NAMIB DUNES

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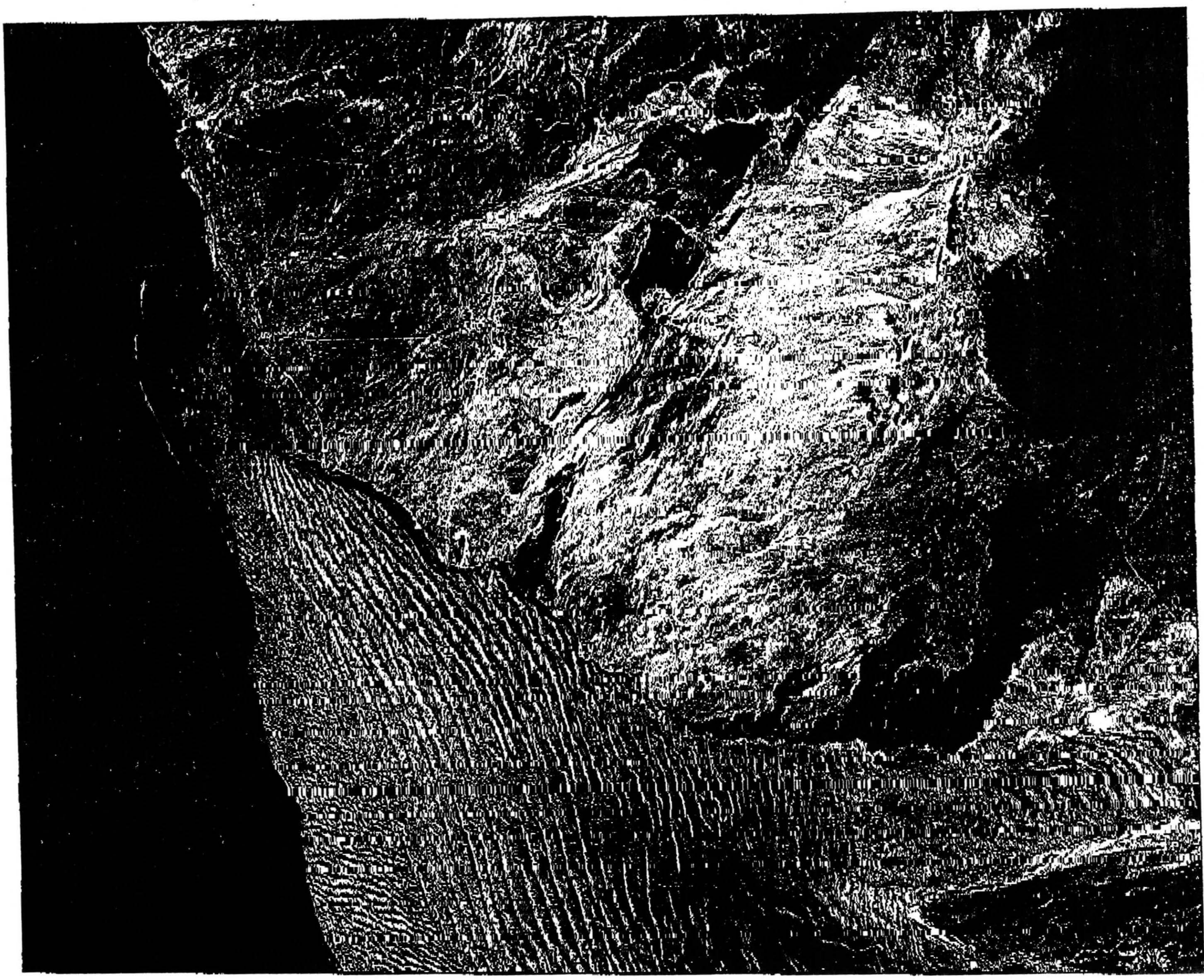
Fog, wind and heat: life in the Namib desert

Researchers working in one of the world's most hostile environments are discovering how scores of species manage to survive. But will the research station itself survive, as Namibia gains its independence?

