Long-term research in western Namibia identifies fundamental processes underlying biodiversity

JOH R. HENSCHEL, MARY K. SEELY & JULIANE ZEIDLER

Desert Research Foundation of Namibia, Gobabeb Training & Research Centre,
P.O.Box 953, Walvis Bay, Namibia, email: gobabeb@iafrica.com.na

Running Title: Long-term research

ABSTRACT

Long-term research (LTR) is valuable for understanding biodiversity processes in arid countries like Namibia. They are also essential for many socio-economic and environmental factors that affect natural resource management and environmental integrity, processes that can ultimately affect biodiversity. Using a wealth of knowledge accumulated over the years in the Central Namib Desert and, more recently, in rural communal areas in western Namibia, the Desert Research Foundation of Namibia (DRFN) is using LTR to connect basic and applied research in an appropriate manner. Various projects concern climate, the biophysical environment, plants, animals, and humans. Examples are given of how these projects are interrelated and how they serve many social and environmental functions in rural Namibia.

INTRODUCTION

Thirty-six years of research in the Namib has enabled the Desert Research Foundation of Namibia (DRFN) to gain significant knowledge on ecosystem processes and biodiversity dynamics (changes) under arid conditions. It is using this knowledge to further the awareness on arid lands and to promote the capacity to manage them appropriately. At the core of this process of gaining understanding, applying it, and monitoring the effectiveness of applications, are long-term research programmes.

Here we use the more general term Long-Term Research (LTR) instead of the more specific ecologically-oriented Long-Term Ecological Research (LTER) (Franklin, Bledsoe & Callahan, 1990; Risser, 1995; Gosz, 1996) in order to incorporate the joint emphases of socio-economic and biophysical factors. LTR projects of the DRFN are an invaluable information source and theoretical framework, not only on environmental processes, but also for generating environmental publications, providing educational opportunities, influencing decision-makers, and training students. They guide sustainable resource management processes and other forms of integrating the socio-economic with the biophysical aspect. Furthermore, long-term studies provide baseline data sets that facilitate the interpretation of short-term studies and provide the connecting framework between different short-term studies. A developing country like Namibia can ill afford to be without LTRs to guide the development process.

Subject to these ultimate goals, the DRFN LTRs have the following proximate objectives: 1) to identify and gain knowledge of long-term environmental phenomena and how short-term studies reflect these; 2) to examine the role of episodic events that may be important despite their rarity; 3) to contribute to the scientific basis of environmental management; 4) to provide data for predictive modelling at large spatial and temporal scales; and 5) to monitor and evaluate changes caused by changes in human activities.

Most of Namibia is arid (Seely & Jacobson, 1994). It has been suggested that in arid regions climatic patterns are very important for population dynamics, biodiversity patterns and other ecosystem processes. Desert organisms are believed to have highly variable, unpredictable populations that are mainly influenced by episodic events rather than by community processes (Wolda, 1978; Weatherhead, 1986). Despite a plethora of studies of one or several year's duration that have addressed this question, the most important long-term significance is rarely addressed. A better understanding of community ecology in deserts is crucial to facilitate the management of biophysical environments facing changes due to land use or climate change.

The long data sets that the DRFN is compiling in the Central Namib Desert (mostly by the Desert Ecological Research Unit, DERU, a branch of DRFN) are of landmark value, as they are unique for hyper-arid environments of the world. Despite the remoteness of Gobabeb in the middle of the desert and in a conservation area (the Namib-Naukluft Park), LTRs conducted there are of country-wide, sub-continental, and global significance. Namib LTRs provide a window into the importance of episodic events and facilitates their interpretation in other regions. By conducting LTRs in a conservation area with relatively little direct human impact, natural processes can be examined, enabling a comparison with relatively more human-influenced environments elsewhere. Furthermore, DRFN can draw on over 2000 published studies on the Namib, which form an important component of its LTR programme.

LTRs are indispensable for the ultimate understanding of biodiversity processes, the subject of this paper. For example, knowledge of long-term processes is required to understand the ultimate relationship between biodiversity and land-uses and management practices, including communal and commercial farming (Seely & Jacobson, 1994). This is embodied in several national programmes, e.g., the Namibian Programme to Combat Desertification (Napcod) and Namibia's National Biodiversity Programme. Humans are an important part of the environment. Research on human-induced environmental changes needs to incorporate both ecological and socio-economic factors so that it can be geared towards promoting change in human behaviour when this is recommended (Behnke & Scoones, 1992; Zeidler, 1998). Ecological and socio-economic databases and monitoring programmes are thus combined.

In this paper, we outline several DRFN-LTR projects and how they relate to biodiversity and other ecological processes. These projects cover a spectrum ranging from climatic and biophysical environmental monitoring to population dynamics in animal-, plant- and rural human communities. We briefly describe our research on the dynamics of particular plant and animal communities in order to emphasise the relevance of such studies to understanding and managing both the natural and the human environments. We concentrate on the example of one particularly good environmental indicator group, the tenebrionid beetles (Tenebrionidae, Coleoptera) to demonstrate how these can be used to understand both biodiversity trends and its relationship to human-related impact.

Besides outlining the proximate aims, procedures and gaps of some of these projects, we also describe some of the data bases that are being generated and how these can ultimately fit into biodiversity-related goals in Namibia (Table 1). In describing new DRFN-LTRs being initiated at Napcod sites outside the Namib Desert, we emphasise the importance of involving people, not only by raising awareness concerning their environment, but by facilitating the process by which rural communities become an integral part of the management of biodiversity in Namibia. Indeed, human and livestock populations become subjects of LTRs that monitor the implications which such human-related processes as rangeland management, migration, and changes of lifestyle have for the natural environment and biodiversity processes.

STUDY AREAS AND GENERAL METHODS

DRFN has several LTR sites in the Central Namib, centred around the Gobabeb Training and Research Centre (23°33'S, 15°02'E). Study sites are in the three major habitats characterising the Central Namib, on the gravel plains, in the Kuiseb riverbed and in the dunefield of the Great Sand Sea. The general climatic, geological, geomorphological and ecological conditions were described e.g. by Besler (1972b), Goudie (1972), Robinson (1978), Robinson & Seely (1980), Lancaster, Lancaster & Seely (1984) and Seely (1990b). Study sites are monitored at regular intervals, varying between projects from daily to monthly, seasonally, annually, or at intervals of several years. Some projects were initiated by short-term research projects when the methods and monitoring protocol were established. Monitoring then continued after the publication of initial results identified the potential value of long-term data.

The first Napcod sites where DRFN has been establishing LTR are situated in the communal farming areas of former Owamboland in northern Namibia (Omusati, Oshana, Oshikoto and Ohanguena Regions) and in the former Damaraland in north-western Namibia (Kunene Region). The north-west sites include farms with a background of commercial, communal and alternating commercial/communal land tenure on the so-called Odendaal farms. In the current paper we use one of the communal farms, Olifantputs (20°26'S, 14°96'E), as example. LTR at the Napcod sites follows the guiding principles of the Convention to Combat Desertification (CCD), such as conducting participatory, community-based and community-relevant research (UNEP, 1995). Besides the establishment of ecological monitoring programmes focusing on climatic, vegetative, soil-related and biotic components of the environment, it is considered important to monitor human-related aspects such as the history of land use practices (Kambatuku, 1996), human and livestock population dynamics and migratory patterns, changes in the use of natural resources and human lifestyles (Zeidler *et al.*, 1998a). The local farmers are actively involved with the DRFN in the collection, management, and interpretation of data.

