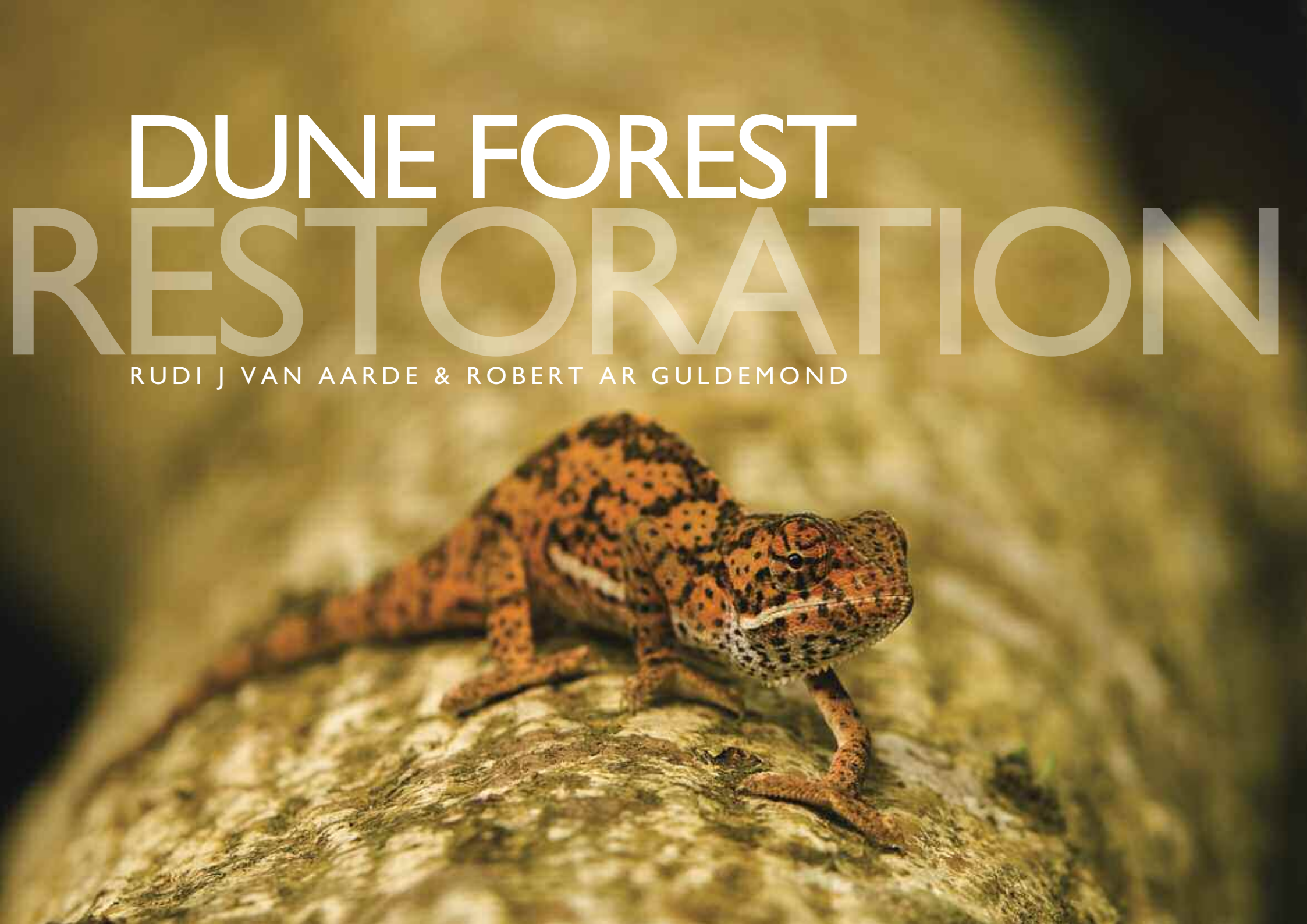
DUNE FOREST RESTORATION

RUDI J VAN AARDE & ROBERT AR GULDEMOND



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DUNE FOREST RESTORATION

2012 A VISUAL JOURNEY

RUDI J VAN AARDE & ROBERT AR GULDEMOND
PHOTOGRAPHY BY RUDI VAN AARDE

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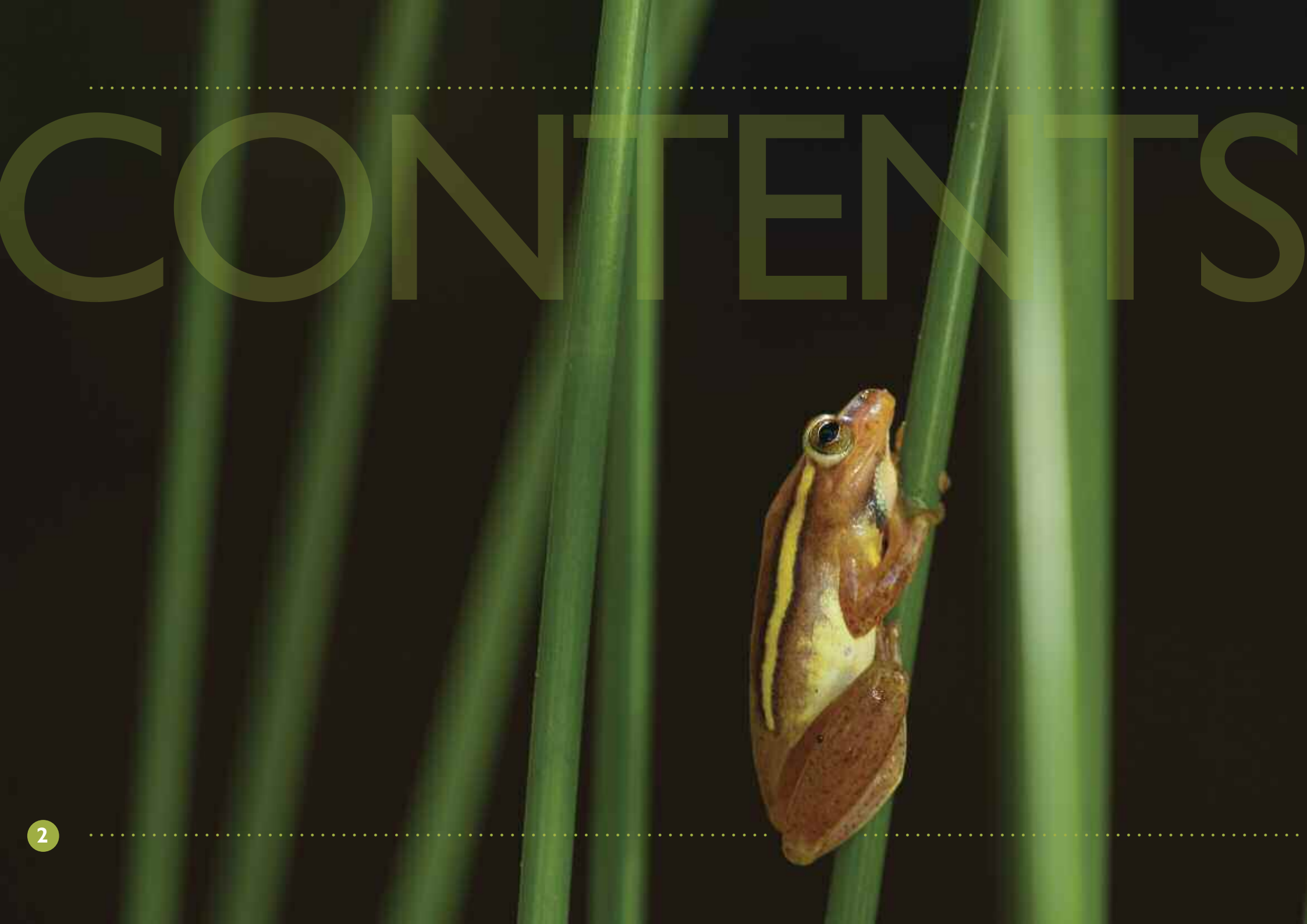

All photographs in this publication were taken in and around Richards Bay Minerals' mining lease areas.

The extraordinary diversity of species living in the new growth forest in RBM's mining lease areas is a testament to the company's long-term ecological restoration programme. In these areas, trees form a dense canopy and provide shade and shelter for lush growths of shrubs, herbs, ferns and some grasses. Brightly coloured flowers, snails, insects, millipedes, frogs, chameleons, snakes, tortoises and birds live here. Mammals, other than shrews and rodents, are rare, but red duikers, bush babies and the occasional leopard do occur. Jointly these plants and animals form a dune forest similar to other indigenous forests along the coast.

RESTORING DUNE FORESTS: A VISUAL JOURNEY

The restoration of degraded landscapes is no longer a luxury. It is a necessity and the only way to regain the essential services lost through the earlier destruction of our natural resources. Ecological restoration is widely recognised as a means to reverse the environmental degradation that often goes hand in hand with economic development and growth. This also holds true for Richards Bay Minerals' (RBM) unique dune forest restoration programme.

SUSTAINABILITY

RBM's commitment to sustainable development has seen 35 years of continuous and dedicated efforts to maintain the ecological processes that drive the restoration of indigenous dune forest on a third of its mining lease areas. Our research proves the rehabilitation programme is successful. It provides for the regeneration of a coastal forest typical of the region on mined sand that is shaped into dunes. The programme also yields environmental dividends in the form of ecological services delivered by the natural capital gained through rehabilitation.

