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Gobabeb – 50 years of Namib Desert research

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ABSTRACT

The Namib is a relatively well-studied hyperarid desert. Much of the research effort was coordinated through the institutional framework of the Gobabeb Research and Training Centre, which was established in the middle of this desert fifty years ago. The initial discoveries focused on the Namib's remarkably high biodiversity and adaptations to desert conditions, analysed against the foundations of research into this desert's particular climate, geomorphology and geology. The antiquity of this desert, its extreme hyperaridity, and strong climatic gradients provided unusual windows into ecosystem drivers in arid lands, past and present. The Gobabeb Centre itself evolved to translate much of its knowledge into application and is today geared to increase this trend even further, driven by the urgent need for knowledge-based environmental management, such as ecological restoration of mining areas.

The current volume collates nine papers which review a cross-section of Namib research, with special focus on projects conducted through Gobabeb. These papers concern different facets of geomorphology where Namib research has led global understanding, reviewed in three papers, and one climatological review of the moisture regime. A review of reptile research illustrates the relationship between biodiversity processes and environmental factors, which is further sharpened in a comparison of dune lizard ecology between continents. The review of botanical research in the Central Namib fittingly binds much of the accumulated knowledge of desert plants into a detailed vegetation map. A review of research on the highly variable ephemeral river systems of the Namib illustrates how academic knowledge accumulated at Gobabeb connects to applied research, which is also the topic of the final paper concerning the knowledge gaps and research needs to provide the information required for ecological restoration.

1. Introduction

Fifty years ago a research station was established on the northern bank of Namibia's ephemeral Kuiseb River at Gobabeb, 55 km inland from the west coast of Southern Africa and 90 km from Walvis Bay, the nearest town (Fig. 1). Fittingly for a research station with a primary focus on the arid environments of the southwestern African coast, Gobabeb, at 23°33′40″S 15°02′29″E, is located in the very middle of the Namib Desert.

The Namib is a 50–150 km wide coastal desert stretching over 2000 km from the Rio Bentiaba (São Nicolau; 14°16′S; 12°22′E) in Angola across Namibia to the Olifants River in South Africa (31°42′S; 18°11′E) (Fig. 2; Werger, 1978). It covers over 130,000 km^2 and lies west of the Great Escarpment of southern Africa, mostly below 1000 m and within the 10–100-mm rainfall isohyets. The Namib comprises several phytogeographic subdivisions (Jürgens et al., 1997): the Northern Namib, Central Namib Plains, Central Namib Dunes including the Namib Sand Sea, and the Southern Namib, which branches into the East Gariep Namib inland, and the Northwestern Namaqualand Sandveld along the coast (Fig. 2).

Fitzsimons (1961a, p. 71) wrote: "The Namib forms one of the oldest unchanged deserts in the world, presenting such extremes of solar radiation both in quality and quantity in its inner section, combined with the highest possible degree of relative humidity in the outer fog-belt, and violent fluctuations in aerodynamic conditions, etc., that scientific research carried out under these peculiar conditions cannot but yield unique results of basic research with a high potentiality of applicability." He proposed a research station at Gobabeb with facilities for undertaking long-term research into both biological problems and all other fields associated with extreme conditions of aridity. This, he felt, can "produce valuable results not only in the more academic scientific field but also in agriculture, mining and other industrial activities" (Fitzsimons, 1961a, p. 72).