THE PROJECTS

Climate

Long-term weather data are fundamental to the understanding of biodiversity processes in the desert (see below). At Gobabeb, weather has been recorded continuously since 1962 at the First Order Weather Station of the Namibian Meteorological Services (Table 1). Furthermore, DRFN operates a network of autographic weather stations covering an area of 10 000 km^2. Of the 45 stations, there are four main ones that are operated continuously. Currently, these are using electronic data loggers and software (Mike Cotton Systems, Steenberg, South Africa). Data are logged and transcribed at hourly intervals.

These records enable one to characterise Namib climate (Lancaster *et al.*, 1984) and they also document episodic events, such as rare, heavy rainfall, or a poor fog season, heavy sand storm, or heat wave. For example, the sources of surface water at Gobabeb differ in their variability. Fog from the Atlantic Ocean is the most regular source (mean = 39 mm per annum; CV = 43%), while summer rain is highly sporadic (11.3 mm; CV = 250%), as is winter rain (4.0 mm; CV = 217%). Runoff in the ephemeral Kuiseb river from rainfall in the inland catchment in the Khomashochland occurs nearly every year, but differs in duration (18 days; CV = 150%). The norms and exceptions in climate are very important in understanding the composition of biotic communities in the Central Namib (Seely, 1978a, b; Robinson, 1978; Seely & Louw, 1980; Seely, 1990a; Berry & Siegfried, 1991; Hachfeld, 1996; Jacobson, 1996, 1997; Jacobson & Jacobson, 1998; Henschel, Seely & Polis, in prep.).

As an important climatic feature of the Namib, fog has been examined since over 60 years (e.g., Walter, 1937) and the DRFN has monitored it since the inception of Gobabeb in 1962 (Lancaster *et al.*, 1984). In the last two years monitoring has been intensified with the aim of evaluating the possibility of harvesting this water source for domestic use in the western Namib Desert (Henschel *et al.*, 1998). The LTR data series is invaluable for this application.

Since the beginning of 1997, rainfall data are collected at DRFN sites in southern Kunene region by communal farmers in a participatory manner, i.e. the farmers and other community members monitor the rain gauges and keep records. Data analyses and interpretation are collaborative with field staff of the Napcod project. Discussions facilitate the understanding of the spatial and temporal variability of rainfall, which assist the farmers in planning sustainable resource management.

Biophysical Environment

The effect of dune dynamics in the Namib desert has been monitored since 1970 (Table 1). Such measurements were established to monitor the geomorphological processes of dune movements *per se* as well as the relation thereof to the biotic system. It has been suggested that the high diversity of certain taxa such as tenebrionids in the Namib Desert can be explained by the mobility and changing configuration of sand dunes (Endödy-Younga, 1982; Penrith, 1986; Irish, 1990). Populations of psammophilous animals become geographically isolated from conspecifics when their dune moves to other areas. Conversely, two dunes that were previously interconnected may become isolated when their configurations change. The Namib Great Sand Sea has many types of dunes with different configurations and dynamics changing along an east-west gradient (Lancaster, 1989). The middle of the dunefield, including the area south of Gobabeb, is dominated by long linear dunes. Since Besler's (1970, 1972a) initial study, DRFN has monitored the physical dynamics of one such linear dune on a monthly basis. This is done by measuring the height of 26 poles placed across the lip of the dune. Analyses of these data contributes to the debate on the biogeographical mechanisms affecting Namib organisms.

The impact of off-road vehicles (ORV) on the desert surface have been monitored since 1978 (Seely & Hamilton, 1978; Daneel, 1992a,b). Vehicles change the properties of the soil, including the desert pavement, calcrete and gypsum crusts, as well as the biota, particularly lichens and dwarf shrubs. For example, ORVs reduce the microtopography and push stones and lichens into the soil, thereby reducing surfaces for lichens to grow on and impeding their recovery; a fresh ORV track destroys 80% of the lichens (Daneel, 1992a). These properties take a long time to recover (Eckardt, 1996) and long-term studies are required to monitor recovery. Seely & Hamilton (1978) and Daneel (1992a), respectively, placed control tracks in an interdune and several gravel plain areas in the Namib respectively. By monitoring these tracks at intervals of several years, the DRFN is learning about the recovery process, including that of lichen fields.

Soil processes play a major role in sustaining productivity of agricultural production areas, including crop-lands as well as range systems (Greenland & Szabolcs, 1994). This is important particularly in view of the concerns about desertification and land degradation in Namibia, but also for biodiversity research because many soil process are mediated by the soil biota (Anderson, 1994). The monitoring of soil processes is part of a long-term research project of DRFN at selected Napcod sites in southern Kunene region (Table 1). This concerns the biological integrity of farms under different land tenure and different land-use intensities, with particular emphasis on the communal farm Olifantputs. At six different monitoring plots of 1 ha each, soil parameters such as nutrient status and biophysical parameters are measured twice a year since 1997. This is done to gauge the impact of human-induced changes on rangeland and habitat condition in western Namibia (Zeidler *et al.*, 1998a). These data are correlated with the biodiversity of soil organisms (see below).

The Kuiseb river ecosystem has been studied from the biophysical and ecological perspectives (Table 1). Since 1963 floods and groundwater level have been monitored, and on several occasions since 1976, aerial photographs were taken (e.g. Huntley, 1985; Jacobson, Jacobson & Seely, 1995a). The effect of changes, natural as well as human induced, on vegetation and ultimately wild and domestic animals are recorded (e.g. Hamilton, Buskirk & Buskirk, 1977; Seely, Buskirk & Hamilton, 1980; Theron & van Rooyen, 1980; Gabriel, 1992; Zeidler, 1995). Such studies were the departure point for the ephemeral rivers project that established similar monitoring points in other ephemeral rivers throughout north-western Namibia during 1994 (Jacobson *et al.*, 1995a), and these are periodically revisited. This scientific information has been transferred into public documents including decision-maker's guides (Jacobson *et al.*, 1995a), a video and a map (Doxa, 1995; Jacobson *et al.*, 1995b). These materials address issues related to the use of natural resources, explaining biodiversity and other important ecological concepts to laymen and form a good example of how DRFN is using its long-term research results for applied purposes.

Vegetation

The vegetation of the Kuiseb river has been subject to a monitoring programme initiated by DRFN in the '70s (see above).

Long-lived plants are affected by long-term processes and long-term study is required to understand these. *Welwitschia mirabiles* is a widespread endemic of the central and northern Namib (Bornman, 1978). In some areas it is the dominant perennial vegetation present and may serve as shelter or food source for various animals. As the only member of the family Welwitschiaceae, this plant is a botanical curiosity and is protected. Marsh (1982, 1987, 1990) and Brinckman & von Willert (1987) emphasised that it is important to know more about the phenology of this plant and its satellite fauna in order to improve the management of Welwitschia fields. Accordingly, the DRFN initiated a monitoring programme in 1981 in which the degree of leaf growth is measured at monthly intervals on 11 male and 10 female plants. By comparing these data with other environmental data (e.g., annual climatic parameters & season), it should be possible to identify and characterise those factors that influence plant growth, reproduction, and survival. Such a data set developed based on Welwitschia can serve as a model for other plants surviving under similar conditions.

For similar reasons, a new project has been launched recently by DRFN monitoring another long-lived and potential keystone species of the Namib dunes (Klopatek & Stock, 1994), the

!Nara *Acanthosicyos horridus* (Cucurbitaceae). This long-lived plant appears to be affected by various environmental factors, such as climate, ground-water availability, herbivory and fruit harvesting (Dentlinger, 1977), while plant condition may affect numerous invertebrates and vertebrates that feed on or shelter in it. The fruits of this plant are used by the local Topnaar people as a cash-crop. This introduces a different perspective to the potential biodiversity research on this plant, including studies on population genetics, which should be linked with long-term monitoring.

