WORKSHOP REPORT

On the rehabilitation of the coastal dunes of KwaZulu-Natal

R.J. van Aarde, M. Coe and W.A. Niering

Enhanced environmental awareness has led to an increase in the legal obligations of many industrial companies to restore, rehabilitate or revegetate parts of those ecosystems they disturb in the course of their activities. The mining of sand dunes for selected minerals (mainly ilmenite, rutile and zircon) at Richards Bay in northern KwaZulu-Natal by the Richards Bay Minerals company (RBM) has, since 1977, been followed by a rehabilitation programme directed at establishing indigenous coastal dune forests on one-third of the mining path. The remaining two-thirds of the area is revegetated with stands of the exotic *Casuarina equisetifolia* for the development of a local charcoal industry. An evaluation of this rehabilitation programme was the subject of a workshop, convened by the University of Pretoria and hosted at Richards Bay by RMB last August. Sixty-five delegates from a wide spectrum of research and conservation bodies participated in the two-day event.

The workshop aimed to:

- consolidate knowledge on the biophysical nature of the coastal dune systems of northern KwaZulu-Natal;
- establish baseline criteria for the evaluation of RBM's rehabilitation programme;
- evaluate the rehabilitation programme and identify its future direction;
- assess the research effort so far and set priorities for future research.

Information on the biophysical nature of the coastal dunes (most of which is unpublished) was provided in the form of 15 oral presentations followed by discussion sessions. Several of these contributions centred on research conducted on the area being rehabilitated by RBM. These reports concentrated on evaluating the success of the rehabilitation programme based on the analyses of community macro parameters. They concluded that the trends associated with the development of the herb, woody vegetation, coleopteran, millipede, bird and rodent communities all suggested that the programme initiates ecological succession. This process results in these communities developing characteristics similar to those of adjacent unmined forests. Dissimilarities between the oldest rehabilitating stands (16 years old at the time of the studies) and the unmined stands were explained by the fact that the former represent only young successional seral stages, whereas the latter (which are more than 35 years old) are later seral stages of a coastal dune forest sere. The apparent success of the rehabilitation programme was ascribed to the design of the mining path allowing potential colonisers the opportunity to move to rehabilitating areas.

Participants in the workshop agreed on the importance of the coastal dune region for conservation. They also agreed that the success of a dune rehabilitation programme in one place should not be considered as an excuse to disturb other dunes, and that research into restoration and rehabilitation, to evaluate the success of such programmes, is of importance.

The workshop placed emphasis on the value of attaining 'benchmark' values, prior to or during any disturbance, with which to assess the rehabilitation and on the importance of employing ecological principles to guide such programmes.

The amicable atmosphere in which the workshop was held provided an ideal platform for discussion and the exchange of information. A set of workshop proceedings will serve as guidelines for those interested in coastal dune rehabilitation programmes in future.

The research programme at Richards Bay

The effectiveness of the rehabilitation programme directed at establishing an 'indigenous' coastal dune forest on part of the mining path may be assessed by comparing structural (in respect of species richness and species diversity) and functional (involving cycling and fixation of energy and minerals) similarities of rehabilitating areas with those of the same area prior to mining, or with adjacent unmined land. Since no information is available on these factors for the land prior to mining, we had to rely on findings from areas adjacent to the mining path. However, with the rehabilitation programme having started less than 20 years ago, there are likely to be differences between rehabilitating and unmined areas. The evaluation of the restoration programme thus has to rely on a) the direction of community development there being either similar to that recorded on disturbed but unmined areas, or b) the temporal trends of community variables on rehabilitating stands either forming, or having a high likelihood of forming, a continuum with values recorded on unmined areas.

The effort to evaluate the rehabilitation of coastal dunes was therefore based on comparing species composition, species

Sizing up the situation. On the left, Rudi van Aarde, Malcolm Coe and Sampie Ferreira on an inspection of one of the rehabilitating stands.

