if they existed) would be spread amongst each plot.

4.5.2 Type of information

Besides the identity of each species observed and its respective abundance, environmental data such as wind speed and direction, temperature and cloud cover were recorded prior to each census. Incidental information, such as the nesting and feeding behaviour of birds and the flowering and fruiting of plants, was also recorded.

4.5.3 Censusing Procedure

Having made a record of the prevailing environmental conditions, the observer moved through the plot in a systematic fashion, stopping at regular intervals to look and listen. Transects through a plot were 50 metres apart , so that a plot of 200 meters x 200 meters would be traversed four times during a census and the observer would have come within 25 meters of every part of the plot. All birds sighted or heard during this time were recorded. Though it was probably seldom achieved, the intention of each census was to record every bird living within the plot rather than sample its population. For this reason there was no strong emphasis on time spent in each plot, though for the most part a census lasted 30 to 35 minutes.

4.6 DATA ANALYSIS

One of the aims of the present study was to identify techniques which could interpret raw data in a meaningful and useful way. There is a need, when monitoring an environment for possible impacts, to be able to pick up - above the background static - stress signals that would otherwise have gone unnoticed until it was perhaps, too late.

Techniques that enhance pertinent data, such as those that identify sensitive species, groups or guilds, would be particularly valuable monitoring instruments if they were found to be reliable and meaningful.

The methods of analysis used in the study are presented below. Each is described and discussed in more detail in later chapters, as well as in Chapter two above.

4.6.1 Correspondence Analysis

This is a method of multivariate analysis in which the rows (plots) and columns (bird species) of a data matrix are displayed as points in corresponding low-dimensional vector spaces. It is thus a graphical display technique which employs geometric principles in its interpretation. A strength of this method is its ability to indicate the quality of fit of the model to the data. In the present study, data were analysed using the programme devised by Greenacre and Underhill (1982). This technique is more fully described in chapter five in which the results are also presented.

4.6.2 Community Characteristics

Two important features of a community, its variety or diversity, and its size or carrying capacity, are illustrated using the following measures :

a) Species Richness. This term refers to the number of species of birds living in a particular habitat. It is described in section 2.6.3.1.

b) Species Diversity. Species diversity is a measure of the variety of a community. It is a composite of two structural properties in a community: the number of species and the distribution of individual organisms among those species. It is described in section 2.6.3.5.

Two indices of diversity are calculated.

1. Simpson's diversity, based on the equation :

$$D = 1 - \frac{N_j(N_j-1)}{N\ (N-1)}$$

Where D is the measure of diversity, N the total number of individual of all species, and Nj the number of individuals in the jth species.

2. The Shannon-Weiner diversity index is calculated in the following way :

$$H = -\sum_{i=1}^{s} \left(\frac{ni}{N}\right) \log2 \left(\frac{ni}{N}\right)$$

Where H is the measure of diversity, N the total number of individuals of all species, ni the number of individuals in the ith species and s the total number of species observed.

c) Density. This term refers to the number of individuals (of all species of birds) living within a particular area. It is expressed in terms of birds per hectare. Density is described in section 2.6.3.2.

d) Biomass. Biomass is a more sophisticated measure of density and is able to provide a clearer understanding of the carrying capacity of a system. Biomass, which is expressed in terms of grams per hectare, is determined using the average mass of each respective species, as given in Maclean (1985). It is described in section 2.6.3.3.

e) Relative Abundance. This is not so much a measure of a community characteristic, as a measure of the prominence of individual species. It does, however, allow for a closer understanding of community composition and is, as such, a very useful measure. It is described in section 2.6.3.3.

Results of the various community characteristics are presented and discussed in Chapter six.

4.6.3 Guild Analysis

Guilds were originally defined as groups of species that were classified according to how they similarly used similar resources. They have since been redefined by Verner (1984) who sees guilds as groups of species that respond in similar ways to disturbances in the environment. The potential of guilds to indicate the existence of stress in the ecosystem is tested in this study. Guild Theory is described in section 2.6.4. Formation of guilds is described and results are presented and discussed in Chapter seven.

4.6.4 Natural Variation

A monitoring programme, particularly one making use of ecological monitoring, should be designed to detect change beyond that which is expected to occur in the absence of stress. For this reason, the range of natural variation in the system must first be determined. Within the different habitats, species richness and density figures are analysed over 12 months. Weather variation is considered by comparing expected and actual precipitation figures . Results are discussed and presented in Section 8.1.

4.6.5 Optimum Censusing Conditions

Fluctuating weather conditions produce results that are widely divergent from one day to the next. In addition, limited resources demand that time spent in the field must be carried out in the most efficient manner possible. There is a need therefore to maximise the information content of each data gathering event. This study identifies those conditions that are most likely to produce quality data in the most effient manner possible. This was done by analysing the degree of influence that each of the following factors had on the ten most successful and the ten least successful censuses in each plot in each habitat:

season
time of day
wind speed
wind direction
temperature
cloud cover.

Results are presented in Section 8.2.

4.6.6 Optimum Censusing Frequency

Seldom, if ever, will a single census provide sufficient data to characterise an entire avian community. The vagaries of bird behaviour and fluctuations in censusing conditions inevitably produce results that are incomplete and different from one day to the next. A number of censuses therefore need to be conducted in order to gain sufficient information on the populations of birds in a community. Determination of the optimum number of counts that need to be conducted is, therefore, an important requirement in any monitoring programme. Surprisingly, no generally accepted methods for arriving at this optimum figure appear to exist.

In the present study, a graphical presentation is used to display the number of species recorded after N number of censuses in order to illustrate the rate at which the number of species increases with each additional census. As will be shown, the curve depicting the number of species is convex with respect to the Y-axis, revealing that total information content increases with each additional census at a diminishing rate. That is, each additional census adds less to the total store of data than every census preceding it. The challenge therefore in determining the optimum number of censuses is to find the level at which information yielded by the additional census becomes insufficient to warrant the additional cost of that census. In reality, this means deciding what proportion of the total information content is necessary to satisfactorily meet the objective in question. In bird communities this is not easily achieved as the species curve does not have an asymptote; additional counts will always result in new species being added to the total. For this reason, it is difficult to establish any concrete rationale for the level at which a cut-off point may be set. In the present study, the number of species recorded in each habitat after 40 censuses is taken as the standard against which to determine the cut-off level.

The graphic presentation was achieved in the following way :

a) Results of all censuses in each plot over 12 months are entered into the computer.

b) Using a random number generator 30 sets of N censuses are selected. That is, each group of 2, 4, 6, 8, 10, 15, 20, 30 and 40 censuses is selected 30 times.

c) Total number of species recorded for each 30 sets of N censuses are calculated to produce a 30 x N matrix for each of the 16 plots.

d) The mean and range for each group of censuses is then calculated and plotted.

Results are presented and discussed in Section 8.3.

This chapter has described the general approach followed in the study and has set out the ways in which the sampling of data, the selection of sites and the collection and analysis of data have been carried out.

In the following chapters the results of the different methods of data analysis are presented and discussed. This is followed by a chapter which looks at ways of resolving some of the sampling and analysis problems that are associated with monitoring a variable environment.

CHAPTER 5

CORRESPONDENCE ANALYSIS

5.1 THEORY OF CORRESPONDENCE ANALYSIS

Correspondence analysis belongs to the branch of statistics known as multivariate analysis, the purpose of which is to treat multivariate data as a whole. Multivariate analysis examines numerous variables simultaneously and is therefore ideally suited to the analysis of ecological communities (Gauch, 1982).

Correspondence analysis is one of many multivariate analyses that have been developed. It is a graphical display technique suitable for use in a wide range of applications. In the present study, data are analysed using the programme devised by Greenacre and Underhill (1982).

Correspondence analysis was developed by a group of French statisticians in the 1960's under the name "analyses des correspondances". It is a technique for displaying the rows and columns of a data matrix (primarily, a two-way contingency table) as points in corresponding low-dimensional vector spaces (Greenacre and Vrba, 1984). The data matrix is usually displayed in two dimensions and may therefore be interpreted as a map (Underhill and Peisach, 1985).

While it is theoretically very nearly equivalent to reciprocal averaging, the importance placed on geometry in its definition and particular style of interpretation, place this method apart from all others. According to Greenacre and Vrba (1984), this geometric approach readily allows the technique to be extended to the display of a wide range of data matrices.

Like other techniques of multidimensional scaling, it is an exploratory method of data analysis. It imposes on the data a minimum of structure in the form of specific hypotheses, so that possible underlying structures in the form of patterns of associations and differences may be revealed. As such, it is better suited to the generation rather than the testing of hypotheses (Greenacre and Vrba, 1984).

5.1.1 Decomposition of Inertia

Correspondence analysis provides a graphical display of two clouds of points, representing the rows and columns of a matrix of frequencies. Each point in the two clouds is weighted in proportion to its respective row or column total. Each displayed cloud of points is the projection of the points' true positions in multi-dimensional space onto the particular subspace of representation. This subspace is usually a line or plane determined by one or two axes respectively.

Correspondence analysis, therefore, is a model which is able to summarise and simplify the data set at hand. Like all other models, it provides at best a modest and tentative explanation of the phenomenon under study. A strength of correspondence analysis, however, and one which adds greatly to its interpretation, is its ability to indicate the quality of fit of the model to the data. This is achieved by calculating the contributions to total inertia.

The principal axes, which define a low-dimensional subspace, is the subspace through the centroid of the cloud which is "closest" to all the points. It reflects the directions of greatest dispersion of the cloud of points. Its orientatior, however, is also influenced by the masses assigned to each point. The measure of closeness, which is to be minimised, is defined as the weighted sum of squared distances from the points to the subspace. The degree to which the axes fit the data, is a reflection of the degree to which the set of high-dimensional points are within the low-dimensional subspace (Greenacre,1984).

The measurement of inertia, therefore, indicates the degree of accuracy of the display. The inertia of the principal axis is equal to the weighted sum of squared distances to the origin of the displayed row (or column) profiles. The contribution by each point to the principal axis therefore may be expressed as a percentage of this first principal inertia. This is called <u>absolute</u> inertia (Greenacre,1984). Points with high contributions will have played a more important role in causing the final orientation of the principal axis. Using the positions of the points on the first principal axis, and their relative contribution to its orientation, it may be possible to assign some descriptive name to the axis as a guide to its interpretation.

Symmetrically the contribution of the <u>axis</u> to the inertia of the points may also be calculated. This is known as the relative contribution, and indicates the quality of representation of each individual point. That is, it is a measure of how well the profile vector "correlates" with the particular dimension that the axis represents (Underhill and Peisach,1985).

It may be readily appreciated, therefore, that an understanding of the decompositions of inertia, "leads to vastly improved interpretation of and insight into one's data over that obtained by merely examining the two dimensional plots" (Underhill and Peisach, 1985).

5.1.2 Dual nature of correspondence analysis.

Another important feature of correspondence analysis is the duality of the geometric concepts of the technique. It is this duality, where practically all of the entities are serving dual purposes, that justifies the name "correspondence analysis" (Greenacre, 1984). The principal axes, for example, correspond in two ways :

a) They correspond by reflecting the same amount of "dispersion" in the two clouds. That is, the principal inertias (and hence also total inertia) are identical in the two clouds of points.

b) The principal axes correspond in the relationship between the co-ordinates of the row points and the column points with respect to corresponding axes in their respective spaces (Greenacre and Vrba, 1984).

A linear relationship therefore exists between row and column points. This relationship is defined by the two equations know as "transition formulae" which are explained and proved by Greenacre (1984). It is these two formulae which justify the merging of the two clouds of points into a single joint display, where row and column points are represented with respect to the same set of principal axes. Thus, for example, in the simultaneous display of plots and bird species, each species tends away from the origin, in the direction of the plots in which it is most prominent. Symmetrically each plot is attracted in the direction of the species which are predominant in that plot. The particular significance of the merging of the clouds of points into a joint display, rests in its ability to show, not only which samples cluster, but also to show why they are clustered (Underhill and Peisach, 1985).

Another use for the transition formulae is to enable supplementary points to be plotted on an existing display. Samples or elements, for example, which are identified as distinct and obvious outliers, and whose presence in the data matrix may mask more subtle multivariate relationships, may be turned into supplementary points. Correspondence analysis is performed on the remaining matrix, and the points identified as outliers are then subsequently plotted onto the display using the transition formulae. In this way, outliers can still contribute to the interpretation of the display without having any effect on the inertia of the model.

In the present study, correspondence analysis was found to be sensitive to species occuring only a few times in the data matrix. In order to prevent these 'rare' species from having undue influence on the overall display, they were first turned into supplementary points and then included in the display.

Correspondence analysis is a potentially useful tool in the analysis of multivariate data. By making use of both a visual display of vector profiles and contributions to inertia, associations and patterns in the data set may be revealed and subsequently tested.

The presentation of results of the present study and their interpretation using correspondence analysis, is found in the following section.

5.2 RESULTS AND DISCUSSION.

Correspondence analysis was performed on a 192x58 matrix, depicting plots and bird frequencies. Twelve supplementary points, representing species which were recorded fewer than five times, were subsequently added to the graphical display using the transition formulae (Greenacre, 1984). Figure 5.1 shows the plots and bird species with respect to their first two principal axes of inertia, which together account for [15.4% + 7.6% = 23%] of the total inertia. The third and fourth axes account for 6.2% and 5.3% of the total inertia respectively. Because these two axes account for a similar proportion of the total inertia as that of axis 2, they will also be considered in the interpretation. The low dimensional graphical display was only able to represent a quarter of the multi-dimensional information. It is nevertheless important to note that the original space had a dimensionality of 58, and the fact that 25% of the inertia can be captured in just two dimensions, indicates a large amount of structure in the data matrix.

In Figure 5.1, each point depicting a plot is the centroid of 12 monthly plot points. Plots are clustered according to their respective vegetation type. The dotted line surrounding these clusters, represents the range within which plots varied over 12 months. No discernible pattern was evident in the movement of plot points from one month to the next. While a split is apparent between the experimental and control Milkwood Thicket plots, no such distinction is evident in either the Strandveld or Fynbos communities. Plots which are situated in the same direction from the origin as particular bird species, have high concentrations of those species.

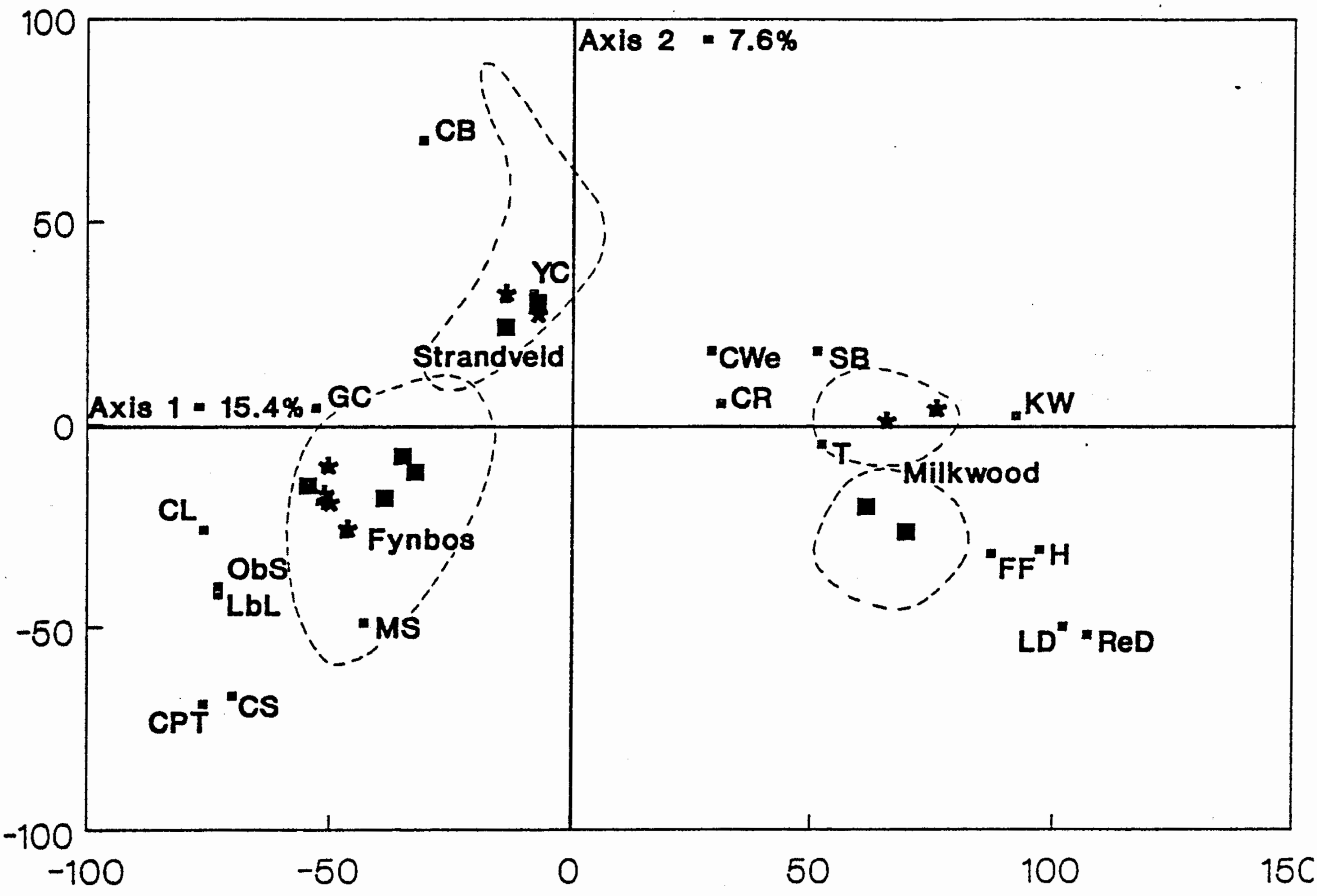


Figure 5.1. Correspondence analysis of bird frequencies:axes 1x2. Disturbed plots framed by squares, undisturbed by stars. Plot variation over 12 months depicted by dotted lines. Abbreviations are given in table 5.1.

Turning our attention to the first principal axis, the projections of the points onto this axis are shown in Figure 5.2. This axis reveals a marked separation between Milkwood Thicket on the one hand, and Fynbos and Strandveld plots on the other. There is also a noticeable distinction between Fynbos and Strandveld plots.

Table 5.1

Key to the abbreviations in Figures 5.1 and 5.5

HG	Helmeted Guineafowl	Numida meleagris
FnN	Fierynecked Nightjar	Caprimulgus pectoralis
ReD	Redeyed Dove	Streptopelia semitorquata
LD	Laughing Dove	Streptopelia senegalensis
H	Hoopoe	Upupa epops
CB	Cape Bulbul	Pycnonotus capensis
KW	Knysna Woodpecker	Campethera notata
CL	Clapper Lark	Mirafra apiata
LbL	Longbilled Lark	Mirafra curvirostris
CPT	Cape Penduline Tit	Anthroscopus minutus
SB	Sombre Bulbul	Andropadus importunus
CR	Cape Robin	Cossypha caffra
GC	Greybacked Cisticola	Cisticola subruficapilla
FF	Fiscal Flycatcher	Sigelus silens
T	Southern Tchagra	Tchagra tchagra
CS	Cape Sugarbird	Promerops cafer
ObS	Orangebreasted Sunbird	Nectarinia violacea
MS	Malachite Sunbird	Nectarinia famosa
CWe	Cape White-eye	Zosterops pallidus
CSp	Cape Sparrow	Passer melanurus
YC	Yellow Canary	Serinus flaviventris

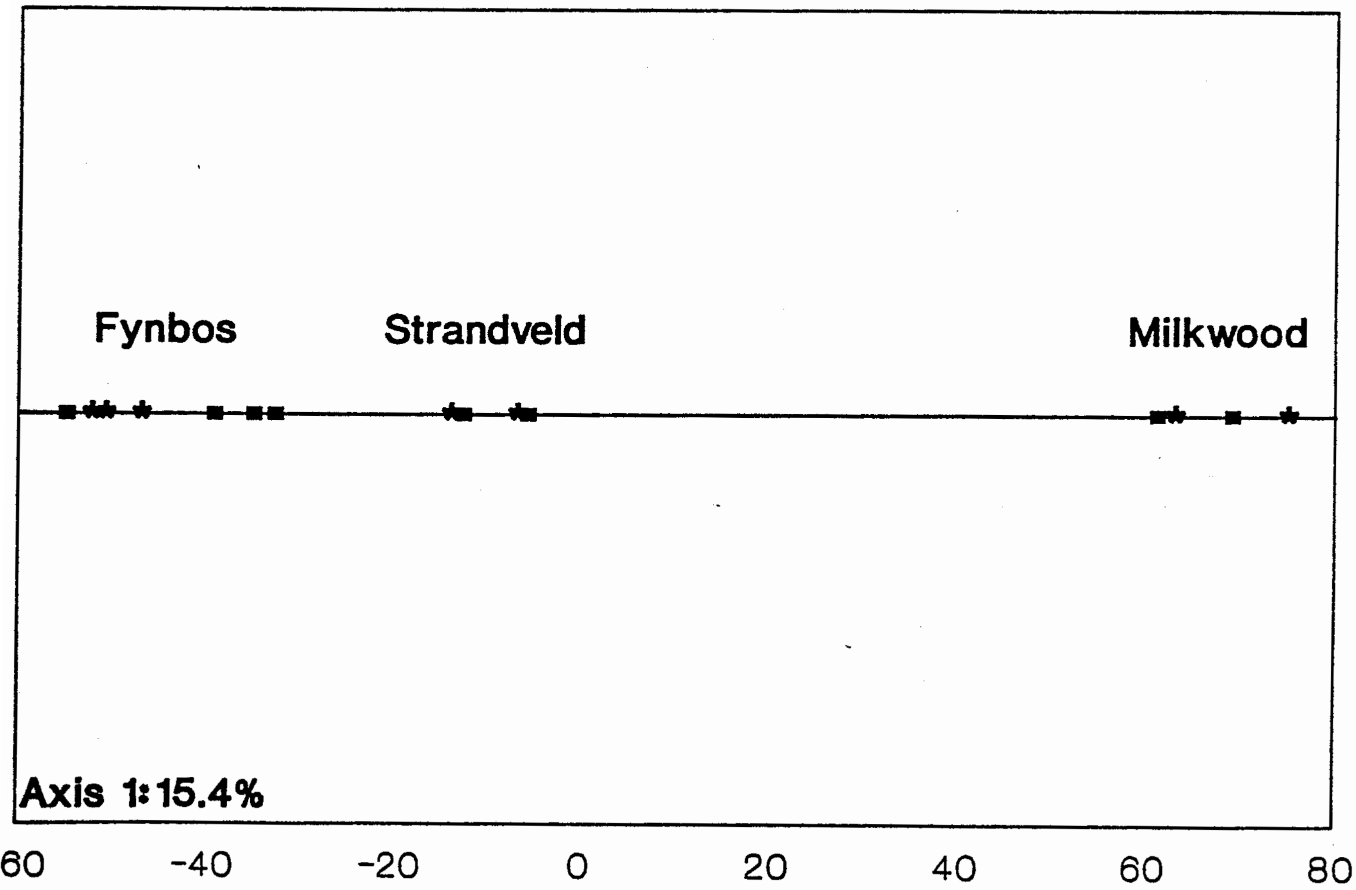


Figure 5.2 Plot points of Figure 5.1 projected onto axis 1 Disturbed plots (squares); Undisturbed plots (stars).