Sue Armstrong


C.S.I.R.

Every type of dune known to the world is found in the Namib desert: from left, crescentic, linear, star and reticular

IN 1938, Henno Martin and Hermann Korn, two young German geologists working in South West Africa, were threatened with internment by Jan Smuts' pro-British Empire government—as were the rest of the German community in the South African colony. Having left Europe in the first place because they wanted "no part in the mass suicide of civilised peoples", they had no intention of sitting out the coming war in a prison cell, so they loaded their lorry and headed into the sun-struck wastes of the Namib desert.

Martin and Korn survived there for nearly three years as fugitives, living on their wits and becoming increasingly beguiled by their harsh desert refuge and its strange variety of inhabitants. Since then, many other scientists have been equally enthralled by the Namib—among them an Austrian entomologist, Charles Koch, who founded a permanent research station there in 1963.

Koch, an expert on the taxonomy of desert insects, first visited the Namib in the mid 1950s as a member of a scientific expedition. So excited was he by the number and variety of tenebrionid—or "tok-tokkie"—beetles he found scuttling across the scorching dunes, and seeming to "swim" through the sand on the slip-faces, that he resigned his job in Germany and moved to South Africa so that he could visit the Namib regularly.

Working for the Transvaal Museum and funded by the Council for Scientific and Industrial Research, Koch explored most of arid southern Africa, discovering in the Namib desert at least 200 species of tenebrionids, most of which showed

Fog is life: the head-standing beetle collects moisture from the fog, virtually the only source of water in the Namib desert

extraordinary adaptations to their environment and were endemic to the area. (These included the only white tenebrionid yet discovered.) By contrast the tenebrionid species he found in the nearby Kalahari Desert tended to be less exclusive.

In its 27 years of existence, more than 1500 scientists from around the world have visited and worked at the Desert Ecological Research Unit of Namibia, which Koch founded at Gobabeb ("The Place of the Fig Tree") on the banks of the rarely flowing Kuiseb river in the heart of the desert. DERU, as the station on the site of an abandoned Hottentot village is known, has generated more than 500 scientific papers and has had the rare distinction of making the cover of both *Nature* and *Science* magazines in the same year, 1976, with papers on the extraordinary ways in which two different species of tenebrionid beetle make use of fog water.

Apart from the fact that the biotic community in a desert is "relatively simple" and processes are easier to identify than in more moderate areas, the Namib has several features that make it particularly attractive to scientists. A long, narrow ribbon that stretches along the entire western coastline of Namibia, this desert is relatively small (one thirtieth the size of the Sahara) and easily accessible. Sandwiched between the Atlantic Ocean and Africa's Great Western Escarpment, it has a tremendously steep climatic gradient from west to east, ranging from an average rainfall below 15 millimetres at the cool coast to about 100 millimetres near the escarpment, with the area in between experiencing the most extreme fluctuations in temperature and humidity. While the southern part of the desert is in Africa's winter rainfall belt, the north is in the summer rainfall belt. The different climatic combinations allow a comparative approach in scientific research.

Besides its climatic variety, the Namib has a number of clearly defined physical environments that show up spectacularly in satellite photographs. Several stretches of rippling sand dunes are divided from flat gravel plains by "linear oases"—river courses, dry most of the time, that cut across the desert from the mountains to the sea. (The march of the dunes, which shift at rates of between 1 and 100 metres a year depending on the strength of the wind, is checked by the occasional flowing of the rivers.) Such a range of conditions and habitats has given rise to a particularly wide variety of plants and animals that, isolated between the escarpment and the sea, have evolved undisturbed for millions of years. Many species are found nowhere else on earth.

