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## Successional changes in rehabilitating coastal dune communities in northern KwaZulu/Natal, South Africa

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### Abstract

Post-mining habitat rehabilitation of coastal sand dunes north of Richards Bay by Richards Bay Minerals commenced in 1978. The reshaping of dunes followed by the spreading of topsoil collected ahead of mining, results in the development of a series of known aged habitat types, varying from young communities dominated by low growing sweet thorns, *Acacia karroo*, to forests dominated by sweet thorns, with broad-leaf trees characteristic of the surrounding indigenous forests establishing themselves. The simultaneous availability of a known-aged series of habitats provides an opportunity to relate temporal changes in selected plant and animal communities to changes in habitat variables.

Studies on millipedes, rodents and birds revealed taxon specific increases in species diversity and in species richness and changes in density with an increase in habitat age. Comparisons of age specific community variables on rehabilitating dunes with those recorded in relatively undisturbed dunes suggest that the development of communities result from autogenic succession initiated through habitat rehabilitation. Several community parameters in the oldest rehabilitating dune forests are similar to those recorded in undisturbed forests. It is concluded that biological diversity can be restored through management options based on principles relating to ecological succession.

*Keywords:* Rehabilitation; Dunes; Ecosystem; Succession; South Africa

### 1. Introduction

In South Africa the growing public interest in the environment is associated with nature conservation changing from an idealistic philosophy to a serious technology, with ecology firmly established as the science of environmental conservation. With conservation embracing preservation, restoration and enhancement of the natural environment (International Union for the Conservation of Nature and Natural Resources, 1980), technologies associated with the restoration or rehabilitation of the environment are

increasingly considered as tools of conservation. The Society for Ecological Restoration defines ecological restoration as 'the process of intentionally altering a site to establish a defined, indigenous ecosystem. The goal of the process is to emulate the structure, function, diversity and dynamics of a specified ecosystem' (Society for Ecological Restoration, 1991). Restoration ecology has thus been established as a discipline directed at establishing ecological principles and applying them to further the goals of conservation. In this regard ecological restoration has even been considered as the 'acid test' of ecology (Bradshaw, 1990) and in reality has become the domain of the community ecologist.

The rehabilitation of coastal sand dunes after

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heavy mineral mining in northern KwaZulu/Natal has resulted in the development of a known aged series of stands representative of the early seral stages of coastal dune succession (see Lubke et al., 1993; Mentis and Ellery, 1994). By assuming that these spatially separated stands develop along a simi-

lar pathway over time, their instantaneous sampling should reveal successional or other forms of changes that are usually associated with ageing (see Fox, 1990).

A useful way of assessing the response of animal communities to environmental disturbances is to