Plots on the left of axis 1 in Figure 5.2 are characterised by a low to mid-high open-shrubland (following Campbell *et al*, 1981). Plants are mostly picophyllous, slow-growing and adapted to survive in a moisture-stressed environment. Structurally the vegetation is rather unstratified.

Plots on the right of the axis, on the other hand, are characterised by a mid-high, broad-leafed vegetation that is associated with subtropical coastal thicket communities. It is a denser and more vigorous vegetation, which grows in areas enjoying a greater abundance of moisture. It is more richly stratified, and supports a number of species of plants that serve as an abundant source of food.

The split between the plots is marked. Because it occurs along the first principal axis, it is the most important feature of the data-set. The vegetation gradient, therefore, is identified as the single most important feature influencing the distribution and abundance of bird species.

An analysis of the decomposition of inertia reveals that the four Milkwood plots contribute 58.3% to the inertia of the principal axis. It is suggested therefore that axis 1 represents a continuum of the proportion of broad-leafed vegetation exhibited in each plot. An analysis of the vegetational composition of each plot supports this hypothesis. If each plot were graded according to the amount of broad-leafed vegetation cover that it exhibited, the distribution of plots would look little different to that which is illustrated in Figure 5.2.

Turning our attention from the samples of our matrix to the elements, an analysis of the distribution of bird species along the first principal axis lends support to the idea that this axis represents a gradient of broad-leafed wooded habitat.

The bird species most closely associated with plots on the left of the axis are :

Namaqua Dove	_Oena capensis_
Clapper Lark	_Mirafra apiata_
Longbilled Lark	_Mirafra curvirostris_
Cape Penduline Tit	_Anthoscopus minutus_
Karoo Robin	_Erythropygia coryphaeus_
Grassbird	_Sphenoeacus afer_
Greybacked Cisticola	_Cisticola subruficapilla_
Cape Sugarbird	_Promerops cafer_
Malachite Sunbird	_Nectarinia famosa_
Orangebreasted Sunbird	_Nectarinia violacea_
Lesser Doublecollared Sunbird	_Nectarinia chalybea_

Of these species, Karoo Robin, Grassbird, Greybacked Cisticola, Cape Sugarbird, Lesser Doublecollared Sunbird - and to a lesser extent Longbilled Lark and Orangebreasted Sunbird - make large contributions to inertia, collectively accounting for 35.7% of the inertia to the principal axis. These species are closely associated with low scrub or grassland vegetation and, with the exception of the Lesser Doublecollared Sunbird, are never found in wooded, broad-leafed habitat. None of these species, however, appear to show much sensitivity to low-level, human-induced disturbance.

Bird species associated with plots on the right of the axis are :

Redeyed Dove	Streptopelia semitorquata
Cape Turtle Dove	Streptopelia capicola
Fierynecked Nightjar	Caprimulgus pectoralis
Speckled Mousebird	Colius striatus
Pied Barbet	Lybius leucomelas
Hoopoe	Upupa epops
Knysna Woodpecker	Campethera notata
Cardinal Woodpecker	Dendropicos fuscescens
Olive Woodpecker	Mesopicos griseocephalus
Southern Grey Tit	Parus afer
Sombre Bulbul	Andropadus importunus
Cape Robin	Cossypha caffra
Barthroated Apalis	Apalis thoracica
Cape Batis	Batis capensis
Southern boubou	Laniarius ferrugineus
Cape Sparrow	Passer melanurus

These species account for 34.6% of inertia to the first principal axis. They are very different to those species associated with plots on the left of the axis. In general, they are found in more wooded habitat and are more widely distributed.

Of the bird species found in the middle of axis 1, Yellow Canary, Serinus flaviventris, Cape Bulbul, Pycnonotus capensis and Redwing Starling, Onychognathus morio, are closely associated with Strandveld. Cape Bunting, Emberiza capensis, Southern Tchagra, Tchagra tchagra and Spotted Prinia, Prinia maculosa, are recorded in all three habitats, and therefore have little effect on the orientation of the first principal axis.

An analysis of the distribution of bird species supports the hypothesis that the first principal axis represents a gradient of broad-leafed, wooded habitat.

The strength of the influence of vegetation on the first principal axis, has meant that little disturbance effect is detected on this axis. Within the Fynbos category, there is a weak contrast between disturbed and undisturbed plots. Fynbos plots, however, are poorly represented along this axis and little store can be placed on their positions. The effect of disturbance on avian communities may yet be revealed in any of the other principal axes.

The second principal axis, depicted in one dimension in Figure 5.3, presents a very different perspective. With respect to the distribution of plots, two features are immediately apparent. The marked contrast between Strandveld plots on the one hand, and Fynbos and Milkwood Thicket plots on the other, is an important feature of this axis. So too is the very clear separation between disturbed and undisturbed Milkwood plots. These plots, however, account for only 10% of the inertia of the second principal axis. The separation between these plots therefore is only weakly related to the governing influence of this axis.

Strandveld plots, on the other hand, account for 60% of the orientation of the axis. The following bird species, which collectively contribute 56% towards the inertia of the axis, are closely associated with Strandveld plots :

Cape Bulbul	*Pycnonotus capensis*
Sombre Bulbul	*Andropadus importunus*
Redwing Starling	*Onychognathus morio*
Cape White-eye	*Zosterops pallidus*
Yellow Canary	*Serinus flaviventris*

With the exception of the Yellow Canary, all these species have fleshy fruit as an important element in their diet and are found almost exclusively in the patches of broad-leafed thicket within the Strandveld.

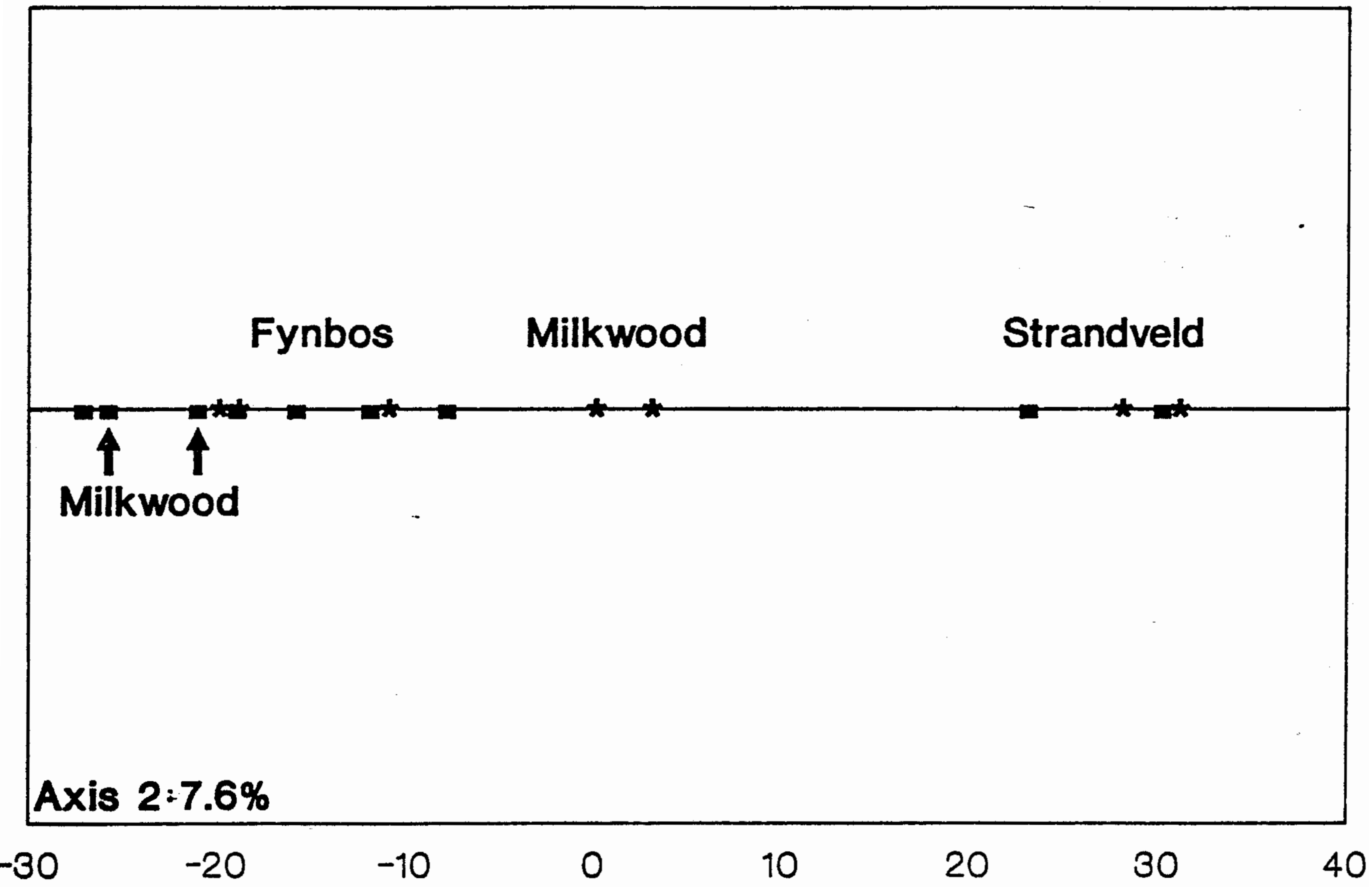


Figure 5.3 Plot points of Figure 5.1 projected onto Axis 2

At the other end of the continuum, the following bird species contributed to the orientation of the second principal axis :

Longbilled Lark	*Mirafra curvirostris*
Karoo Robin	*Erythropygia coryphaeus*
Cape Sugarbird	*Promerops cafer*
Malachite Sunbird	*Nectarinia famosa*

These species are mostly associated with Fynbos habitats and are never (bar the Malachite Sunbird) found in broad-leafed habitats. This axis therefore also appears to be influenced by a vegetational component. The particular features of this gradient, however, are not clear.

Interestingly, the third principal axis, like the second axis, also distinguishes between disturbed and undisturbed Milkwood Thicket plots. In this instance, Milkwood plots make a significant contribution (91%) to the final orientation of this axis. The nature of this distinction, therefore, ought to be more readily apparent along this axis which, it has been shown, is only marginally less important that the second axis in its contribution to total inertia.

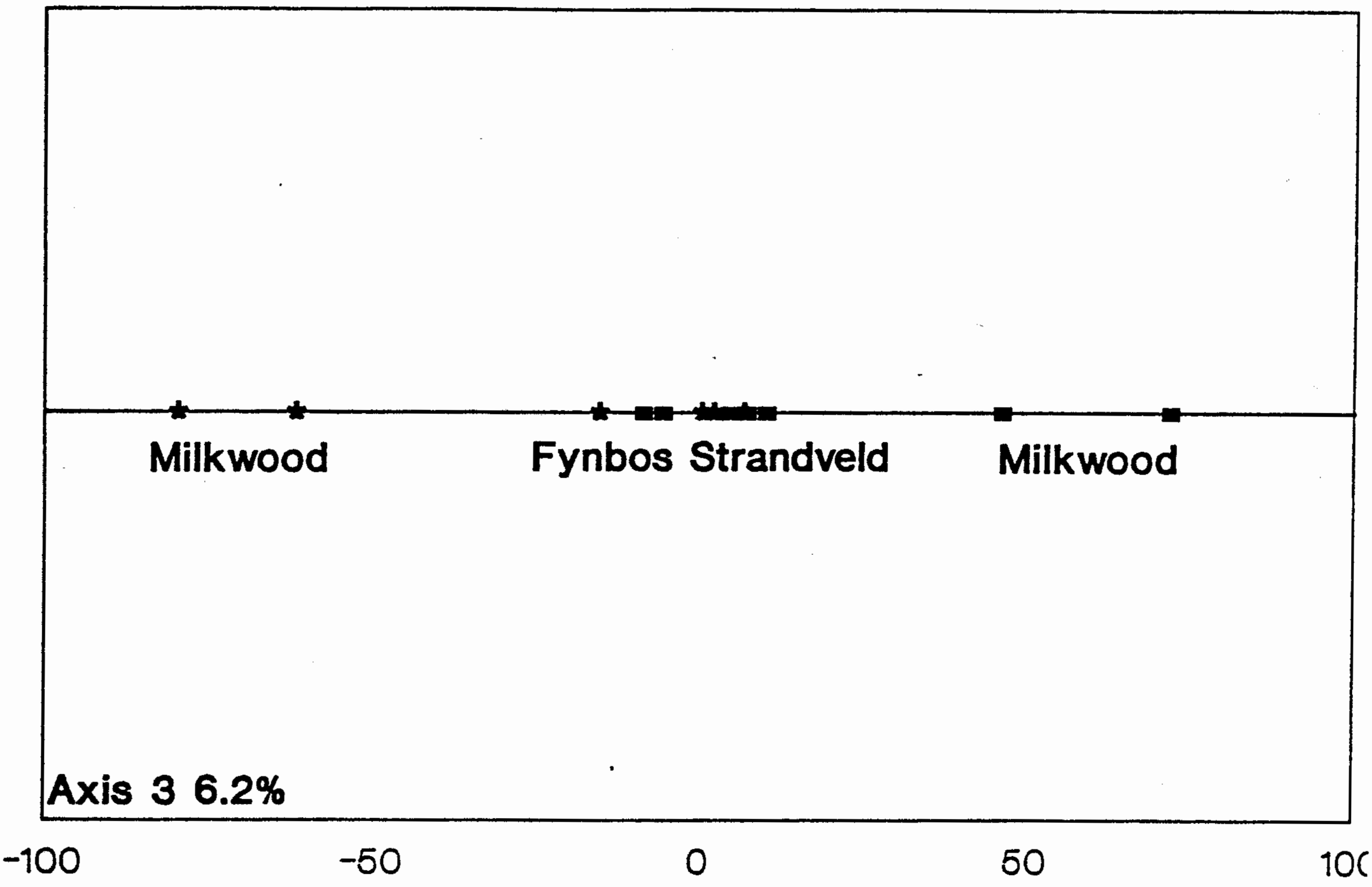


Figure 5.4 Plot points of Axis 3 showing separation of disturbed and undisturbed milkwood thicket.

Bird species that influenced the orientation of this axis were clearly divided in the following way :

Disturbed Plots

Helmeted Guineafowl	*Numida meleagris*
Redeyed Dove	*Streptopelia semitorquata*
Laughing Dove	*Streptopelia senegalensis*
Speckled Mousebird	*Colius striatus*
Hoopoe	*Upupa epops*
Fiscal Shrike	*Lanius collaris*
Cape Sparrow	*Passer melanurus*

Undisturbed Plots

Spotted Eagle Owl	*Bubo africanus*
Fierynecked Nightjar	*Caprimulgus pectoralis*
Knysna Woodpecker	*Campethera notata*
Cardinal Woodpecker	*Dendropicos fuscescens*
Cape Batis	*Batis capensis*
European Starling	*Sternus vulgaris*
Pied Starling	*Spreo bicolor*
Common Waxbill	*Estrilda astrild*

It is interesting to note that the species characterising disturbed Milkwood, are all species that have successfully colonised towns, cities and farmland throughout Southern Africa. It is perhaps not surprising, therefore, that such species should be associated with disturbed habitat.

Species more closely associated with undisturbed Milkwood plots are (with the exceptions of European Starling and Pied Starling) less likely to be attracted to disturbed areas. Two species, Rameron Pigeon, *Columba arquatrix* and Olive Woodpecker, *Mesopicos griseocephalus* which were included as supplementary points into the analysis, were also found to be associated with undisturbed habitat.

points into the analysis, were also found to be associated with undisturbed habitat.

That the separation of plots should coincide with the separation of species according to their tolerance for disturbance, adds weight to the suggestion that the third principal axis represents a gradient of disturbance in Milkwood Thicket communities. Correspondence analysis of bird species frequencies using axes 1 and 3 is presented in Figure 5.5

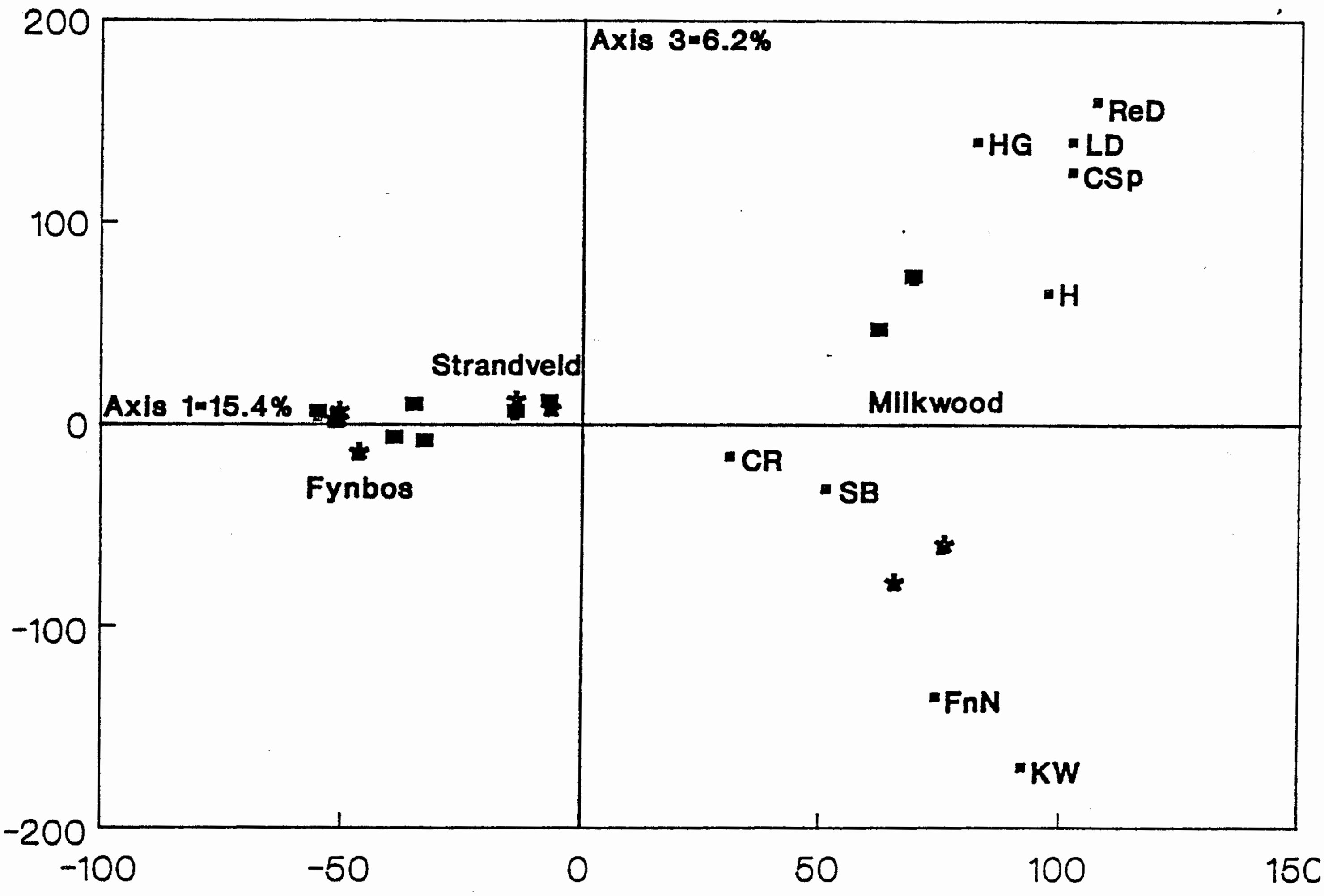


Figure 5.5 Correspondence analysis, axes 1x3, showing distribution of bird species between disturbed and undisturbed Milkwood Thicket.

Just as Milkwood Thicket was well represented on axes 1 and 3, and Strandveld was well represented on axis 2, so axis 4 displayed Fynbos samples and elements particularly well, with absolute inertia totalling 97%. Only a very few species were found to contribute to the inertia of this axis, with the Cape Penduline Tit, Anthoscopus minutus accounting for 50% of this inertia.