Koch, who died in 1970, believed the Namib to be the oldest desert in the world, but this is still a matter of hot debate. Some date it back to the breaking up of the super-continent, Gondwanaland, about 130 million years ago. Others date it at 80 million years or even less, when, they believe, the climate of the area has fluctuated no more than between semiarid and the hyper-aridity of today. During that time the landscape will have changed continually with variations in the climate.

One of the unique and most fascinating features of the Namib is the presence of an ancient dune desert, in fossilised form, beneath the current active dunes that stretch from the Kuiseb to the Orange River. Dating back between 40 and 20 million years, these ancient dunes cover roughly the same area as the present dunes, and appear to have been formed in the same way: sand carried from the highlands of Lesotho by the Orange River to the sea was washed on shore and blown northwards by the strong southwesterly winds that prevailed then as they do today. Furthermore, there is evidence in the fossil record of plants and animals living then that show remarkable similarities to some present day forms, such as termites, beetles, and even the eyeless, sand-swimming golden mole.

The scientists believe that climatic and environmental conditions of the Namib as it is known today have been relatively stable for at least 5 million years, one of the main influences on both being the cold-water upwelling system of the Benguela Current.

Established 10 to 7 million years ago, the Benguela Current, flowing northwards from the Antarctic, is responsible for one

Peter Johnson/NHPA

Leaves for all seasons: Welwitschia *is famed for its longevity*

of the most important features of the Namib—fog. On an average of 60 days a year, fog, created by moist air from the Atlantic condensing as it passes over the icy waters of Benguela, rolls inland during the night for up to 100 kilometres. This is the Namib's life-blood—the main source of free water for hundreds of species of plants and animals, many of which have developed intriguing ways of using it.

The head-standing beetle, *Onymacris unguicularis*, for example, creeps to the crest of the dune when fog is present, faces into the wind and stretches its back legs so that its body tilts forward, head down. As the fog precipitates on its body and runs down to its mouth the beetle drinks, taking on board sometimes as much as 40 per cent of its original weight in water. Normally active on the dune surface during warm daylight hours, this beetle will emerge from its refuge in the sand during the cold night or early morning to take advantage of the fog before the fierce sun rises and evaporates the moisture.

Three other species of tenebrionid beetle found in the dunes close to Gobabeb construct shallow trenches to trap fog water. In digging their trenches, which may be a metre or more long, *Lepidochora discoidalis*, *L. porti* and *L. kahani* create two parallel ridges above the sand surface. These ridges gather moisture from the fog as it blows over them, and may contain as much as 10 per cent water by weight, compared with 4 per cent for the flat surrounding sand. The rather flat, button-shaped beetle extracts this water as it returns along the trench a while later.

Other animals not specifically adapted to take advantage of the fog nevertheless use it for their water requirements; snakes and lizards drink their droplets from their skin, and many insects drink the drops that collect on plants and rocks.

Arthraerua leubnitziae, the very characteristic dwarf shrub of the Namib plains, is entirely restricted to the fog belt along the coast, and appears to have some extraordinary mechanisms for extracting moisture from the air. The kind of dreary little plant that most people pass without a second glance is the subject of fascinated research by Gobabeb's visiting botanists at the moment.

A few short-lived leaves appear after rain, otherwise the plant above ground consists only of green stems. In cross section these stems have deep grooves, radiating from the centre like the spokes of a wheel and harbouring the stomata. This arrangement cuts down water evaporation, while there is some evidence that salt crystals on the surface of the plant are instrumental in extracting moisture from the atmosphere. However, research is continuing to establish if this is in fact the case. From excavations it appears that the roots can be dormant for long periods, and that they may serve to store water taken up by the stems. After rain small roots and root hairs regrow rapidly.

Another aspect of the slow-growing and long-lasting *A. leubnitziae* that is intriguing scientists is the presence of apparent growth rings. These are thought to relate to rainfall and could thus reveal a picture of the desert climate before rainfall records began in 1880.