Grass is a major source of primary productivity and the generation of detritus and forms the basis of a major food web. For example, Seely (1990b) described the long-term development of hummocks of the perennial dune grass *Stipagrostis sabulicola*, which are being monitored at intervals of several years since 1976. In some areas, *S. sabulicola* is the only food for herbivores during long dry spells. Ephemeral grasses germinate and can complete their life cycle after a minimum rainfall event of 10-12 mm (Seely, 1978a, b; Jacobson, 1992; Günster, 1993) and the biomass increases with increasing rainfall. In most years since 1988, the annual distribution of ephemeral grasses have been monitored in the central Namib (Günster, 1995). This provides not only information on the primary productivity of Namib desert plains after rainfall events but information that may also explain biogeographic patterns in other organisms such as tenebrionid beetles (see below) and gemsbok.

Another important LTR project with a strong element of biodiversity is the re-examination of all plant communities on the gravel plains of the southern Central Namib (Hachfeld, pers.comm.) over 20 years after Robinson's (1976) study. By comparing the spatial distribution of various plant species and of the species composition of various communities, long-term changes in community development can be determined. Furthermore, this study is providing an invaluable baseline for understanding plant biogeography (and associated fauna; e.g., Wharton, 1980) in the Namib (Hachfeld, 1996). Similarly, re-examining mycorrhiza and lichens at existing study sites (Daneel, 1992; Schieferstein & Loris, 1992; Jacobson, 1997), provide important insights into the dynamics of biotic components of the soil surface, particularly in the dunes and on the gravel plains.

On long-term monitoring plots established on three farms in southern Kunene region along gradients of different land-use intensities and different types of land tenure (see above) various vegetation parameters are monitored (Table 1). These include plant species composition and annual net primary production. These are commonly used indicators of range condition (Behnke, Scoones & Kerven, 1994) and are included in an index of biological integrity developed for Namibian rangelands by DRFN (Zeidler *et al.*, 1998a).

Fixed point photography is a convenient and objective method of monitoring changes of vegetation over seasons, years and decades. This technique lends itself to qualitative and quantitative analyses (e.g. identity, number and size of plants and their relative cover) (e.g., Rohde, 1997a, b). The DRFN has established fifty fixed points in the Namib and along a transect between Gobabeb and Windhoek and another similar set in southern Kunene region at all Napcod sites. These photographs lend themselves to a very broad application.

Animals

Knowledge of the long-term population dynamics and movements of large mammals is very important for their effective management. The Ministry of Environment and Tourism, for example, found that the distribution of gemsbok was primarily determined by the availability of water, whereas grazing affected abundance (Berry & Siegfried, 1991; Kilian, 1995; Kok & Nel, 1996), as established through longer-term data records. It is important to continue this monitoring and it is suggested to in future include mountain zebra into the monitoring (e.g. Joubert, 1974), as the Namib-Naukluft Park is the distribution centre of this endemic species. Troops of baboons living along the Kuiseb River are being monitored at regular intervals by DRFN research associates since 1970 (Hamilton, Buskirk & Buskirk, 1976; Hamilton, 1985, 1986; Brain, 1992). For them water is the limiting resource and its availability affects reproduction, infant mortality, disease, and inter-troop relationships in troops living at the most arid extreme of the species. Domestic animals, particularly donkeys and goats, are common in and near the lower Kuiseb riverbed. Their changing populations may affect indigenous species, including plants, game, and invertebrates (Gabriel, 1992; Zeidler, 1995).

A major contribution to the long-term account of Namib Desert animal populations is the intensive pit-trapping programme of DRFN (Table 1). Although it focuses primarily on the monitoring of Tenebrionid beetles as "key organisms", it also provides a model for other desert organisms. The concepts that are derived in this study underpin many biodiversity studies undertaken in hyper-arid and arid environments, specifically Namibia. Because of its significance, the tenebrionid long-term research will be dealt with in some detail below. However, the long-term pit-trapping programme is also monitoring many other animals besides tenebrionids in the Namib, e.g. other beetles, solifugids, and lizards. The repeated monitoring technique has been used for the lizard *Meroles anchietae* (Robinson, 1990; Muth, pers.comm.), golden mole *Eremitalpa granti* (Fielden, 1989; Seymour & Seely, 1996) and rodents (Dickman, pers.comm.). These small vertebrates appear to track long-term trends in rainfall. Ants (Marsh, 1986) and soil microarthropods (André, Noti & Jacobson, 1997) are also good candidates for repeated monitoring due to their importance. Annual monitoring of three spider species since 1987 is revealing how their populations relate to different aspects of the environment, namely food (mainly tenebrionids and ants), and substrate instability, e.g., in sand storms or by livestock trampling. Long-term monitoring and modelling demonstrate how these factors affect clusters of spiders and how clusters develop, shift, and decline over generations (Henschel, 1990, 1995; Henschel & Lubin, 1992; Eisinger *et al.*, 1998). Such work also serves as a model for other animal populations surviving in extreme and variable environments such as the Namib desert.

At the DRFN research sites in the farming areas in southern Kunene region pit-trapping studies of Tenebrionid beetles (see below) as well as monitoring of biodiversity of abundant representatives of the soil fauna, namely termites (Isoptera), were recently established (Table 1). Working over most of Namibia, Zeidler (1997) analysed termite communities throughout Namibia 30 years after Coaton & Sheasby (1972) had done so. Further current studies are directed at elucidating some underlying reasons for differences in termite communities, such as changes in rainfall and land use patterns (e.g. Zeidler, Hanrahan & Scholes, 1998b). The biodiversity measures of the termites are related to the soil processes and resources affected by them.

At the farming LTR sites the monitoring of domestic animals plays a particularly important role (Table 1). In order to establish land use histories and long-term records of land use intensity, livestock and domestic animal demographics need to be constructed (Zeidler, 1998). In the past the agricultural extension officers have been collecting data which are also integrated into the DRFN databases that also include our current data and information on historic trends obtained from the rural community members, e.g. by Participatory or Rapid Rural Appraisal (PRA & RRA) methods. The data set should also incorporate data on fodder subsidies during periods of drought ("drought relief") and their effects on the numbers of livestock that are being kept beyond the numbers that can be sustained by the natural grazing available (Henschel, 1996).

Humans

Long-term data on rural human populations assist the interpretation of human impact on the natural environment and the management of natural resources. At the Napcod study sites in southern Kunene region baseline data on human demography have been recorded (Table 1) using PRA and RRA methods. Long-term records include human demography and the use of natural resources, e.g. borehole water and grazing. Information on village populations and migration patterns to emergency grazing areas are being incorporated into this monitoring programme. This information is being compared to our concurrent data on environmental indicators, such as vegetation, termites, tenebrionids and soil characteristics. The latter, in turn, is compared to the Namib LTR data. The people can thereby develop an understanding of the interactions they have with their environment and sustainable resource management. A similar approach is being used to monitor natural resource management by the Topnaar community along the Kuiseb River, particularly concerning !Nara, water and livestock (Table 1).

Tenebrionid Beetles

The long-term pit-trapping project that focuses on tenebrionid beetles (Coleoptera) in the Namib serves as an example of the DRFN marrying findings from Namib-LTR with case studies in farming-LTRs. Tenebrionids are good indicators of environmental conditions because their populations integrate several environmental factors, namely, detritus, leaves and dung on which they feed, vegetation cover under which they shelter, the hardness, moisture and stability of the soil, and the availability of water from rain, fog, and runoff. Furthermore, tenebrionids are abundant, conspicuous, diverse, flightless, and easy to capture and identify. Taxonomic, ecological, behavioural and ecophysiological studies have devoted much attention to Namib Tenebrionidae (at least 180 published papers), making it by far the best-known group. All of these factors make these beetles excellent subjects for further in-depth research and for environmental education.