Courtesy of Richards Bay Minerals

On the right, Theo Wassenaar and Bheki Mpanza sample vegetation in one of the experimental plots. Photographs by Anthony Bannister.

richness and a similarity index for herbaceous, woody plant, beetle, millipede, bird and small mammal communities of transforming areas of known age with those of abutting unmined areas, for some of which the date of disturbance is known. Although there are many problems inherent in the use of these variables to evaluate a rehabilitation programme, we believe that they are easy to understand and, when measured over a broad range of taxa, give a good overview of ecosystem-wide community changes. The stands sampled during the study do not represent a complete successional sere, they are representative of relatively early (0–16 years) seral stages of biotic development. The 30–35-year-old unmined areas represent a later stage, and the other unmined area (Zulti North) an older and apparently mature coastal dune forest.[1]

The workshop reported that taxon-specific species richness (total number of species recorded during the summers of 1992 to 1994 corrected for sampling effort) for all but the mammalian taxa increased with age of the rehabilitating stands (see Table 1). Furthermore, for all taxa, with the exception of mammals and the herbaceous layer, the unmined stands harboured more species than the rehabilitating stands after mining. In the case of woody plants and millipedes, species richness increased with stand age through the addition of species. In the case of the beetles and birds, however, the rise in species richness was characterized by both species addition and replacement.

The relative density of pioneer species (species with highest densities in stands less than five years old) increased with the age of rehabilitating stands. The relative densities of pioneer species among all the taxa were considerably lower on unmined stands than elsewhere, suggesting that although maturing stands are not always associated with species replacement, the densities of those species first to colonize areas disturbed by mining eventually decline. The relative density of secondary species (all but pioneer species recorded on unmined stands) progressively increased with stand age and values for all taxa studied were higher on unmined than mined stands. These trends serve to illustrate a unidirectional change in species composition, as is expected during ecological succession. It thus seems that ecological succession is driving the development of rehabilitating biological communities from the relatively simple

The rehabilitation programme

This policy, dictated by the landowner (the KwaZulu government), is based on the historical circumstance that at the onset of mining some 60% of the mining lease areas, known as the Tisand Lease, comprised stands of exotic plantations, about 20% was covered by secondary grasslands and the remaining 20% by stands of indigenous coastal dune forests.

Rehabilitation begins with the spreading of a 10–15-cm layer of topsoil collected from the dunes prior to mining. This layer is then enriched with a mixture of the seeds of indigenous grasses, trees and fast-growing cereals. In having used the same procedure to rehabilitate these dunes for the last 18 years, the mining path, which varies in width from about 100 to 400 m all along the coast, now comprises a known-age sequence of stands of transforming dune vegetation covering an area of some 400 hectares. This is flanked on the coastal side by a narrow (50–150 m) strip of indigenous forests fragmented by insular patches of *C. equisetifolia* established by the Department of Forestry some 30 years ago. To the interior, the rehabilitating stands are bordered by a strip, 100 to 200 m wide, of *Casuarina* plantations which in turn lie adjacent to a relatively densely populated area dominated by subsistence farming and also fragmented through the relatively recent establishment of patches of commercial plantations (mainly blue gum and pine). To both the south and the north of the mining path lies a coastal strip of uninhabited forest exposed to varying levels of disturbance due to irregular grazing (mainly by cattle) and the collection of building material and medicinal plants by adjacent landowners. The region therefore is characterized by different forms of man-made disturbances. Because some parts are inaccessible and restrictions have been imposed on occupancy of the narrow coastal cordon for some 50 years, however, some patches of apparently mature coastal dune forests are still present. Protective measures brought about by moving people out of the area resulted in much of the vegetation of the area having recovered by 1974.

This rehabilitation programme is giving rise to the development of a known-age platform where scientific research into ecological disturbance and the development of biological communities can be conducted. It also provides the opportunity to set criteria for the evaluation of rehabilitation and restoration programmes and to propose mitigating actions of relevance in the rehabilitation of disturbed ecosystems. In this regard rehabilitation is considered of special significance in the conservation of biological diversity. The transforming area and unmined stands of indigenous vegetation in various stages of recovery from disturbance served for some years as a natural laboratory in which to study the development of selected biological communities. Academics from several universities and other organizations are involved in this research, which has now reached the stage where the considerable knowledge so gained should be consolidated.