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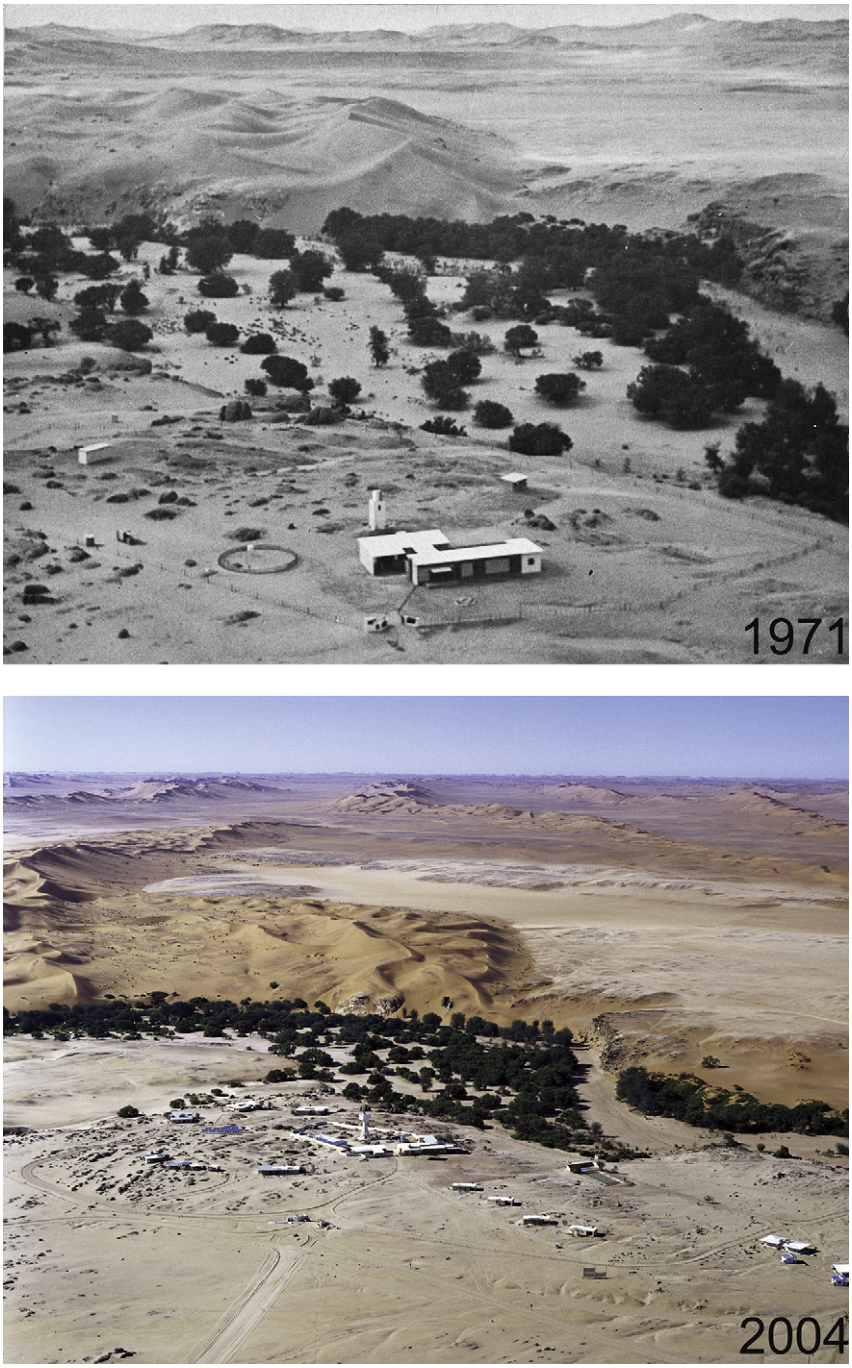

Fig. 1. Aerial views of Gobabeb in 1971 showing the infrastructure as originally installed and 2004, showing the station as it is today. Photographs from Gobabeb archive. 1971 image by Alice Mertens; 2004 by Markus Weiss. Both views are to the south from the gravel plains over the Kusieb River to the linear dunes of the Namib Sand Sea.

The establishment of a First Order Weather Station on the 13th September 1962 marked the start of permanent operations at Gobabeb. Within a year, a laboratory, offices and housing for staff were inaugurated, and later extended. What is today the Gobabeb Research and Training Centre has always been a partnership between many institutions. It underwent several name changes over the course of the years as well as one major reconstitution, between 1990 and 1998, when it transferred from the shared direct management by the Ministry of Environment and Tourism and the Desert Research Foundation of Namibia (and their respective predecessors and parent bodies), to become a separate institution dedicated to research, training, and their applications towards development (Seely et al., 2000).