In an ongoing study initiated in 1976 (Table 1), we are investigating the long-term population dynamics and the species composition of tenebrionid beetles in six habitats near Gobabeb, namely the Kuiseb riverbed, gravel plains, the interdune plains, dune hummocks, dune slope and dune slipface (Henschel, 1994; Henschel, Seely & Polis, in prep.). In the first three habitats, pit traps are monitored once to thrice per week, while the latter three are operated bimonthly. Various diversity indices are derived from the pit trap data and population trends are revealed by comparing the time sequences of abundance data for each species. Different population trends (increasing / decreasing, rapid / slow, abundant / rare / absent) characterise changes in species composition and diversity. Possible causal factors, such as climate, community interactions, habitat characteristics, and periodicity are examined by correlation and autocorrelation.

The extraordinary high diversity of Namib tenebrionids (total >200) has attracted much attention (e.g., Koch, 1962; Endödy-Younga, 1982; Penrith, 1986; Irish, 1990). Most of the 82 species found near Gobabeb are endemic to the Namib. To date, we have live-trapped 450 000 tenebrionids in the 22-year study period since the studies of Louw & Seely (1980), Wharton & Seely (1982) and Seely (unpubl.) initiated the project. We found that abundance was highest in those habitats where food was richest (riverbed and slipface), while diversity was relatively high in the habitat where food resources fluctuated most strongly (gravel plains) (unpubl. data). The time series for various species at first appear to be chaotic (e.g., Fig.1) and difficult to interpret (Zhou *et al.*, 1997), but some patterns emerge upon closer examination (Thomas, 1996). Many of these patterns seem to be related to water availability. Rainfall, fog and river floods appear to be important for population growth of most (but not all) Namib tenebrionid species, but the species differed in the type of water source to which they responded as well as in response rate ("response" being defined as an annual increase in population) (e.g., Fig.1). Population decline after growth was equally variable between species. These differences may explain sympatry of so many species that use a common food source. The long-term data series on tenebrionid populations demonstrate how LTR can form a valuable backdrop to the interpretation of short-term studies (Fig. 1). Beetle community composition appeared to differ in relation to food, soil, vegetation cover, water availability and climatic variability. Some of these factors are susceptible to local change by humans, and this forms part of the study at Olifantputs.

Tenebrionids can serve as key organisms in understanding ecosystem processes in western Namibia. For example, local populations in apparently hostile environments may depend on regular immigrants from more suitable regions. The latter regions, termed "sources", are areas where reproduction exceeds mortality and can be sources of migrants to "sinks", areas in which mortality exceeds local reproduction (Pulliam, 1988; Lewin, 1989; Watkinson & Sutherland, 1995). It is therefore important for ecologists and land managers to recognise the location, size and importance of source areas because the destruction of source areas, which are often relatively small compared to sinks, may lead to population extinction in large areas (Pulliam, 1988). Identifying and understanding the dynamics of source areas thus has important consequences for the conservation of biodiversity.

We found that during the years between effective rainfalls at Gobabeb (enough to enable plants to germinate and to produce seeds), Namib tenebrionid populations underwent substantial decline (e.g., Fig. 1). Only few small areas appeared to remain relatively rich in species and biomass. By placing pit traps in and next to these rich patches, we are gaining knowledge of their dynamics (e.g., what factors affect their richness) and how these areas relate to other rich areas (metapopulations) and to poor areas between the rich patches. By examining long-term changes we endeavour to improve our understanding of biodiversity and other ecological processes and to improve the management of source areas. Consequently, the Namib tenebrionid LTR includes areas that can be compared as possible sources and sinks, such as dune slopes (near Kahani 23°39'S; 15°01'E and at Khommabes located 10 km SW and 10 km W of Gobabeb respectively) with different quantities of perennial vegetation such as hummocks of the grass, *Stipagrostis sabulicola*, and/or !Nara, *Acanthosicyos horridus*.

At the DRFN rangeland study sites, we are examining how potential source areas of tenebrionids and termites (e.g., areas where land use by livestock is light) can serve as potential areas to recolonise disturbed areas (e.g., areas heavily grazed and trampled by livestock). This demonstrates one way by which the knowledge gained in the Namib LTR can be applied in communal farming areas such as Olifantputs (Parenzee, pers.comm.). Here, pit trapping and other monitoring research activities of tenebrionid and termite biodiversity have been initiated to investigate these organisms' potential as indicators of biological integrity at sites with different levels of land use intensity. Diversity measures such as species richness, diversity (e.g. Shannon index), dominance (e.g. Simpson index), abundance, activity patterns, size differences, and community composition are determined to compare high land use intensity sites to low intensity sites (Parenzee, pers. comm.). This study draws on the knowledge of population dynamics of invertebrates from the Namib LTR.

USING & APPLYING LTR DATA

Various examples of how DRFN is using, combining and applying short-term and long-term research data were given throughout the paper. This section describe the general research processes of the DRFN as well as the outputs that are geared towards increasing the awareness and understanding of arid lands, including its biodiversity. Firstly, all DRFN research is connected to an explicit training component involving students as well as natural resource users and managers in the collection and interpretation of the data. Such a participatory research process contributes to the capacity building of natural resource users and managers. Secondly, research results are housed in a central place, advertised and made accessible for further use. Information available has been incorporated in text books on desert ecology (e.g. Louw & Seely, 1982; Louw, 1993), resource materials for Namibian school teachers through DRFN's EnviroTeach programme (e.g du Toit, Karita & Sguazzin, 1995a-d), natural history and environmental overviews (e.g. Holm & Scholtz, 1980; Seely 1987, 1990a; Jürgens *et al.,* 1997) and coffee table books (e.g. Lovegrove, 1993; Seely, 1994). Numerous nature films have been made at Gobabeb and these often incorporate knowledge accumulated through LTR. Thirdly, many short term research results, particularly those that feature aspects of biodiversity in arid environments, can be interpreted against the background of long-term trends. This is of great value for studies conducted throughout arid Namibia, but also when looking at arid land ecology worldwide. Fourthly, national resource management schemes and policy-making projects require long-term data (e.g. National Drought Policy). Popular information packages incorporating such data and contributing to management and policy making are, e.g.: "Managing Water Points and Grazing Areas in Namibia" (Forbes-Irving, 1996), "Sharing Water in Southern Africa" (Pallett, 1997), "Decision Makers Guide to Water" (Montgomery, in press), and the "Update" Series produced for Parliament. Although some of these materials do not explicitly address biodiversity issues, their format and targets provide good examples of how scientific information can be applied to a broader audience.

GENERAL DISCUSSION

Biodiversity reflects a combination of environmental and historical events at a site and changes in biodiversity can provide a sensitive measure of ecologically relevant changes in the environment. LTR can provide historical data, while allied studies focus on the proximate relationship between organisms (including humans) and the environment.

The DRFN LTRs are part of a larger network of LTR sites concerning arid lands. Prominent among these are the Kalahari Transect covering parts of South Africa, Namibia, Botswana and Zambia (Scholes & Parsons, 1997), the Desert Margin Transects in Namibia, South Africa, Sudan and Egypt (Jürgens, Henschel & Hachfeld, submitted) and transects covering other deserts of the world (Koch *et al.*, 1995).