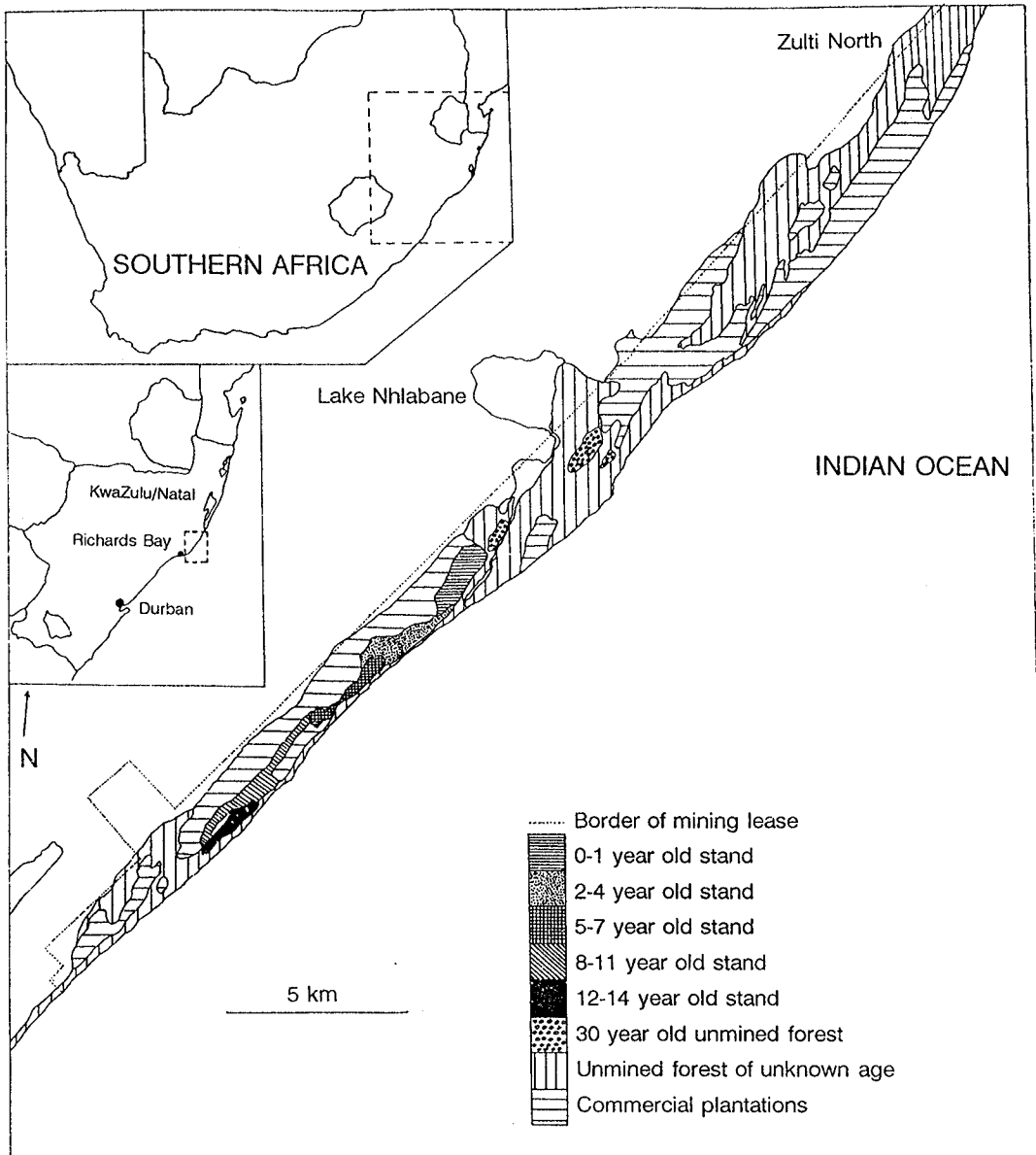


Fig. 1. Map of the study area north of Richards Bay (28°43'S/32°12'E) on the coast of KwaZulu/Natal, South Africa illustrating the locations of the different habitats (rehabilitating stands and unmined forests) selected for the present study.

consider their recovery following a well defined disturbance event. To do this the actual pattern of changes in community structure after disturbance has to be described. This should lead to an improved understanding of community structures and offer insight into the process of ecological succession (Fox, 1990).

The replacement of species during succession means that the abundance of specific species as a function of time can not be monotonic (Fox and McKay, 1981), since the habitat requirements of species differ. In the present paper temporal changes in density, species diversity and species richness of millipedes, rodents and birds after intense disturbance through dune mining are considered and interpreted in terms of ecological succession.

## 2. The study area

The area where dune mining is taking place (28°40'S, 32°14'E) is situated approximately 13 km north-east of Richards Bay (Fig. 1). Here Richards Bay Minerals uses a wet-mining process to extract the heavy minerals ilmenite, zircon and rutile from coastal dunes after which rehabilitation is initiated. The method of rehabilitation following mining has been described by Camp (1990). Here the mechanical reshaping of dunes followed by the spreading of topsoil collected ahead of mining after forest clearing, results in the development of a series of known aged stands, varying from young communities dominated by low growing *Acacia karroo* to woodlands also dominated by *A. karroo*, with broad-leaf species characteristic of the surrounding indigenous forests (i.e. *Sideroxylon inerme*, *Celtis africana*, *Mimusops caffra*, *Vepris undulata* and *Trichelia emetica*) colonising the area. On the 14 year old rehabilitating areas a few *A. karroo* specimens are already becoming senescent.