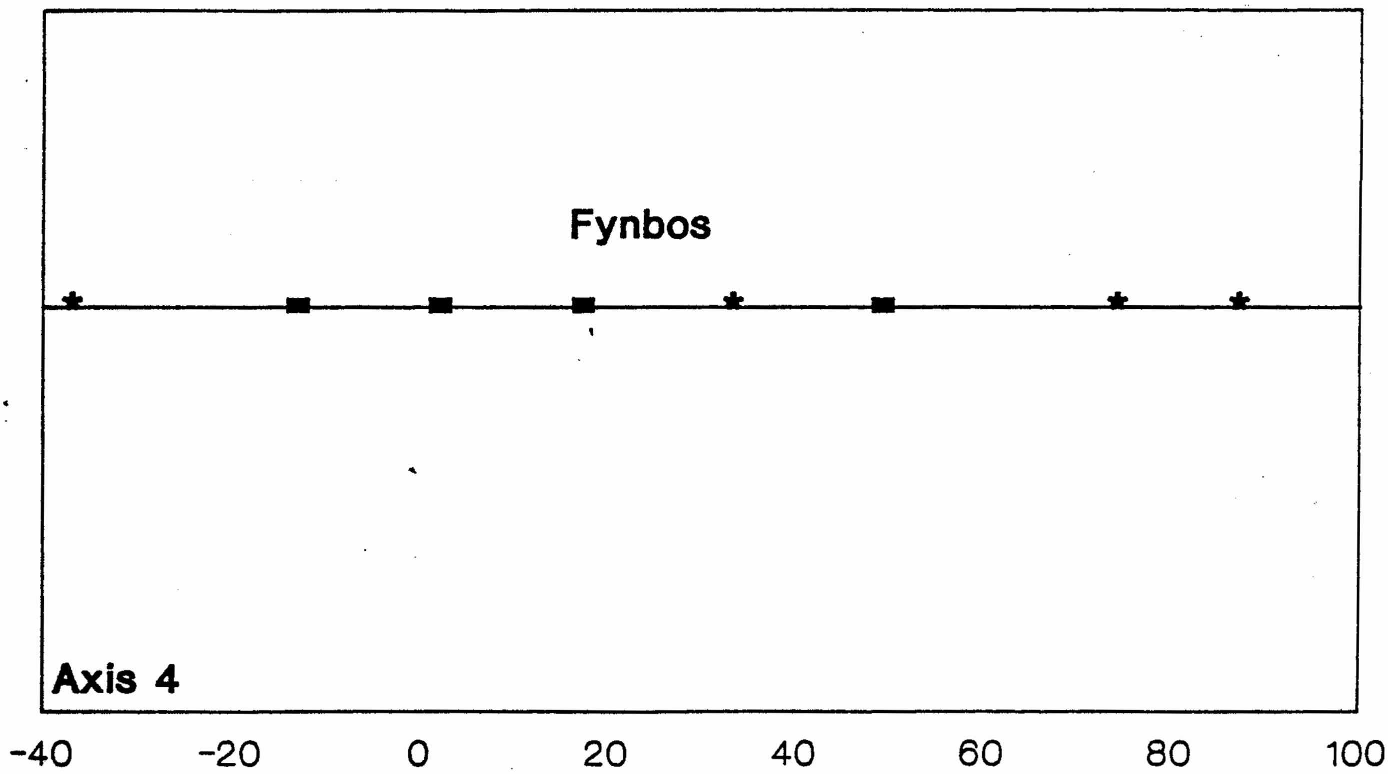


Figure 5.6 Plot points of axis 4 showing distribution of Fynbos plants.

In Figure 5.6 the distribution of plots is similar to that found on axis 1. Those plots whose vegetational cover has a greater broad-leafed component to it, are distributed towards the left of the axis. The right side of the axis, however, does not appear to reflect the vegetational composition very well. All plots are evenly distributed across the axis, with no evidence of any clustering. It is therefore not easy to identify a particular gradient influencing this axis.

5.3 CONCLUSION

Correspondence analysis was performed on a matrix of bird frequencies. The major influence responsible for the distribution and abundance of bird species, was identified as vegetational composition. The three vegetational types - Lowland Limestone Fynbos, Southcoast Strandveld and Milkwood Thicket - were clearly identified in the graphical display. More particularly, sample points were distributed according to the extent of broad-leafed shrub thicket that was exhibited in each plot. A number of reasons are presented to explain the overriding influence of broad-leafed vegetation :

1. It is more productive than the surrounding picophyllous heath scrub, and hence is an abundant source of food.

2. This vegetation is structurally more diversified, and thus offers a greater range of niches to be exploited.

3. Broad-leafed shrub thicket is related taxonomically to a widespread and faunistically rich vegetation type that spreads up the eastern seaboard of Southern Africa. This vegetation is, therefore, suitable habitat to many species of birds that may be widely distributed, and which may derive from a range of habitats. Fynbos and Strandveld vegetation, on the other hand, is confined to the southern and western Cape. It is a relatively inhospitable vegetation that in the main attacts species of a more specialised nature.

4. Because this broad-leafed shrub thicket is set amid a vegetation that supports a relatively low bird species richness and abundance, the effect of this richer vegetation is amplified in a technique such as correspondence analysis.

Each vegetation type was well displayed in at least one of the four principle axes analysed. Except for Milkwood

Each vegetation type was well displayed in at least one of the four principle axes analysed. Except for Milkwood Thicket, no disturbance effect was detected. A number of reasons may account for this:

1. Low densities of birds recorded in the Strandveld and Fynbos reduce the chances of a disturbance effect being revealed.

2. Low species richness in these habitats reduces the possibility of there being species that may be sensitive to the particulr disturbance at hand.

3. Disturbance in the experimental Fynbos and Strandveld plots was very mild and may not have significantly affected the bird communities in these habitats.

4. The patchy distribution of the faunistically important broad-leafed shrub thickets were very difficult to control, with the result that variations resulting from vegetational differences invariably overrode any variations that may have occurred through disturbance.

Despite the fact that the graphical display was only able to represent 23% of total inertia, correspondence analysis was nevertheless able to provide a very useful overview of bird communities at De Hoop. While it has identified weaknesses in the study design, it has also lent support to the hypothesis that certain species of birds may well discriminate between disturbed and undisturbed habitat and therefore may be of use as indicators of disturbance. It is now up to analyses of a more detailed nature to test this hypothesis.

CHAPTER 6

COMMUNITY CHARACTERISTICS

6.1 INTRODUCTION

A biotic community is more than an assemblage of living material. The myriads of organisms that compose a community are integrated and interdependent of one another. A community is multi-faceted and dynamic and, as such, may be measured and analysed in many different ways, no one of which is comprehensive.

A community is often seen as being characterised by two important attributes. The first refers to the variety or diversity of the habitat and the organisms that inhabit it. It is a feature which has often been seen as relating to the stability (ability to withstand perturbations) of the system. Two methods, species richness and diversity indices, are used to explore and describe this attribute of a community.

If the first attribute of a community may be seen as being qualitative in nature, then the second is more quantitative. It refers to the carrying capacity of the system, or how much life the habitat is able to support. Clearly, a change in the carrying capacity of a system may be reflective of disturbances to it. It is measured in the present study using bird density and biomass.

Species richness, density, biomass and diversity all describe features of a biotic community in a single numeric figure. As such they are all relatively easy to comprehend and communicate. The results of these measures,and their potential as indicators of disturbance,will be presented and evaluated below. Thereafter, the more detailed measure of relative abundance will be discussed.

6.2 RESULTS AND DISCUSSION

6.2.1 Species Richness

Species richness can be calculated in a number of ways, each of which may yield different results. The following calculations were made :

Total number of species recorded in each plot over 12 months.

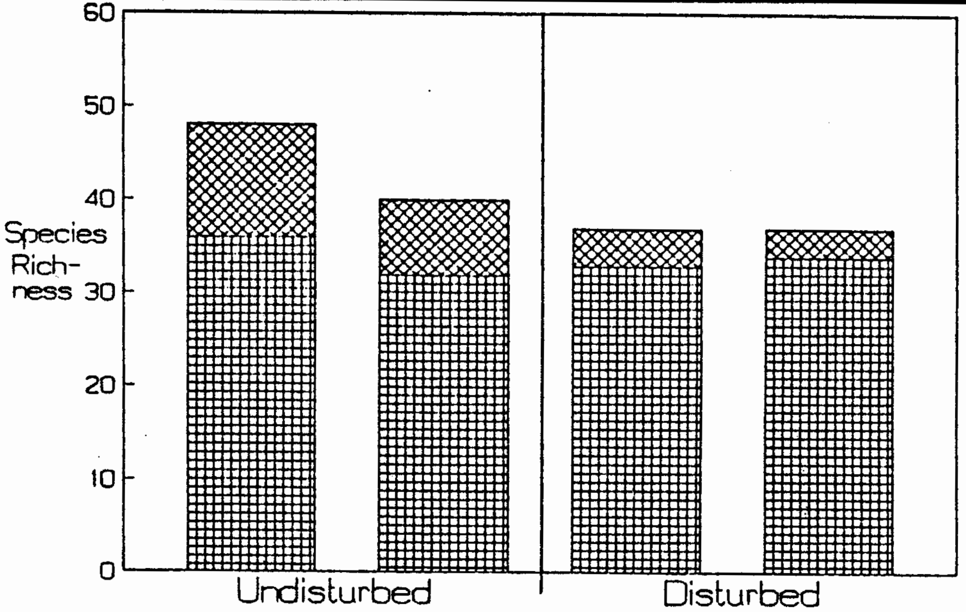
Total number of species recorded in each plot per month.

Average number of species recorded in each plot per census, per month.

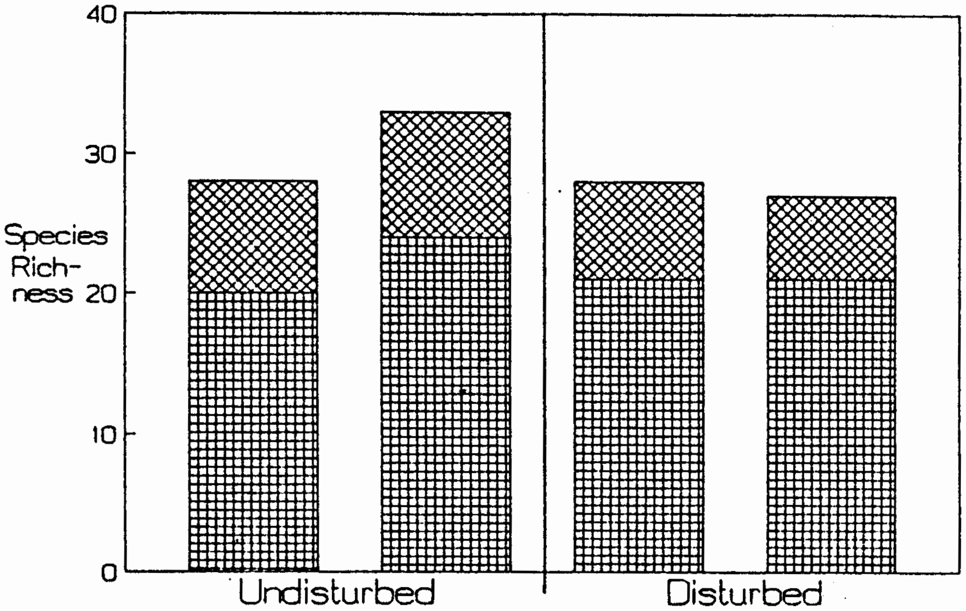
As each measure reflected the same relative differences between plots, only the first measure (total species richness for the year) will be discussed. The results of this measure are presented in Figure 6.1 below.

The most immediate aspect of note in these results is the significantly richer composition of bird species in the Milkwood Thicket plots, compared to those of the Strandveld and Fynbos categories. Because species richness is partly a function of the size of the area studied, such a finding is given added weight by the fact that Milkwood plots were considerably smaller than those in the Fynbos or Strandveld.

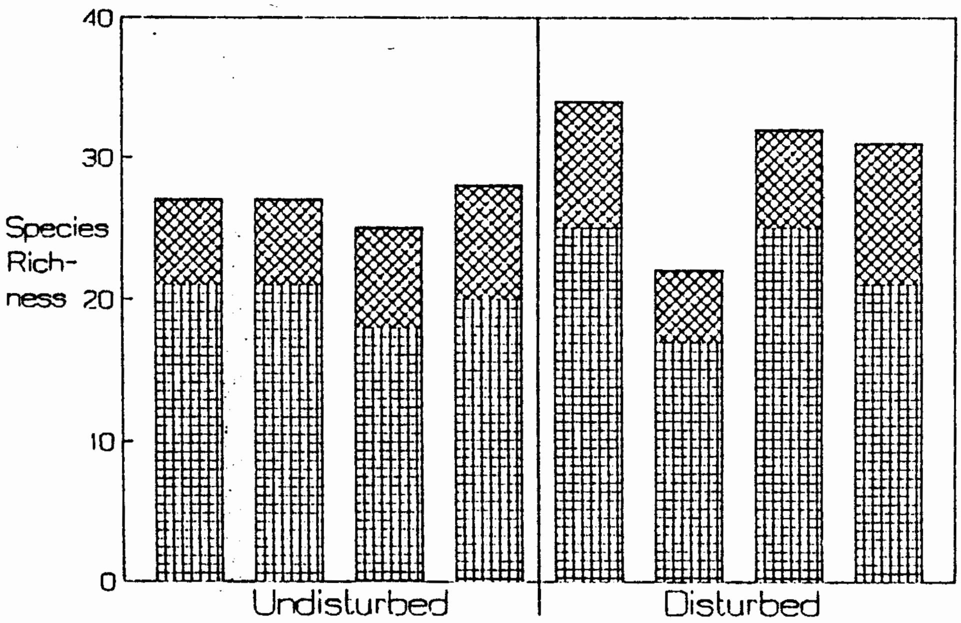
There are a number of reasons for the inherently richer nature of Milkwood Thicket. The broad-leafed vegetation of this community is related to the wooded habitats that line the eastern seaboard of southern Africa. As a result, it is able to accommodate many of the bird species associated with these faunistically rich habitats. In addition, Milkwood vegetation is structurally more diverse and able to provide a relatively rich and varied source of food. There are thus greater opportunities for bird species to successfully colonise this community and sufficient resources to support viable populations of a relatively large number of species.



Milkwood Thicket



Strandveld



Fynbos

Figure 6.1 Total number of species recorded in each plot over 12 months. Diagonal hatching refers to number of species recorded on only one occasion.

Strandveld and Fynbos, on the other hand, are less benign habitats which do not have very close links with vegetation complexes outside of the Cape Floral Kingdom. This relatively unproductive and structurally poorly stratified vegetation, therefore, is home to a comparatively few species.

The second noteworthy feature of figure 6.1 is the significant difference recorded between disturbed and undisturbed Milkwood Thicket plots. No such differences were found in the Strandveld or Fynbos categories. Looking more closely at Figure 6.1, it is apparent that the higher species richness recorded in the undisturbed Milkwood plots, is attributed to the greater number of rare species occuring in those plots. While the rarity of these species precludes them from being considered individually as potential indicators, it is instructive to consider why rare species as a group appear to be more sensitive to disturbance.

A species considered to be rare may be at the edge of its distributional range (and hence in an environment which may not entirely suit its needs). It is possible that such a species would have a narrower range of tolerance for environmental disturbance, than those species living at the centre of their distributional ranges. It would then be more vulnerable to environmental change and may select against living in disturbed areas, thereby producing a differential in the number of species living in disturbed and undisturbed areas.

While the finding that control and experimental Milkwood plots exhibited differences in species richness suggests that there may be merit in the use of birds as indicators of environmental disturbance, species richness itself is too crude an indicator to be of much value. The differential caused by species which are selective of <u>undisturbed</u> areas, for example, may be cancelled out by other species which perhaps are selective of disturbed areas. Measures which have the ability to stratify community data and thereby allow a researcher to be more selective of the data may prove to be considerably more powerful. Development of such indicators will be considered in section 6.4.2 and Chapter 7.

While differences emerged between disturbed and undisturbed habitat in Milkwood Thicket, no such trends were detailed in either Strandveld or Fynbos. A number of reasons for the inability of species richness to detect disturbance in these habitats are considered.

First, the relatively low number of species in Strandveld and Fynbos reduces the number of possible species sensitive to disturbance and hence capable of producing a disturbance effect.

Second, Fynbos and Strandveld do not support many rare bird species. Those that do live in these fairly inhospitable habitats, such as the Greybacked cisticola, Cisticola subruficapilla, the Spotted Prinia, Prinia maculosa and the Grassbird, Sphenoeacus afer seem capable of withstanding a wide range of climatic disturbances and appear to be unafraid of living near to human structures and activities.

Third, shrub cover (particularly broad-leafed shrub cover) in or nearby the plot is the single most important determinant of community composition (see Section 5.2). Yet the highly variable nature and overriding influence of this vegetation on the structure and function of the Fynbos and Strandveld communities, is very difficult to control. Data are therefore noisy and comparison is difficult, with the result that changes registered as a result of disturbances are overshadowed by the influence of vegetation.

Fourth, unlike those in Milkwood Thicket, disturbances to which experimental plots in the Strandveld and Fynbos are subjected, are very mild and perhaps did not elicit effects sufficiently strong enough to be detected.

6.2.1.1 Summary

Species richness is an unambiguous, easily understood and widely used measure of a community. Data is more accurate and is gathered more efficiently than measures which involve the estimation of numbers of organisms.

It is, however, a crude measure which showed little evidence of merit as an indicator of environmental disturbance. While it did indicate that the composition of bird species in Milkwood Thicket was affected, it was not able to specify the nature of this change. This finding, furthermore, depended on the collection of data over a 12 month period - thus bringing into question the cost-efficiency of such a measure.

6.2.2 Density

Density, expressed as birds per hectare, may be used as a measure of the carrying capacity of an ecosystem. While species richness and density are not necessarily positively correlated, data from each of the three vegetation types studied, shows that in the present study this is, in fact, the case. It appears, therefore, that species richness is, very generally, able to predict density - a factor which may possibly be used to streamline the monitoring of terrestrial bird populations at De Hoop.

From Figure 6.2 it is clear that Milkwood Thicket is able to support the greatest number of birds per hectare. It is a habitat that is both more diverse and more productive than either of the other two habitats uand perhaps, therefore deserving of special protection - particulary in view of its limited distribution at De Hoop

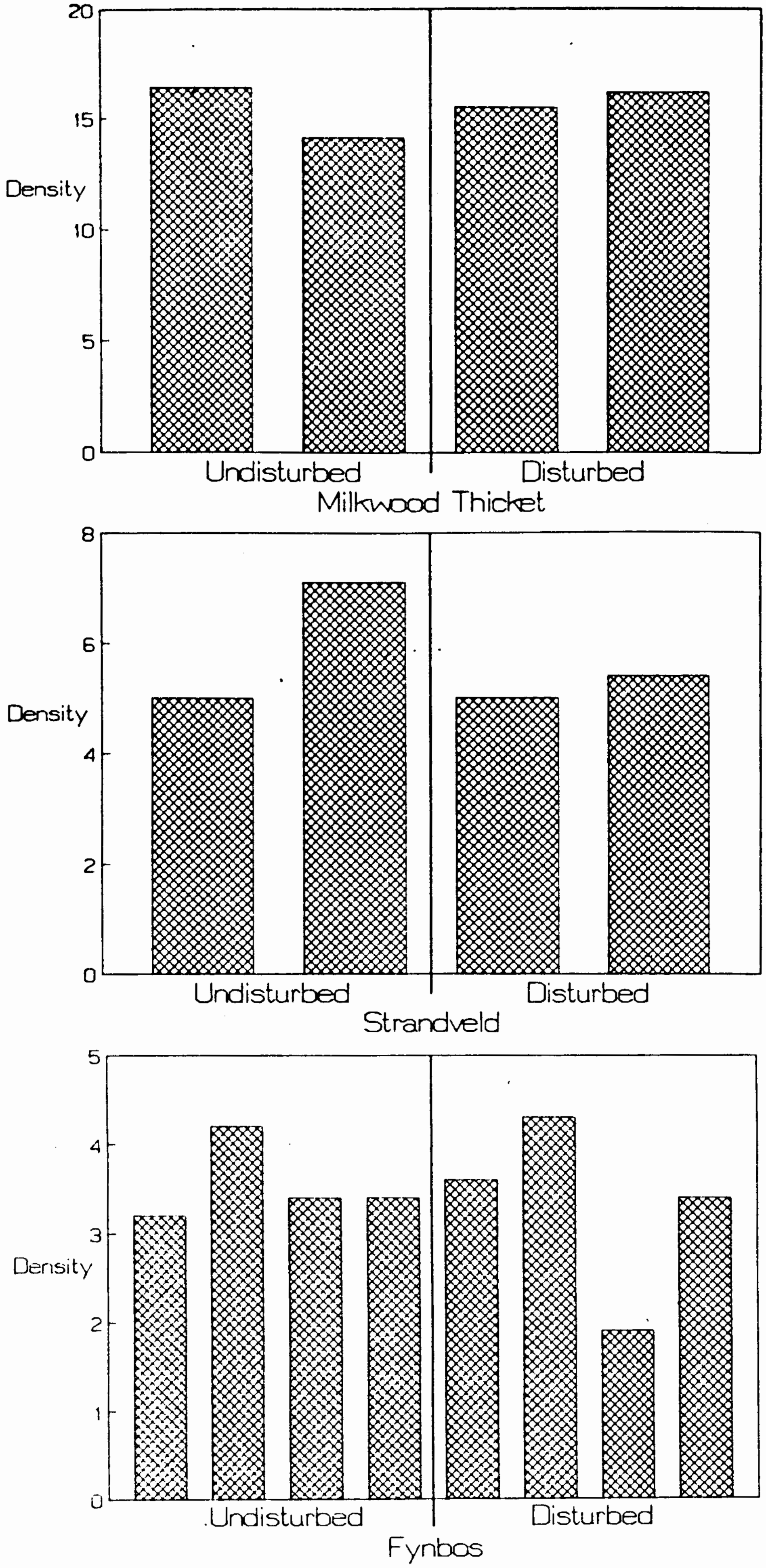


Figure 6.2 Average density (birds per hectare) recorded in each plot over 12 months.

In the Milkwood community, there are no significant differences in density between any of the plots. This suggests that there is a sort of 'compensation effect' in operation, in which plots of low species richness nevertheless have a density similar to those of the richer plots. This is, to some extent, borne out in the Relative Abundance section below. Disturbance, therefore, does not appear to affect the carrying capacity of the community.

In the Strandveld or Fynbos vegetation types too, density figures do not appear to elicit any evidence of a disturbance effect. As with species richness, the density of each plot is determined in large measure by the extent of the shrubby component of each respective plot. Differences in density that may have resulted from disturbance, therefore, are eclipsed by the overriding influence and variable nature of the vegetation. No conclusive statement can therefore be made regarding the effect of disturbance on the abundance of bird populations in these two vegetation types.

The level of bird densities recorded in the Fynbos is in agreement with densities found elsewhere in this biome. Siegfried (1983), for example, recorded similar density levels of birds per hectare in coastal Fynbos. Because these low densities require greater effort in the collection of data, the value of using bird densities as indicators of environmental disturbance is limited.

Milkwood Thicket, on the other hand, with its greater densities of birds, requires far less effort in the gathering of data and is therefore a more suitable habitat in which to monitor bird populations.

The estimation of abundance or density in the field is a problematic task which cannot be very accurate. Birds are very mobile, making detection, identification and estimation of numbers more difficult. Because some species are secretive, while others are visually or audibly conspicuous, the contribution by each species to total abundance will not necessarily be equally represented. In a large plot in difficult terrain, the accurate counting of birds is a difficult exercise and one which often lacks replicabity between different fieldworkers. Because of these difficulties, results from this measure must always be viewed with caution.

Density,however, does convey important ecological information. When used as a descriptive measure in conjunction with measures such as species richness, it has much to recommend it. As an indicator of disturbance, however, it appears to have little value. The crudeness of using a single figure to describe the community and the apparent existence of a compensation effect both, argue against the use of this measure as an indicator of disturbance. An understanding of how the constituent species of a community contribute to the total density figure may prove to be more fruitful. Relative abundance is considered in section 6.4.