Continuity and consistency in methods are required for LTR. However, LTR should be more than generating and interpreting data and it ultimately needs to involve human communities. DRFN's Namib LTR projects demonstrate that baseline information and understanding derived from an undisturbed, arid environment is invaluable to the interpretation of shorter-term data collected in other arid areas. This should ultimately enable brief assessments of biodiversity to be used to describe habitat quality. Likewise, it allows an interpretation of human effects on biodiversity and facilitates the planning of projects in populated areas that may change these effects.

Biophysical and socio-economic LTR projects are extremely important for the Namibian environment. This has long been recognised by several other organisations besides the DRFN, e.g. the Ministry of Agriculture, Water and Rural Development, and the Ministry of Environment and Tourism, as well as other NGO's like the Save the Rhino Trust. However, today it becomes more and more difficult to maintain long-term sites. There appear to be several reasons. Firstly, the maintenance of long-term research is costly and demands much dedication. Secondly, the value of long-term data collection is often not fully recognised. This may partly be because LTR data and conclusions are sometimes not published appropriately and timely nor made accessible. The current paper demonstrates the value of published LTR data for many social and environmental fields, including those affecting biodiversity.

CONCLUSIONS

In this paper we show how the DRFN is making use of LTR data in an applied context, including using and applying basic research results for training and management purposes. LTR is important for arid land studies. Its ultimate value depends on the alliance between basic research and applied research that underlines the importance of both. In the long run both types of research cannot do without the other. Basic research is vital because it provides first-hand knowledge that can be translated and applied into relevant information to relevant target groups. Basic research often comes up with novel insights that were not initially predicted. Knowledge can in this way advance in quantum leaps. However, without its application, basic research can develop into an ivory-tower condition that a developing country can ill afford. It is the fruitful interaction between basic and applied research that increase the value of both. Well-tested conclusions and honed skills can be transferred from basic to applied research, while applied questions, form a guiding framework for basic research. Understanding and managing biodiversity processes are an excellent example of this alliance.

ACKNOWLEDGEMENTS

Ministry of Environment and Tourism granted permission and facilities at Gobabeb. The National Museum of Namibia played an important supporting role over the years. Technical assistants at Gobabeb were Angela Suttle, Linda Malan, Christine Hänel, Vilho Mtuleni and these were assisted by numerous other staff, research associates, and volunteers. The participatory research approach at Olifantputs involved numerous enthusiastic members of the community, and, in particular, we would like to thank Dudu Murorua, Lesley Parenzee and Deon Sharuru for assistance. Barbara Paterson kindly assisted with the development of a computerised management information system. Kathy Jacobson and Mark Robertson commented on the manuscript.

REFERENCES

ANDERSON, J.M. 1994. Functional attributes of biodiversity in land use systems. In: Greenland, D.J. & Szabolcs, I (eds.). *Soil resilience and sustainable land use*. Oxon, UK: CAB International: 267-290.

ANDRÉ, H.M., Noti, M.-I. & JACOBSON, K.M. 1997. The soil microarthropods of the Namib Desert: a patchy mosaic. *J. Afr. Zool.* 111: 499-517.

BEHNKE, R. H., & SCOONES, I. 1992. Rethinking range ecology: implications for rangeland management in Africa. *International Institute for Environment and Development, Overseas Development Institute, London, Report* 33: 1-43.

BEHNKE, R.H., SCOONES, I., & KERVEN, C. (eds.). 1994. *Range ecology at disequilibrium*. London: ODI, 248 pp.

BERRY, H.H. & SIEGFRIED, W.R. 1991. Mosaic-like events in arid and semi-arid Namibia. In: Remmert, H. (ed). *The mosaic-cycle concept of ecosystems*. Berlin: Springer: 147-160.

BESLER, H. 1970. Geomorphologie der Wüste. *Namib und Meer* 1: 59-68.

BESLER, H. 1972a. Geomorphologie der Dünen. *Namib und Meer* 3: 25-35.

BESLER, H. 1972b. Klimaverhaltnisse und klimageomorphologische Zonierung der zentralen Namib (Südwestafrika). *Stuttgarter Geographische Studien* 83: 1-209.

BORNMAN, C.H. 1978. Welwitschia: paradox of a parched paradise. Cape Town: Struik Publishers, 71 pp.

BRAIN, C. 1992. Deaths in a desert baboon troop. *International Journal of Primatology* 13: 593-599.

BRINCKMANN, E., & VON WILLERT, D.J. 1987. Injury and recovery of *Welwitschia mirabilis*. *Dinteria* 19: 69-76.

COATON, W.G.H., & Sheasby, J.L. 1972. Preliminary report on a survey of the termites (Isoptera) of South West Africa. *Cimbebasia Memoir* 2: 7-129.

DANEEL, J.L. 1992a. *The impact of off-road vehicle traffic on the gravel plains of the Central Namib Desert, Namibia*. M.Sc. thesis. Pietermaritzburg, South Africa: Dept. Agronomy, University of Natal, 117 pp.

DANEEL, J.L. 1992b (ed.). *The visual effects of off-road vehicles on the gravel plains of the Central Namib*. Gobabeb, Namibia: Seminar series of the Desert Ecological Research Unit, 14 pp.

DENTLINGER, U. 1977. An ethnobotanical study of the !Nara plant among the Topnaar hottentots of Namibia. *Munger Africana Library Notes* 38: 3-39.

DOXA PRODUCTION. 1995. *Lifelines of Namibia: Ephemeral rivers project video*. Windhoek, Namibia: Desert Research Foundation of Namibia.

DU TOIT, D., KARITA, A. & SGUAZZIN, T. 1995a. *Lives in the balance - people and the Namibian environment*. Swakopmund, Namibia: Desert Research Foundation of Namibia, 221 pp.

DU TOIT, D., KARITA, A. & SGUAZZIN, T. 1995b. *My land my life*. Swakopmund, Namibia: Desert Research Foundation of Namibia, 115 pp.

DU TOIT, D., KARITA, A. & SGUAZZIN, T. 1995c. *Sink or swim: water and the Namibian environment*. Swakopmund, Namibia: Desert Research Foundation of Namibia, 226 pp.

DU TOIT, D., KARITA, A. & SGUAZZIN, T. 1995d. *Wholly ground*. Swakopmund, Namibia: Desert Research Foundation of Namibia, 39 pp.

ECKARDT, F. 1996. *The distribution and origin of gypsum in the Central Namib Desert, Namibia*. PhD thesis. Hertford College, Oxford: University of Oxford, 320 pp.

EISINGER, D., JELTSCH, F., HENSCHEL, J., ULBRICH, K., LUBIN, Y. & WISSEL, C. 1998. Das lokale Ausbreitungsmuster der Wüstenspinne *Seothyra henscheli* – ein räumlich-explizites gitterbasiertes Simulationsmodell. (The local dispersal pattern of the desert spider *Seothyra henscheli* – a spatially-explicit grid-based simulation model.) *Verhandlungen der Gesellschaft für Ökologie*: in press.

ENDÖDY-YOUNGA, S. 1982. Dispersion and translocation of dune specialist tenebrionids in the Namib area. *Cimbebasia (A)* 5: 257-271.

FIELDEN, L. J. 1989. *Selected aspects of the adaptive biology and ecology of the Namib Desert golden mole (Eremitalpa granti namibensis)*. Ph.D thesis. Pietermaritzburg, South Africa: Dept. of Zoology and Entomology, University of Natal, 247 pp.

FORBES-IRVING, T. 1996. *Managing water points and grazing areas in Namibia.* Windhoek, Namibia: Desert Research Foundation of Namibia, 101 pp.