The new growth of forest that develops on dunes after mining and in response to rehabilitation follows patterns predicted by ecological theory. Teeming with life regained through the nurturing of natural processes, it is an asset to society that exceeds all other long-term potential land use options of coastal dunes. Respect for this forest as an asset comes through knowledge of its value and an appreciation of the beauty that it encapsulates.

In this booklet we share some of the knowledge we have accumulated over 20 years of research. Our conclusions are based on the many peer-reviewed papers that we have published in scientific journals. A 'picture paints a thousand words' and hence our decision to support our words with images that may make people aware of the special features of a dune forest. This booklet is one of the fruits of a team of enthusiastic, hard working and dedicated postgraduates, research assistants and research fellows. We are grateful for the opportunities provided by the University of Pretoria and the continuing support from the National Research Foundation (NRF), the Department of Trade and Industry's THRIP programme and RBM.

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Ecological Restoration: Countering Biodiversity Loss

The ecological, sociological and economic necessity of ecological restoration provided momentum for the development of restoration ecology as an academic sub-discipline. Within 20 years, it has matured into a well-defined and respected science that provides for the development of approaches to restore nature and allow for the testing of many primary ecological principles. This also holds true for the coastal dune forest that is developing in response to rehabilitation after mining along a 24 kilometre stretch of coast-line north of Richards Bay, under the stewardship of Richards Bay Minerals. This 'outdoor laboratory' provides for innovative research on the ecological processes that sustain restoration and opportunities to evaluate and direct RBM's rehabilitation programme.

> “Teeming with life regained through the nurturing of natural processes, the new growth forest is an asset to society that exceeds all other long-term potential land use options of coastal dunes.”

The number of papers on restoration ecology published yearly in ten scientific journals (Scopus search engine)

A variety of vines and creepers dominates the forest floor. To the casual observer these plants may appear to smother others, but this is not the case. Vines and creepers entice a large variety of insects and birds to eat their brightly coloured fruit and seeds, such as those of one of the *Coccinia* species that commonly grow in new growth forest. The leaves of this creeper apparently serve as a traditional medicine to lower blood sugar levels.

PERSPECTIVE

DUNE FORESTS: AN ECOLOGICAL PERSPECTIVE

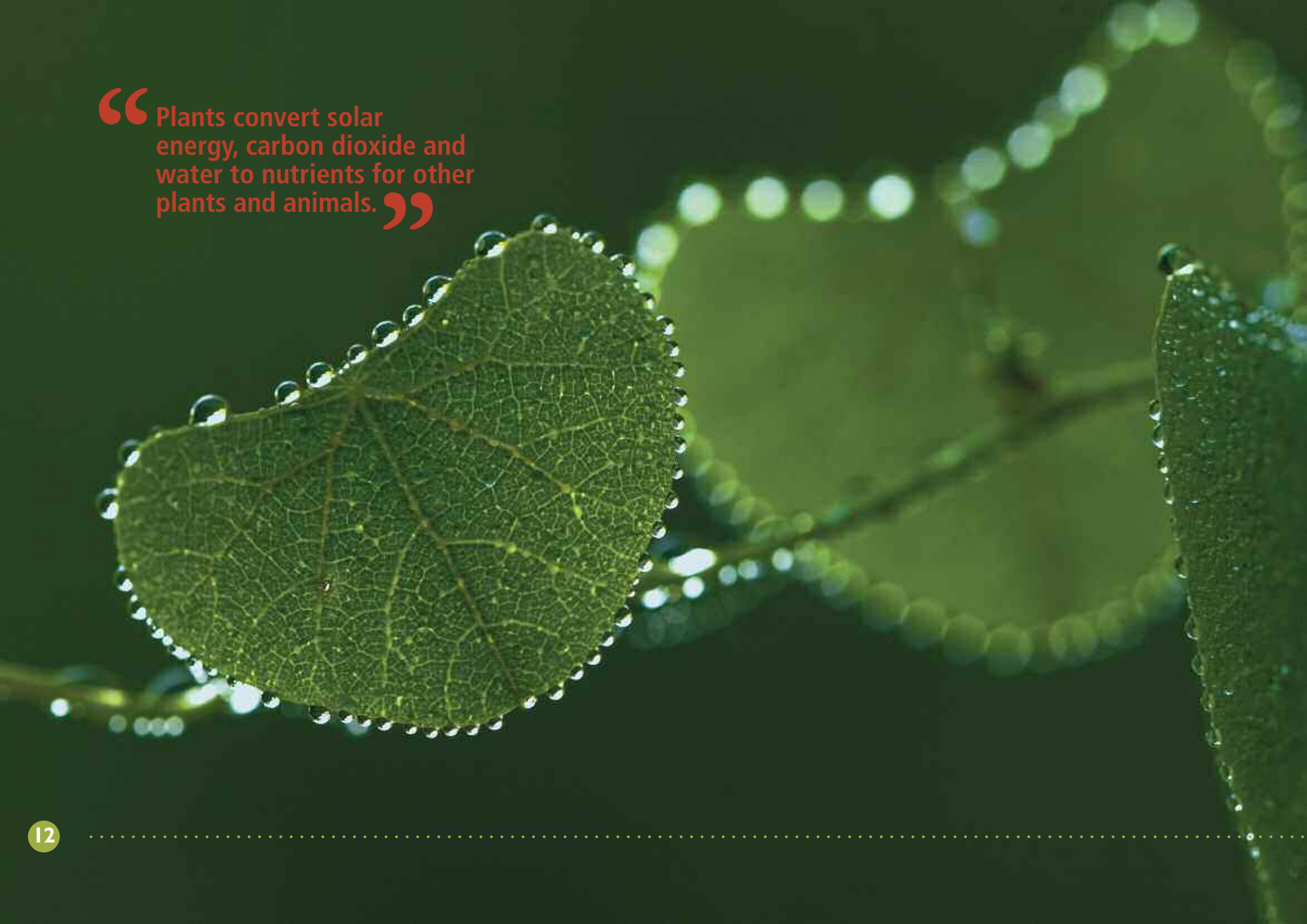
Only 7% of South Africa has a climate suitable for the development of forests. Despite this, forests account for a mere 0.6% of the area of the country and are often fragmented into isolated patches that seldom exceed 100 hectares. Broadly, two main types of forests occur in South Africa: the Afromontane forest and the Indian Ocean coastal belt forest (IOCB). The IOCB occurs as a narrow strip (at some places less than ten kilometres wide) along 800 kilometres of the eastern seaboard. The dune forest is part of the IOCB and makes up 2.5% of the country's forested areas.

The dune forest at Richards Bay is located at the southern tip of the Mozambican coastal plain and originated in response to climate and sea level changes some 8 000 to 10 000 years ago. This narrow, young forest only occurs on coastal sand dunes and seldom extends further inland than 500 metres from the coastline. Prevailing weather systems and tropical conditions maintained by the warm Agulhas Current along the eastern coastline of South Africa lend a sub-tropical ambience to this forest. These conditions attract some species from tropical forests to the north, while species from temperate forests to the south reach their northern-most distribution here. At the same time, some species more commonly associated with hinterland savannas and mountain forests also persist in the coastal forest, the edge of their ranges. The dune forest is therefore a rich and diverse melting pot of species. None of the species living here seem unique or endemic to dune forests in South Africa. However, as the meeting place of three different biomes, the forest around Richards Bay is of special value, not only for the conservation of species, but also for the ecological services it provides to society.

Essential ecological services include the conversion of solar energy, carbon dioxide and water to plant biomass, thereby storing carbon and providing nutrients. Dune forests also protect the hinterland from storms, provide medicinal plants, and stabilise local climate and dunes. Their role as a barrier or buffer from storms and ocean conditions is of huge economic importance. In 2007, a storm destroyed not only property worth millions of rands but livelihoods along the coast as well. Significantly, the areas most affected were those without indigenous dune forests to dissipate the force of the sea. With global warming predicted to increase storm events, the value of a barrier to protect human life and livelihoods is apparent. Consequently, these forests provide huge immediate and future benefits for people living in the hinterland.

The sweet thorn (*Acacia karroo*) is the most common tree species in new growth forest on coastal dunes. Acacia species, such as the sweet thorn, are known for their ability to enrich soil fertility by fixing nitrogen and hence improve growing conditions for forest species that flourish in the undergrowth and in the shade of the sweet thorns. The latter are generally short-lived and their numbers decrease rapidly as the forest matures. In dune forests, most sweet thorn trees die within 40 years. Consequently their dominance in new growth forests decreases progressively as they are replaced by species typical of old growth forests. Sweet thorn seedlings seldom establish under the canopies of their own kind.

“With global warming predicted to increase storm events, the value of a barrier to protect human life and livelihoods is apparent. Consequently, coastal forests provide huge immediate and future benefits for people living in the hinterland.”


“Plants convert solar energy, carbon dioxide and water to nutrients for other plants and animals.”

Dune forests grow on soft, leached sand, deposited by a retreating Indian Ocean during the end of the last glacial period. Strong winds blew the sand into parabolic-shaped dunes. Those close to the sea are usually only a few metres high, but dunes further inland can attain heights of up to 80 metres. Variability in the aspect, direction and slope of dunes generates varying habitat conditions that provide for the needs of many plant and animal species.

Dune forests are narrow and thus exposed to edge effects. The intensity of these edge effects depends on the type of neighbouring landscapes. Adjoining wetlands, grasslands, savannas and forests contribute to the biological diversity of dune forests, but adjoining pine, blue gum and beefwood plantations, as well as sugar cane fields and stretches of urban development threaten the ecological processes that maintain dune forests.