Today, the Gobabeb Research and Training Centre continues to be an important scientific institution in the field of arid-land research in Namibia and world-wide. Although its focus has always been the Namib Desert, it contributes significantly to knowledge, understanding and sustainable development of arid lands in general. A large proportion of the research that has been conducted in this desert was connected to Gobabeb: about 43% of the scientific and environmental information publications on the Namib Desert housed in the institutional library emanated from

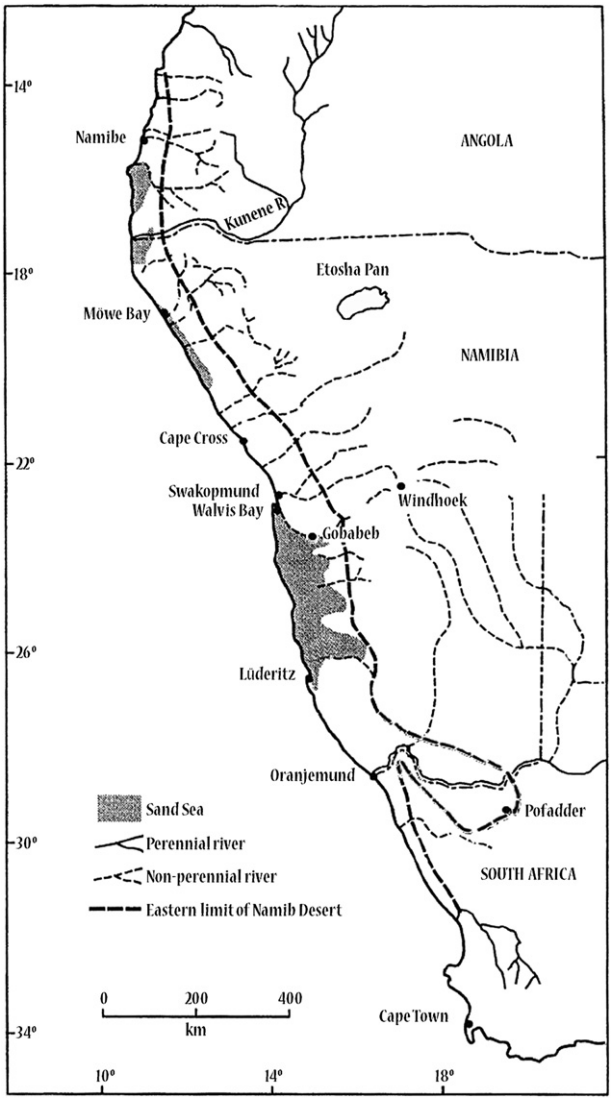

Fig. 2. Map of the Namib Desert, showing the position of Gobabeb and some of the other major features mentioned in this volume. The stippled line indicates the eastern boundary.

staff or affiliated scientists of Gobabeb. The current Special Issue on the Namib Desert collates nine articles that review some of this research, or summarise results which have built on the legacy of 50 years of research at Gobabeb.

2. Leading up to Gobabeb

The first known research expedition in the area was undertaken by Alexander (1838), who traversed southern Namibia and passed Gobabeb with oxen, describing the landscape, the people, fauna and flora along the way. Several other explorers followed suit in nearby areas, including Thomas Baines (1864), who recorded *Welwitschia mirabilis*. Around the turn of the century, numerous reports from settlers, prospectors and soldiers include several scientific reports (e.g., Gulland, 1907; Marloth, 1909). Walter's (1936) syntheses and detailed descriptions laid down the foundation for ecological research in the area, as did those of Korn and Martin (1937) for geology and geomorphology. The fundamental recognition of the importance of fog was recognised in these early works.

Between 1948 and 1959, the Transvaal Museum, joined by several other institutions from South Africa, the United States of America and Namibia, undertook twelve research expeditions through the southern and northern Namib and the Kalahari in South Africa, Namibia and Angola (Koch, 1962). Following a multidisciplinary investigation in 1959, Gobabeb was recommended as an appropriate site for a research station (Lawrence, 1960). This recommendation was based on several factors, most importantly the ecotonal location at an ephemeral river (the Kuiseb) separating the Namib Sand Sea and the Central Namib gravel plains, and the setting within a game reserve (Fitzsimons, 1961b). In 1961, the South West African Administration (which governed Namibia at the time) granted a 50-year lease of Gobabeb to the Transvaal Museum, who established the Namib Desert Research Station in partnership with the then Department of Nature Conservation, the National Museum of Namibia, and the Namibia Scientific Society (Fitzsimons, 1961a,b). Funding for the institution and its research programme was pledged by the South West Africa Administration, the South African Council for Scientific and Industrial Research and the South African Museums Association, supplemented by several donors.