As well as being able to make use of whatever moisture there is, conserving water is also very important in a desert environment. Many of the tenebrionid beetles secrete "waxes"—long chain hydrocarbons mostly saturated with hydrogen — which cover the surface of their bodies in a waterproof layer. Researchers have found that evaporation from the cuticle of one species of dune beetle exhibiting the waxy bloom is as low as 0·11 milligrams per hour—one of the lowest rates recorded for any animal. The bloom dissolves quickly when humidity is high.

The sabre-horned gemsbok, *Oryx gazella*—a Namib-dweller that can survive for weeks without drinking—simply ceases to sweat when deprived of water. At such times its body temperature, normally around 39 °C, might reach as high as 45 °C and be sustained at this level throughout the heat of day. The animal has an intriguing mechanism for protecting the brain from such damaging temperatures: in a network of fine blood vessels, known as a rete, at the base of the brain, heat is exchanged between the hot arterial blood from the heart and cool venous blood draining from the nasal sinuses. As the two bloodstreams flow through the rate in opposite directions and close to one another, the arterial blood is cooled by several degrees before entering the brain.

The ostrich, commonly seen as a big blur in the shimmering heat of the plains, is able to conserve as much as 25 per cent of its daily water turnover by exhaling unsaturated air. Whereas most animals breath out saturated air, researchers at Gobabeb have found that the air exhaled by ostriches has a relative humidity of only between 80 and 85 per cent. No one has yet been able to discover the mechanism behind this extraordinary phenomenon.

Baboons living in the Kuiseb Canyon have excited particular interest, too, because the Namib is the most arid environment in which any non-human primate has ever been found. Studies from everywhere else report that baboons drink daily, but scientists have very recently observed a Namib troop going without free water for close on a month. They appear to exist on a knife-edge of survival, eating plants with a high moisture content, chewing the moist bark of acacia trees, and totally modifying their behaviour to minimise heat stress. The young do not play; males do not chase females; all day the animals rest in whatever shade they can find, scratching away hot surface sand before lying belly-down like dogs.

Many of the desert life forms, while adapted to surviving the driest periods, are also ready to respond to rain whenever it should fall. This was demonstrated most graphically in 1976 when 100 millimetres of rain fell near Gobabeb. As the dunes darkened under the downpour, DERU's director, Mary Seely, and an assistant excitedly snapped away with their cameras. "We were lucky to have already initiated a study into the simple population dynamics of the sand dune environment and how it changes throughout the year," says Seely. "After the unusual rains we were able to repeat the measurements to see how a naturally very arid area responds. A lot of germination went on and in time we found that there had been a 56-fold increase in the standing biomass of plants, and a several hundred-fold increase in the animal population." The rain fell between January and March 1976 and the population of tenebrionid beetles peaked the following November and December. The unusually rich grazing also attracted a herd of 120 gemsbok to the Gobabeb area; today they are again a rare sight.