The state of South Africa's dune forests

- Approximately 0.6% of terrestrial South Africa comprises forests and of that only 2.5% consists of coastal dune forests
- The dune forest of KwaZulu-Natal is an eco-region within the Maputaland Centre of Plant Endemism, highly valued for its contribution to conservation
- Species from tropical forests to the north, temperate forests to the south, as well as the savannas of the hinterland converge on the relatively young dune forest
- Geographic and ecological realities render the dune forest sensitive to disturbances
- Only a third of all dune forests are formally protected. Those in the north of the country enjoy better protection, while forests between Richards Bay and Durban are poorly protected, highly fragmented and increasingly disturbed through ongoing urban development, tourism, forestry and mining

Paintbrush lily *(Scadoxus puniceus)*; umphompo in Zulu; rooikwas in Afrikaans) is a kind of amarylla (family Amaryllidaceae) that bears attractive red-orange flowers. They are common in the undergrowth of new growth forests restored by RBM, where they usually flower during August. Traditional uses of the plant include the treatment of coughs and stomach problems. It is also taken during pregnancy to ensure safe births. Alkaloids from these plants are, in reality, highly poisonous and have limited medicinal value. Their indiscriminate use can be lethal.

CONSERVATION

The coastal dune forest of KwaZulu-Natal forms an eco-region within the Maputaland Centre of Plant Endemism, which is situated in the Maputaland-Pondoland-Albany biodiversity hotspot. South Africa boasts three such globally recognised hotspots. Their status as regions of special conservation value is justified by the presence of a disproportionate number of endangered and vulnerable species that live nowhere else.

Natal tree frog (*Leptopelis natalensis*)

The sub-tropical nature of the mining lease areas means these forests harbour several rare species at the edge or end of their tropical ranges to the north, or their temperate distribution to the south, or the seaboard end of their ranges that extend further to the hinterland. This lends to the dramatic diversity of species living in these forests. The Richards Bay area is especially rich in frogs and 48 of South Africa's 115 frog species occur in the region. The Natal tree frog is among one of a dozen spectacular species that also occur in the regenerating dune forest. Although none of these frogs is poisonous, they are all easily disturbed by handling.

In South Africa, some dune forests are excessively disturbed by human activities including tourism-related development, informal settlement, and mining for minerals. Their geographic location in relatively high rainfall regions, which are suitable for commercial forestry, places additional pressure on their existence through the establishment of exotic plantations for timber production. Some dune forests are well protected, but others not, especially along the coast from Richards Bay towards Durban and beyond.

Some 36% of dune forests are under legal protection, almost two thirds thereof as national and provincial parks, wilderness areas and special protected forests. The iSimangaliso Wetland Park is the largest protected area in the region, a 3 320 km^2 World Heritage Site that protects about 280 kilometres of dune forests between Kosi Bay and the Maphelane Nature Reserve, just south of St Lucia. State forests, where people can harvest natural resources, have almost 13% of the protected forests under their jurisdiction. Private land contributes to less than 1% of dune forest protection.

Restored and intact dune forests

- Protect the hinterland from damage during storm surges
- Stabilise the shoreline and prevent sand dunes from slumping into the sea
- Serve as locations of ground water recharge and assist in the retention of fresh water, buffering the land against saltwater intrusion
- Protect inland villages from storms and prevent sand from drifting onto sensitive grasslands and wetlands in the hinterland
- Are important repositories of a variety of plants and animals that collectively provide essential ecological services
- Contribute to soil formation and help regulate climate, produce oxygen, absorb carbon and purify water
- Are valued for their beauty and sense of place

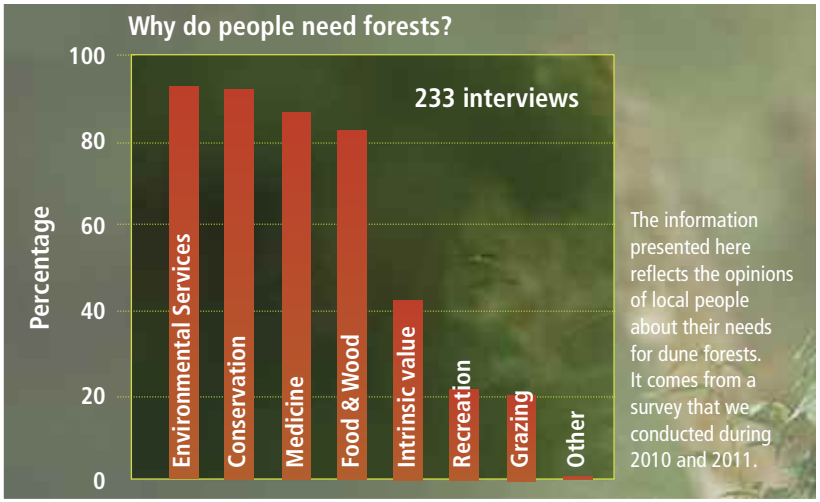
> “Some 36% of dune forests are under legal protection, almost two thirds thereof as national and provincial parks, wilderness areas and special protected forests.”

Setaro’s dwarf chameleon (*Bradypodion setaroi*)

Previously considered endangered, this rare chameleon has a very limited distribution and has recently been down-listed to ‘least concern’. It is endemic to South Africa and Mozambique where it lives in coastal dune forests between Richards Bay and Maputo. It sometimes occurs in city gardens. Adults are only ten centimetres long (tail included). These chameleons do best when not disturbed and people should not keep them. They are a prey item of the boomslang (*Dispholidus typus*) and the twig snake (*Thelotornis capensis*) that commonly occur in dune forest. Chameleons are not poisonous, stalk their prey and catch a variety of grasshoppers, crickets and flies with an elastic tongue that can extend as far as the length of their bodies.

PEOPLE AND DUNE FORESTS

People have exploited dune forests for at least 1 600 years. Some 400 years ago Zulu people (especially members of the Mbonambi clan) cleared stretches of forests for subsistence agriculture and charcoal production to fuel iron smelting. By 1937 much of the dune forests between the Umfolozi River and Richards Bay were degraded. Between 1937 and 1974 commercial forestation with blue gums and pines, as well as the planting of beefwood to stabilize dunes further affected the forests. Commercial mining of sand dunes commenced in 1977 and added to the damage. However, at that stage, at least two thirds of the mining lease areas was degraded.



The information presented here reflects the opinions of local people about their needs for dune forests. It comes from a survey that we conducted during 2010 and 2011.

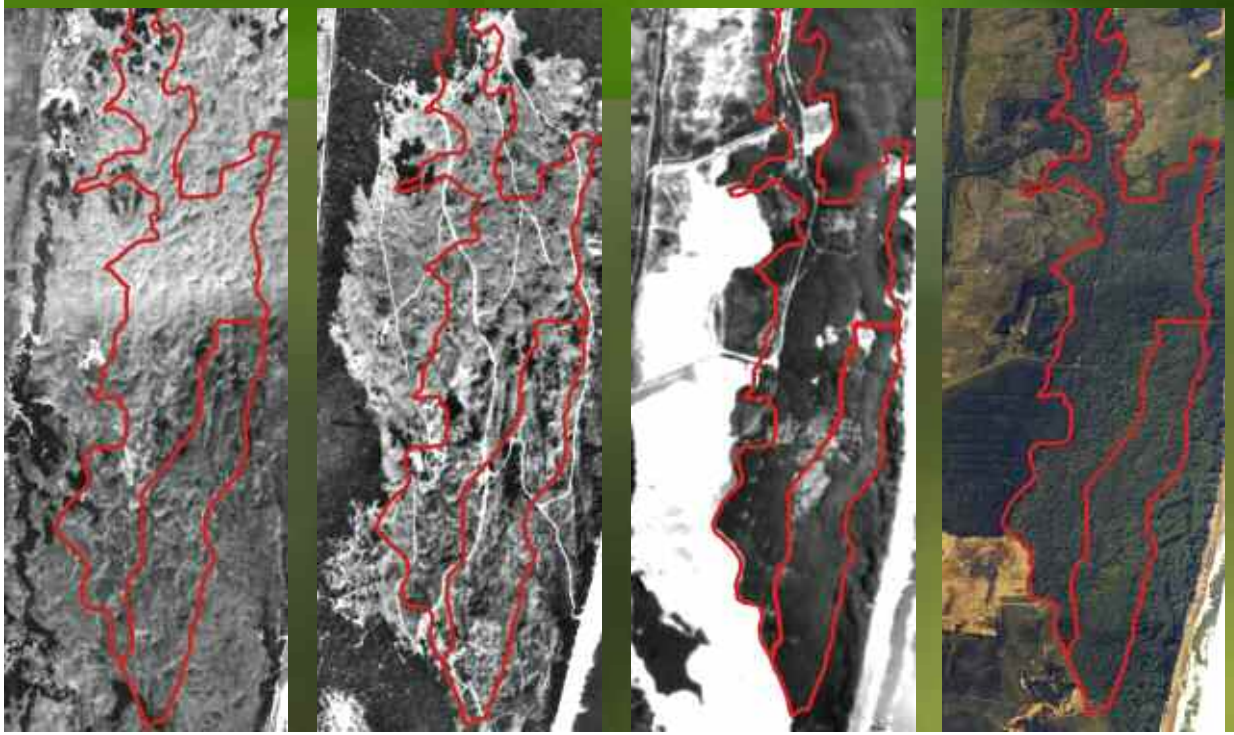
Why do people visit the dune forests?