3. Growth of excellence

Following the establishment of the Namib Desert Research Station, the number of affiliated scientists, institutions, and funding grew steadily, bolstered by the allocation of several post-doctoral posts to the Desert Ecological Research Unit (DERU) at Gobabeb and good financial support for research from the predecessor of the National Research Foundation of South Africa (Seely, 1979). The publication of the journal, Scientific Papers of the Namib Desert Research Station, continued between 1962 and 1969. Later, this journal merged with another Namibian journal, Madoqua (which was discontinued in 1997). In the first decade, 122 research papers, books and theses were published under the umbrella of the institution at Gobabeb (Fig. 3). This increased to 266 publications in the second decade (1972–1981) and 456 in the third as the research broadened and intensified. In 1990 alone, DERU produced 97 publications (Fig. 3) as a culmination of growth of the research programmes prior to Namibian Independence.

The initial focus of this institutional growth phase was a description of the fauna and flora of the Namib, with emphasis on its many unusual or biodiversity-rich taxa (Seely et al., 2000). In addition, major cross-cutting themes in many research projects were fog and other water sources (Louw and Seely, 1982), dunes (Lancaster, 1989), ephemeral rivers (Huntley, 1985) and inselbergs

Fig. 3. Number of research publications per year produced by staff and research affiliates of the Gobabeb Research and Training Centre between 1961 and 2011. Publications of 1961 are combined with prior ones.

(Goudie and Eckardt, 1999). Studies of Namib climates have been important since Gobabeb's inception (Lancaster et al., 1984), and continue to provide the basis for many studies of Namib ecology. The review and analysis of the occurrence, patterns and dynamics of rainfall and other moisture sources (Eckardt et al., in this volume) is thus of fundamental importance for many other fields of research, today and in the future.

The abundant and highly diverse darkling beetles (Coleoptera, Tenebrionidae), with over 300 species found in the Namib Desert (Koch, 1962; Penrith, 1977, 1979), 82 near Gobabeb (Henschel et al., 2003), garnered considerable attention, described in 183 (12%) of the institution's publications. Besides the Namib's biodiversity, there was growing interest in Namib ecology in general (Seely, 1990) and ecophysiology (Louw, 1993). The Namib's characteristics that affect biodiversity include its hyperaridity, regular fog in the west, daily heat, microclimatic complexity, and strongly fluctuating availability of water and food between years and decades. Herrmann and Branch (in this volume) review how these ecological characteristics are reflected in the systematics, ecology and ecophysiology of reptiles, where several families have radiated and have high species-richness; new techniques spurn further studies to reveal how adaptive radiation is related to the habitat characteristics. The case of extreme habitat specialists, sand-diving lizards, bears out several of the underlying principles of evolution and ecosystem structure and function in the Namib in comparison to other deserts (Robinson and Barrows, in this volume).

Over many years a plant database and knowledge on the ecology of Namib plants was gradually developed, which now comes to fruition in the form of a vegetation map of the Central Namib (Jürgens et al., in this volume). This follows an analysis of biodiversity drivers and patterns and plant functional types and how this plays out in the plant communities. It reflects the Namib's strong zonation of climate and soils with distance from the coast and how it interacts with landscape features in shaping biotic communities.

Underlying the increasing understanding of its ecology was the realisation of the antiquity of hyper-arid conditions in the Namib (Ward and Corbett, 1990; Ward et al., 1983). The persistence of aridity in the region is reflected in the antiquity of its landforms and the generally low rates of weathering and erosion, as discussed by Viles and Goudie (in this volume).