"One of the most important things to come out of our

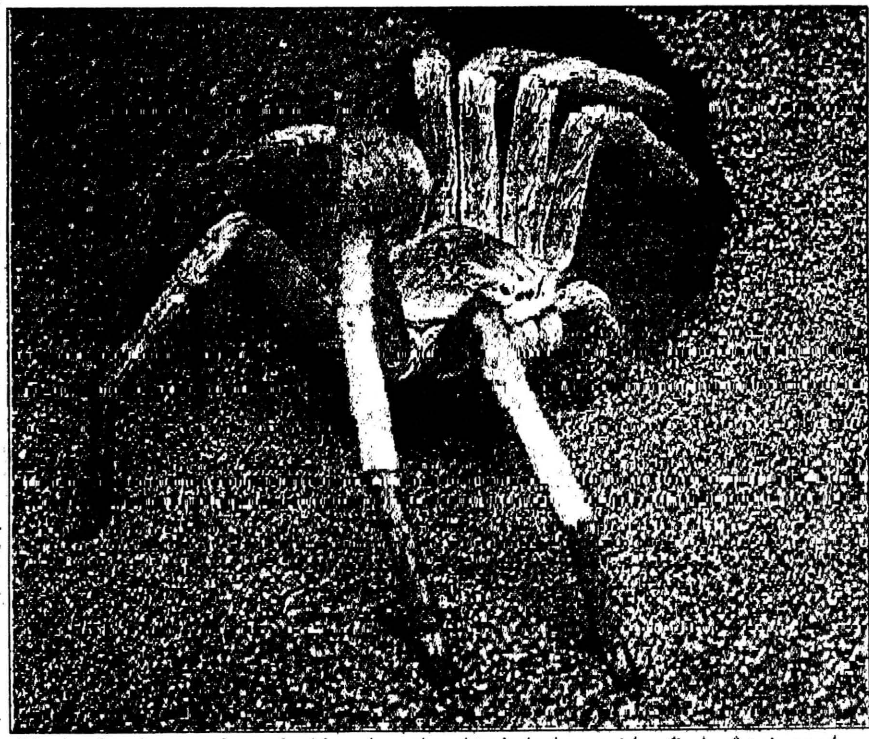
Freewheeling spiders spin out of danger

DURING their time in the desert, Martin and Korn frequently came across footprints of some kind of buck they could not identify. The two scientists were particularly mystified by the fact that the prints were in clusters and led nowhere.

Korn provided a working hypothesis: "It can only be the trail of the excessively rare feathered water waddler," he said. "It never shows itself in daylight because it feels ashamed when other birds laugh at its silly feet. It nests in inaccessible rock crevices and feeds exclusively on fudge and fiddlesticks. On account of its weak understanding it can take only two or three steps at a time."

Today it is known that the footprints of Korn's fictitious "water waddler" were in fact the highly distinctive nest of a sand-burrowing spider, *Seothyra*. This spider spreads its web on the surface, leaving the sticky edges open to catch insects running on the sand. The "buck-spoor" spider, as it is commonly called, is just one of about 163 spiders found in the Namib, and is the subject of research by Gobabeb's resident Spider Man, Joh Henschel.

Another arachnid that Henschel has been studying closely and that shows particularly interesting adaptations to its sand-dune habitat is the "wheeling spider", *Carparachne aureoflava*. In a paper awaiting publication Henschel describes what he believes is the first conclusive evidence of the use of the wheel by a member of the animal kingdom.



Digging for victory: a host of spiders, here the white lady dune spider, find safety in sand

Carparachne aureoflava, which lives exclusively on the dune slipfaces of the central Namib, uses wheeling as an effective means of escape from danger. Its most important predator is the female pompilid wasp, a specialist spider-hunter that paralyses its prey before laying a single egg on its body and burying it in the sand. When the egg hatches weeks later, the wasp larva feeds on the still living, and therefore fresh, spider.

The female wasp spends most of her time searching the dune slopes for spiders' silk-lined burrows which she will excavate, sometimes displacing as much as 10 litres of sand to get at her quarry. When flushed from its burrow or threatened on the surface by any danger, the wheeling spider does a short run before curling its legs into semicircles, flipping its body sideways and rotating wheel-like at high speed to get away.

The spider relies totally on gravity for momentum, and Henschel has recorded speeds of 0·5 to 1·5 metres per second and rotation rates of between 10 and 44 per second, depending on the steepness of the slope and the size of the spider.

Wheeling appears to have several advantages over running. It is faster and can be sustained for longer periods because it requires less energy. And it blurs the outline of the spider and leaves fainter tracks in the sand, making it more difficult for the hunting wasp to follow. Disadvantages of wheeling, however, are that the spider can travel only in the direction of the slope, and go as far as gravity will take it.