FRANKLIN, J.F., BLEDSOE, C.S. & CALLAHAN, J.T. 1990. Contributions of the long-term ecological research program. *BioScience* 40: 509-523.

GABRIEL, M. 1992. *The impact of stock along a defined stretch of the Lower Kuiseb River, Central Namib Desert: a first attempt at quantification*. Gobabeb, Namibia: Desert Research Foundation of Namibia, Final Report, 19 pp.

GREENLAND, D.J. & SZABOLCS, I. (eds.). 1994. Soil resilience and sustainable land use. Oxon, UK: CAB International, 565 pp.

GOSZ, J.R. 1996. International long-term ecological research: priorities and opportunities. *TREE* 11: 444.

GOUDIE, A. 1972. Climate, weathering, crust formation, dunes, and fluvial features of the central Namib Desert, near Gobabeb, South West Africa. *Madoqua* 1: 15-31.

GÜNSTER, A., 1993. *Seed bank dynamics of serotinous plants in the central Namib*. Ph.D. thesis. Münster, Germany: University of Münster, 103 pp.

GÜNSTER, A. 1995. Grass cover distribution in the central Namib - a rapid method to assess regional and local rainfall patterns of arid regions? *Journal of Arid Environments* 29: 107-114.

HACHFELD, B. 1996. *Vegetationsökologische Transektanalyse in der nördlichen Zentralen Namib*. M.Sc. thesis. Hamburg, Germany: Institut für Allgemeine Botanik, Universität Hamburg, 137 pp.

HAMILTON, W.J. 1985. Demographic consequences of a food and water shortage to desert Chacma baboons, *Papio ursinus*. *International Journal of Primatology* 6: 451-462.

HAMILTON, W.J. 1986. Namib Desert Chacma baboon (*Papio ursinus*) use of food and water resources during a food shortage. *Madoqua* 14: 397-408.

HAMILTON, W.J., BUSKIRK, R.E. & BUSKIRK, W. H. 1976. Defense of space and resources by Chacma (*Papio ursinus*) baboon troops in an African desert and swamp. *Ecology* 57: 1264-1272.

HAMILTON, W.J., BUSKIRK, R.E. & BUSKIRK, W.H. 1977. Intersexual dominance and differential mortality of Gemsbok *Oryx gazella* at Namib Desert waterholes. *Madoqua* 10: 5-19.

HENSCHEL, J.R. 1990. The biology of *Leucorchestris arenicola* (Araneae: Heteropodidae), a burrowing spider of the Namib dunes. In: Seely, M.K. (ed.). *Namib Ecology - 25 years of Namib research*. Pretoria: Transvaal Museum Monograph 7: 115-127.

HENSCHEL, J.R. 1994. Pithy pits: population dynamics of Namib tenebrionids. *Namib Bulletin* 11: 4-5.

HENSCHEL, J.R. 1995. Tool use by spiders: stone selection and placement by corolla spiders *Ariadna* (Segestriidae) of the Namib Desert. *Ethology* 101: 187-199.

HENSCHEL, J.R. 1996. Subsidisation empoverishes local resources and increases dependency of local consumers: a lesson from spiders and aquatic insects. *Namib Bulletin* 13: 13.

HENSCHEL, J.R. & LUBIN, Y.D. 1992. Environmental factors affecting the web and activity of a psammophilous spider in the Namib Desert. *Journal of Arid Environments* 22: 173-189.

HENSCHEL, J., MTULENI, V., GRUNTKOWSKI, N., SEELY, M. & SHANYENGANA E. 1998. Namfog, Namibian application of fog-collecting systems, I: Evaluation of fog water harvesting. *Desert Research Foundation of Namibia, Occasional Paper* 8: 1-75.

HENSCHEL, J.R., SEELY, M.K. & POLIS, G.A. 1998. Long term population dynamics of tenebrionid beetles in the Namib Desert. *Ecological Monographs,* in prep.

HOLM, E. & SCHOLTZ, C.H. 1980. Structure and pattern of the Namib Desert dune ecosystem at Gobabeb. *Madoqua* 12: 3-39.

HUNTLEY, B.J. (ed.). 1985. The Kuiseb environment: the development of a monitoring baseline. *South African National Scientific Programmes Report* 108: 1-138.

IRISH, J. 1990. Namib biogeography, as exemplified mainly by the Lepismatidae (Thysanura: Insecta). In: Seely, M.K. (ed.). *Namib Ecology - 25 years of Namib research.* Pretoria: Transvaal Museum Monograph 7: 61-66.

JACOBSON, K.M. 1992. *Factors affecting VA-mycorrhizal community structure in the Namib Dune Field; and the population biology of an ectomycorrhizal Basidomycete: Suillus granulatus*. Ph.D. thesis. Blacksburg, Virginia, USA: Virginia Polytechnic Institute, Virginia State University.

JACOBSON, K.M. 1996. Macrofungal ecology in the Namib desert: a fruitful or futile study? *McIlvainea* 12: 21-32.

JACOBSON, K.M. 1997. Moisture and substrate stability determine VA-mycorrhizal fungal community distribution and structure in an arid grassland. *Journal of Arid Environments* 35: 59-75.

JACOBSON, K.M. & JACOBSON, P.J. 1998. Rainfall regulates decomposition of buried cellulose in the Namib Desert. *Journal of Arid Environments* 38: (in press)

JACOBSON, P.J., JACOBSON, K.M. & SEELY, M.K. 1995a. *Epheral rivers and their catchments: sustaining people and development in western Namibia.* Windhoek, Namibia: Desert Research Foundation of Namibia, 160 pp.

JACOBSON, P.J., JACOBSON, K.M. & SEELY, M.K. 1995b. Epheral rivers and their catchments: a resource map. Windhoek, Namibia: Desert Research Foundation of Namibia.

JOUBERT, E. 1974. Notes on the reproduction in Hartmann zebra *Equus zebra harmannae* in South West Africa. *Madoqua-Series I* 8: 31-35.

JÜRGENS, N., BURKE, A., SEELY, M.K. & JACOBSON, K.M. 1997. Desert. In: Cowling, R.M., Richardson, D.M. & Pierce, S.M. (eds.). *Vegetation of Southern Africa.* Cambridge: Cambridge University Press: 189-214.

JÜRGENS, N., HENSCHEL, J. & HACHFELD, B. 1998. Shifting desert margins biodiversity monitoring macro-transects: an outline of an international project being initiated. *Madoqua*: submitted.

KAMBATUKU, J.R. 1996. Historical profiles of farms in former Damaraland: notes from the archival files. *Desert Research Foundation of Namibia, Occasional Report* 4: 1-58.

KILIAN, J.W. 1995. The ecology of gemsbok (*Oryx gazella gazella*) in the southern Namib. Windhoek, Namibia: Report of the Ministry of Environment and Tourism.

KLOPATEK, J.M. & STOCK, W.D. 1994. Partitioning of nutrients in *Acanthosicyos horridus*, a keystone endemic species in the Namib Desert. *Journal of Arid Environments* 26: 233-240.

KOCH, C. 1962. The Tenebrionidae of southern Africa 31: Comprehensive notes on the tenebrionid fauna of the Namib Desert. *Annals of the Transvaal Museum* 24: 61-106.

KOCH, G.W, SCHOLES, R.J., STEFFEN, W.L., VITOUSEK, P.M. & WALKER, B.H. 1995. The IGBP terrestrial transects: Science plan. *International Geosphere-Biosphere Programme, Stockholm, Report* 36: 1-53.

KOK, O.B., & NEL, J.A.J. 1996. The Kuiseb river as a linear oasis in the Namib desert. *Afr. J. Ecol.* 34: 39-47.