An important focus of studies of geomorphology and Quaternary geology in the central Namib has been the Kuiseb River, with its suite of river terraces (Ward, 1987). The paleoenvironmental and paleohydrological significance of these and other fluvial deposits has been much debated (Lancaster, 2002), but new dating methods have provided much needed clarification of chronologies and thereby correlation to other sources of palaeoclimatic data (Stone and Thomas, in this volume). The extensive dunes of the Namib Sand Sea have been a further focus of research. Their proximity to Gobabeb has provided opportunities for long-term monitoring of their dynamics in addition to detailed studies of their processes and sediments (Livingstone, in this volume). These studies have lead to new models for linear dune formation and sand sea organization.

Several other important fields have not received as much attention in Namib research, although they have been touched on, e.g., archaeology (Kinahan, 2005a,b; Sandelowsky, 1977; Shackley, 1985).

4. Growth of societal relevance

By Namibian Independence in 1990, Gobabeb had established itself as a sound research institution with a strong network of support, and an accumulation of knowledge documented in over 800 publications. However, the founding contract was now invalid and it was necessary to reconstitute the institutional framework. As a consequence, the Desert Research Foundation of Namibia (DRFN) was established in 1990 as an independent NGO (non-government organisation), incorporating DERU (Seely et al., 2000). In 1998, the Ministry of Environment and Tourism and DRFN entered a joint venture agreement to form the Gobabeb Training and Research Centre as a single-entity institution to follow the legacy of the previous institutional partnership located at Gobabeb.

For the first few years, the German Ministry of Economic Cooperation funded the development of Gobabeb through the Southern African Development Community (SADC), particularly in support of developing training as the second institutional mainstay. The institution comprehensively broadened its training programme to include learners and students from primary to tertiary education levels in many different disciplines, specifically focused on the need for Namibians to gain awareness and experience in matters concerning the environment (Du Toit et al., 1995; Seely et al., 2003). During this transformation, research continued unabated, despite significant hurdles such as scant funding, and the consequent inability to continue the previously highly productive post-doc programme. Nevertheless, in the first decade following Independence, a total of 374 publications emerged from research conducted by or under the auspices of the Gobabeb Centre, and in the following decade (2002–2011) this level was maintained with 362 publications (Fig. 2).

The Gobabeb Centre was designated as southern African research and training focal point connected to the United Nations Convention for Combating Desertification (UNCCD) (Seely and Wöhl, 2001). Namibia's Programme to Combat Desertification, which was led by the DRFN, had its origins as well as its research and training hub at Gobabeb (Zeidler et al., 2002), and had a profound influence on the direction of the Gobabeb Centre's other programmes. Various projects involved natural resource management and pastoralism in relation to land care by communal farmers (e.g., Henschel et al., 2004; Ward et al., 1998; Zeidler et al., 2002). An important research thrust concerned the ephemeral rivers of the Namib Desert in Namibia (Jacobson and Jacobson, in this volume), which built on early observations along the Kuiseb River of flooding (Koch, 1963), the riparian forest (Huntley, 1985) and the local community living along the Kuiseb River (Dentlinger, 1983). Over 20% of the publications from Gobabeb concerned the Kuiseb. Jacobson & Jacobson (op. cit.) elucidated the implications of the Namib Rivers' extreme annual hydrological variability and depicted the crucial importance of ephemeral rivers for the ecology of the Namib Desert as well as human communities and industry, with clear implications for managing these vulnerable systems in support of sustainable development.

The thrust of research relating to water, its various sources and dynamics broadened significantly to encompass human uses and requirements (Shanyengana et al., 2004). This included the application of knowledge gained from atmospheric moisture (Henschel and Seely, 2008), and tests were conducted to adapt the Atacama fog-harvesting technology to the Namib Desert (Henschel et al., 1998). The extreme climatic conditions in the desert, especially the high incidence of solar radiation and heat made Gobabeb well-suited to test the application of appropriate technology in such isolated locations, so as to refine their application for use by isolated rural communities (Seely et al., 2009).