The strategy appears successful. On three occasions he saw spiders escape from wasps by wheeling, while on three further occasions the spiders that did not adopt this strategy were captured. □

research into the effect of the rain was that a natural area which has not been destroyed in any way can respond tremendously. By contrast, heavy rain on land that has been damaged by overgrazing or the like causes erosion and all kinds of negative effects," says Seely.

The other elements—heat and wind—play an equally important role in the life of the Namib. Many of the desert's creatures survive the extreme temperatures by exploiting favourable micro-climates in the environment. Small animals on the plains retreat from the fierce sun under rocks, pebbles and plants, while on the dunes such creatures as beetles, lizards and spiders disappear into the sand in search of more favourable temperatures or climb into vegetation. The free-moving sand on the slipface of the dunes is not a suitable medium for burrowing, and many of the species that live there literally "swim" through it. Many come to the surface only to eat, drink and mate, while a few species (such as the golden mole) live almost entirely within the sand.

Despite its obvious importance, very little is known about the environment beneath the surface, or the interactions that occur there. To a large extent, scientists have been constrained by lack of affordable or sufficiently sensitive instruments for measuring such things as subsurface humidity. "Most probes work very well between about 10 and 90 per cent relative humidity, but what we want are the extremes," explains Seely. "We want to know what's happening between 90 per cent and 100 per cent during fog, or at the other end of the scale when the hot east wind is blowing and the air is very dry." Furthermore, no one has yet come up with a device that will hold steady the loose sand on a slipface while scientists dig below the surface.

Seeking cooler temperatures within the sand is not the only way of coping with the extreme heat on the surface. The lizard *Aporosaura anchietae* does a "thermal dance", lifting two feet off the ground for a few seconds at a time in alternate fashion (left front foot with right rear foot, and vice versa). The long-legged beetle *Onymacris plana* can lower its body temperature by up to 10 °C by running across the scorching sand at a speed of 1m per second; while other beetles take advantage of the steep temperature gradient immediately above the desert floor by stretching their hind legs, or "stilting".

Many deserts plants are ephemeral but have seeds that can withstand extreme temperatures and remain dormant for decades until the right conditions arrive for germination. Birds that visit the desert can escape unfavourable conditions by migrating. However, several species besides the ostrich are well adapted to desert living. One of the most extraordinary adaptations is exhibited by the sandgrouse, *Pterocles namagua*, which eats mainly small seeds and nests often on the waterless gravel plains. The male bird saturates his belly feathers at a water source, sometimes up to 40 kilometres from his nest, and transports water in this way back to his chicks who thrust their beaks under him and drink as if from a sponge.

Winds of change

The third element, wind, fashions the desert environment. Besides sculpting the dunes into distinctive shapes, it maintains the loose condition of the sand which is so vital for the animals that need to retreat to the subsurface for survival. Furthermore, many of the beetles are detritivores; they depend on the wind to carry the dead plant and animal material on which they feed across the dunes, and are only active above the surface when it is blowing.

The wind also plays a part in the scant rainfall of the Namib. Most of the year a strong southwester blows, resulting in a cool inversion layer over the desert that reduces the turbulence necessary for cloud development.

And of course the wind transports the fog which, besides being a major source of water for living things, has helped create the distinctive gravel plains of the Namib. Occasionally the nutrient-rich Benguela upwelling brings sulphur to the surface from the mass of decomposing plant and animal life at the bottom of the sea. Carried on shore in the fog, this is the source of the sulphate in the gypsum that covers the gravel plains.

Nothing like as spectacular as the dunes, the gypsum-covered plains are no less characteristic of the Namib. Nor are they any less interesting to science, though until recently most research was concentrated on the dunes, because these were thought to represent the most extreme environment for living things. The gravel plains support several hundred species of lichen, many of which are endemic and thought to include individual plants that are thousands of years old. The lichen fields of the Namib, which still hold many secrets, are now recognised as unique in extent and variety.