6.2.3 Biomass

Biomass is partly a function of density and therefore suffers from similar inadequacies. It is, however, able to provide a more meaningful reflection of carrying capacity, and interestingly, appears to be able to discriminate more successfully between disturbed and undisturbed areas.

The greater carrying capacity of Milkwood Thicket and the relative paucity of the Fynbos habitat, is again illustrated in the table above. Strandveld, while displaying a biomass greater than that of Fynbos, is considerably poorer than Milkwood. This pattern, is also reflected in the measures of species richness and density.

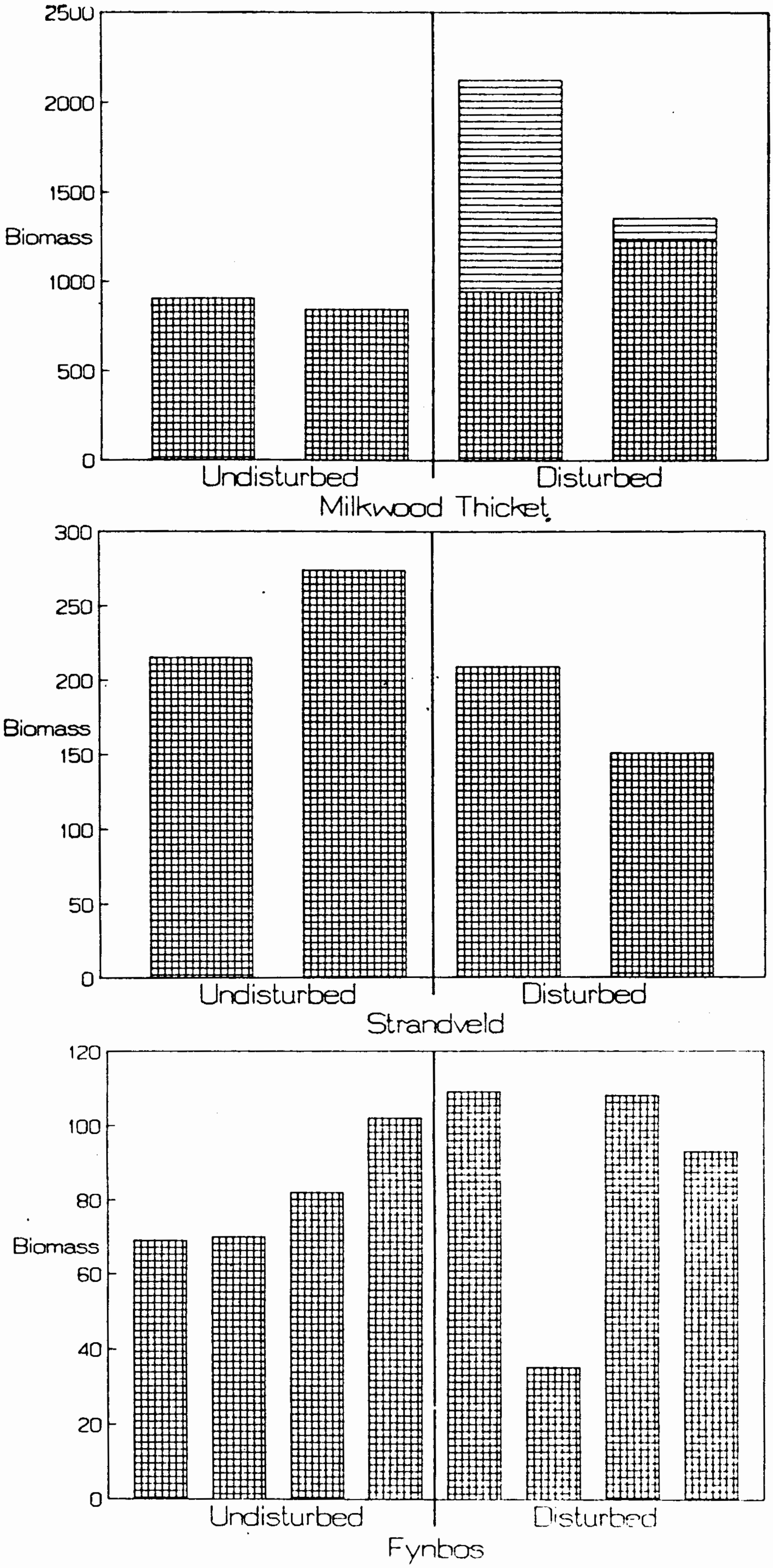


Figure 6.3 Average biomass of birds (grams per hectare) in each plot over 12 months. Horizontal hatching refers to biomass of Helmeted Guineafowl.

In the Milkwood community (even without the contribution of the Helmeted Guineafowl, which does not occur in undisturbed areas) the biomass of the disturbed plots is appreciably greater than that of the undisturbed plots. This finding is not reflected in the density figures, and is counter to the significantly greater species richness found in undisturbed areas. Disturbed Milkwood Thicket supports fewer species and a greater biomass and, it would appear, accommodates a species composition which is qualitatively different from that of an undisturbed Milkwood community. This finding will be explored in the Relative Abundance section below.

In the Strandveld community, undisturbed plots have a higher biomass than disturbed plots. This pattern matches that described by species richness and is therefore probably determined by vegetational differences between plots rather than disturbance. Biomass, however, is not always reflective of density, and hence it would appear that certain species or groups of species have populations which are different in disturbed and undisturbed areas. This possibility will be further analysed below.

In the Fynbos there is no distinction between disturbed and undisturbed areas. The biomass of each plot is in general matched by its respective density and species richness, and is probably determined to a large degree by the vegetational composition of each plot.

Biomass, like species richness and density, provides a certain perspective of a biotic community. Like species richness and density, it is a useful descriptive measure of a particular feature of a community, but is limited as an indicator of disturbance. Used in conjunction with these other two measures, however, it is able to provide new insights into a community. For example, it may be concluded that the species compositions of the plots of a particular community are qualitatively different when the trends between these plots described by biomass do not match those of species richness or density. The nature of that difference, however, is not made clear because biomass, like species richness and density, is a blanket measure describing the community in terms of a single figure. More detailed measures will be tested in section 6.5 and Chapter7.

6.2.4 Diversity

Diversity is a much researched and widely used concept for the analysis and description of biotic communities. Two well-known methods of measuring this concept, the Shannon-Weiner and Simpson Diversity indices, were applied to the data of the present study. The results are presented graphically below.

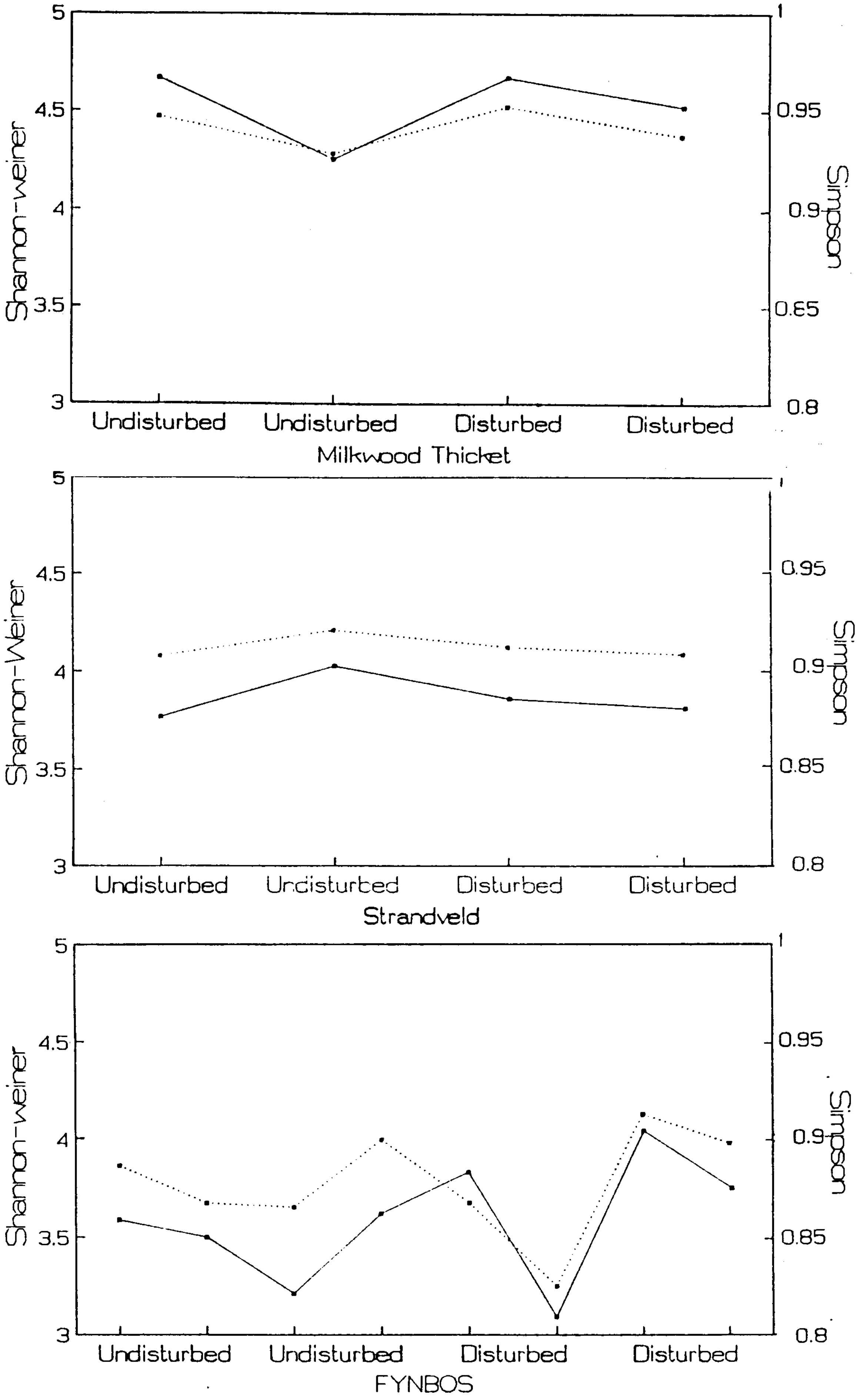


__Figure 6.4__ Shannon-Weiner (solid line) and Simpson (dotted line) diversity indices for each plot over 12 months.

The differential between plots appears to be at times exaggerated and at others it appears to be dampened down. Nevertheless, the patterns between plots and between vegetation types matches the patterns laid down by species richness and density.

An exception appears in the species diversity of Milkwood Thicket. While it is clearly revealed as the most diverse avian habitat, the relative diversities between plots of the community contradict the findings of species richness and density. This is illustrated in figure 6.5 below.

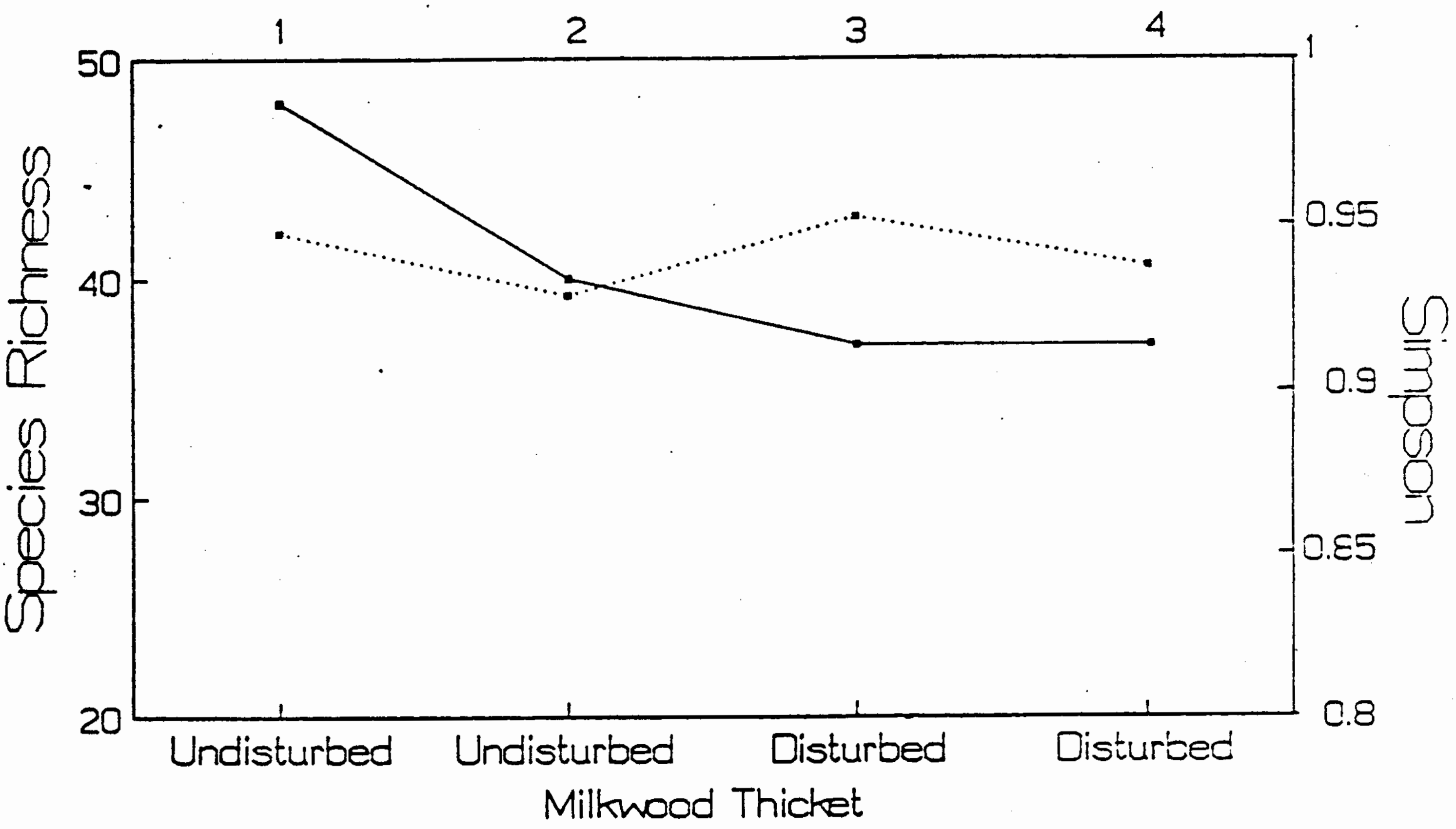


Figure 6.5 The relative differences in species richness (solid line) and Simpsons diversity index (dotted line) between Milkwood Thicket plots.

The explanation of this apparent anomaly is to be found in the way that diversity indices respond to rare and common species. That is, the particular spread of individual organisms among the species present is an important determinant of diversity. While plot 1 supports the greatest number of species and the greatest number of birds, it is not in fact the most diverse. This distinction falls to plot 3 which rates third in terms of richness and abundance. The reason why plot 1 is not the most diverse, is because a relatively large number of species recorded in this plot are rare. Consequently, the bulk of the population belong to relatively few species. The same may be said for plot 4 which, while it lacks many rare species, is also dominated by a relatively few (though very different) species.

Thus, while diversity appears at first glance to offer little more than that which was revealed by richness and density, it is in fact describing a different aspect of community structure. Diversity is describing, in numerical fashion, the relationship between rare and common species. As such, the term "diversity" is misleading, particularly as the same numerical value may describe a community with very many species or one with very few species.

What then, does the spread or evenness of organisms among the species reveal about the degree of disturbance to which a habitat has been subjected? Theoretically, at least, it has a great deal to say. Disturbances which cause the demise of sensitive species may alter the whole balance of resource allocation so that the community comes to be dominated by a few very numerous organisms. This is particularly true in the case of organic pollution of freshwater bodies where species diversity is reduced with increasing levels of pollution. In terrestrial ecosystems, however, where disturbances may be multi-faceted and may stem from more than one source, alterations to community structure may be more complex than that which can be described by 'spread' or 'evenness'.

In the case of a Milkwood community, it would appear that the evenness of the distribution of species does not discriminate plots on the basis of disturbance. While plot 1 (undisturbed) is 'penalised' for having too many rare species, plot 4 (disturbed) is 'penalised' for being dominated by a few abundant species.

Evenness is not merely a function of disturbance, and conclusions based on indices of diversity must therefore be made with circumspection. This is not to say that the use of diversity indices is invalid. While it is difficult to draw conclusions based on a side-by-side comparison of plots which may differ in numerous subtle ways, the use of diversity indices in the same plot over time may prove very useful. A change in the relative sizes of the different populations of a community over time may be well worth closer investigation. The usefulness of diversity indices in this respect has yet to be tested.

In the Strandveld and Fynbos communities, diversity follows very closely the trends of species richness and density. It therefore does not show any evidence of being able to detect disturbance. As has previously been stated this is probably more a function of the influence of the composition of the vegetation in each plot, and the low level of disturbance to which experimental plots were subjected rather than in the inability of diversity indices to detect disturbance.

With regard to the relative merits of the two indices used, each was remarkably similar in the patterns they revealed. According to Westman (1985) the Simpson index is more sensitive to changes in common species and the Shannon-Weiner index more sensitive to changes in rare species. As such, it is suggested that in any future attempts to use diversity indices <u>both</u> indices should be employed, as each may provide information on different aspects of the same problem.

6.2.4.1 Summary

The use of indices of diversity in the present study has illustrated some of the strengths and weaknesses of the community measures discussed so far. A diversity index is a composite measure which condenses important ecological information into a single figure. As a descriptive measure it is concise and communicates well, although much information is lost through the process of simplification.

As an indicator of disturbance it is very limited. A unitary measure cannot adequately sum up a multi-faceted problem. Disturbances may be numerous and each may have a different effect on the biota. When a single, blanket measure is used to account for these effects, important trends or contrasts may be cancelled out.

This same argument may be used for measures such as species richness or density where, the disappearance of species or individuals due to some disturbance may be matched by the entry of new species or individuals into the community. In this instance, however, our indicator of disturbance would remain unchanged.

No single measure ought to be used to detect disturbance or describe a community. Together the indicators discussed so far may prove useful. More flexible measures which are able to handle data from a stratified community, are also needed. Attempts to develop such indicators are discussed below.

6.2.5 Influence of vegetation

A review of the findings of this chapter thus far and, those of the previous chapter, shows that consistent differences in the composition of bird populations occur between plots which are not (except in the case of Milkwood Thicket) related to disturbances.

Patterns generated by correspondence analysis (Chapter 5) suggest that these differences are best explained by the influence of vegetation, particularly broad-leafed vegetation, on the composition of bird communities. So strong was this influence, it is suggested, that it overshadowed the effect of all other possible factors (such as disturbance).

A retrospective investigation into the botanical composition of each plot revealed the existence of a positive relationship between bird density and species richness on the one hand, and the amount of broad-leafed vegetation displayed in each plot on the other. Possible reasons for this relationship are discussed in section 5.2.

As was described in section 3.2.3, small pockets of broad-leafed scrub are found throughout the coastal plain wherever deeper soils occur. This broad-leafed scrub cover appears to have a positive influence on the species composition of each Fynbos plot. This is explained by the fact that these patches are abundant and varied sources of food. According to Skead (1967), shrubs of the genera Lycium and the Rhus are of exceptional importance to birdlife, as they harbour a great many insects and provide abundant nectariferous flowers and fruits for large parts of the year. Thus, despite their very small size, these patches have an important influence in the relatively unproductive and species depauperate fynbos and account, in part, for the variability of the findings.

In the Strandveld, only one plot was markedly different from the rest. As in the Fynbos, this denser and more species rich plot was found to enjoy a greater amount of broad-leafed thicket growing within, or in close proximity to, its borders.

The vegetation in Milkwood Thicket is more homogeneous than that of Fynbos or Strandveld. It does, however, differ with respect to the density of the vegetation - disturbances having resulted in a more open habitat. Denser (or undisturbed) vegetation supports a greater variety of bird species, though not necessarily a greater abundance. More open, disturbed habitat, on the other hand, attracts certain species which are not normally associated with Milkwood Thicket. Unlike Strandveld or Fynbos, therefore, Milkwood vegetation is more homogeneous with any differences being largely attributable to the influence of disturbances, thus allowing more meaningful conclusions to be drawn.

The difficulties involved in the selection of comparable vegetation, and the apparent effect that vegetation has on the composition of bird species, point to a limitation of the present study. The ability to make valid deductions and conclusions is undermined to the extent that plots cannot be said to be truly comparable. The varying population characteristics of each plot, nevertheless, do emphasize the fact that birds are highly selective of the environment in which they live. Disturbances which affect the <u>habitat</u> therefore are likely to have a significant effect on bird populations. In addition, both the influential nature of the vegetation and its variability, highlight the need in ecological monitoring for particular care to be taken in the selection of sites.

Two remedies are suggested to overcome the problems posed by a diverse and highly influential vegetation.

The first method analyses the individual proportionate contribution of each species to the total abundance of each plot. On the assumption that species within a particular habitat allocate resources in the same proportion throughout that habitat, it may be possible to control for small, though influential components (such as broad-leafed scrub patches in the Fynbos) by comparinq the relative abundance of only those species seen as being typical of a certain habitat. This method is tested in the following two sections.

Using the second suggested remedy, that of guild analysis, an attempt is made to provide a systematic and more focussed approach to the analysis of animal populations by dividing habitats into management guilds. In this way habitats (such as Fynbos and Strandveld, where scrub thickets form a distinctive component of the vegetation, and in Milkwood where a greater proportion of open habitat is found in disturbed areas) may be analysed according to their individual components. Guild theory is discussed in section 2.6.4 and tested in Chapter 7.

6.2.6 Relative abundance

Relative abundance measures the numerical importance of each species in a community. It is a measure which sheds light on the species composition of a community, and is therefore able to compensate for some of the limitations of abundance and species richness. Because it considers each species population as a proportion to the whole it may also be able to overcome the difficulties of controlling for a very variable vegetation. That is, plots whose vegetational composition supports a rich and dense community of birds, may be little different from plots supporting bird communities that are relatively poor and sparsely populated, when they are compared in terms of the relative abundances of their respective bird populations. While relative abundance provides more detailed information, it is nevertheless a more cumbersome measure with which to work and communicate.

The relative abundances of each plot are found in appendix (1).