At the institutional beginnings of Gobabeb, long-term monitoring of the desert environment was initiated and assiduously followed through. It started by monitoring climate (Eckardt et al., in this volume; Lancaster et al., 1984), and dune movement (Besler, 1975). Further aspects grew out of the continuation of measurements that were initiated by short-term projects (Livingstone, 2003; Seely and Ward, 1988). With decades of data (Henschel

et al., 2000), Gobabeb brought significant potential to the Environmental Long-Term Observatories Network of Southern Africa (ELTOSA) (Henschel et al., 2003) and the International Long-Term Ecological Research Network (ILTER) (Parr et al., 2003) as well as other broad-based programmes in the region, such as BIOTA (Hoffman et al., 2010; Jürgens et al., 2010; Schmiedel and Jürgens, 2010). Today, Gobabeb is custodian to a wealth of environmental data sets and time-series, many not yet processed, but with the potential to support current and future needs for long-term broad-scale multivariate data sets required for environmental policies and management in general (Driscoll et al., 2012).

5. Future research

Fifty years after Fitzsimons (1961a,b) had motivated research to meet the needs for environmental management of anthropogenic changes, especially mining and industrial development, Gobabeb is now getting to this juncture. Good knowledge of the Namib, the capability to monitor its environment and manage data, multidisciplinary research to cover gaps, and the know-how to mitigate and restore environmental degradation is now required to guide mining and other industrial and urban developments in the Namib (MME, 2010). For this purpose, the Namib Ecological Restoration and Monitoring Unit (NERMU) (Wassenaar et al., in this volume) was started at Gobabeb in 2012, which will guide some of the institution's own research including visiting scientists in the years to come. While this research builds up on the existing knowledge gathered over fifty years it also drives new research initiatives into as yet little-known avenues which need to be understood in order to restore degraded environments. Knowledge will translate into policy and the technical competence to mitigate, restore and manage environmental degradation and sustainable use of the Namib.

The Gobabeb Research and Training Centre remains an important springboard for future multidisciplinary research by local and foreign institutions into many important questions such as the effect of climate change on desert ecosystems, refining the understanding of climatic drivers as well as nutrient pathways. The knowledge base established at Gobabeb can be used in many ways to facilitate research and management. For example, new remote sensing data sets (e.g. ASTER digital elevation models) can be validated using field data collected over decades to develop new models for dune pattern and sand sea development (Bullard et al., 2011), as well as understand processes affecting land surface temperatures (Olesen and Göttsche, 2009). The long period of aridity, the specific importance of frequent fog events for many organisms, and the very slow rate of some of the geomorphic and ecosystem processes and population turnover makes the Namib Desert an important location for calibrating climate change (Eckardt et al., in this volume; Jürgens et al., in this volume). The remote terrestrial location of Gobabeb far from greenhouse gas production centres, makes it ideal for understanding the sensitivity of systems to the carbon cycle (McGuire et al., 2009), and Gobabeb is part of the Global Atmosphere Watch system.

Similar to other places, past ecological and biological research in the Namib has tended to focus on small-scale phenomena. Overall, there is a need for incorporation of this extensive fine-scale knowledge into integrated models (and understanding) of large-scale ecosystem dynamics. A new challenge lies in using approaches and analytical tools that elucidate landscape processes, connectivity and fragmentation, including patchiness, and ecosystem drivers across strong climatic gradients of the Namib (MET, 2012). This will in turn help develop concepts concerning factors underlying this desert's extraordinary biodiversity. DNA techniques promise to shed light on many vexing phylogenetic and phylogeographic problems, and to analyse population differentiation, fragmentation, and genetic bottlenecks (Steckel et al., 2010; Herrmann and Branch, in this volume). Research should also be conducted on the population ecology of several range-restricted species (e.g., Cunningham et al., 2012) or other species of special conservation status, such as *W. mirabilis* (MME, 2010), that are potentially threatened by future developments. Other major gaps that beg future research are nutrient processes and pathways (Louw, 1993), the importance of allochthony (Polis and Hurd, 1996), and microbiological processes (Büdel et al., 2009), which have only been barely touched on in the Namib. Some of the above-mentioned research directions and many others, not mentioned here, are currently being developed.

The age of scientific discovery in the Namib has barely begun, and Gobabeb is right in the centre of this effort. Some of the knowledge this can build on is aptly outlined in the review chapters of the current volume.

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