This information, on the activities of local people in dune forests, is based on a questionnaire survey that we conducted during 2010 and 2011. Many activities reflect on the aesthetic and essential values of the dune forest but traditional hunting with spears and packs of hounds, as well as the setting of snares, threaten small antelope such as the red duiker (*Cephalophus natalensis*) that live here.

Dune forests in KwaZulu-Natal experience some of the highest population pressures in the country. Some 60 people per hectare live within a five kilometre radius of forest patches. They impinge on forests, primarily by allowing their cattle to disturb vegetation, through the collection of firewood and medicinal plants, as well as the dumping of building rubble and garden refuse. Past and present disturbances have reduced much of the dune forest to isolated pockets, or fragments of old growth forests.

Some of these fragments are situated in protected areas, but most are embedded in mosaics of new growth forests, regenerating after the withdrawal of disturbances, or in patches of plantations where exotic timber species are grown, and areas cleared and disturbed through formal and informal settlement.

Current research suggests that 56% of dune forests are already transformed, with commercial plantations the biggest contributor, representing 17% of the total area. Threats to remaining patches of forest include clearance for agriculture, housing, tourism, commercial forestation and mining. Between Kosi Bay and Durban mining lease areas account for about 13% of coastal areas where forests could persist, but much of these lease areas comprise disturbed landscapes dominated by neglected plantations and stands of exotic invading plant species.



Aerial photographs taken on several occasions between 1937 and 2010 clearly show that many rehabilitated areas comprised bare sand before mining started in 1977. Some 400 years ago Zulu people (especially members of the Mbonambi clan) cleared large stretches of these forests for subsistence agriculture and for charcoal production to fuel iron smelting. By 1937 much of the dune forests between the Umfolozi River and Richards Bay were degraded. Commercial forestation with blue gum, pine and beefwood between 1937 and 1974 further ruined the dune forests. The red lines show some of our study areas in this outdoor laboratory.

Justifying Restoration

Human activities threaten to destroy the few patches of remaining old growth dune forest. Forest specialist species are threatened by habitat loss due to human activities, while interferences with ecological processes could destabilise the essential services provided by these forests.

Restoring dune forests through rehabilitation incentives therefore makes ecological, economic and conservation sense. This is exactly what Richards Bay Minerals aims to achieve through its post-mining dune rehabilitation programme which started soon after mining commenced in 1977. Since then some 1000 hectares, representing about a third of the mining path, have been set aside to regenerate into forests through active rehabilitation.

MINING EMBRACES FOREST RESTORATION

Mining is destructive, especially when intact dune forests tumble in the wake of mining operations. However, that only happens in some parts of the mining lease areas north of Richards Bay. Before mining commenced, the lease areas supported only a few patches of forests. By 1972 two thirds of the land earmarked for mining comprised degraded forests, bare sand dunes and stretches of unkempt plantations, mostly blue gum and pines planted for timber. Lines of beefwood planted by forestry departments to stabilise dunes, further dotted the landscapes. All lent to the degraded appearance of the landscape. At the time, the land was further degraded by people frequenting the areas to undertake slash-and-burn practices to promote grass growth for cattle. Then, along came mining.

Assisting with the Recovery of Ecosystems after Mining

Mining started during 1977 and involves an open-cast dredging process. The minerals extracted from the sand account for less than 5% of its volume. The clearing of vegetation and collection of topsoil precede the mining process. After the removal of the minerals from the sand, the "tailings" (the stockpiled sand that has been through the dredging process) are shaped to reform dunes. Post-mining rehabilitation aims at two pathways to establish vegetation on mine tailings. The first provides for the establishment of a commercial land-use in the form of beefwood (*Casuarina equisetifolia*) plantations, and the second involves the restoration of indigenous coastal dune vegetation. Stressors that may derail the development of dune vegetation are minimised through the active control of bush fires, the control of illegal grazing by cattle and the control of exotic species that invade new growth forests.

Our research in the outdoor laboratory that developed in response to forest rehabilitation kicked off in 1991. The regeneration profiles that we have compiled for several plant and animal groups show that the rehabilitation programme is effective. Its success is largely due to a sustained and dedicated effort to take care of the ecological processes that restore indigenous coastal dune forest along a third of the mining path.

Different to earlier disruptions, mining removed all vegetation in its path. It severely disrupted forest life and all exotic elements that dominated the landscape. In a similar vein, it also cleared the land of all earlier disruptions. In its aftermath followed a concerted rehabilitation programme to restore the dune forest.

In South Africa, coastal dunes belong to the people and the state is the legal guardian of these forests. Mining in mining lease areas is a legitimate land use option. However, this mining option includes an important stipulation. South Africa's Mineral and Petroleum Resources Development Act of 2002 requires mining companies to "*...as far as it is reasonably practicable, rehabilitate the environment affected by the prospecting or mining operations to its natural or predetermined state or to a land use which conforms to the generally accepted principle of sustainable development...*".

RBM is committed to rehabilitating the dune landscape after mining. This option includes: 1) the establishment of commercial plantations on two thirds of the mining path, and 2) the restoration of indigenous vegetation on one third of the mining path. In essence, this means that mining aims at sustainable development and the betterment of society.

A great variety of fungi flourishes in coastal dune forests. Bracket fungi grow on dead trees and contribute to the decay of wood. Like mushrooms, they are neither plants nor animals. Fungi do not have chlorophyll and they rely on their hosts for sustenance. Saprobic fungi grow on dead animals and plant tissue and contribute to the recycling of nutrients. Parasytic fungi attack plants and animals that are alive and may kill plants weakened by stress and induce unpleasant diseases in people and other animals. Symbiotic fungi form associations with algae and blue-green bacteria to produce lichens.

Our studies on the development of dune forest vegetation on the mining lease areas and on millipedes and birds that live here provide opportunities to evaluate restoration success against set goals derived from theory and from our research on un-mined forests in the region. Our postgraduate education programme is supported by RBM, the NRF and THRIP.

GIVING NATURE A HELPING HAND:
RESTORING DUNE FORESTS

Ecological restoration plays an internationally recognised role in sustainable development and conservation. The mining of dune forests certainly detracts from conservation, but restoration of the mined path contributes to conservation, especially where formerly unprotected, degraded areas are managed in order to develop into forests typical of the region. In these areas mining clears exotic plants and replaces disruptive processes with indigenous ecological processes. Restoration is an ambitious option, but in line with modern-day approaches, aims to regaining natural landscapes lost through earlier human activities. Hence, mining followed by a well-designed ecological restoration programme makes environmental and conservation sense.

RBM's Environmental Commitment

RBM's commitment to dune forest restoration stems from the ecological, social and conservation importance of dune forests. The restoration of degraded landscapes is a cure for habitat loss and degradation. Nowadays it is integral to many conservation incentives and is often a legally binding requirement of mining permission. The mining company's commitment to restore one third of the lease area to indigenous vegetation is the longest running rehabilitation programme in South Africa. It is in line with the restoration target for companies mining in this country and complies with the South African Constitution, which gives all people the right to an environment that is not harmful to their health and well-being.

The methods adopted to restore forests have remained unchanged since the start of the rehabilitation programme in 1978. Rehabilitation begins with reshaping mined sand into dunes similar to those that existed before mining. Reshaped dunes are then covered with a thin layer of indigenous topsoil, collected before mining and enriched with the seeds of fast growth annuals to stop the sand from being eroded by wind and rainwater. Windbreaks placed at 30 to 50 metre distances across the dunes further assist in the stabilisation of dunes. Beyond this, development of the vegetation takes place of its own accord, but for the removal of invasive exotic species. The recipe works.

Within weeks of covering the bare sand with topsoil, enriched with the seeds of annuals, the dunes are 'painted' green. Two years later, indigenous grasses replace most annuals. These grasses in turn give way to dense stands of shrubs, mostly sweet thorn, which is a pioneer species that flourishes on disturbed land all along the east and north coasts of South Africa. Some ten years later, gaps appear in the canopy of the new growth forest, as some of the sweet thorn trees succumb to storms and competition. These events reduce sweet thorn numbers from approximately 20 000 to fewer than 500 per hectare within 15 years. At this stage forest species such as the coastal red milkwood (*Mimusops caffra*), white stinkwood (*Celtis africana*), Natal karee (*Searsia natalensis*), and common turkey-berry (*Canthium inerme*), mostly spread by birds and mammals, take advantage of the opportunities to colonise rehabilitating areas. In time, more forest plants establish themselves as conditions become favourable - with them return a range of forest animals typical of the region. Slowly the forest reclaims the dune, mostly through ecological succession followed by gap dynamics.

After the stabilisation of the dunes and spreading of forest topsoil, management mainly includes the control of unnatural disturbances, such as fires and grazing by cattle, as well as the elimination of invasive exotic plants. Indigenous ecological processes therefore drive forest development.

> RBM aims at maintaining ecological processes that will ultimately result in the composition, structure and function of a new growth forest indistinguishable from undisturbed old growth forests.

NEW BEGINNINGS:
SETTING RESTORATION GOALS

Restoration is best achieved through the cost-effective rehabilitation and maintenance of ecological processes. RBM subscribes to this goal and therefore goes beyond the legally binding responsibility of rehabilitating a third of the mined path to indigenous vegetation. The company's emphasis calls for long-term sustained actions to minimise disruptions that could derail ecological processes. More so, RBM's commitment to the independent evaluation of the outcomes of its rehabilitation programme, through scientific research, heralds ethical responsibility beyond the call of duty, as does the sustained support of basic research to enhance restoration.