Considering Milkwood Thicket first, it was shown in sections (6.2.1) and (6.2.3) that a greater biomass and smaller species richness was recorded in the experimental plots. This finding suggested that disturbance had in some way altered the structure of the bird community. By comparing the relative abundances of species in each plot, it is hoped that the nature of this alteration will be elucidated.

The greater biomass found in Milkwood Plots may be attributed to the substantially greater numbers of a few species found in these areas, of which the following are the most important :

Redeyed Dove	Streptopelia semitorquata
Laughing Dove	Streptopelia senegalensis
Fiscal Shrike	Lanius collaris
Bokmakierie	Telophorus zeylonus
Cape Sparrow	Passer melanurus

Speckled Housebird colius striatus and Cape Weaver Ploceus capensis contributed substantially to one disturbed plot, but not to the other.

It is interesting to note that these species are all closely associated with disturbed environments - having very successfully colonised towns and cities throughout Southern Africa. Their greater relative abundance in disturbed plots therefore should come as no surprise. (The presence of a group of European Starlings Sturnus vulgaris in the undisturbed Milkwood, however, is a caution against placing too much emphasis on the value of the individual species as indicators).

In addition to these 'disturbance loving' species, there were certain species found exclusively (or in greater numbers) in undisturbed areas. These apparently 'disturbance intolerant' species are listed below :

Rameron Pigeon	Columba arquatrix
Fierynecked Nightjar	Caprimulgus pectoralis
Knysna Woodpecker	Campethera notata
Cardinal Woodpecker	Dendropicos fuscescens
Olive Woodpecker	Mesopicos griseocephalus
Sombre Bulbul	Andropadus importunus
Cape Robin	Cossypha caffra
Barthroated Apalis	Apalis thoracica
Southern Boubou	Laniarius ferrugineus

With the exception of the Cape Robin which, nevertheless, is of a fairly retiring nature, the above species do not appear to be closely associated with disturbed habitats. This finding (that species which appear to discriminate between experimental and control plots are also more broadly associated with either disturbed or undisturbed areas), lends weight to the present analysis and suggests that the differences recorded are substantive and that the goal of developing an indicator using these differences is worthy of pursuit.

Before this is attempted, however, the relative abundance of Strandveld and Fynbos will be analysed.

In the Strandveld community, all four plots are dominated by the same species with the Lesser Doublecollared Sunbird Necatrinia chalybea, Cape Bulbul Pycnonotus capensis, Greybacked Cisticola Cisticola subruficapilla, Spotted Prinia Prinia maculosa and Yellow Canary Serinus flaviventris accounting for 50 to 60 percent of the abundance in each plot. Each species was represented in roughly the same proportions with little in the respective relative compositions of each plot to indicate any disturbance effect. Thus, even in the more populous and species-rich undisturbed plot, the relative abundances of each species is little changed from the other three plots.

As in the Strandveld, little can be said about the usefulness of relative abundance as a measure of disturbance in the Fynbos habitat. Each plot is dominated by the same species with the Lesser Doublecollared Sunbird Nectarinia chalybea, Karoo Robin Erythropygia coryphaeus, Greybacked Cisticola Cisticola subruficapilla and Spotted Prinia Prinia maculosa accounting for between 50 and 70 percent of the abundance of each plot. In plots with a lower species-richness,these dominant species often account for a correspondingly higher proportion of the community population. In general, though, the basic taxonomic composition remains the same,with little evidence of a disturbance effect shown.

Unlike Milkwood Thicket, community composition in the experimental plots of the Strandveld and Fynbos remains unchanged. While such a conclusion does not do much to further our understanding of ecological monitoring, it does indicate that low levels of disturbance (such as traffic and the presence of people in fairly low concentrations) do not appear to affect the avifauna of the Strandveld and Fynbos detrimentally.

The community composition of the more densely populated Milkwood Thicket, on the other hand, does appear to have been modified by the greater degree of disturbance to which the experimental plots have been subjected. This disturbance is more continuous, multi-faceted and intensive,and stems from the everyday activities associated with human habitation. The finding that such disturbance appears to have an effect on the avifauna of the Milkwood community has implications regarding the siting of the proposed new village for reserve personnel, the visitor accommodation and the housing for senior staff.

6.2.6.1 Summary

The ojective of this section was to control for the unequal species richness and density levels of each plot that resulted from the overriding influence of a highly variable vegetation landscape. This was to be achieved by analysing the relative proportionate contributions of each species population to total abundance.

While no disturbance effect was detected in the Strandveld and Fynbos communities, the fact that relative abundance of resident species differed little in each plot, suggests that this technique is able (at least in part) to control for the influence of vegetation. In the more populous and heavily disturbed Milkwood Thicket community, the concept of relative abundance showed promise and will be further developed in the following section.

6.2.7 An index of relative abundance

From the previous section, it was found that in the Milkwood Thicket community the relative contributions of certain species showed marked differences in disturbed and undisturbed plots. These differences will now be exploited in devising an index of disturbance.

An index is a measure which is compared to a standard and expressed as a ratio. In developing an index, therefore, a standard must be decided upon against which to measure the disturbance factor. In the case of detecting for disturbance, the measure yielded by undisturbed habitat may be used as a standard.

By analysing the relative abundance of bird species in the Milkwood community, two groups of species were found to discriminate between disturbed and undisturbed areas. One group was found to be closely associated with disturbed areas, while species in the other group were found to be associated with undisturbed areas.

The ability of these two groups to make this distinction qualifies them as potential indicators of environmental disturbance. The relative abundance of one group, or the relative paucity of the other group, may be used to detect disturbance. By combining both groups into a single index, the sensitivity of our disturbance measure may be enhanced.

One way of doing this would be to calculate the total number of individuals falling into each group. Then, by giving the 'disturbance intolerant' group a positive value, and the 'disturbance loving' group a negative value, the two groups could be summed and the resulting value compared to the standard which would form the denominator of the ratio - the standard having been calculated in the same way.

In algebraic notation the index is summarised thus :

$$D = \frac{\Sigma A - \Sigma B}{\Sigma As - \Sigma Bs}$$

where : D = Disturbance ratio

A = Abundance of 'disturbance intolerant' species in experimental plots

B = Abundance of 'disturbance loving' species in experimental plots

As = Abundance of 'disturbance intolerant' species in undisturbed plots

Bs = Abundance of 'disturbance loving' species in undisturbed plots

Using this formula, a ratio of 1 would indicate that the habitat being measured was undisturbed and a ratio of anything less than 1 (including negative values) would indicate that the habitat may be disturbed and in need of closer monitoring.

Use of this formula is illustrated with data from the present study. Census data collected over 11 months from Milkwood Thicket plots are analysed using the relative abundance index. The disturbance ratio is calculated for the two disturbed plots using the two undisturbed plots as the standard. Results are presented in Table 6.1 and figure 6.6 below.

Table 6.1

Experimental plots compared to control plots (standard) using the relative abundance index formula

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Experi-mental	1	11	24	23	23	4	12	-1	-14	-3	-7
Standard	52	64	54	66	65	86	69	48	47	45	50
Ratio	.0019	.171	.444	.348	.353	.046	.173	-0.02	-.29	-.066	-.14

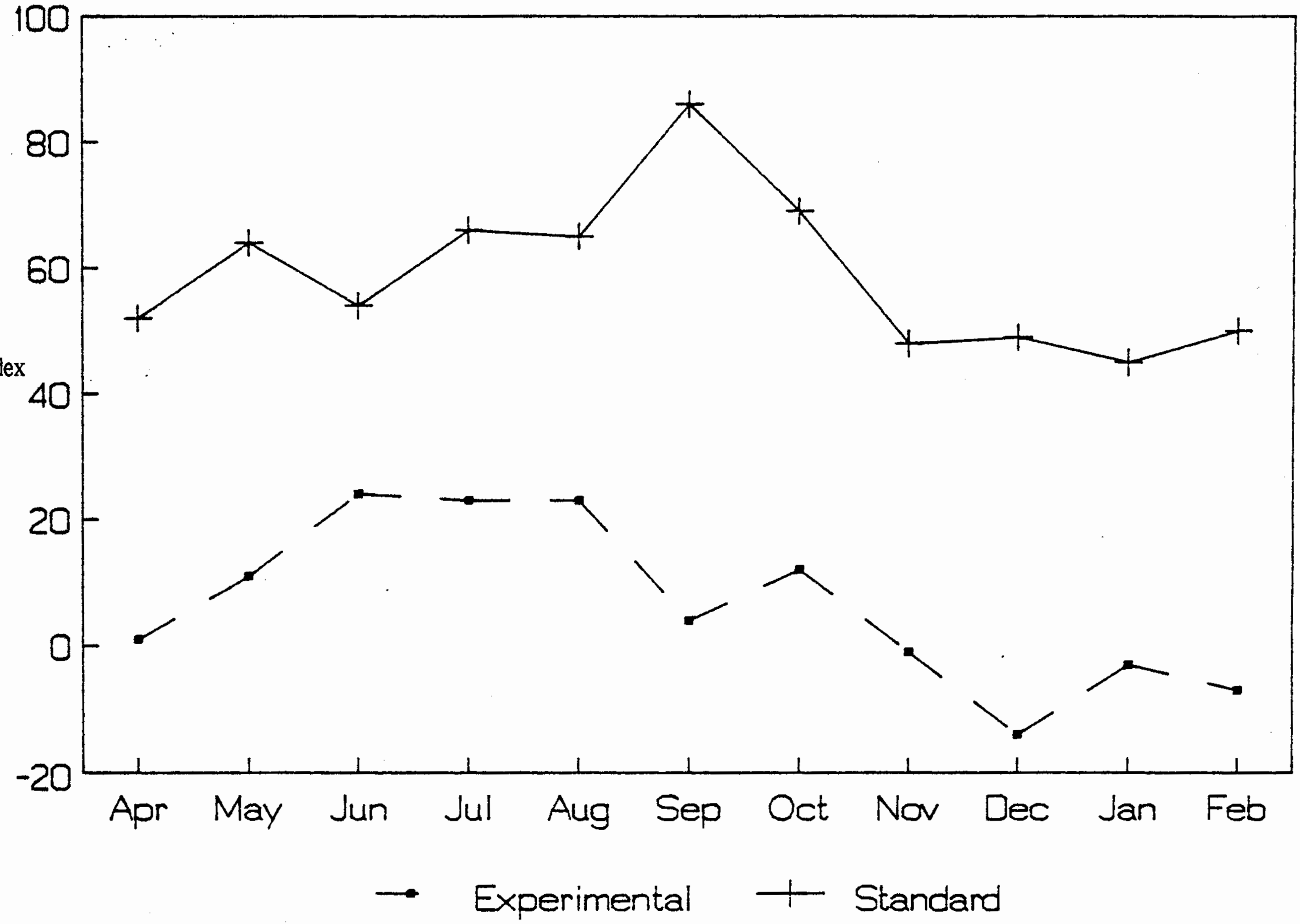


Figure 6.6 Monthly values calculated using the relative abundance formula. The numerator (experimental plots) and denominator (standard or control plots) of the formula are depicted separately. The difference between the two represents the disturbance effect recorded for each month.

Whilst it is not possible to validate the formula with the same data used to develop it, the table and graph are nevertheless useful in illustrating not only how this index may be used, but also the differences that exist between disturbed and undisturbed plots within certain groups of species.

In the table, the calculated values for the numerators and the denominators of the formula for each month are given, as well as the resulting ratios. The ratios for each month reflect the discrepancy that exists between disturbed and undisturbed plots.

This discrepancy is seen graphically in figure 6.6 where calculated values for the undisturbed plots are compared to those of the experimental plots. For each month the difference between the two points represents the extent to which the experimental plots fall short of being classified as undisturbed. Months showing the greatest discrepancy would be, perhaps, the most favourable months in which censusing ought to be conducted.

The latter point highlights an important feature of monitoring. This is, that the norm or standard against which measurements are made is not a static measure, but one which changes with the seasons and one which fluctuates from day to day. In developing an index, therefore, the range of variation, within which the index is likely to fluctuate in the absence of any anthropogenic disturbance, must be defined. Seasonal variation must be determined so that measurements of disturbance using ecological data are able to be weighed against a standard derived from a comparable time period. Seasonal fluctions are considered in this study in Section 8.1.

In addition to annual seasonal changes that occur during the course of a year, both variations in the patterns of an annual cycle as well as longer term trends need to be controlled for. This is best achieved if control measurements of comparable undisturbed communities are made throughout the period that ecological monitoring is carried out.

The determination of the minimum number of censuses is necessary to control for daily fluctuations in order to gain a reliable estimation of the characteristics of a community is discussed in Section 8.3.

6.4.2.1 *Summary*

In the present section, it has been shown that it is possible to develop a means of detecting disturbance using biological measures. By comparing the combined relative abundances of a selected number of species, it was possible to clearly distinguish disturbed from undisturbed plots.

The apparent success of this technique is due to its more focussed approach. By selecting only those components of the community that discriminated between disturbed and undisturbed areas, background noise is reduced and data yielded is more harmonious, thus amplifying patterns, trends and differences in the community.

The idea of using the combined relative abundances of groups of selected species as a means to detect disturbance, however, needs to be further tested. The data used to devise the relative abundance index cannot also be used to validate it. It must be shown to be usable throughout the Milkwood Thicket community - and preferably in other very different communities as well. Importantly, it needs to be more fully established that the variable that is discriminating between Milkwood plots is, in fact, 'disturbance' and not an artefact serving to confound the analysis. Further testing may also point to ways of increasing the sophistication and usability of the technique. In calculating the index, for example, it may be possible to weight certain species, such as those that are highly characteristic of either disturbed or undisturbed habitats, and thereby further refine the indicator value of the index.

In the next chapter, the notion of using selected groups of species (instead of a single blanket measure) to refine the ability to detect disturbance, is taken a step further with the use of guild analysis.

CHAPTER 7

GUILD ANALYSIS

7.1 INTRODUCTION

In Chapter 2, guild theory was described. Using Root's (1967) definition, Severinghaus (1981) suggested that guilds may be used as a mechanism for assessing environmental impact. Building on this idea, Verner (1984) put forward the concept of the "management guild". That is, species may be grouped according to how they similarly respond to disturbances or changes in the environment, and not according to the particular resources they utilize. Root's original definition is therefore made operational so that it has immediate relevance to the management of the ecosystem. A systematic methodology for the delineation of management guilds is proposed by Verner.

In Chapter 2, it was suggested that management guilds may enable environmental stress to be detected at a finer level of resolution. The more focussed approach allows similarly grouped species to respond in unison to particular stresses, enabling background 'noise' to be reduced and emerging trends in the data to be enhanced.

7.2 APPLICATION OF VERNER'S METHODOLOGY.

According to Verner (1984), a review of avian literature shows a disquieting lack of consistency in how various workers assign bird species to guilds. Each study using guilds must be examined on its own merits and caution must be exercised when comparing guild analyses between studies. To correct this failing, he proposed a systematic methodology for the delineation of species into guilds.

In developing procedures that permit sound management, the first priority in environmental assessment and monitoring should be the maintenance of viable populations of all species that breed in the habitat under consideration (Verner, 1984). An appropriate basis for the formation of guilds, therefore, is the feeding and nesting behaviour of each species.

In addition to nesting and feeding behaviour, it will be remembered that guild categories are also derived from consideration of those zones of the habitat that are likely to respond in similar ways to anticipated perturbations. Delineation of habitat zones is best done, according to Verner, by a vertical stratification of the habitat. The number of categories, however, must be kept to a minimum in order to keep the system as simple as possible and to maximise the number of species in each guild.

The following zones are proposed for the Milkwood Thicket community: ground layer, shrub thicket, tree trunks and branches, and tree canopy. In the Fynbos plots, ground layer, restiod layer and shrub vegetation were recognised, while in the Strandveld, ground layer, restiod layer, shrub thicket and shrub canopy were identified as habitat zones.

Habitat zones, nesting, and feeding behaviour, therefore, are used to define guilds. This is done by matching the feeding and nesting behaviours of each species with the habitat zones in which these behaviours primarily occur. The habitat categories for the nesting zone are placed along one axis, and those of the primary feeding zone along the other to form a matrix. Each cell within this matrix defines a potential guild into which bird species may be placed, according to their primary nesting and foraging zones. Information in this regard was gleaned from the literature and from personal observations.

Having assigned each species in the community to its respective cell, the abundance, richness and composition of each guild may be calculated and comparisons between control and experimental plots made.

This matrix approach to guild delineation permits considerable flexibility (Verner, 1984). In a habitat in which four nesting and four feeding zones are identified, 16 guilds could potentially be represented, if each cell of the matrix is used to delineate a guild. . This fine subdivision, however, may not provide very meaningful results in low density communities like Strandveld and Fynbos. By combining into larger guilds all species in any row or column, it is possible to identify guilds defined by either feeding or nesting zone. These much larger guilds result in substantial increases in -the total number of individuals in a census and, in so doing, increase the cost-effectiveness and hence feasibility of monitoring.

7.3 RESULTS AND DISCUSSION

Following Verner's (1984) methodology, the abundance and species richness of disturbed and undisturbed areas within each guild zone are compared in the table below.

Table 7.1

Mean monthly counts of birds on disturbed (d) and undisturbed (u) Fynbos plots, by cell of the guild matrix. The number of species recorded is shown in parentheses for each guild. Rows and columns are totalled to give the aggregate count along each axis of the matrix; each total represents either a feeding (row) or nesting (column) guild for each habitat zone.

PRIMARY FEEDING ZONE		Ground	Scrub/ Restio	Shrub	Breeds Elsewhere	Totals
Perches	d			.25 (1)		.25 (1)
	u					
Shrub	d			57.5 (15)	1.8 (1)	59.3 (16)
	u			70.9 (13)	.5 (1)	71.4 (14)
Scrub/Restio	d		105 (6)			105 (6)
	u		107 (6)			107 (6)
Ground	d	17.9 (10)		13.3 (6)		31.2 (16)
	u	15.3 (9)		12.2 (6)		27.5 (15)
Totals	d	17.9 (10)	105 (6)	71 (22)	1.8 (1)	196 (39)
	u	15.3 (9)	107 (6)	83 (19)	.5 (1)	206 (35)

PRIMARY NESTING ZONE

Of the six cells which are occupied by at least one species in the above matrix, only one cell shows any appreciable difference between control and experimental plots. This cell is found in the 'shrub' zone. It shows undisturbed plots to be more abundant than disturbed plots, suggesting therefore that disturbance has a detrimental effect on the density of bird species found in the shrubby zone.

Table 7.2

Mean monthly counts of birds on disturbed (d) and undisturbed (u) Strandveld plots,by cell of the guild matrix.

PRIMARY FEEDING ZONE			PRIMARY NESTING ZONE: Ground	Restio/ Scrub	Shrub Thicket	Shrub Canopy	Breeds Elsewhere	Totals
	Perches	d				.08 (1)		.08 (1)
		u				.25 (2)		.25 (1)
	Shrub Canopy	d			8.2 (2)	55.2 (7)	3.2 (1)	66.6 (10)
		u			13 (3)	68.3 (6)	7.1 (1)	93 (10)
	Shrub Thicket	d			13.5 (5)			13.5 (5)
		u			17.2 (5)			17.2 (5)
	Restio/ Shrub	d		37.9 (3)				37.9 (3)
		u		37.7 (3)				37.7 (3)
	Ground	d	2.8 (4)	7.8 (1)	14 (1)	4.8 (4)		29.4 (10)
		u	3.5 (5)	7.5 (1)	15.3 (1)	7.3 (4)		33.8 (11)
	Totals	d	2.8 (4)	45.7 (4)	35.7 (8)	60 (12)	3.2 (1)	147 (29)
		u	3.5 (5)	45.2 (4)	45.5 (9)	75.8 (11)	7.1 (1)	182 (30)

Interestingly, this same pattern is also found in the Strandveld (Table 7.2 above). That is, a remarkable similarity between control and experimental plots was found in all zones outside that of the 'shrub canopy'. Here, as in the Fynbos, undisturbed plots were found to be considerably more populous.

One explanation for this finding may be that the species inhabiting this zone are more sensitive to disturbances, choosing quieter areas in which to live. This argument may be discounted, however, by the finding that almost no differences were found in the composition of species in each respective area within this zone, in both Fynbos and Strandveld communities.

An alternative reason, which may better explain the imbalance in the abundance figures, may be found in the difficulties involved in identifying truly comparable samples in a vegetation notorious for its variability. That is, vegetational differences, rather than disturbance, may better explain the greater density found in undisturbed shrubby vegetation.

In the Strandveld, undisturbed plots exhibited a greater proportion of broad-leafed thicket than that found in disturbed plots, and it is suggested that this factor resulted in the greater abundances recorded in these plots.

In the Fynbos, a closer look at the individual plots reveals that of the eight plots, all but one are very similar in the abundance figures that were calculated for the 'shrub' zone. The outstanding plot (which had been subjected to disturbance) is distinguished by its very low shrub component, and serves to explain the lower abundance figures which were collectively calculated for disturbed areas.

Turning back to Table 7.1, a zone labelled "perches" was identified, in order to account for the influence of fence poles and telephone wires that lined each of the four disturbed fynbos plots. While a number of bird species made use of these structures, no change in the composition of species occurred, with the exception of the Forktailed Drongo <u>Dicrurus adsimilis</u> which was occasionally recorded in disturbed plots.

While guild analysis recorded little, if any, disturbance effect in either the Fynbos or Strandveld communities, it did identify the most important feeding and nesting zones for each respective community. In the Fynbos, for example, the 'restio/shrub' zone accounted for the greatest number of individuals but supported only six species. The 'shrub' and 'ground' zones, on the other hand, accommodated lower densities of birds but much higher numbers of species.

Information such as this may be of use in assessing management practices such as veld burning. Fires are likely to result in a decline in certain species and an increase in others, with this pattern changing to match the various successional stages of the regenerating vegetation. While a fire will result in a drastic decline in species associated with shrub vegetation, large-scale fires (resulting, for example, from increased human presence) may actually increase the numbers of such species in areas which are unaffected by the fire.

Table 7.3

Mean monthly counts of birds on disturbed (d) and undisturbed (u) Milkwood Thicket plots,by cell of the guild matrix.