LANCASTER, J., LANCASTER, N. & SEELY, M.K. 1984. Climate of the central Namib Desert. *Madoqua* 14: 5-61.

LANCASTER, N. 1989. *The Namib sand sea: dune forms, processes and sediments.* Rotterdam: A.A.Balkema, 180 pp.

LEWIN, R. 1989. Sources and sinks complicate ecology. *Science* 243: 477-478.

LOUW, G. 1993. Physiological animal ecology. London & NY: Longman, 281 pp.

LOUW, G. & SEELY, M. 1982. Ecology of desert organisms. London & NY: Longman, 184 pp.

LOVEGROVE, B. 1993. *The living deserts of southern Africa.* Vlaeberg, South Africa: Fernwood Press, 224 pp.

MARSH, A.C. 1986. Checklist, biological notes and distribution of ants in the central Namib Desert. *Madoqua* 14: 333-344.

MARSH, B. 1982. An ecological study of *Welwitschia mirabilis* and its satellite fauna. *Namib Bulletin* 4: 3-4.

MARSH, B.A. 1987. Micro-arthropods associated with *Welwitschia mirabilis* in the Namib Desert. *South African Journal of Zoology* 22: 89-96.

MARSH, B.A. 1990. The microenvironment associated with *Welwitschia mirabilis* in the Namib desert. In: Seely, M.K. (ed.). *Namib Ecology - 25 years of Namib research.* Pretoria: Transvaal Museum Monograph 7: 149-153.

MONTGOMERY, S. (ed.). 1998. *Decision makers guide to water.* Windhoek, Namibia: Desert Research Foundation of Namibia, in press.

PALLETT, J. (ed.). 1997. *Sharing water in southern Africa.* Windhoek, Namibia: Desert Research Foundation of Namibia, 121 pp.

PENRITH, M.-L. 1986. Relationships of the tribe Adesmiini (Coleptera: Tenebrionidae) and a revision of the genus *Stenodesia* Reitter. *Annals of the Transvaal Museum* 34: 275-302.

PULLIAM, H.R. 1988. Sources, sinks and population regulation. *American Naturalist* 132: 652-661.

RISSER, P.G. 1995. *Long-term ecological research: An international perspective, SCOPE 47.* Chichester: John Wiley, 294 pp.

ROBINSON, E.R. 1976. Phytosociology of the Namib Desert Park, South West Africa. M.Sc. thesis. Pietermaritzburg, South Africa: University of Natal.

ROBINSON, E.R. 1978. Phytogeography of the Namib Desert of South West Africa (Namibia) and its significance to discussions of the age and uniqueness of this desert. In: Van Zinderen Bakker, E.M. & Coetzee, J.A. (eds.). *Palaeoecology of Africa and the surrounding islands. Vol.10.* Rotterdam: A.A.Balkema: 67-74.

ROBINSON, M. D. 1990. Comments on the reproductive biology of the Namib desert dune lizard, *Aporosaura anchietae*, during two years of very different rainfall. In: Seely, M.K. (ed.). *Namib Ecology - 25 years of Namib research.* Pretoria: Transvaal Museum Monograph 7: 163-168.

ROBINSON, M.D. & SEELY, M.K. 1980. Physical and biotic environments of the southern Namib dune ecosystem. *Journal of Arid Environments* 3: 183-203.

ROHDE, R.F. 1997a. Looking into the past: interpredations of vegetation change in Western Namibia based on matched photography. Dinteria _:_.

ROHDE, R.F. 1997b. Nature, cattle thieves and various other midnight robbers: images of people, place and landscape in Damaraland, Namibia. PhD thesis. Edinburgh: University of Edinburgh.

SCHIEFERSTEIN, B. & LORIS, K. 1992. Ecological investigations on lichen fields of the Central Namib. *Vegetatio* 98: 113-128.

SCHOLES, R.J. & PARSONS, D.A.B. 1998. The Kalahari Transect: research on global change and sustainable development in southern Africa. *International Geosphere-Biosphere Programme, Stockholm, Report* 42: 1-63.

SEELY, M.K. 1978a. Standing crop as an index of precipitation in the central Namib grassland. *Madoqua* 11: 61-68.

SEELY, M.K. 1978b. Grassland productivity: the desert end of the curve. *S.Afr.J.Sci.* 74: 295-297.

SEELY, M.K. 1987. *The Namib - Natural history of an ancient desert.* Windhoek: Shell Oil Namibia.

SEELY, M.K. (ed.) 1990a. *Namib Ecology - 25 years of Namib research.* Pretoria: Transvaal Museum Monograph 7: 1-223.

SEELY, M.K. 1990b. Patterns of plant establishment on a linear desert dune. *Israel Journal of Botany* 39: 443-451.

SEELY, M.K. (ed.) 1994. *Deserts*. Sydney: Weldon Owen, 160 pp.

SEELY, M.K. & JACOBSON, K.M. 1994. Desertification and Namibia: a perspective. *J.Afr.Zool.* 108: 21-36.

SEELY, M.K., BUSKIRK, W.H. & HAMILTON III, W.J. 1980. Lower Kuiseb river perennial vegetation survey. *Journal of the South West Africa Scientific Society* 35: 57-86.

SEELY, M.K. & HAMILTON, W.J. 1978. Durability of vehicle tracks on three Namib Desert substrates. *South African Journal of Wildlife Research* 8: 107-111.

SEELY, M.K. & LOUW, G.N. 1980. First approximation of the effects of rainfall on the ecology and energetics of a Namib Desert dune ecosystem. *Journal of Arid Environments* 3: 25-54.

SEYMOUR, R.S. & SEELY, M.K. 1996. The respiratory environment of the Namib Desert golden mole. *Journal of Arid Environments* 32: 453-461.

THERON, G.K. & VAN ROOYEN, M.W. 1980. Vegetation of the lower Kuiseb River. *Madoqua* 11: 327-345.

THOMAS, L. 1996. Monitoring long-term population change: why are there so many analysis methods. *Ecology* 77: 49-58.

UNEP, 1995. *Convention to Combat Desertification.* Geneva, Switzerland: United Nations Environmental Programme, 71 pp.

WALTER, H. 1937. Die ökologischen Verhaltnisse in der Namib-Nebelwüste (Südwestafrika). *Jahrbucher für wissenschaftliche Botanik* 84: 58-222.

WATKINSON, A.R. & SUTHERLAND, W.J., 1995. Sources, sinks and pseudo-sinks. *Journal of Animal Ecology* 64: 126-130.

WEATHERHEAD, P. J. 1986. How unusual are unusual events? *American Naturalist* 128: 150-154.

WHARTON, R.A. 1980. Insects and arachnids associated with *Zygophyllum simplex* (Zygophyllaceae) in the central Namib Desert. *Madoqua* 12: 131-139.

WHARTON, R.A. & SEELY, M.K. 1982. Species composition of and biological notes on Tenebrionidae of the lower Kuiseb River and adjacent gravel plain. *Madoqua* 13: 5-25.

WOLDA, H. 1978. Fluctuations in abundance of tropical insects. *Am.Nat.* 112: 1017-1045.

ZEIDLER, J. 1995. *Spatial and temporal abundance of Rhipicephalus gertrudae (Acari, Ixodidae) along a degradation gradient along the Lower Kuiseb river, Namibia.* MSc thesis. Frankfurt-am-Main, Germany: Johann-Wolfgang Goethe University, 55 pp.

ZEIDLER, J. 1997. *Distribution of termites (Isoptera) throughout Namibia - environmental connections.* MSc thesis. Johannesburg: University of Witwatersrand, 91 pp.