Restoration ecologists agree that the setting of restoration goals calls for benchmark values, which are best obtained through scientific knowledge of the state of a natural landscape before disturbances. This information is often not available. In such cases, goals can be set from knowledge of the natural and intact landscapes in the region where restoration takes place.

Old growth coastal dune forest, not exposed to mining or other forms of artificial disturbances, may therefore serve as benchmark areas. However, even natural landscapes are in a continuous state of change for a variety of reasons. Setting targets for restoration, based on fixed properties does not make sense. That is why RBM's decision to focus on ecological processes to recover coastal dune forest raised its incentive from mere rehabilitation, as dictated by law, to restoration. Such restoration provides for the environmental needs of society.

The company aims at maintaining ecological processes that will ultimately result in the composition, structure and function of a new growth forest indistinguishable from undisturbed old growth forests.

The ecological process that drives the recovery of ecological systems after disturbances is succession. Succession, in its simplest form, is defined as the continuous addition and replacement of species until all species typical of the benchmark area persist within the previously disturbed site. RBM's rehabilitation programme aims to set conditions that induce and maintain succession.

Succession calls for the removal of unnatural disturbances to provide opportunities for species typical of benchmarks to disperse naturally to target sites. Suites of established species have to persist until conditions favour their replacement by other suites of species. This process should repeat until conditions support the so-called climax species typical of the end state(s) of succession.

By then the new growth system should be similar to a natural system typical of the region. It follows that rehabilitation to achieve the restored state is a sustained long-term activity.

RBM's Restoration Goals

- Establish and sustain ecological processes that will lead to a revived coastal dune forest on one third of the mining path
- Minimise unnatural hindrances that could derail ecological processes and forest development
- Integrate restored new growth forests with sustainable land use options to promote conservation and benefit local communities

MONITORING RESTORATION

Ecological restoration is expensive and time-consuming. Evaluating the outcomes of restoration is equally time-consuming. It calls for adherence to scientific protocols and for well-designed research to establish whether restoration goals can be, or have been achieved. We base the evaluation of dune forest restoration on the monitoring of changes in the presence and absence of species, as well as changes in their numbers over time.

To do this we continually survey the new and old growth forest, obtain regular estimates of the numbers of individuals of a variety of plant and animal species, and determine the growth rates of trees. For some 20 years, we have followed strict scientific protocols to identify species of trees, shrubs, millipedes and birds on survey plots in various stages of forest development.

Our sampling protocols meet international standards and we emphasise measuring the variability and precision of all our estimates. We take special care to ensure the repeatability from year to year and from one survey area to another. For instance, we

replicate and randomly locate survey quadrats for our plant and millipede studies within each of the sampling sites. Quadrat surveys allow a direct estimate of species numbers or numbers of individuals per unit area.

Birds are identified and counted along survey lines called transects. This is essentially a "plotless" method, where total density (numbers per unit area) is estimated using a mathematical relationship between area and distance, corrected for the decline in visibility of individual birds the further away they are from the line transect. The completeness of sampling for all groups is determined from accumulation curves. We therefore plot the cumulative number of species that have been encountered against sampling effort. Such plots level off once all (or most) of the species in a habitat have been encountered. At that point the community has been adequately sampled and we have a reliable estimate of the species contained in that plot. This approach ensures cost efficiency and scientific rigour.

We identify species against reference collections. For this reason, a herbarium and a reference collection of millipede species is maintained at the field station at Richards Bay, and we frequently confirm identifications against national reference collections.

We analyse data and compare our results against ecological theory, hypotheses and our own empirical experiences over the years. We publish our research findings in peer-reviewed scientific journals. Postgraduate training and research are integral to our approach and we regularly disseminate our findings at national and international conferences. Regular feedback meetings to mining management also ensure the implementation of our research outcomes and maintain management capacity.

Millipedes

Despite their name, millipedes do not have a thousand legs! Most species have between 40 and 400 legs, which are always arranged in two pairs per body segment. Most millipede species eat decaying plant matter and are thus detritivores, but some eat green leaves, algae as well as lichens. Millipedes defend themselves by curling into a tight coil when disturbed, or by producing offensive smelling hydrogen cyanide gas or iodine-like liquids that irritate or stain the human skin. Some highly specialised slugs, and several bird and mammalian carnivores eat millipedes. Not all millipedes are cylindrically shaped. A case in point being the ovalesque pill millipedes (left) who also live in these dune forests. Over the 20 years of study we have identified at least 21 species of millipedes in new growth forests that have regenerated in response to RBM's dune rehabilitation programme.

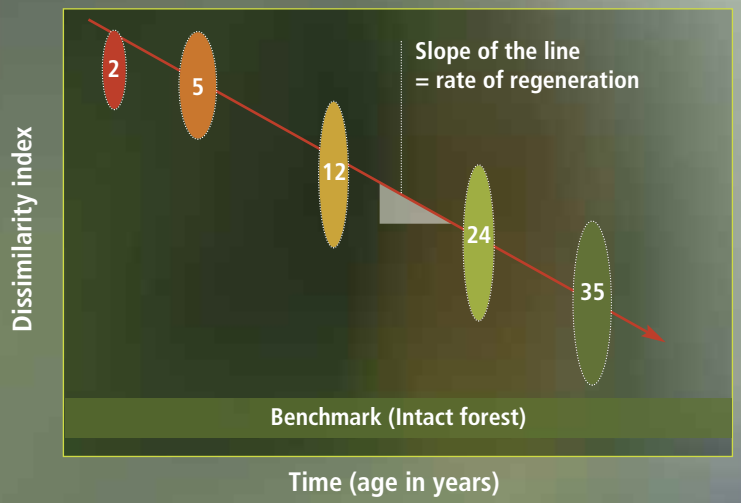
Important drivers of restoration success

- Stability of ecological processes
- Availability and maintenance of sources of species pools to colonise regenerating landscapes
- Environmental laws and regulations
- Company environmental policy
- Shareholder expectations and management structure
- Needs and perceptions of neighbouring communities and future land owners
- Land use practises in surrounding landscapes
- Effective monitoring and evaluation of rehabilitation
- Scientific research on ecological questions
- An adaptive restoration and management strategy

Our Benchmarking Process

We assess restoration success by determining the similarity of several sets of plant and animal community properties derived from surveys on sites of known regeneration age, with those that we regularly record on several benchmark sites. This diagram provides a visual model of our approach. Here the numerical value in each elliptical denotes the age of the regenerating site (years since mining). The length of the elliptical reflects variability between survey plots on each site and the width on the mean dissimilarity value for that site with that of the benchmark value. The green band denotes the variability in dissimilarity on the benchmarks. The red line represents the regression that models changes in dissimilarities as a function of age. The slope of the line models the rate of regeneration. It intersects the time axis at the expected time to full recovery.

Monitoring framework



MONITORING CRITERIA

Monitoring ecological restoration is an essential component of the rehabilitation programme. It is therefore important that we set and define reasonable restoration targets. Consequently, we made a special effort to measure, describe and characterise undisturbed dune forests to set restoration targets. These 'reference' forests provide measures against which we evaluate restoration success.

This means that we check that the development of the rehabilitating stands conforms with the predicted developmental path that will lead to an intact forest system. Intact forests are a benchmark for restoration success. At the same time, they serve as source areas from which plants and animals disperse to colonise rehabilitating sites. Rehabilitating areas, in turn, may also serve as source pools for each other.

It is important that suitable indicators of restoration success are selected and measured. These indicators should faithfully represent the structure and function of a dune forest, as well as the natural variability (both over time and across space) that is typical of an intact or regenerating dune forest.

We selected trees, herbs, millipedes and birds, as well as key soil properties as indicators of the full trophic diversity and functioning (cycling of nutrients and minerals) of a forest. These indicators of the ecosystem's structure must meet certain criteria, which define the standards against which we judge success.

Criteria that we have developed from the information collected during years of research allowed us to develop methods to predict the rate and direction of ecological changes towards the endpoints of restoration. These endpoints are targets that may, or may not be reached within the period of active restoration management. Our monitoring programme therefore aims to establish whether development of the new growth forest is on its way to the benchmark as an endpoint that is similar to that represented by old growth dune forests in the region.

Bell's hinged tortoise (*Kinixys belliana*)

Bell's hinged tortoises occur throughout tropical Africa, but in South Africa live mainly in coastal dune forest. Adults are about 25 centimetres long. These tortoises feed primarily on green plants but occasionally eat snails, millipedes and insects. They may live for 22 years. A unique hinge in their carapaces allows the rear of the shell to close when disturbed, thereby protecting the hind feet and tail. The beak of Bell's hinged tortoise has a single cusp, while that of the Natal hinged tortoise (*Kinixys natalensis*), which lives in the lowlands of KwaZulu-Natal's hinterland, has several cusps. Tortoises should not be moved from one area to another.

RESEARCH MATURES
AND EXPANDS

Apart from monitoring, we research topics that we deem important to explain concordances and deviations from expected trends in forest development. Our early research focused on establishing what lives in new growth forests regenerating in response to forest rehabilitation. We selected plant and animal groups of the different trophic levels that collectively represent a forest ecosystem. Of the primary producers, we opted to study woody plants, herbs and grasses. Our choice of primary consumers (herbivores) fell on birds and rodents, while birds and spiders accounted for secondary consumers (carnivores). Millipedes reflected on detritivores (decomposers), as did our occasional surveys of dung beetles and soil arthropods.

Over 20 years we have accumulated data on the presence and number of species on survey transects and quadrats in new growth forests of which the age is known, as well as in old growth forests. Species beyond the scope of our research, such as frogs and reptiles, are recorded whenever and wherever we encounter them. Our work, however, goes well beyond the recording of species and changes in their numbers across time and space.