			PRIMARY NESTING ZONE					
PRIMARY FEEDING ZONE			Ground	Shrub Thicket	Tree Boles & Limbs	Tree Canopies	Breeds Elsewhere	Totals
	Tree Canopies	d		18.7 (3)	35.3 (8)	7.4 (3)	3.6 (1)	65 (15)
		u		22.1 (3)	43 (13)	10.7 (3)	1.5 (2)	77.3 (21)
	Tree Boles and Limbs	d						
		u			2.5 (3)			2.5 (3)
	Restio/ Schrub	d		40.4 (6)				40.4 (6)
		u		44.7 (6)				44.7 (6)
	Ground	d	18.2 (7)	1 (1)	40.5 (9)			59.1 (17)
		u	15.1 (7)	.5 (1)	17.5 (7)			33.1 (15)
	Totals	d	18.2 (7)	60.1 (10)	75.8 (17)	7.4 (3)	3.6 (1)	165.1(38)
		u	15.1 (7)	67.3 (10)	63 (23)	10.7 (3)	1.5 (2)	157.6(45)

In the Milkwood Thicket community, a different pattern emerges. In Table 7.3 it is clear that the 'tree canopy' is the most important feeding zone while 'tree boles and limbs' is the most important nesting zone. Any disturbance that affected either of these two zones, therefore, would have a major impact on the avian community of this habitat.

Of the four feeding zones, three are marked by appreciable differences between control and experimental plots. In the 'tree canopy' zone, undisturbed plots are significantly denser and more species rich than disturbed plots. The reverse is true for the ground feeding category, where birds in disturbed plots outnumber those found in undisturbed plots. Clearly, the composition of species between experimental and control plots is different.

A number of reasons for this difference may be considered. The nature of the disturbances themselves have had an effect on the vegetation of the area. Houses, living areas and pathways have contributed to 'open up' these disturbed areas and the presence of domestic fowl, it is suggested, have contributed importantly to the poor regeneration of Milkwood Thicket. Disturbed Milkwood habitat, therefore, is less dense and provides less protection and concealment for bush dwelling birds. In addition, the lower densities of certain species of birds in disturbed Milkwood suggests that their resource base may also have been affected by disturbance.

In addition to habitat deterioration, human presence in disturbed areas has attracted certain species not normally associated with Milkwood. Species such as Redeyed Doves Streptopelia semitorquata, Laughing Doves Streptopelia senegalensis, House Sparrows Passer domesticus and Cape Sparrows Passer melanurus abound in disturbed Milkwood. The more open areas have suited the feeding habits of these ground dwellers and, it is suggested, the existence of human inputs such as chicken feed and household scraps may have contributed to increase their numbers.

In addition to attracting new species to Milkwood Thicket, disturbances also appear to have prevented certain species from inhabiting such areas. This is most clearly seen in the 'tree boles and limbs' zone, where three species of Woodpecker, which were regularly encountered in undisturbed thicket, were not recorded on a single occasion in disturbed areas. Disturbances such as noise and human presence, it is suggested, as well as decreased cover have contributed to exclude these species from disturbed areas.

Thus, it may be seen that by using a methodology such as guild analysis (in which the habitat is stratified into zones according to anticipated use or change) it may be possible, in part at least, to reflect something of the multifaceted nature of disturbances associated with human habitation.

Turning to the 'primary nesting zone', the most important guild and the one showing the greatest difference between disturbed and undisturbed areas is the 'tree boles and limbs' guild. Here, the differential between number of species is very marked, with nearly all species which differentiate between disturbed and undisturbed habitat occupying this guild. 'Tree boles and limbs' is identified, therefore, not only as a habitat zone of great importance in the conservation of many bird species living in Milkwood Thicket, but also as the guild most vulnerable to disturbances associated with human habitation.

7.4 CONCLUSIONS

Verner's (1984) system of guild analysis holds promise for the management of natural systems. His systematised method of guild delineation provides a framework which has as its basis the management of such systems. His methodology will also enable comparative work to be done in other areas by other workers.

Stratification of the habitat into zones which reflect areas of anticipated impact, provides a more focussed approach to disturbance detection. This approach is freed from many of the problems associated with measures seeking to characterise a community by a single figure, and has the advantage of being able to identify important or vulnerable habitat zones. In this way, it may be possible to avoid or lessen potential impacts and even to determine their nature and cause.

Guild analysis is nevertheless limited. It is an artificial measure which, despite its systematic approach, is not entirely immune from subjective notions to guild delineation asserting themselves. Before guild analysis is widely applied, therefore, much testing must be done.

CHAPTER 8

OVERCOMING THE PROBLEM OF VARIABILITY

At the root of many of the problems besetting ecological monitoring, is the dynamic and diverse nature of natural systems. Measures, therefore, which are able to successfully address the problem of an unpredictable environment (even in a limited sense) will greatly enhance the power and applicability of ecological monitoring. This chapter identifies ways in which this might be achieved.

8.1 SEASONAL FLUCTUATIONS

Determining whether or not substantive change has occurred in an ecosystem, is a major challenge facing any monitoring programme. Obstructing the attainment of this goal are the difficulties of adequately catering for type I errors (where an impact is proclaimed when none exists) and type II errors (where no impact is proclaimed when an impact does, in fact, exist) and of distinguishing natural stress from human induced stress. By gaining an understanding of the range within which bird populations are likely to vary in the absence of disturbance, during the course of a year, and possibly within each season, situations resulting from stress may be more confidently identified.

This section attempts to determine the extent of background noise that exists, so that variations resulting from human perturbations may be distinguished from those that result from natural fluctuations.

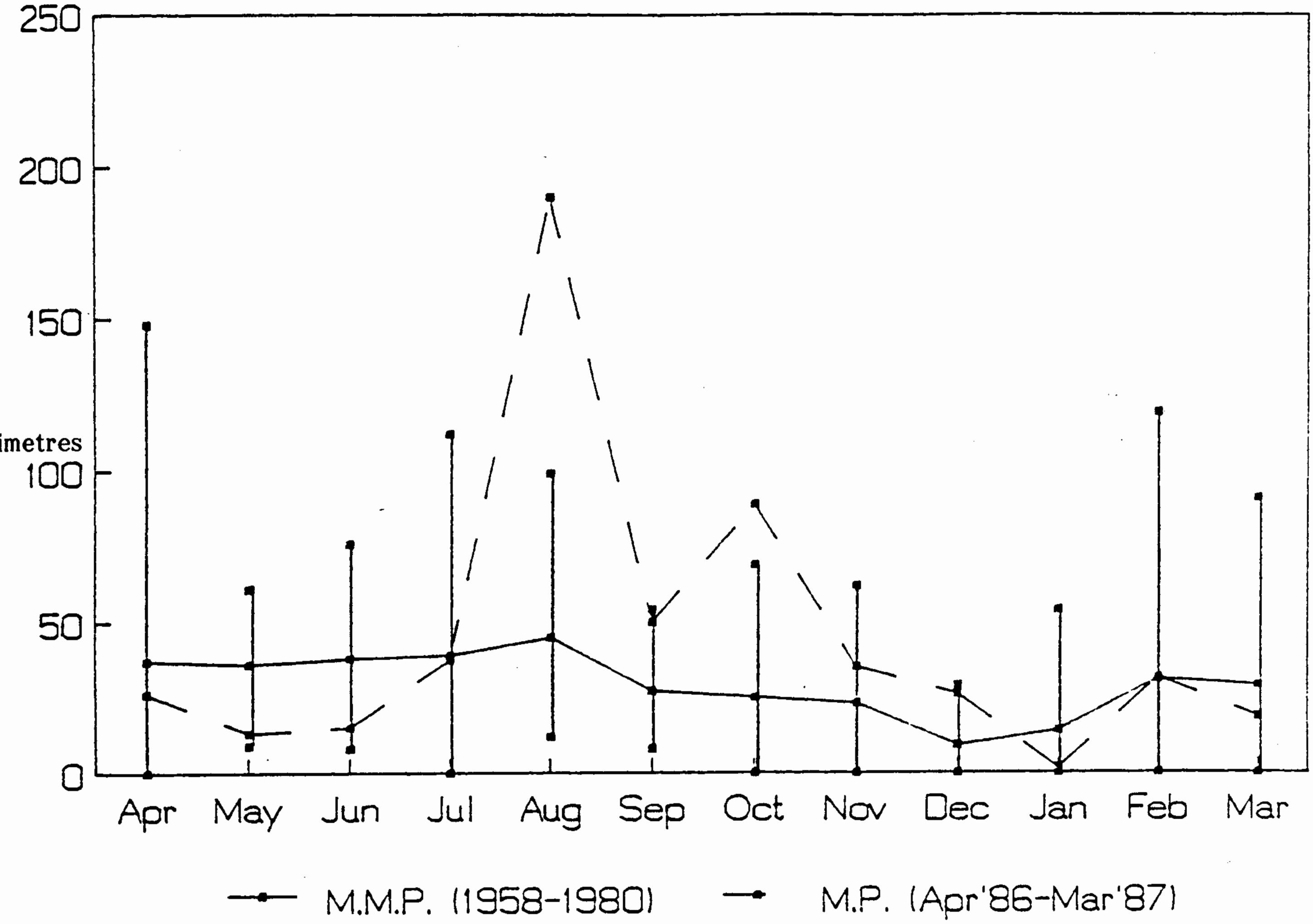


Figure 8.1 Mean monthly precipitation, 1958-1980 (solid line) compared to monthly precipitation, April 1986 - March 1987 (dotted line). Monthly range of rainfall during the 22 year period is indicated by the solid vertical lines.

Table 8.1

Standard deviation of birds per hectare: a) over 12 month study period, b) over most favourable censusing period (March to August) and c) between plots of each habitat.

	Milkwood	Strandveld	Fynbos
a) 12 months	3.8	0.96	1.63
b) March - August	3.09	0.82	1.37
c) Between plots	1.04	1	0.73

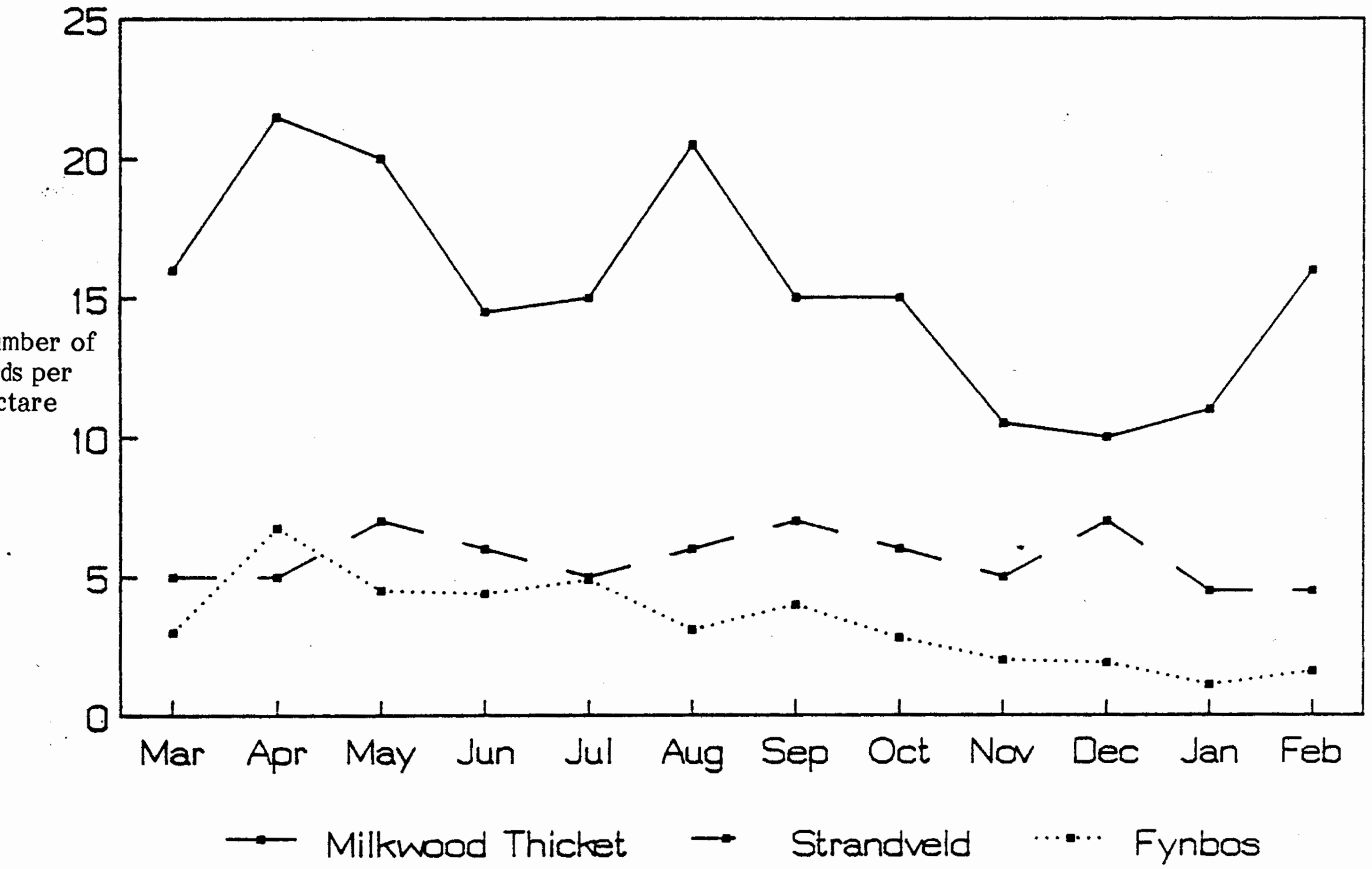


Figure 8.2 Mean monthly density of birds recorded in Fynbos, Strandveld and Milkwood Thicket. Monthly levels of species richness follow a similar pattern

From Figure 8.1, it can be seen that precipitation varies greatly during the course of a year and from one year to the next. It is also clear that rainfall over the twelve month study period differs from the average recorded rainfall, both in terms of total annual amount, and in terms of how that rainfall is spread between each month. The wide range of rainfall recorded for each month, however, shows that deviations away from the average is by no means an unusual occurrence.

During August and October, rainfall exceeded the ranges recorded for those months, resulting in large measure in the appreciably greater total precipitation for the twelve month period.

Climate, particularly precipitation, has an overriding influence on the condition of natural systems. The system at De Hoop has, over two decades, been subjected to wide extremes in precipitation. While it is thus presumably well adapted to cope with such uncertainties, the species richness and density of birds must surely fluctuate to match such changes. As such, climatic vagaries do little to improve the reliability of a monitoring system.

In figure 8.2, average bird densities are illustrated for each month in all three vegetation types. The monthly patterns depicted in this graph closely follow those of species richness. Table 8.1 depicts the standard deviation of recorded bird densities: a) over the 12 month period, b) over the most favourable censusing period (March to August) and c) between plots of each habitat.

In Milkwood Thicket, very large fluctuations in bird density are displayed from one month to the next, while in the Strandveld, bird density is much more constant. No discernible trends can be detected in these two habitats. From this, it may be tentatively assumed that the maximum and minimum density and richness figures recorded during the twelve month study period, represent the range within which they are likely to fluctuate in the absence of any natural or artificial disturbances. Such an assertion, however, will need to be tested as more data becomes available.

In the Fynbos, on the other hand, density and species richness patterns indicate that forces other than seasonal change are at work. Abundance levels in the last four months of the study period, for example, are a fraction of the levels recorded during the previous eight months. The period from December to February was a particularly dry spell. During this time, it was noticed that over extensive areas of Fynbos, young Proteaceae plants were dying. It has been suggested that this may be attributed to a fungus which attacks members of the Proteaceae family. Such a phenomenon could well affect bird densities in the Fynbos. It may also serve to explain the particularly striking increase in the number of Lesser Doublecollared Sunbirds recorded in the Milkwood, at a time when their numbers in the Fynbos were at their lowest.

The existence of such a phenomenon, illustrates some of the difficulties involved in monitoring for environmental change. The problems of determining normality from abnormality, and of distinguishing impacts resulting from natural forces from those that originate from human-induced disturbances, are not easily overcome.

One way of circumventing the difficulties imposed by an ever-changing environment, is to incorporate into one's monitoring programme an ongoing system of control measurements against which to determine disturbance. Areas which are, as far as possible, free from any known disturbance need to be identified and set aside and used as a standard. The recently proclaimed marine reserve along the shores of De Hoop fulfills just such a function for the inter-tidal habitat. Such areas also serve the purpose of building a bank of information relating to longer term trends and cycles. Disturbances, however, are multifaceted, often unseen, and may have a cumulative and widespread effect which may serve to degrade even those areas that have been set aside. It is against such an eventuality that historical baseline measurements come into their own, for here, despite the problems of a dynamic environment, are measurements recorded in the absence of the particular disturbance in question.

8.1.1 Summary

Monitoring requires a standard against which to compare environmental change. The problems of a diverse and dynamic environment, however, militate against this requirement. The problem is not easily overcome, though the use of historical baseline records and ongoing measures taken in 'disturbance free' reserves,together with an understanding of the range within which bird populations fluctuate in the absence of disturbance, will go a long way to making monitoring programmes meaningful and practical.

8.2 OPTIMUM CENSUSING CONDITIONS

Day to day fluctuations in weather conditions severely limit the quality of data collected. Determination of environmental change from data that is inconsistent from one day to the next, severely limits the effectiveness of monitoring. An important requirement for any monitoring programme, therefore, is that each sampling effect yields information that is homogenous and as complete as possible.

A further important requirement for any monitoring programme, is that is is cost-effective. Even the most carefully designed programme is rendered useless, unless it can operate within the constraints of available resources. The opposing requirements of accuracy and cost demand, therefore, that a compromise solution be found. To this end, the efficiency of each sampling effort must be maximised so that time spent in the field may be reduced to a minimum.

This section attempts to determine those conditions under which censusing may be most profitably undertaken. The ten most 'successful' and the ten least 'successful' censuses undertaken in each plot during the study period were identified, and the conditions under which they took place were analysed ("Success" in this instance refers to the greatest number of birds recorded in a census). In this way, it is hoped to elucidate those conditions that are most favourable and those that are least favourable for censusing. Prior to every census that was undertaken environmental conditions, date and time of day were recorded. Each is separately discussed below.

8.2.1 Season

In the three vegetation types the greatest densities and the greatest number of species were recorded between the months of April and August. Equally striking was the finding that of the ten least successful censuses in each plot, a considerable proportion were carried out between the months of November and February.

It is suggested that this finding, which is of much importance to any future monitoring programme, is partly explained by the winter breeding season of many species of birds in the south-western Cape and partly by the particular climatic conditions that prevail at that time of year.

<u>Table 8.2</u>
Percentage of summer and winter censuses that yielded the 10 most successful and the 10 least successful censuses. Months of March and September are excluded.

	Most	Least	Most	Least	Most	Least
Winter	70	20	45	35	83	12
Summer	20	75	35	53	4	88
	Milkwood		Strandveld		Fynbos	

8.2.2 Time of Day

In general, the first three hours of sunlight is the time when censusing is most successfully carried out. This, however, is by no means a fixed rule and very successful censusing was also undertaken during midday and late afternoon. The chances of achieving such success during the latter two periods, however, was considerably reduced, particularly in Milkwood Thicket and Strandveld. In Fynbos, the time of day appeared to be less critical as a factor determining successful censusing.

Table 8.3
Comparison of 10 most successful and 10 least successful censuses in each habitat showing the influence of time of day on censusing success. Figures show the percentage of successful and unsuccessful censuses within each time category.

	Milkwood		Strandveld		Fynbos	
	Most	Least	Most	Least	Most	Least
Early morning	68	15	55	0	39	26
Late morning/ early afternoon	28	38	33	52	31	31
Late afternoon	4	47	12	48	30	43

8.2.3 Wind Speed

Wind speed was found to be an important factor determining the success of a census. Calm conditions achieved the greatest results, with increasing wind speeds being matched by a decrease in the number of birds recorded. In addition to being less visible as wind speed increased, so it became more difficult to hear birdcalls, thus further reducing the effectiveness of censusing under such conditions.

Table 8.4
Influence of wind speed on censusing success.Figures represent percentage of calm,moderate or strong winds found within each category.

	calm	moderate	strong	calm	moderate	strong	calm	moderate	strong
Most successful	72	52	5	81	56	23	67	50	24
Least successful	28	48	95	19	44	77	33	50	76
	Milkwood			Strandveld			Fynbos		

8.2.4 Temperature

Temperature was also found to influence census results. Mild, cool conditions produced, in general, good censusing results. Warm conditions, too, were often very productive, though to a lesser degree, while higher temperatures were found to be strongly associated with poor census results. As efficient data gathering is dependent in large measure on the efficiency of the field worker, conditions that reduce his or her efficiency ought to be avoided. Temperature, therefore, is an important consideration in deciding when to census.

Table 8.5
Influence of temperature on censusing success. Figures represent percentage of successful and unsuccessful censuses within each temperature category

	cool	warm	hot	cool	warm	hot	cool	warm	hot
Most successful	94	72	9	81	41	36	85	48	18
Least successful	6	28	91	9	59	64	15	52	82
	Milkwood			Strandveld			Fynbos		

Cloud cover and wind direction were also recorded and analysed. In each case, they were found to bear little association with census results.

While the above factors have been described individually, it must be remembered that it is the set of all factors which ultimately determine censusing success. So, too, it must be remembered that the above factors are not independent of one another. Cool conditions are closely associated with early mornings, winter months and to a lesser degree with windless conditions. Which of these factors, if any, is the critical one, cannot be determined from the results of the present study. Often the success of a census could not be explained by the conditions recorded and it may be that other factors such as humidity or barometric pressure may be of greater single importance.

What can be concluded from the results of this study is that cool, windless mornings between the months of April and August are likely to result in the greatest number of birds and the greatest number of species being recorded. Hot, windy days between November and February, on the other hand, will result in fewer birds, fewer species and more exhausted fieldworkers.

8.3 OPTIMUM CENSUSING FREQUENCY

In order to gain an understanding of the characteristics of a bird community, a number of censuses need to be conducted. Determination of the optimum number of counts that need to be conducted, is therefore an important requirement in any monitoring programme. Results to this effect are presented and discussed below.

A glance at figure 8.3 shows that even after 40 censuses new species continue to be added to the list for each habitat. From these graphs it is clear that it would take a great deal of effort to record 90% of the species that were observed after 40 censuses. In the Milkwood Thicket and Strandveld about 25 censuses are needed to produce this data, while in the Fynbos as many as 28 counts are required.

While the 90% level may be needed for the purposes of research, it clearly cannot be justified for the purposes of ongoing and long term monitoring. The question is therefore posed as to whether a more modest requirement would not be sufficient to meet the needs of a monitoring programme.