Table 1. The number of species of different biological taxa on rehabilitating stands of known age and on unmined stands on the coast of northern KwaZulu-Natal. The values in parentheses represent sample sizes (number of trapping grids, quadrats, transects or sample points). For a description of the methods used see refs 5–7.

	Number of species								
				Beetles					
Age of stand (years)	Herbaceous layer	Woody plants	Millipedes	Sweeping	Flight intercept	Pitfall	Birds	Rodents	Shrews
0 to <1	–	–	–	24 (2)	67 (4)	23 (4)	–	4 (4)	0 (4)
1 to <2	–	–	–	26 (2)	55 (4)	23 (4)	17 (1)	4 (4)	2 (4)
2 to <5	–	5 (129)	2 (7)	42 (2)	84 (4)	35 (4)	20 (3)	3 (9)	2 (9)
5 to <8	41 (7)	12 (104)	3 (9)	54 (2)	74 (4)	25 (4)	40 (3)	1 (1)	0 (1)
8 to <11	53 (11)	18 (122)	4 (10)	–	–	–	39 (3)	3 (7)	2 (7)
11 to <16	94 (48)	22 (108)	6 (12)	80 (2)	107 (4)	16 (4)	39 (3)	3 (11)	1 (11)
30 to <35	–	21[1]26[2] (40)	9 (10)	–	–	–	51 (3)	–	–
Mature stand	52 (4)	–	11 (3)	116 (2)	188 (4)	40 (4)	–	4 (2)	1 (2)

[1]Denotes a 30-year-old stand dominated by *Acacia natalitia*.

[2]Denotes a 30-year-old stand dominated by *Apodytes dimidiata*.

Table 2. Stand-specific Bray-Curtis similarity indices of mature unmined stands for different biological taxa recorded during the summer months in rehabilitating and unmined 30-year-old forests on the coast of northern Kwazulu-Natal. All similarities are with unmined mature stands of coastal dune forest at Zulti North, except where indicated otherwise. Similarities between the different stands and the unmined stands were calculated using the Bray-Curtis similarity coefficient.[8] Details on survey methodology are provided in refs 5–7.

	Bray-Curtis similarity indices for mature unmined stands							
				Beetles				
Age of stand (years)	Herbaceous layer	Woody plants	Millipedes	Sweeping	Flight intercept	Pitfall	Birds	Rodents
0 to <1	–	–	–	12.5	12.6	18.9	–	56.1
1 to <2	–	–	–	11.9	14.7	19.1	58.3	58.9
2 to <5	–	12.3	28.0[1] 31.0[2]	17.6	22.6	28.6	57.2	63.1
5 to <8	16.7	26.3	36.3[1] 51.9[2]	15.8	21.6	27.8	60.8	34.1
8 to <11	30.4	28.0	39.7[1] 59.7[2]	–	–	–	82.2	63.2
11 to <16	36.1	39.0	58.8[1] 75.3[2]	23.4	24.8	31.5	90.0	87.1
30 to <35	–	–	76.0[1]	–	–	–	–	–

[1] Denotes similarity with unmined mature forest at Zulti North.

[2] Denotes similarity with 30-year-old forest. We excluded a 30-year-old stand dominated by *Apodytes dimidiata*.

(communities dominated by relatively few pioneer species) to the relatively complex (communities dominated by more secondary species).

The analysis of patterns of similarity for all the taxa studied indicates that rehabilitating stands become progressively similar to unmined land (see Table 2).

The differences between rehabilitating stands and unmined areas are apparent in terms of stand-specific species richness, and of the relative densities of colonizing species and secondary species. The difference in species richness between rehabilitating and unmined stands probably results from the absence and/or rarity of some forest specialists in the former. However, with many species typical of unmined areas now present in the oldest rehabilitating parts, it seems as if conditions within these areas are changing to facilitate the establishment of communities with characteristics similar to those of unmined parts, with possible later colonization by forest specialists. In the case of the vegetation this probably results from changes in light intensity and soil characteristics. Colonization of older rehabilitating areas by plant species typical of adjacent unmined areas is facilitated by fruit-eating birds and vervet monkeys foraging in unmined as well as transforming areas.[2]