ZEIDLER, J., 1998. *Establishing indicators of biological integrity for western Namibian rangelands*. PhD research proposal. Johannesburg: University of the Witwatersrand, 70 pp.

ZEIDLER, J., HANRAHAN, S., SCHOLES, M. & SEELY, M. 1998a. Establishing methods for range condition assessment in arid north-western Namibia – combining ecological and participatory community-based research approaches. *Proceedings of theKalahari Transect Meeting, Gaborone 10-13 June 1998.*

ZEIDLER, J., HANRAHAN, S. & SCHOLES, M. 1998b. Termite (Isoptera) species richness, composition and diversity under differing land-uses in southern Kunene region, Namibia. *Journal of African Zoology*: submitted.

ZHOU, X., PERRY, J.N., WOIWOD, I.P., HARRINGTON, R., BALE, J.S., & CLARK, S.J. 1997. Detecting chaotic dynamics of insect populations from long-term survey data. *Ecological Entomology* 22: 231-241.

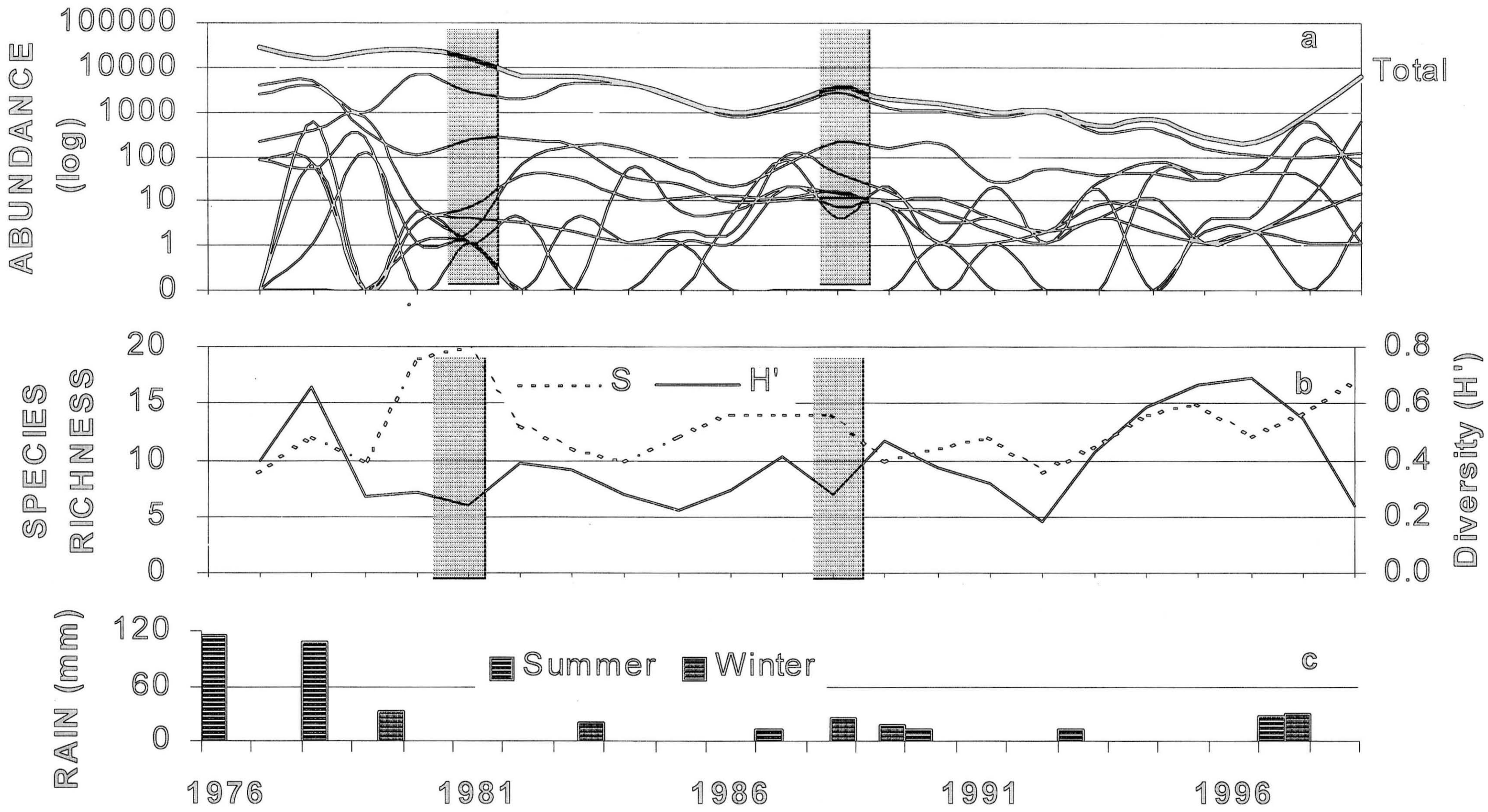
PERSONAL COMMUNICATION

DICKMAN, Chris - School of Biological Sciences, University of Sydney, Sydney, Australia.
HACHFELD, Berit – Botanical Institute, University of Cologne, Cologne, Germany.
MUTH, Allan – Boyd Deep Canyon Desert Research Center, Palm Desert, California, U.S.A.
PARENZEE, Leslie – Desert Research Foundation of Namibia, Gobabeb, Namibia.

FIGURE 1: Long-term data series at an interdune LTR site in the Namib dunes of (a) abundance of the 10 most common tenebrionid beetles, (b) Shannon-Wiener diversity index H' of all species in the habitat, and (c) effective rainfall (>10 mm per week) during summer or winter. Compare data from the shaded areas as examples of short-term studies within long-term trends.

TABLE 1: Long Term Research projects being carried out by the Desert Research Foundation of Namibia.

	Conservation areas e.g. ○ Nature reserves ○ Restricted areas		Agricultural areas e.g. ○ Rangelands ○ Cultivated fields
	Existing long-term record from pristine/undisturbed area		
	NAMIB	YEAR started	ELSEWHERE IN NAMIBIA (since 1997)
Climate	○ Automatic & autographic weather stations ○ Fog	○ 1962 ○ 1970	○ Participatory rainfall tracking with local farmers ○ Fog harvesting
Biophysical environment	○ Dune dynamics ○ Kuiseb river ecosystem ○ Off-road vehicle impact on surfaces	○ 1970 ○ 1976 ○ 1978	○ Soil processes monitoring programme ○ Ephemeral river ecosystems
Vegetation ○ crops ○ natural vegetation	○ Welwitschia leaf growth ○ Grass production ○ Plant community dynamics ○ Fixed point photography	○ 1976 ○ 1974 ○ 1976 ○ 1997	○ Vegetation dynamics monitoring (composition & biomass) ○ Fixed point photography
Animals ○ livestock ○ other vertebrates & invertebrates	○ Tenebrionid beetle population dynamics ○ Game, small mammal, lizard & invertebrates ○ Livestock along Kuiseb	○ 1976 ○ 1976 ○ 1976	○ Livestock demographics ○ Effects of subsidies ○ Invertotbrate biodiversity appraisal and monitoring (Tenebionids & termites)
Humans ○ demography ○ land uses	○ Topnaar natural resource management, esp. Nara & water	○ 1976	○ Household demographics ○ Natural resource use ○ Land use practices


ABUNDANCE (log)
100000
10000
1000
100
10
1
0
a
Total
SPECIES RICHNESS
20
15
10
5
0
S
H'
b
0.8
0.6
0.4
0.2
0.0
Diversity (H')
RAIN (mm)
120
60
0
Summer
Winter
c
1976
1981
1986
1991
1996