In all three habitats most birds belong to a relatively few species. In the Milkwood between 58% and 74% of all birds are found amongst the 10 most abundant populations. In the Strandveld the 10 most common species constitute between 78% and 86% of the total abundance, while in the Fynbos this figure ranges from 85% to 92% of the total population. In the Milkwood and Strandveld two counts yield, on average, over 10 species, while in the Fynbos 9 species are on average recorded over two censuses. Thus most birds in each community can be recorded in only a few censuses.

Because of this finding, it would appear that a lower cut-off point is justified. It is suggested that the response time used in the physical sciences of (1-1/e), or 63% of the total, may be a more appropriate goal for data collection and one which would involve considerably less effort. Using this level, only 6 censuses in the Milkwood and Strandveld would be needed to provide 63% of all species recorded over 40 censuses, while in the Fynbos 8 counts would be required.

In conclusion, it should be pointed out that this analysis has been carried out without regard to weather or seasonal conditions or time of day. If data collection is done only in favourable conditions such as those proposed in the previous section, then clearly for the same effort, considerably more information will be yielded and the variation from one count to the next will be reduced.

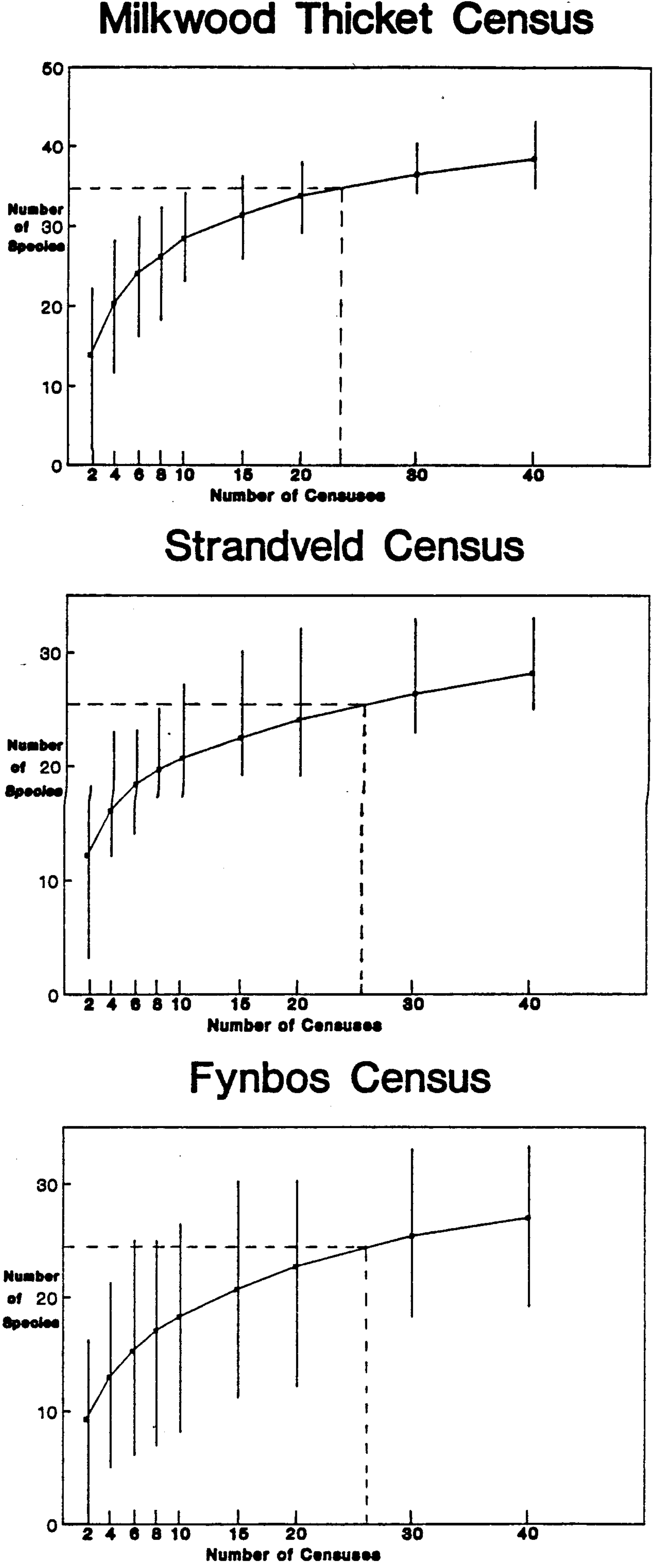


Figure 8.3 Number of species recorded with increasing numbers of censuses. Range between different plots is illustrated as is the number of counts required to yield 90% of the information after 40 counts.

8.4 SUMMARY

This chapter has investigated the various conditions affecting census results, the range of natural variation to be expected in the absence of disturbance, and the optimum number of times a census needs to be repeated in a plot in order to gain sufficient information concerning the characteristics of that particular avian community.

The use of biotic communities in monitoring studies is limited by the extent of temporal and spatial variation displayed by it. An understanding of the limits of that variation, the conditions under which variation may be minimised and the number of times a community needs to be counted in order to produce more homogenous results, can considerably increase the reliability of using birds as monitoring instruments.

CHAPTER 9

REVIEW AND CONCLUSIONS

This study arose out of two topical issues in the field of environmental resource management: conflict resolution and multiple land-use management. It set out to initiate the process of developing an integrated, reliable and workable monitoring programme, the underlying purpose of which was to further the aims of sound land management at De Hoop. It was, however, an initial study and its specific aims were rather less ambitious. Briefly these objectives were:

a) To provide a theoretical framework for an understanding of the scope, limitations and application of ecological monitoring;

b) To determine the value of birds as indicators of disturbance and, more particulary, to assess the feasibility of their incorporation into a monitoring programme;

c) To address ecological monitoring problems that are associated with an unpredictable environment;

d) To assess analytical techniques used in this study.

A review of the degree to which each of these objectives was achieved, and of the conclusions that were drawn, is presented below.

9.1 A FRAMEWORK FOR ECOLOGICAL MONITORING

This study attempted to introduce and provide a perspective of the nature, scope and limitations of ecological monitoring. Towards this end, the study focussed on birds as one class of organism that may hold promise as an indicator of disturbance. In this, it was emphasised that the study was more concerned with impacts to an ecosystem as a whole, rather than with changes in the bird populations themselves. For this reason, the study was less concerned with specific species, as it was with monitoring of groups or whole communities. Emphasis was placed on the need for monitoring to form an integral part of the management process.

A number of potential ecological indicators were described. These ranged from those that used individual species to detect environmental impact to those that employed whole communities of birds.

Finally, the principles of ecosystem development were used as a theoretical framework for the monitoring of ecosystem degradation. Degradation was seen as a reversal of the successional sequence which, because it conforms to a basic pattern and is therefore broadly predictable, has important implications for the management of natural systems.

In developing a framework for ecological monitoring, its multi-faceted nature and its practical and theoretical difficulties became evident, as did its potential, both as a management tool and as a means of detecting impacts. It is suggested that the obstacles that have so far hindered the wider application of ecological monitoring are not insurmountable, and that an attempt should be made to introduce a system of ecological monitoring at the Overberg Missile Test Range.

9.2 VALUE OF BIRDS AS INDICATORS OF DISTURBANCE

Ecological monitoring makes use of living organisms which act as convenient full-time monitors of environmental stresses (Thomas, 1972). According to Steele et al (1984), birds are suitable communities to monitor because they use a wide variety of food and other resources, and hence reflect the conditions of many aspects of an ecosystem.

By monitoring communities of birds, information from many ecosystem components may be integrated. Alternatively, communities may be subdivided into trophic groups or guilds so that changes in the total community may be related to changes of specific characteristics of an ecosystem.

Many species at De Hoop are resident. Their population levels therefore may be expected to reflect local conditions. Birds are also very mobile and are therefore likely to show a quick response to environmental change. As a community they are relatively easy to measure, being taxonomically well known, fairly conspicuous and abundant.

As a community, terrestrial birds were found to be selective of the environment in which they live and sensitive to disturbances which affect the resources on which they depend. This study has shown that birds can indeed be used to detect environmental disturbance, and has therefore paved the way for their incorporation into a viable ecological monitoring programme at the Overberg Missile Test Range, once certain difficulties have been overcome.

The finding that birds may be used to detect environmental disturbance was conclusively demonstrated in the Milkwood Thicket, but not in the Strandveld or Fynbos. Reasons for this include the following :

a) Impacts in the Milkwood Thicket were more severe than those in the Fynbos or Strandveld;

b) These impacts had a more direct effect on the resources utilized by the avian community;

c) Milkwood Thicket supports a considerably richer and more abundant bird community,and therefore the opportunities that exist for detecting disturbance and overcoming background noise are similarly greater.

The lack of definitive results in the Strandveld and Fynbos does not mean that birds are incapable of detecting disturbance in these habitats, nor does it invalidate the procedures that were employed. While a lower species richness and bird density may well reduce the effeectiveness of monitoring for disturbance, the lack of positive results may be explained by the mildness of the disturbances to which these habitats were subjected and the fact that these disturbances had little or no effect on the resources used by the avian community. The use of birds to detect for disturbance in any future ecological monitoring programme should, therefore, include Strandveld and Fynbos habitats as well as that of Milkwood Thicket.

9.3 FEASIBILITY OF USING BIRDS WITHIN ECOLOGICAL MONITORING

This study began with the premise that organisms which rely on the resources of a particular habitat (for feeding, breeding or shelter) are intimately connected with those resources and are affected by any changes to them. The nature and number of these organisms, therefore, is reflective of the ability of the land to support life, and may be used to detect changes in the habitat, and to answer questions regarding the general vigour of the system in question and the existence of any stresses threatening it.

The organism (or class of organism) chosen to fulfil such a task, however, must be sensitive to environmental change, must be suitably abundant and must be easy to detect, to identify and to measure. In all respects, birds appeared to be admirably suited for use in ecological monitoring and to have definite advantages over other categories of organism such as small mammals, antelope, reptiles or vegetation.

Ecological monitoring, however, still has a long way to go before it is considered an 'early warning system', with a number of practical and theoretical problems that must first be overcome.

An important obstacle impeding the more universal acceptance of ecological monitoring, is found in the difficulties of knowing when substantive change has taken place and when the system is under stress and in need of attention. There are numerous factors contributing to this most important aspect of monitoring.

Related to this, is the difficulty of distinguishing, out of the many potential causal factors, human-induced stress from naturally occurring stress. Ecological monitoring is designed to detect change in relation to stress, particularly slow-paced, cumulative changes. It attempts to discern trends and patterns in the data and relate these to known or suspected disturbances. The limits beyond which these identified trends may be attributed to anthropogenic factors, however, have yet to be precisely determined. So too, natural system thresholds beyond which degradation becomes irreversible, are not fully understood.

It is clear, therefore, that there are still obstacles to be overcome before ecological monitoring can be said to have 'come of age'. While birds appear to be well suited as indicators of change, their incorporation into a reliable and valid monitoring system has yet to be achieved.

Yet the goal of a reliable and useful monitoring programme is not impossible and the potential that such a goal holds is sufficient to warrant further research towards this end. In this respect the problems posed by an unpredictable environment may constitute a very useful avenue of research.

9.4 PROBLEMS POSED BY A DYNAMIC ENVIRONMENT

Birds, like most other biotic components of an ecosystem, are highly variable in time and space, and subject to numerous influences other than broad seasonal or climatic forces. The unpredictable nature of natural systems, is the most serious factor undermining the viability of ecological monitoring. Cost of any such programme is increased by the larger sample size and greater replication required. The reliability of statistical findings is also reduced, thus compounding the many difficulties of knowing if and when substantive change has occurred. Determination of substantive change is limited by the difficulties of adequately catering for type I and type II errors, and of distinguishing natural stress from human-induced stress. These problems, moreover, are common to all ecological monitoring programmes.

Clearly, the diverse and dynamic nature of natural systems lies at the root of many of the difficulties of ecological monitoring. The degree to which these difficulties are resolved, therefore, is in good measure dependent on the degree to which ways can be found of addressing the obstacles posed by a variable environment.

Ecosystems change in different ways: they follow a successional pattern of development; they change with each season during the course of a year; they are subjected to varying atmospheric conditions from one day to the next; and they are spatially diverse. This study has identified ways in which each of these components of variability may be to some extent resolved.

9.4.1 Seasonal Changes

The difficulties that seasonal changes pose for the identification of ecosystem stress, may be to some extent offset by an understanding of the limits to which bird populations are likely to fluctuate during the course of a year. Bird population levels which go beyond the limits, are a warning signal that the ecosystem in question may be under stress. Milkwood Thicket showed definite seasonal change, though large fluctuations in its bird populations could be expected from one month to the next. Strandveld populations displayed a remarkable stability, while fluctuations in the Fynbos could not be clearly defined as they did not appear to conform to any clear pattern. Indeed, the very low population levels in this community during the latter part of this study appeared to have moved beyond the limits of normal seasonal fluctuations, giving the impression that the community was under some form of stress. An examination of the poor condition of the vegetation of this habitat supported this hypothesis.

9.4.2 Daily Fluctuations

With respect to the incomplete and divergent data that results from daily changes in atmospheric conditions, two remedies are forwarded. First, by sampling only during the most favourable weather conditions, season and time of day, the efficiency of data collection will be improved and data yielded will be more complete and homogenous. These conditions were found to be cool, windless mornings between the months of April and August. A second remedy relates to the frequecy with which counts are repeated. It was found that the optimum sampling frequency required to produce a data set sufficiently complete for the purposes of monitoring, was six counts in each plot in the Milkwood and Strandveld communities, and eight counts in the Fynbos commnity. Should sampling be conducted under favourable conditions fewer censuses would be required to produce to an adequate data set.

9.4.3 Spatial Diversity and Succession

The task of detecting environmental change over time is further complicated in vegetation types that are not only spatially diverse, but also follow a relatively rapid cyclical pattern of succession, such as in the Fynbos. At different stages of succession within this vegetation, the composition of species is likely to be different - thus invalidating the comparison of plot measurements over time.

The solution to the problems posed by succession and a spatiially diverse environment, lies in the establishment of adequate control measures. The careful and meticulous selection of comparable control sites is again emphasised. Because of the time and effort demanded by such an exercise, it is recommended that, where possible, common sites are used for difficult monitoring programmes.

9.5 ASSESSMENT OF DATA ANALYSIS TECHNIQUES

One objective of this study was to assess the value of different analytical techniques in the interpretation of ecological data. Interpretation is an important aspect of ecological monitoring which, because of the complexity of biotic communities, is also a major stumbling block to its successful implementation.

The identification of birds as a class of organism that is sensitive to disturbance and easily measurable, is only the first step towards the establishment of a viable ecological monitoring programme. Birds, like all other biotic components of an ecosystem, are constantly responding to the opportunities and stresses presented by a dynamic environment. For this reason, ecological data are often both positive and negative in nature and, when analysed as a whole, may reveal information that is contradictory and of little substance or meaning. Data analysed in such a manner are merely an expression of the collective average of the whole spectrum of influences to which a community is subjected, and are unlikely to be of much benefit in the detection of anything but the most severe stresses, with all the lesser disturbances lost amid the collective clamour of a complex and varied environment.

It is in the lessening of this clamour that the crux to successful ecological monitoring lies, and the thrust of future efforts towards this end. Data will become meaningful to the extent to which techniques are devised which provide a more focussed approach and thereby serve to exclude all contradictory, neutralising signals in the environment so that trends and patterns in the data may be highlighted. An illustration of this may be seen in A.A.Milne's snail, James, who "gave the cry of a snail in danger. And nobody heard him at all." He was left unrescued, not because nobody knew he was there or because he was not understood, but rather because his boisterous friends were too noisy to allow his cry of help to be heard. Analytical techniques employed in this study were assessed for their ability to provide this more focussed approach, so that small, slow-paced, and apparently insignificant changes - like the disappearance of a snail - will not go unnoticed before it is too late.

Three categories of analytical techniques were employed in this study: correspondence analysis, measures of community characteristics and guild analysis.

9.5.1 Correspondence analysis

Correspondence analysis is a potentially useful tool in the analysis of multivariate data. By making use of both a visual display of vector profiles and contributions to inertia, associations and patterns in the data set may be revealed and subsequently tested. In this way, major influences responsible for the distribution and abundance of bird species may be identified. It is thus an exploratory method of data analysis well suited to the generation of hypotheses and the summarization and simplification of data. A particular strength of this technique, is its ability to indicate the quality of fit of the model to the data.

Unfortunately, correspondence analysis requires the services of a large computer and a person capable of interpreting the graphical display produced by it. Should conservation authorities ever have access to such resources, this technique may prove extremely useful for a wide range of monitoring applications.

9.5.2 Community characteristics

In contrast to the indicator species approach, which suffers from being too volatile a measure (in that a large number of factors unrelated to the health of the local ecosystem may influence populations of individual species) community measurements are too stable. In a single figure they attempt to characterise an entire bird community, and are therefore no more than an expression of the collective set of all environmental influences. As such they may be ambiguous, misleading and often lack sensitivity.

Species richness appeared in some instances to be able to detect disturbance, while density, because of an apparent compensation effect, was found to have no value as an indicator of disturbance. Biomass is a more sophisticated measure of density and is able to provide a clearer understanding of the carrying capacity of a system. As an indicator of environmental change, however, it suffers from the same limitations as species richness and density.

Diversity was another commonly employed community measurement which was tested in the present study. Indices of diversity reveal the spread of evenness of organisms among the species. Neither the Simpson nor the Shannon-Weiner diversity indices, revealed any ability to discriminate disturbed from undisturbed habitat. It is suggested that, while they are unsuited as comparative measures between sites, their sensitivity makes them more suitable as measures of community change at one site over a period of time. Their usefulness in this respect has yet to be tested. It is suggested that in any future attempts to use diversity, that both the Simpson and Shannon-Weiner indices should be employed.

The most effective measures of community change, it would appear, lie somewhere between the extremes of indicator species and community indicators. Indices of relative abundance and guild analysis, are two innovations which seek to achieve an enhancement of the data through a more focused approach to analysis.

The relative abundance technique selects groups of species likely to respond in the same manner to environmental disturbances, and in this way attempts to reduce background noise and enhance the detection of stress signals By comparing the relative abundance of each species between disturbed and undisturbed areas, it was possible to see if such groups of species existed. This proved to be the case in the denser, more varied and heavily disturbed Milkwood Thicket, where groups of 'disturbance loving' and 'disturbance intolerant' species were identified. While much potential is shown by such an approach, it needs to be further tested and possibly refined.

9.5.3 Guild analysis

Following this same approach, guild analysis attempts to systematise the selection of groups of species that respond similarly to environmental disturbance. Using Verner's (1984) adaptation of guild theory (in which a systematic methodology is proposed for the delineation of species into management guilds) it is possible to reflect something of the multifaceted nature of disturbances in terrestrial ecosystems. While guilds are perhaps not as sensitive as the groups identified by relative abundance, they have the advantage of enabling a researcher to compare different sectors of an ecosystem. In this way, the ecologically most important feeding and eating zones, and those that are most vulnerable to disturbances, may be identified. Because its rationale is based on anticipated impacts to the land, it is well suited as a management tool. By stratifying the habitat into zones according to likely impact , it is possible to group species acccording to how they similarly respond to disturbances in the environment. In this way disturbances which have a differential impact on each zone , or those which affect only particular sectors of the habitat may be identified where they would otherwise have been lost amid the many conflicting signals given by the data.

While Verner's system of guild analysis holds promise for the management of natural systems, it's value has yet to be fully substantiated and appreciated. It needs further testing and possibly refining (particularly in the area of identification of management zones). It is, nevertheless, relatively easy to use, is widely applicable and its inclusion as an analysis tool for monitoring and further testing is recommended.

This chapter has reviewed the findings made in this study. In the following chapter, recommendations concerning the establishment of a monitoring programme at the Overberg Missile Test Range will be made.

CHAPTER 10

RECOMMENDATIONS

10.1 IMPORTANT FEATURES OF THE AREA

Before embarking on any specific recommendations regarding the future management options of De Hoop Nature Reserve and the surrounding Overberg Missile Test Range, it would do well to consider a few important features of this subregion.

The very large area of land between Waenhuiskrans and Cape Infanta is owned by a single authority, tenure is secure and land usage is fixed. In addition, there is a commitment by the landowner to maintain the integrity of the natural ecosystems of the area, to upgrade disturbed land, and to conduct ongoing and long term monitoring. This same area encompasses a number of diverse ecosystems, some of which are representative of previously much larger ecosystems which have been considerably reduced in size by human activities. As such, the area fulfils two very important functions. Firstly, the protection of natural and semi-natural habitat serves to conserve ecosystems (and not merely individual species) thereby maintaining both biological diversity and stability of the biosphere. Secondly, these ecosystems are representative of major ecosystem types, and hence have much value as 'baseline' sites, research findings from which may be extrapolated for other areas (di Castri and Loope, 1977).

Another important feature of this subregion is the gradation in intensity of land usage that it displays. Land usage ranges from the pristine, unexploited core area of De Hoop Nature Reserve, to the old farmland bordering the reserve, to the large infrastructural developments occuring to the west of this area. By including natural as well as modified land within the same conservation area, a number of possibilities for applied research become possible.

Research conducted in undisturbed areas serves to improve our understanding of the structure, function and dynamics of natural ecosystems, and highlights their value as reservoirs of genetic material and providers of stability in the biosphere. By comparing these findings with those of modified areas, the effect of human exploitation may be better understood. In this way, questions concerning the ability of ecosystems to recover from disturbances, and the levels of disturbance beyond which ecosystems begin to degrade, may be addressed. Ways of developing modified ecosystems, particularly those which are beneficial to man, may then be found.

A final notable feature of the area may be found in the environmental education programme that has run at De Hoop Nature Reserve for a number of years. While the programme is centered around a particular establishment, it does make use of the various habitats found in the reserve.

The above features all contribute to shaping the many possibilities and problems that characterise the Overberg Missile Test Range, and hence need to be considered when making recommendations regarding a management plan for the area. Suggestions in this regard are presented below.

As it is a declared aim of the De Hoop Nature Reserve to conserve the integrity of the ecotypes found within its borders, it is strongly recommended that the entire area be treated as a single ecological unit and that it be managed as such. In this regard, attention is drawn to the recommendation made by the Hey Commission (1983), in which it is proposed that all land purchased in order to establish a weapons test range, excluding those portions required for the necessary infrastructure, be declared a nature reserve. It is suggested that management personnel be allowed greater access to those areas bordering De Hoop, so that they may take a more active role in managing and monitoring the area as a whole. If this is not possible, it is suggested that greater co-ordination between the different management authorities be practised.