Another ancient and mysterious inhabitant of the gravel plains is the *Welwitschia mirabilis*, a botanical paradox which, since its discovery in 1859, has excited the curiosity of more scientists than any other plant. The *Welwitschia* is grouped among the conifers but shares some characteristics with flowering plants and also with simple club mosses. A single plant may live for over a thousand years, its two fibrous, strap-like leaves curling into fantastic shapes along the ground. They are the longest lived leaves of any member of the plant kingdom.

In order to minimise water loss, *Welwitschia* in the driest parts of the desert open their stomata and take in carbon dioxide at night, completing the process of photosynthesis during daylight hours. Those growing in more temperate areas, however, photosynthesise in the normal way. The *Welwitschia's* method of pollination is a subject of controversy: once thought to be wind-pollinated, it now appears that wasps might be the agents but the evidence is not yet conclusive.

Besides the continuing mysteries of the *Welwitschia* many other questions remain to be answered about the Namib. Not least of these, for Seely, is how DERU will continue to be funded in a newly independent country strapped for cash. "Visiting scientists bring their own finance, and that will carry on," she says. "But we badly need funds to maintain the facilities of the unit, the computers, the long-term data base and the library—all the things that enhance the effectiveness of research work." One possibility, she suggested, might be for a consortium of interested bodies to support DERU in much the same way as research in the Galapagos Islands is supported.

Although DERU is a private foundation, the station is within a National Park run by the Namibian Department of Nature Conservation, which also owns the buildings at Gobabeb and foots the bill for basic services. Seely knows that if it is to gain the support of the new government and continue operating out of Gobabeb, DERU must succeed in conveying the relevance of its work to an independent Namibia.

Research has always been biased towards basic science, and the unit has a high international reputation among scientists. But Seely believes the knowledge they have accrued must be made available to a wider public. "We have a tremendous contribution to make because in all Namibia we have the most information about a certain environmental type—which actually occupies 97 per cent of the country," she says.

She is hoping to do something about what she sees as the "serious and ever-widening communication gap between basic science and people for whom the information could be useful" by training science journalists at DERU. One or two candidates a year—preferably from Namibia—would spend time at Gobabeb, gaining experience of basic research and an understanding of the scientific method.

Another plan is to expend the environmental education they already provide through open days visiting schoolchildren and workshops for teachers. Science teaching is particularly poor in Namibia, and DERU hopes to offer short- and long-term in-service training to science teachers. A new post at Gobabeb is already being negotiated for someone who will incorporate the unit's research information into the science syllabi for Namibia's schools and create other educational materials.

Another area in which DERU could contribute to the new young country is in tourism one of the mainstays of the economy. With its wide horizons, weird life forms and dramatically changing colours, the Namib is a stunning place to visit yet few people stop on their way to the sea. Seely is enthusiastic about encouraging tourism to the desert. But she also calls for careful organisation and controls: the desert environment is extremely fragile. Unrestricted driving across the gravel plains, for instance, destroys the lichens which take centuries to recover. And litter, too, is particularly damaging to the desert, she explains: "In the most arid parts practically nothing decomposes. Apple-cores and orange peel, and even human faeces, simply dry up and last almost forever."

DERU is already producing attractive and much-needed information for visitors that explains these points. The unit is looking for funds, too, to prepare a more detailed brochure describing the essential characteristics of an arid environment, which Seely believes are not well enough understood or respected in Namibia. Many of the basic principles demonstrated by scientists at the unit are directly relevant to conservation management, but are often overlooked. Agriculture is a particular culprit: it follows largely imported ideas and models that are not in harmony with the land or the climate. Furthermore, says Seely, farmers frequently blame failures on drought, which is nothing more than the normal condition in Namibia.

Like everything else in this new young country, DERU is at a crossroads. The future is uncertain. But Seely is going out of her way, with invitations to Ministers to visit her desert "laboratory", to see that the research unit is recognised by those now in power as a unique asset rather than a luxury or an anachronism. □

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