Although we want to know how and why species do or do not colonise new growth forests, we also wish to identify the factors that promote or inhibit their return after efforts to rehabilitate dune forests. In addition to recording the presence and numbers of species, we also study the habitat conditions associated with their presence. These include measures of forest structure, primary production, soil fertility and the mineral contents of sand. In addition, we identify other local (e.g. dune topography) and regional (e.g. rainfall, changes in landscapes) forces that might limit the ability of specific species to colonise new growth forests.

Our ecological research focuses on collections of species (i.e. communities, rather than individual species). Much of our analyses therefore focuses on the community level to address hypotheses that relate to how communities change over time and which environmental variables drive these changes. To us the new growth forest is an outdoor laboratory, not only where we can study their regeneration, but also test ecological concepts that may explain patterns in the composition and structure of communities. The importance of our work therefore stretches beyond local interests.

The early days of recording species has given way to the testing and building of models: 1) to explain how different communities respond to their environments, and 2) to identify key habitat measures that promote or inhibit the development of communities. However, our research also has an applied side to it. Most importantly to evaluate the progress and outcomes of the rehabilitation programme. Beyond evaluation, we also assisted in the development of a science-based, adaptive management programme with goals and objectives that make ecological sense, enhance the conservation of coastal dune forests, and ensure the sustainability of the outcomes of restoration.

Gaboon adder (*Bitis gabonica*)

Gaboon adders prefer moist, wooded, lowland areas and in the new growth forests they live at the southern end of their tropical distribution range. They are mainly active at night, slow to move and although poisonous and extremely dangerous to people, are rarely encountered. Gaboon adders prefer to ambush their prey, but unlike the puff adder (*Bitis arietans*) – which also lives in dune forest – Gaboon adders hang on to their prey while the venom takes effect. They prey on rodents, hares and ground-dwelling birds. Adders should be left alone when encountered.

	Rehabilitating Forests (New growth forests)		Benchmark Forests (Old growth forests)	
	Number of species	Number of old growth forest species missing	Number of species	Number of new growth forest species missing
Trees	78	34	93	19
Millipedes	16	7	23	0
Birds	73	14	53	34

IS THE RESTORATION PROCESS SUCCESSFUL?

The answer is a qualified yes. The rehabilitation of the mined path started in 1978, soon after the mining of the sand dunes began. We evaluate the outcomes of rehabilitation through independent ecological research and monitoring to establish whether rehabilitation induces ecological succession. Such succession is driven by natural dispersal of species, their self-establishment and persistence until habitat conditions favour their natural replacement by other species, with the eventual accumulation of species and the establishment of typical self-sustaining dune forest communities. This is happening.

Table: Our monitoring of coastal dune forest development focuses on trees, millipedes and birds. Most species present in benchmark forests (old growth forests not exposed to mining) also occur in new growth forests, but several forest specialist species are yet to colonise rehabilitating forests. In a similar vein, it should be noted that several species that live in new growth forest do not occur in old growth forest. The absence of forest specialists in new growth forests may be due to the relatively young age of these forests, prevailing habitat conditions not yet catering for the needs of forest specialists, or regional forces that inhibit dispersal from old to new growth forests. Our research on the drivers of colonisation of new growth forests continues to address these limitations.

South African pouched mouse
(*Saccostomus campestris*)

Pouched mice occur throughout southern Africa and are usually active at night. Hamster-like in appearance and relatively docile, these mice are one of five kinds of rodents that live in dune forests. They store food (a variety of seeds) in their burrows, possibly to consume at leisure while in their burrows and not exposed to predators such as snakes. These small animals (body weight 80 to 115 grams when adult) go into torpor (spontaneous sleep characterised by low body temperature) almost daily to conserve energy.

FOREST DEVELOPMENT

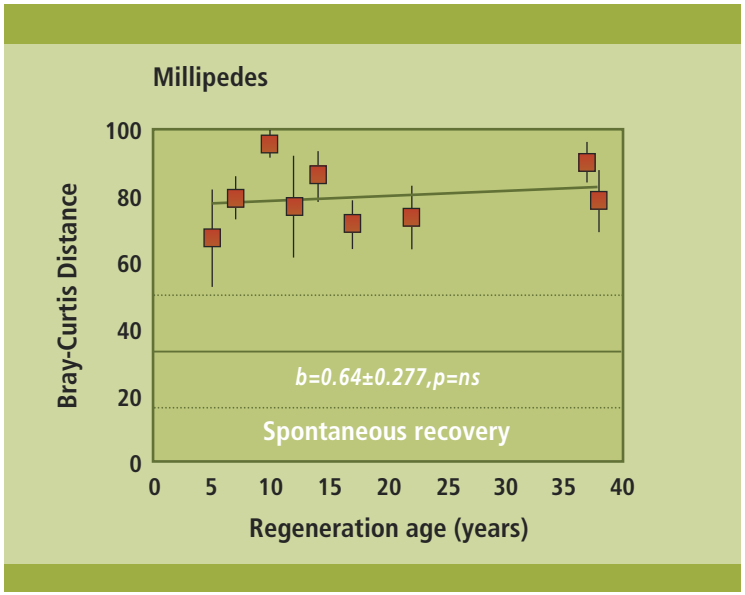
Successional development of dune forests follows on rehabilitation that 'kick-starts' the process. Annual species sown in indigenous topsoil, spread thinly over reshaped dunes, stabilise conditions for the early grass cover and are then replaced by a dense stand of indigenous *Acacia karroo* trees that serve as pioneers.

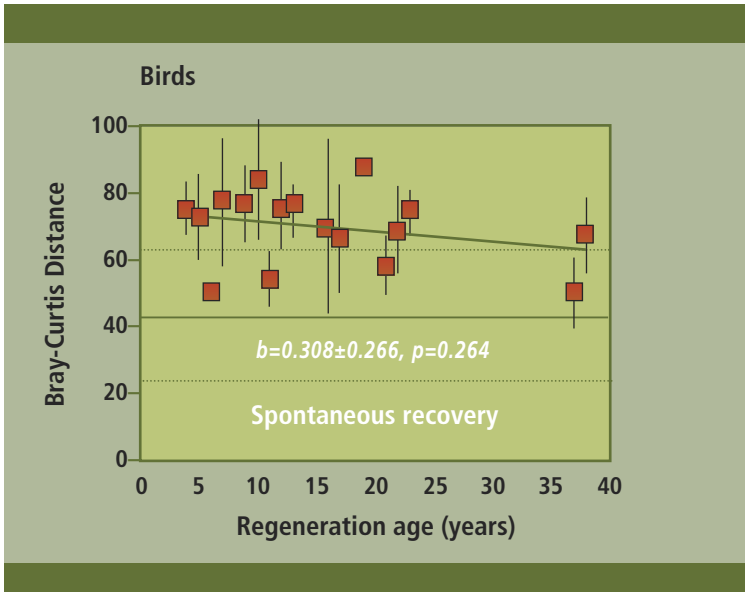
Within ten years, these quick-growing pioneers form a woodland canopy that provides the shade for broad-leaved forest trees and shrub species to colonise. From 15 years on canopy gaps (that form naturally as some trees senesce and die) increasingly enable mid- and late-successional trees to establish and become part of the new canopy. By then a foundation layer of sub-canopy shrubs and creepers is well established, leading to a well-structured dune forest landscape 25 years after succession was initiated. Approximately 60% of forest tree species are still absent after some 32 years of development. This calls for adaptive management protocols to further enhance and stabilise the recovery process.

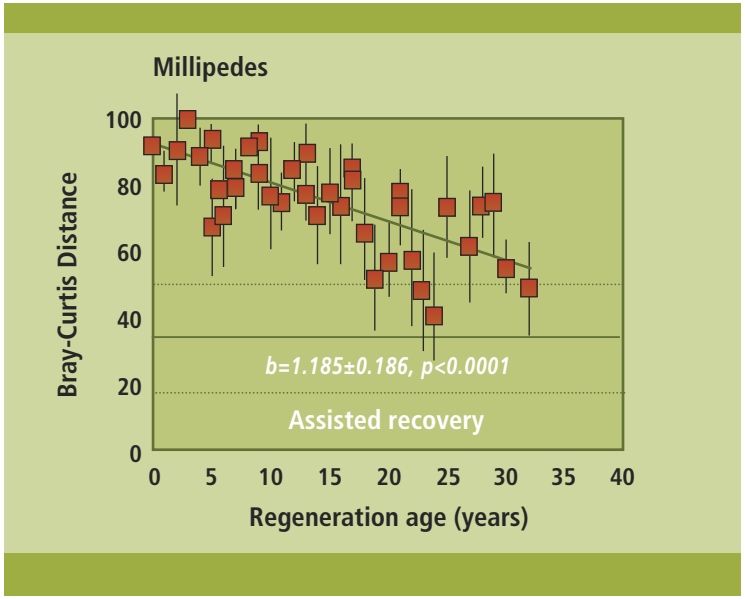
However, unlike the plants, most beetles, millipedes, spiders, mammals and birds that commonly occur in intact dune forest also occur in regenerating areas.