For ecological monitoring to be meaningful, it must cover a wide range of facets of the environment. The monitoring of birds is limited in the breadth of information it is able to provide, and other programmes should be implemented to support and validate it. These programmes ought to be integrated so that results from each may serve, not only to validate or invalidate one another, but also to provide a fuller picture of the environment's ability to support life. Where possible, monitoring sites for different programmes should co-incide with one another. In this way, comparisons are facilitated, much time is saved in the important task of selection of sites, and associations between the different programmes may come to light over time and help to refine the monitoring process further.

Another recommendation suggests that the future monitoring and management of the Overberg Missile Test Range be guided by the principles embodied in UNESCO's Man and Biosphere Programme of biosphere reserves .

The biosphere reserve is an idea which arose as a response to the rapid alteration of natural ecosystems that is occuring worldwide as a result of human activity. It stresses the importance of setting aside sites representative of the world's major ecosystem types. The intention within these sites, is to combine ecological preservation of representative ecosystems, with research into the functioning of these ecosystems. Man-modified ecosystems are to be included in sites for comparative studies of natural and modified systems. Emphasis is placed upon conservation of ecosystems rather than conservation of individual species and upon providing sites for long-term continuity of research and monitoring. A further emphasis is that of environmental education. In all respects, therefore, the Overberg Missile Test Range appears to qualify as a biosphere reserve.

Thus far, many nations throughout the world have formally designated areas to be included into the international network of biosphere reserves (di Castri and Loope, 1977).

Biosphere reserves are similar to the United States programme of establishing National Environmental Research Parks, for the purpose of "developing techniques for quantitative and qualitative continuous assessment of the ecological impact of man's activities and technology" (Osburn, 1980).

The significance of biosphere reserves and National Environmental Research Parks in the present discussion, is that they represent a progression away from mere preservation of species or habitat towards a more active and experimental approach to management. Ecosystems are seen as outdoor laboratories, and management is viewed as a continuous learning process in which new techniques and ideas are devised, and tested for their ability to better achieve the stated objectives. In this way, according to Mentis (1984), management becomes more research-oriented and research becomes more management-oriented.

It is suggested that management of the ecosystems within the Overberg Missile Test Range would benefit greatly if it embraced more the spirit of Mentis's 'scientific management'. To do this, however, requires that the centrality of monitoring be recognised. It is to the practicalities of this important management function that we now turn.

10.2 NEED FOR OBJECTIVES

According to Mentis, the practice of monitoring, without periodically assessing the degree of goal attainment, is a contradiction in terms. Assessing goal attainment is done by testing the null hypothesis of no change in predefined properties of a system that is vulnerable to impacts (Mentis, 1984). Ecological monitoring, therefore, is fashioned by the particular goals set. At De Hoop Nature Reserve a goal, for example, may be to ensure that each ecosystem remains at its most productive and vigorous. This goal may then be translated into a determination to maintain bird density and species richness at their highest possible levels. In this way, the objective becomes operational and more easily assessed against the null hypothesis of no change. The objective, however, needs to be articulated clearly and precisely in order to be able to detect departures from it.

10.3 ANTICIPATED DISTURBANCES

Design of a monitoring programme is also guided by the nature of anticipated disturbances that threaten the attainment of management goals. Surveillance of these disturbances may help guide the implementation and refining of the programme itself. In addition, trends and patterns which are detected in the disturbances, and compared to changes in the biotic community, may also help to determine possible causes of ecosystem stress. In this respect, it is suggested that wherever possible, disturbances should be quantified.

Listed below are some of the disturbances that may be expected at De Hoop Nature Reserve. All are associated with a greater human presence, whether they be as a result of Armscor's activities or those of Nature Conservation.

Infrastructural development
Flood lighting
Air traffic
Uncontrolled fires
Livestock
Paths
Alien fauna and flora
Vegetable gardens
Sports fields
Roads
Vehicles
Noise
Fencing
Litter
Organic waste
Rubble
Poaching

10.4 SITE SELECTION

From the above disturbances, it is clear that De Hoop and its environs is to be used for a variety of purposes. Slow paced, cumulative impacts, therefore, are a distinct possibility, as are synergistic effects resulting from combinations of different disturbances. Such effects may only be detected by an integrated and sensitive monitoring system. Even with such a system, however, the identification of causal factors is likely to meet with limited success.

10.4.1 Location

Correct selection of monitoring sites determines, to a large degree, the quality of all resulting data. In the Strandveld, the new coastal road, observation stations and the Koppie Alleen Environmental Education Centre, would be obvious foci for monitoring sites. In the Fynbos, sites may be located near to the road to detect for possible effects of increased traffic flow. Of perhaps greater interest in this vegetation type, though, are the changes that will occur in the bird community as a result of vegetational succession after fire. In this respect, sites ought to be located in the blocks of land that form part of management's cycle of veld burning.

Disturbances in the Milkwood will continue to centred around the De Hoop homestead complex. New visitor and staff accommodation is planned in this area and the effects of this development will need to be closely watched.

Control sites ought to be chosen for each vegetation type, and for each successional stage within the different habitats. In the selection of comparable control sites, vegetational composition is paramount.

10.4.2 Size

In determining the size of each sample site, factors such as the nature of the organism being sampled, the homogeneity of the landscape, and the demands for cost-efficient monitoring, need to be weighed against one another. In the Fynbos, it is suggested that the vegetational mosaic be treated as an integral part of the landscape. In the Strandveld, too, it is not possible to separate the populations of birds inhabiting the Euclea Thickets that dot the landscape, from those that frequent the more widely dispersed Strandveld itself. In these vegetation types, therefore, large plots would more accurately express the richness and density of the birdlife.

Limited human resources and, in the case of the Fynbos, difficult terrain, require that plot size be kept as small as possible. The conflicting demands of efficiency and representativeness may both be met, it is suggested, with monitoring sites with an area of about 4 hectares each.

Milkwood Thicket, on the other hand, is far less extensive, more homogenous, and supports a considerably greater density of birds. Plots of 1.5 hectares, therefore, would suffice for the purposes of monitoring.

10.4.3 Shape

Long, rectangular plots (with the transect being the extreme example) are easier plots in which to collect data. Their greater 'edge-effect', however, makes them more vulnerable to influences around their perimeters, thus exacerbating the difficulties of selecting comparable plots. The closer the plot is to being square, therefore, the easier it is to define its characteristics and to compare it with others.

10.4.4 Replication

The replication of plots determines, in large measure, the power with which statistical inferences may be made from the data. It also adds to the cost of monitoring. By striving to ensure that each plot is representative of the habitat in which it is set, however, the replication of plots may be kept to a minimum. Once again, therefore, it is strongly suggested that much care be taken in selecting plots. Because of the time and effort involved in such an exercise, it is also suggested that, where possible, these same sites be used to coincide with other monitoring programmes.

10.5 DATA COLLECTION

The collection of data must be standardised to allow for comparison over time, and must be conducted as efficiently as possible so that the information content of each sampling effort is maximised.

It is suggested that a bird list of all commonly encountered species be prepared, so that observations may be swiftly recorded. Together with this list all other relevant information should be recorded, such as plot number, date, time of day and prevailing environmental conditions. With respect to the latter category, information such as temperature and wind conditions may prove useful in later analysis of the data. These two factors, however, are by no means the only ones determining the activity levels of birds, and it is suggested that other possible factors, such as humidity and barometric pressure, be explored. Finally, space should be made to record information on the flowering and fruiting of plants, and the nesting and feeding behaviour of bird species.

With respect to the censusing of birds, it is suggested that the procedure used during the present study be followed. That is, the fieldworker moves through the plot in a systematic pattern, stopping regularly to listen, and recording all birds seen or heard within it. Clearly, some species are more conspicuous and more mobile than others. Care should therefore be taken not to overlook shy species and not to exaggerate the numbers of conspicuous ones. To reduce discrepancies in data collection, systematic fieldwork, conservative measurements and standardised procedures should be emphasised, and the competence of new fieldworkers ought to be established.

10.6 MANAGING THE OVERBERG MISSILE TEST RANGE

This study had its origins in the Hey Commission of 1983, which was established to investigate the apparent conflict of land uses that arose with the announcement that Armscor intended building a missile test range on the Southern Cape coast.

Its appointment was an expression of the immense value of the large and relatively undeveloped tract of land between Waenhuiskrans and Cape Infanta. It was also an affirmation of the right of the public both to be informed on matters affecting communal resources, and to insist on their continued well-being. This right still exists, and the recommendations and conditions laid down by the commission still hold.

In agreeing to allow weapons testing to proceed alongside environmental conservation, the commission heralded in a new era of land ownership and usage for the subregion, with the future well-being of the natural environment entrusted to the hands of Armscor.

It is five years since the commission was first appointed and much infrastructural development has already occured. Yet very little has been heard of the progress made with respect to the management of the area, the detection of impacts, or the compliance with conditions agreed to in the commission's report.

This report, therefore, recommends that the authority responsible for the area take stock of the very great responsibililty with which it has been entrusted, and recognises its accountability to the broader public with respect to its stewardship of the subregion.

It is recommended that the area be recognised as a single ecological and management unit, and that an active and experimental management policy be pursued along the lines of the UNESCO's Man and Biosphere Programme of biosphere reserves.

Active management, impact detection and communication are all encapsulated in the functions of a monitoring programme. If such a programme were to be successfully established, and if it were able to employ living material to indicate the ability of each ecosystem to support life, it would go a long way towards reassuring a sceptical public, improving management's knowledge of the natural environment and ensuring the long-term well-being of the area.

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APPENDIX 1 (A)

Relative abundances of bird species in Undisturbed Milkwood Thicket.

Cape Robin	*Cossypha caffra*	13%
Barthroated Apalis	*Apalis thoracica*	9%
Cape Batis	*Batis capensis*	9%
Sombre Bulbul	*Andropadus importunus*	8%
Spotted Prinia	*Prinia maculosa*	8%
Cape White-eye	*Zosterops pallidus*	6%
Cape Turtle Dove	*Streptopelia capicola*	6%
Speckled Mousebird	*Colius striatus*	5%
Cape Bulbul	*Pycnonotus capensis*	4%
Southern Tchagra	*Tchagra tchagra*	3%
Lesser Doublecollared Sunbird	*Nectarinia chalybea*	3%
Southern Boubou	*Laniarius ferrugineus*	3%
Cape Francolin	*Francolinus capensis*	2%
Common Waxbill	*Estrilda astrild*	2%
Cape Bunting	*Embriza capensis*	1%
Whitethroated Canary	*Serinus albogularis*	1%
European Starling	*Sternus vulgarus*	1%
Water Dikkop	*Burhinus vermiculatus*	1%
Fiscal Flycatcher	*Sigelus silens*	1%
Redfaced Mousebird	*Colius indicus*	1%
Pied Starling	*Spreo bicolor*	.9%
Longbilled Crombec	*Sylvietta rufescens*	.9%
Hoopoe	*Upapa epops*	.8%
Cape Weaver	*Ploceus capensis*	.8%
Fierynecked Nightjar	*Caprimulgus pectoralis*	.6%
Knysna Woodpecker	*Campethera notata*	.6%
Cardinal Woodpecker	*Dendropicos fuscescens*	.6%
Fiscal Shrike	*Lanius collaris*	.6%
Malachite Sunbird	*Nectarinia famosa*	.6%
Southern Grey Tit	*Parus afer*	.5%
Pied Barbet	*Lybius leucomelas*	.4%
Spotted Eagle Owl	*Bubo africanus*	.3%
Forktailed Drongo	*Dicrurus adsimilis*	.3%
Cape Sparrow	*Passer melanurus*	.3%

Cape Wagtail	*Motacilla capensis*	.3%
Redwinged Starling	*Onychognathus morio*	.3%
Yellow Canary	*Serinus flaviventris*	.3%
Olive Woodpecker	*Mesopicos griseocephalus*	.2%
Bokmakierie	*Telophorus zeylonus*	.1%
Greater Honeyguide	*Indicator indicator*	.1%
Rameron Pigeon	*Columba arquatrix*	.1%
Cape Penduline Tit	*Anthoscopus minutus*	.1%
Klaas's Cuckoo	*Chrysococcyx klaas*	.05%

APPENDIX 1 (B)

Relative abundances of bird species in Disturbed Milkwood Thicket

Speckled Mousebird	*Colius striatus*	11%
Spotted Prinia	*Prinia maculosa*	8%
Cape Robin	*Cossypha caffra*	8%
Cape Turtle Dove	*Streptopelia capricola*	6%
Barthroated Apalis	*Apalis thoracica*	5%
Lesser Doublecollared Sunbd	*Nectarinia chalybea*	4%
Cape Sparrow	*Passer melanurus*	4%
Sombre Bulbul	*Andropadus importunus*	4%
Whitethroated Canary	*Serinus albogularis*	3%
Southern Tchagra	*Tchagra tchagra*	3%
Cape White-eye	*Zosterops pallidus*	3%
Cape Francolin	*Francolinus capensis*	3%
Helmeted Guineafowl	*Numida meleagris*	2%
Bokmakierie	*Telophorus zeylonus*	2%
Cape Bulbul	*Pycnonotus capensis*	2%
Fiscal Flycatcher	*Sigelus silens*	2%
Fiscal Shrike	*Lanius collaris*	2%
Laughing Dove	*Streptopelia senegalensis*	2%
Longbilled Crombec	*Sylvietta rufescens*	1%
Pied Barbet	*Lybius leucomelas*	1%
Southern Boubou	*Laniarius ferrugineus*	1%
Cape Bunting	*Emberiza capensis*	1%
Hoopoe	*Upupa epops*	1%
Cape Weaver	*Ploceus capensis*	1%
Spotted Dikkop	*Burhinus capensis*	1%
Redeyed Dove	*Streptopelia semitorquata*	.9
Redfaced Mousebird	*Colius indicus*	.7%
Cape Wagtail	*Motacilla capensis*	.5%
Malachite Sunbird	*Nectarinia famosa*	.5%
Greybacked Cisticola	*Cisticolla subruficapilla*	.5
Greywing Francolin	*Francolinus africanus*	.5%
Cape Batis	*Batis capensis*	.4%

Common Waxbill	<u>Estrilda astrild</u>	.4%
Pied Starling	<u>Spreo bicolor</u>	.2%
Crowned Plover	<u>Stephanibyx coronatus</u>	.2%
Rock Pigeon	<u>Columba guinea phaenota</u>	.1%
Greater Honeyguide	<u>Indicator indicator</u>	.1%

APPENDIX 1 (C)

Relative abundances of bird species in Undisturbed Fynbos

Lesser Doublecollared Sunbd	Nectarinia chalybea	21%
Greybacked Cisticola	Cisticola subruficapilla	15%
Karoo Robin	Erythropygia coryphaeus	14%
Spotted Prinia	Prinia maculosa	11%
Cape Bunting	Emberiza capensis	5%
Cape Bulbul	Pycnonotus capensis	4%
Grassbird	Spenoeacus afer	3%
Yellow Canary	Serinus flaviventris	3%
Malachite Sunbird	Nectarinia famosa	3%
Cape Robin	Cossypha caffra	2%
Bokmakierie	Telophorus zeylonus	1%
Cape Turtle Dove	Streptopelia capicola	1%
Cape Penduline Tit	Anthoscopus minutus	1%
Whitethroated Canary	Serinus albogularis	.8%
Longbilled Crombec	Sylvietta rufescens	.8%
Longbilled Lark	Mirafra curvirostris	.7%
Clapper lark	Mirafra apiata	.7%
Cape White-eye	Zosterops pallidus	.5%
Fiscal Shrike	Lanius collaris	.4%
Cape Francolin	Francolinus capensis	.4%
Cape Sugarbird	Promerops cafer	4%
Speckled Mousebird	Colius striatus	.3%
Orangebreasted Sunbird	Nectarinia violacea	.3%
Yellowrumped Widow	Euplectes capensis	.3%
Barthroated Apalis	Apalis thoracica	.2%
Cape weaver	Ploceus capensis	.2%

Redfaced Mousebird	*Colius indicus*	.2%
Southern Tchagra	*Tchagra tchagra*	.2%
Greywing Francolin	*Francolinus africanus*	.2%
Black Korhaan	*Eupodotis afra*	.1%
Rufouscheeked Nightjar	*Caprimulgus rufigena*	.1%
Fiscal flycatcher	*Sigelus silens*	.08%
Cape Sparrow	*Passer melanurus*	.04%
Fierynecked Nightjar	*Caprimulgus pectoralis*	.04%

APPENDIX 1 (D)

Relative abundances of bird species in Disturbed Fynbos

Lesser Doublecollared Sunbd	*Nectarinia chalybea*	24%
Greybacked Cisticola	*Cisticola subruficapilla*	13%
Spotted Prinia	*Prinia maculosa*	9%
Karoo Robin	*Erythropygia coryphaeus*	8%
Cape Bunting	*Emberiza capensis*	6%
Cape Bulbul	*Pycnonotus capensis*	4%
Cape Sugarbird	*Promerops cafer*	3%
Cape Robin	*Cossypha caffra*	3%
Grassbird	*Spenoeacus afer*	3%
Orangebreasted Sunbird	*Nectarinia violacea*	3%
Malachite Sunbird	*Nectarinia famosa*	2%
Cape White-eye	*Zosterops pallidus*	2%
Yellow Canary	*Serinus flaviventris*	2%
Cape Turtle Dove	*Streptopelia capicola*	1%
Bokmakierie	*Telophorus zeylonus*	1%
Longbilled Crombec	*Sylvietta rufescens*	1%
Cape Weaver	*Ploceus capensis*	.9%
Longbilled Lark	*Mirafra curvirostris*	.8%
Whitethroated Canary	*Serinus albogularis*	.8%
Fiscal Shrike	*Lanius collaris*	.7%
Cape Pendulite Tit	*Anthoscopus minutus*	.6%
Speckled Mousebird	*Colius striatus*	.6%
Sombre Bulbul	*Andropadus importunus*	.5%
Greywing Francolin	*Francolinus africanus*	.5%
Sombre Bulbul	*Andropadus importunus*	.5%
Cape Francolin	*Francolinus capensis*	.4%
Southern Boubou	*Laniarius ferrugineus*	.3%
Clapper Lark	*Mirafra apiata*	.3%
Redfaced Mousebird	*Colius indicus*	.2%
Southern Tchagra	*Tchagra tchagra*	.2%

Barthroated Apalis	<u>Apalis thoracica</u>	.2%
Forktailed Drongo	<u>Dicrurus adsimilis</u>	.2%
Namaqua Dove	<u>Oena capensis</u>	.1%
Fiscal Flycatcher	<u>Sigelus silens</u>	.08%
Yellowrumped Widow	<u>Euplectes capensis</u>	.08%
Rufouscheeked Nightjar	<u>Caprimulgus rufigena</u>	.08%
Laughing Dove	<u>Streptopelia senegalensis</u>	.04
Fierynecked Nightjar	<u>Caprimulgus pectoralis</u>	.04%
Black Korhaan	<u>Eupodotis afra</u>	.04%

APPENDIX 1 (E)

Relative abundances of bird species in Undisturbed Strandveld

Lesser Doublecollared Sunbd	*Nectarinia chalybea*	15%
Cape Bulbul	*Pycnonotus capensis*	13%
Greybacked Cisticola	*Cisticola subruficapilla*	10%
Spotted Prinia	*Prinia maculosa*	8%
Yellow Canary	*Serinus flaviventris*	8%
Cape Robin	*Cossypha caffra*	7%
Sombre Bulbul	*Andropadus importunus*	5%
Speckled Mousebird	*Colius striatus*	4%
Cape Bunting	*Emberiza capensis*	4%
Redwinged Starling	*Onychognathus morio*	4%
Grassbird	*Spenoeacus afer*	3%
Cape White-eye	*Zosterops pallidus*	3%
Barthroated Apalis	*Apalis thoracica*	2%
Cape Turtle Dove	*Streptopelia capicola*	1%
Southern Tchagra	*Tchagra tchagra*	1%
Whitethroated Canary	*Serinus albogularis*	1%
Common Quail	*Coturnix coturnix*	.8%
Bokmakierie	*Telophorus zeylonus*	.7%
Cape Francolin	*Francolinus capensis*	.7%
Fiscal Shrike	*Lanius collaris*	.5%
Longbilled Crombec	*Sylvietta rufescens*	.3%
Greywing Francolin	*Francolinus africanus*	.2%
Redfaced Mousebird	*Colius indicus*	.2%
Southern Boubou	*Laniarius ferrugineus*	.1%
Malachite Sunbird	*Nectarinia famosa*	.1%
Greater Honeyguide	*Indicator indicator*	.1%
Rock Pigeon	*Columba guinea*	.1%
Streakyheaded Canary	*Serinus gularis*	.1%
Ground Woodpecker	*Geocolaptes olivaceus*	.09%
Cape Weaver	*Ploceus capensis*	.04%

APPENDIX 1 (F)

Relative abundances of bird species in Disturbed Strandveld

Cape Bulbul	_Pycnonotus capensis_	14%
Lesser Doublecollared Sunbd	_Nectarinia chalybea_	14%
Greybacked Cisticola	_Cisticola subruficapilla_	10
Spotted Prinia	_Prinia maculosa_	9%
Yellow Canary	_Serinus flaviventris_	9%
Cape Robin	_Cossypha caffra_	6%
Grassbird	_Spenoeacus afer_	5%
Cape Bunting	_Emberiza capensis_	5%
Speckled Mousebird	_Colius striatus_	3%
Cape White-eye	_Zosterops pallidus_	3%
Sombre Bulbul	_Andropadus importunus_	2%
Barthroated Apalis	_Apalis thoracica_	2%
Redwinged Starling	_Onychognathus morio_	2%
Cape Turtle Dove	_Streptopelia capicola_	1%
Cape Francolin	_Francolinus capensis_	1%
Southern Tchagra	_Tchagra tchagra_	1%
Whitethroated Canary	_Serinus albogularis_	1%
Bokmakierie	_Telophorus zeylonus_	.6%
Longbilled Crombec	_Sylvietta rufescens_	.6%
Blackcrowned Night Heron	_Nycticorax nycticorax_	.5%
Pied Barbet	_Lybius leucomelas_	.3%
Common Quail	_Coturnix coturnix_	.2%
Fiscal Shrike	_Lanius collaris_	.1%
Southern Boubou	_Laniarius ferrugineus_	.1%
Malachite Sunbird	_Nectarinia famosa_	.05%
Fiscal Flycatcher	_Sigelus silens_	.05%
Hoopoe	_Upupa epops_	.02%
Greywing Francolin	_Francolinus africanus_	.02%
Pied Starling	_Spreo bicolor_	.02%

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