The occupation of rehabilitating stands by animal taxa through species addition and replacement is probably made possible by changes in the vegetation. Thus, the nature of the bird community is best explained by two suites of highly correlated habitat variables (canopy gaps, dense lower and middle vegetation layer and a decrease in the relative density of *Acacia natalitia*) related to stand age. Furthermore, a study on the rodents revealed that the species found on rehabilitating stands can be explained by species-specific habitat preferences.[3]

The workshop noted that the criteria described here reflect only on temporal trends in structural variables from which patterns can be deduced. The evaluation of the rehabilitation programme, however, also requires a consideration of functional variables. These are being investigated at present. By using the criteria (sustainability, productivity, nutrient retention, invasability and biotic interaction) set by Ewel,[4] it was noted that the natural increase in species richness in most taxa, the large number of species occurring in the oldest rehabilitating stand, together with the enrichment of soil, support the notion that these criteria are met to some as yet undefined degree.

Presentations by several authors led to the conclusion that the rehabilitation of community structure has been 'successful', but so far not yet completed. The same probably applies to the functioning of the rehabilitating ecosystem.

1. Mentis M.T. and Ellery W.N. (1994). Post-mining rehabilitation of dunes on the north-east coast of South Africa. *S. Afr. J. Sci.* **90**, 69–74.
2. Foord S.H., van Aarde R.J. and Ferreira S.M. (1994). Seed dispersal by vervet monkeys in rehabilitating coastal dune forests at Richards Bay. *S. Afr. J. Wildl. Res.* **24**, 56–59.
3. Ferreira S.M. and van Aarde R.J. (in press). Changes in community characteristics of small mammals in rehabilitating coastal dune forests in northern KwaZulu-Natal. *Afr. J. Ecol.*
4. Ewel J.J. (1990). Restoration is the ultimate test of ecological theory. In *Restoration Ecology: A Synthetic Approach to Ecological Research*, eds W.R Jordan, M.E. Gilpin and J.D. Aber. Cambridge University Press, Cambridge.
5. Van Aarde R.J., Ferreira S.M. and Kritzinger J.J. (in press). Millipede communities in rehabilitating coastal dune forests in northern KwaZulu-Natal, South Africa. *J. Zool., Lond.* **238**.
6. Van Aarde R.J., Ferreira S.M., Kritzinger J.J., van Dyk P.J., Vogt M. and Wassenaar T.D. (in press). An evaluation of habitat rehabilitation on coastal dune forests in northern KwaZulu-Natal, South Africa. *J. Rest. Ecol.*
7. Vogt M. (1993). *Succession of Coleoptera in a Natal coastal dune forest rehabilitation programme.* M.Sc thesis. University of Pretoria.
8. Bray R.J. and Curtis J.T. (1957). An ordination of the upland forest communities of southern Wisconsin. *Ecol. Monogr.* **8**, 325-349.

Professor R.J. van Aarde is in the Mammal Research Institute, University of Pretoria, Pretoria, 0002 South Africa; Dr Malcolm Coe is in the Department of Zoology, University of Oxford, UK, and Dr W.A. Niering is the editor of the *Journal of Restoration Ecology*, Department of Botany, Connecticut College, USA.

Mining to yield to tourism at St Lucia: government decides

The Cabinet has ruled against the expansion of mining for titanium dioxide on the eastern shores of St Lucia. The decision, taken on 6 March, ends six years of controversy between environmentalists, the government, and the mining company, Richards Bay Minerals, the owners of the prospecting lease for the eastern shores, which is part of an area of outstanding natural beauty in KwaZulu-Natal. The implications of continued mining were the subject of a major environmental impact assessment exercise conducted by the CSIR.

The cabinet committee that reviewed the issue consisted of the ministers of Environmental Affairs and Tourism; Water Affairs and Forestry; Arts, Culture, Science and Technology; Land Affairs; and Mineral and Energy Affairs. The government intends to apply to have the St Lucia wetland park declared a World Heritage site, and to encourage the development of its eco-tourism potential. The mining of titanium dioxide at a dune site farther along the coast north of Richards Bay will continue (see accompanying article).