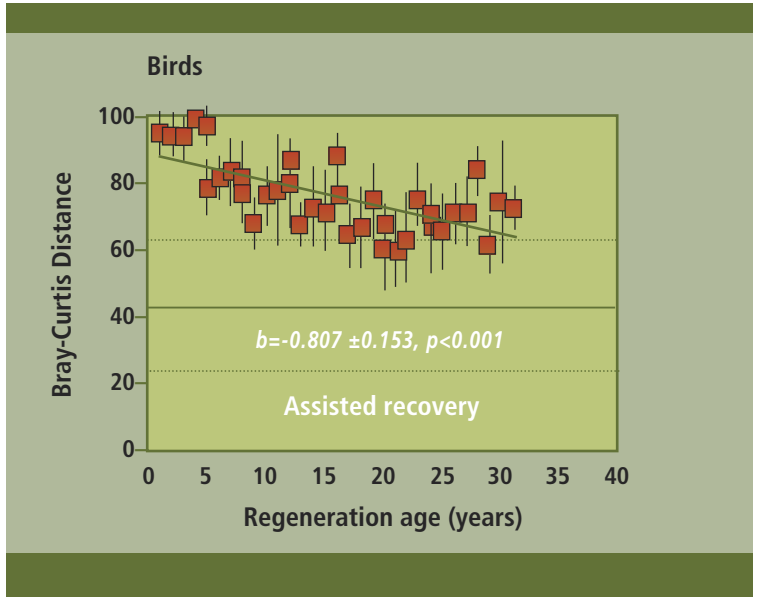
Some forest specialists, especially among bird assemblages, continue to be either rare or absent.









Dune forest regeneration after disturbances may either be spontaneous or assisted through dedicated rehabilitation incentives, such as those employed by RBM. The question that arises is whether assisted recovery benefits forest regeneration. Based on our surveys of millipedes and birds, assisted recovery of forest development has cascadal effects on forest living species and results in a faster convergence of new growth forest towards old growth forests.
The horizontal solid and stippled lines represent mean ± one standard deviation of the mean values recorded in benchmark old growth forests. The Bray-Curtis distance values are measures of how dissimilar communities are from benchmark communities. In new growth forests regenerating in response to rehabilitation, dissimilarity decreases significantly faster with regeneration age than in new growth forests that regenerate spontaneously.

> Local people value dune forests for their aesthetic appeal, but also consider these forests important providers of essential resources.

Lichens are composite organisms comprising closely associated fungi, green algae and blue-green bacteria. Their symbiotic lifestyles benefit all participants. For example, algae and bacteria provide starch through photosynthesis and hence carbohydrates for the fungi. The fungi in turn protect the algae from drying out, assisting the lichens to survive under the harshest of living conditions. Lichens occur in a rich variety of colours, from bright red to nearly black.

The new growth forest that is developing in response to RBM's forest restoration programme is a unique outdoor laboratory for studies in restoration ecology. Long-term support for independent research provides special opportunities for ecological research along a well-kept chronosequence of forest regeneration. We use the data that we collect to prepare primary scientific papers, for postgraduate training, and for the continuous evaluation of the rehabilitation programme.

SOME OF OUR RESEARCH FINDINGS

Our research shows that soil properties, herb, tree, dung beetle, millipede, bird and mammal assemblages regenerate in response to rehabilitation. Regeneration responses differ among groups. For instance, age-related trends in woody plant species follow expectations as pioneer species are replaced by secondary species typical of intact forest in the region. Dung beetles respond to micro-climatic conditions rather than the age of rehabilitating sites, while millipede and bird assemblages regenerate through the addition and replacement of species, but distances to source areas do limit some species from colonising new growth forest.

Soil micro-arthropod communities are re-assembling at much slower rates than all other groups and edge effects of roads altered the community composition and structure in different ways for millipedes, birds and rodents. Edges along roads favour exotic invaders but these species have no discernable effects on non-native plant species.

Assemblages converge within a reasonable period towards those in the benchmark areas that we have studied, but trends differ between groups. Few assemblages converge exponentially and variability in composition and structure may be natural and due to local natural disturbances.

We developed techniques to identify divergences in forest development and now management can mitigate these and improve restoration success. We also identified colonisation constraints due to distance and isolation effects, but we cannot ignore regional limitations. For instance, we illustrated that three quarters of bird populations in our study area decline at about 12% per year. Aberrant rainfall may contribute to declines, but species with larger ranges declined more sharply than others. Declines thus may be due to forces that operate beyond the strip of coastal dune forests.

Most of our research findings have been published in peer-reviewed scientific papers. We have listed these papers below and the interested reader can visit our website (www.ceru.up.ac.za) for further information and to retrieve copies of these papers.

OUR PUBLICATIONS

Davis, A.L.V., van Aarde, R.J., Scholtz, C.H. & Delport, J.H. (2002) Increasing representation of localized dung beetles across a chronosequence of regenerating vegetation and natural dune forest in South Africa. *Global Ecology and Biogeography* 11, 191-209.

Davis, A.L.V., van Aarde, R.J., Scholtz, C.H. & Delport, J.H. (2003) Convergence between dung beetle assemblages of a post-mining vegetational chronosequence and unmined dune forest. *Restoration Ecology* 11, 29-42.

Dippenaar-Schoeman, A.S. & Wassenaar, T.D. (2002) A checklist of the ground-dwelling spiders of coastal dune forests at Richards Bay, South Africa (Arachnida: Araneae). *Bulletin of the British Arachnological Society* 12, 275-279.

Dippenaar-Schoeman, A.S. & Wassenaar, T.D. (2006) A checklist of spiders from the herbaceous layer of a coastal dune forests ecosystem at Richards Bay, KwaZulu-Natal, South Africa (Arachnida: Araneae). *African Invertebrates* 47, 63-70.

Ferreira, S.M. & van Aarde, R.J. (1996) Changes in community characteristics of small mammals in rehabilitating coastal dune forests in northern KwaZulu-Natal. *African Journal of Ecology* 34, 113-130.

Ferreira, S.M. & van Aarde, R.J. (1997) The chronosequence of rehabilitating stands of coastal dune forests: do small mammals confirm it? *South African Journal of Science* 93, 211-214.

Ferreira, S.M. & van Aarde, R.J. (1999) Habitat associations and competition in *Mastomys-Saccostomus-Aethomys* assemblages on coastal dune forests. *African Journal of Ecology* 37, 121-136.

Ferreira, S.M. & van Aarde, R.J. (2000) Maintaining diversity through intermediate disturbances: evidence from rodents colonizing rehabilitating coastal dunes. *African Journal of Ecology* 38, 286-294.

Foord, S.H., van Aarde, R.J. & Ferreira, S.M. (1994) Seed dispersal by vervet monkeys in rehabilitating coastal dune forests at Richards Bay. *South African Journal of Wildlife Research* 24, 56-59.

Grainger, M.J., van Aarde, R.J. & Wassenaar, T.D. (2011) Landscape composition influences the restoration of subtropical coastal dune forest. *Restoration Ecology* 19(101), 111-120.

Grainger, M.J. & van Aarde, R.J. (2011) The resilience of the medicinal plant community of rehabilitating coastal dune forests, KwaZulu-Natal, South Africa. *African Journal of Ecology*. 50, 120-123.

Greyling, M.D., van Aarde, R.J. & Ferreira S.M. (2001) Seasonal changes in habitat preferences of two closely related millipede species. *African Journal of Ecology* 39, 51-58.

Guldemond, R.A.R. & van Aarde, R.J. (2010) Forest patch size and isolation as drivers of bird species richness in Maputaland, Mozambique. *Journal of Biogeography* 37, 1884-1893.

Guldemond, R.A.R. Grainger, M.J. & Trimble, M.J. (2012) Where is the evidence for assessing evidence-based restoration? Comments on Ntshotsho et al. (2010). *Restoration Ecology* 20, 7-9.

Jackson, T.P. & van Aarde, R.J. (2003) Sex- and species-specific growth patterns in cryptic African rodents, Mastomys natalensis and M. coucha. *Journal of Mammalogy* 84, 851-860.

Jackson, T.P. & van Aarde, R.J. (2004a) Diet quality differentially affects breeding effort of Mastomys coucha and M. natalensis: implications for rodent pests. Journal of Experimental Zoology Part A: *Comparative Experimental Biology* 301A, 97-108.

Jackson, T.P. & van Aarde, R.J. (2004b) Do *Mastomys natalensis* pups develop more quickly than M. coucha pups? *African Zoology* 39, 153–156.

Koekemoer, A.C. & van Aarde, R.J. (2000) The influence of food supplementation on a coastal dune rodent community. *African Journal of Ecology* 38, 343-351.

Kritzinger, J.J. & van Aarde, R.J. (1998) The bird communities of rehabilitating coastal dunes at Richards Bay, KwaZulu-Natal. *South African Journal of Science* 94, 71-78.

Kumssa, D.B., van Aarde, R.J. & Wassenaar, T.D. (2004) The regeneration of soil micro-arthropod assemblages in a rehabilitating coastal dune forest at Richards Bay, South Africa. *African Journal of Ecology* 42, 346-354.

Neluvhalani, M.J., Ferreira, S.M. & van Aarde, R.J. (1995) The effect(s) of carbaryl-treated seed on body maintenance and survival of the multi-mammate mouse, *Mastomys natalensis* (sensu lato). *Onderstepoort Journal of Veterinary Science* 62, 235-240.

Redi, B.H., van Aarde, R.J. & Wassenaar, T.D. (2005) Coastal dune forest development and the regeneration of millipede communities. *Restoration Ecology* 13, 284-291.

Smit, A.-M. & van Aarde, R.J. (2001) The influence of millipedes on selected soil elements: a microcosm study on three species occurring on coastal sand dunes. *Functional Ecology* 15, 51-59.

Trimble, M.J. & van Aarde, R.J. (2011) Decline of Birds in a Human Modified Coastal Dune Forest Landscape in South Africa. *PLoS ONE* 6(1), e16176.
van Aarde, R.J., Ferreira, S.M. & Kritzinger, J.J. (1996) Millipede communities in rehabilitating coastal dune forests in northern KwaZulu/Natal, South Africa. *Journal of Zoology*, London 238, 703-712.
van Aarde, R.J., Ferreira, S.M. & Kritzinger, J.J. (1996) Successional changes in rehabilitating coastal dune communities in northern KwaZulu/Natal, South Africa. *Landscape and Urban Planning* 34, 277-286.
van Aarde, R.J., Coe, M. & Niering, W.A. (1996) On the rehabilitation of the coastal dunes of KwaZulu-Natal. *South African Journal of Science* (News & Views) 92, 122-124.
van Aarde, R.J., Ferreira, S.M., Kritzinger, J.J., van Dyk, P.J., Vogt, M. & Wassenaar, T.D. (1996) An evaluation of habitat rehabilitation on coastal dune forests in northern KwaZulu-Natal, South Africa. *Restoration Ecology* 4, 334-345.
van Aarde, R.J., Smit, A-M & Claassens, A.S. (1998) Soil characteristics of rehabilitating and unmined coastal dune forests. *Restoration Ecology* 6, 102-110.
van Aarde, R.J., Wassenaar, T.D., Niemand, L., Knowles, T. & Ferreira, S.M. (2004) Coastal dune forest rehabilitation: a case study on rodent and bird assemblages in northern KwaZulu-Natal, South Africa. In: Coastal sand dunes: Ecology and restoration (Eds Martinez, M.L. & Psuty, N.), Springer Verlag, Heidelberg.
Wassenaar, T.D. & van Aarde R.J. (2001) Short-term responses of rehabilitating coastal dune forest ground vegetation to livestock grazing. *African Journal of Ecology* 39, 329-339.
Wassenaar, T.D., van Aarde, R.J., Pimm, S.L. & Ferreira, S.M. (2005) Community convergence in disturbed subtropical dune forests. *Ecology* 86, 655-666.
Wassenaar, T.D., Ferreira, S.M. & van Aarde, R.J. (2007) Flagging aberrant sites and assemblages in restoration projects. *Restoration Ecology* 15, 68-76.
Wassenaar, T.D. & van Aarde, R.J. (2008) Towards better restoration assessment: a review of the bioindicator concept in rehabilitation. Proceedings of the Third International Seminar on Mine Closure, 14-17 October, Johannesburg, South Africa.
Weiermans, J. & van Aarde, R.J. (2003) Roads as ecological edges for rehabilitating coastal dune assemblages in northern KwaZulu-Natal, South Africa. *Restoration Ecology* 11, 43-49.

Post-doctoral studies

Mccallum, C. (1997) Coastal dune ecology.
Sinclair, R. (2000) Forest regeneration.
Davies, A.L.V. (2001) Dung beetle community regeneration.
Jackson, T.P. (2002) Sexual selection in rodents.

PhD studies

Ferreira, S.M. (1997) Determinants of small mammal community structure on rehabilitating dune forests in KwaZulu/Natal, South Africa. PhD thesis, University of Pretoria, Pretoria, South Africa.
Wassenaar, T.D. (2004) Convergence in coastal dune forests. PhD thesis in Zoology, University of Pretoria, Pretoria, South Africa.
Grainger, M.J. (2012) An evaluation of coastal dune forest restoration in northern KwaZulu-Natal, South Africa. PhD thesis, University of Pretoria, Pretoria, South Africa.
Ott, T. (in progress) Integrating landscape ecology and conservation. PhD in progress, University of Pretoria, Pretoria, South Africa.
Olivier, P.J. (in progress) Conservation evaluation of coastal dune forests. PhD in progress, University of Pretoria, Pretoria, South Africa.

MSc studies

Ferreira, S.M. (1993) The effects of habitat rehabilitation on small mammal communities at Richards Bay. MSc thesis, University of Pretoria, Pretoria, South Africa.
Kritzinger, J.J. (1996) Bird community structure in rehabilitating coastal dune forests. MSc thesis, University of Pretoria, Pretoria, South Africa.
Van Dyk, P.J. (1997) Population biology of *Acacia karroo* as a pioneer species in rehabilitating coastal dune forests. MSc thesis, University of Pretoria, Pretoria, South Africa.
Wassenaar, T.D. (1998) Influence of grazing by cattle on succession in rehabilitating coastal dune forest communities. MSc thesis, University of Pretoria, Pretoria, South Africa.
Weiermans, J. (1999) Edge effects on rehabilitating coastal dune forests. MSc thesis, University of Pretoria, Pretoria, South Africa.
Koekemoer, A. (2000) The influence of food supplementation on coastal dune rodent community structure. MSc thesis, University of Pretoria, Pretoria, South Africa.
Niemand, L. (2001) The contribution of the avian community of rehabilitating coastal dune forests to regional diversity in northern KwaZulu-Natal. MSc thesis, University of Pretoria, Pretoria, South Africa.
Theron, L. (2001) Distribution abundance relationships in coastal dune forest communities. MSc thesis, University of Pretoria, Pretoria, South Africa.
Knowles, T. (2002) Landsat images as surrogates for vegetation regeneration on coastal sand dunes. MSc, University of Pretoria, Pretoria, South Africa.
Marthews,T. (2003) Marcovian change in forest development. MSc thesis, University of Pretoria, Pretoria, South Africa.

Woolley, L-A. (2004) Conservation planning for coastal forest dunes. MSc, University of Pretoria, Pretoria, South Africa.
Kumssa, D.B. (2004) Soil minerals and soil arthropods in coastal dune forests. MSc, University of Pretoria, Pretoria, South Africa.
Redi, B. (2004) Millipede community development in dune forests. MSc, University of Pretoria, Pretoria, South Africa.
Sweeney, O.F.M.D. (2004) Colonisation of coastal dunes. MSc, University of Pretoria, Pretoria, South Africa.
Ntsotsho, P. (2005) Carbon sequestration in rehabilitating coastal dune forests. MSc thesis, University of Pretoria, Pretoria, South Africa.
Taylor, M. (2007) Coastal dune forest bird communities. MSc thesis, University of Pretoria, Pretoria, South Africa.
Owens, L. (2008) Forest fragmentation and millipede communities. MSc, University of Pretoria, Pretoria, South Africa.
Mohale, O.M. (in progress) Ecological limitations of Acacia seedling development. MSc study in progress , University of Pretoria, Pretoria, South Africa.

BSc (Honours) students

Foord, S. (1993) Vervet monkeys as agents of seed dispersal in rehabilitated dune forests. BSc (Honours) , University of Pretoria, Pretoria, South Africa.
Neluvhalani, J. (1994) Influence of seed treatment on survival of forest dwelling rodents. BSc (Honours) , University of Pretoria, Pretoria, South Africa.
Greyling, M. (1994) Competitive exclusion in a millipede community. BSc (Honours), University of Pretoria, Pretoria, South Africa.
Venturi, F. (2001) Environmental predictors of the distributional ranges of Mastomys species in southern Africa. BSc (Honours), University of Pretoria, Pretoria, South Africa.
Mohale, O.M. (2011) Primary productivity and millipede communities. BSc (Honours), University of Pretoria, Pretoria, South Africa.
Visser, N. (in progress) Spatial gradients of millipede assemblages. BSc (Honours), University of Pretoria, Pretoria, South Africa.
Niemandt, C. (in progress) Forest gap dynamics and the structuring of millipede communities. BSc (Honours), University of Pretoria, Pretoria, South Africa.



MESSAGE FROM RBM

"Leaving a healthy and safe environmental legacy behind our operations is non-negotiable for Richards Bay Minerals, as it is for all Rio Tinto Group companies. Richards Bay Minerals takes a long-term approach to sustainable development, with biodiversity management an important facet of our efforts. Our partnership with the Conservation Ecology Research Unit of the University of Pretoria helps us to maintain our status as one of the best examples of ecological restoration in the mining industry, and enables the ecological succession processes taking place to be documented for the benefit of scientists and restoration practitioners worldwide. From this year we will increase our efforts to highlight the benefits of coastal dune forest restoration to all stakeholders. We hope to develop collaborative solutions for the long term protection of restored coastal dune forests with our stakeholders, working with our host communities, our NGO partners, and local, provincial and national government. The measure of our success will be a net positive impact on the biodiversity in the region in conjunction with improved local economic opportunity and social benefits."

– Elaine Dorward-King, Managing Director, Richards Bay Minerals

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Text editing: Kim Trollip
Published: March 2012

Professor Rudi van Aarde directs the Conservation Ecology Research Unit (CERU), a self-sufficient research entity in the Department of Zoology and Entomology at the University of Pretoria. **Dr Robert Guldemond** is a research fellow at CERU, who focuses on restoration ecology.

CERU was established in 1998 and funded through grants from national and international organisations and private industry. These grants provide for the employment of research fellows, support staff and postgraduate bursaries. Research focuses on a scientific foundation for conservation and CERU is widely recognised for its research on dune forest restoration.

Van Aarde's research on the restoration of dune forest in northern KwaZulu-Natal (South Africa) started 20 years ago, when he approached the mining company, Richard Bay Minerals, to support basic research into restoration ecology. The company's management agreed and has since provided both logistical and financial support to maintain an outdoor research laboratory on the coast north of Richards Bay. Robert joined the research programme in 2007 and now coordinates the annual monitoring activities as well as assisting graduate students with their research projects.

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