At present the landscape includes a diverse range of habitats, amongst others a series of regenerating areas varying in age from a few months to 15 years, abutted on the seaward side by a belt of unmined coastal dune forests fragmented by plantation patches (mainly *Eucalyptus saligna* and *Casuarina equisetifolia*) and on the interior by a belt afforested with *C. equisetifolia* following dune mining, ranging in age

from a few months to 8 years. It also includes patches of sand dunes stripped of vegetation in preparation for mining, and dunes being reshaped and prepared for rehabilitation. In addition, the inspection of aerial photographs allowed us to age several unmined patches of forests, these ranging from 30 to 50 years at the time of the study.

## 3. Materials and methods

Rehabilitating stands surveyed for the species composition, density, richness and diversity of millipedes, rodents and birds ranged in age from 0–14 years at the time of the study, with the area separated into stands representing the following ages: 0–1 year, 2–4 years, 5–7 years, 8–11 years and 12–14 years old. In addition, a patch of unmined forest that according to aerial photographs, developed over the last 30 years, and another relatively undisturbed forest in the Zulti North mining lease area, 20 km north-east of the known aged stands, were also used as study locations (see Fig. 1).

Diversity for the millipede, rodent and bird communities was calculated as described by Dickman (1968) using the equation  $H = -\sum(p_i)(\log_2 p_i)$  where  $H$  is the index of species diversity and  $p_i$  is the relative density of the  $i$ th species. The summation is for all species.

Similarities between different sites were calculated on the basis of relative density using Steinhaus's similarity coefficient,  $S = 2W/(A + B)$ , where  $W$  is the sum of the minimum relative density of each species between the sites, and  $A$  and  $B$  are the total relative density of the two sites respectively (thus if  $A = B = 1$ ,  $S = W$ ) (Legendre and Legendre, 1983).

Species turnover for the bird community was calculated using the equation  $T = (R_1 + R_2 - 2B)/(R_1 + R_2)$ , where  $R_1$  and  $R_2$  refer to total species richness in each stand, and  $B$  refers to species occurring in both stands.

### 3.1. Millipedes

The sampling sites (fixed width transects of 35 × 6 m) were selected randomly for each stand. Each transect was surveyed only once by two observers, either during the mornings between 04.00 h and

07.00 h, or the afternoons between 16.00 h and 19.00 h. Two strata were distinguished, with the tree stratum defined as > 30 cm but < 3 m above ground surface and the ground stratum < 30 cm above ground surface. For practical reasons millipedes occurring out of reach (> 3 m) could not be collected but were recorded separately. Eight soil samples of 0.25 m<sup>2</sup>, approximately 10 cm deep and placed at equal distances along the transects were also searched for the presence of millipedes.

During the study period of 3 weeks in December 1992, approximately 3200 millipedes were collected and identified to the morphospecies level. Specimens of each of these were photographed and collected for later identification at the Natural Science Museum in Durban. Density is expressed as the mean number of millipedes per transect.

### 3.2. Rodents

Rodents were trapped, marked and released at monthly intervals using 100 Sherman live traps set for five consecutive days and nights on trapping grids in four stands ranging in age from 3 to 14 years. Early colonisation was quantified by a similar live-trapping programme over the first 8 weeks of

habitat development after the spreading of topsoil (0–1 year old stand). Densities were estimated using the Jolly-Seber stochastic model (Jolly, 1965; Seber, 1965) and the relationship between estimated and trap density (see Caughley, 1977) determined. This relationship was used to infer densities for species and areas for which the original capture data were not sufficient to use the Jolly-Seber stochastic model. Colonisation and extinction were calculated on the presence or absence species recorded in each stand.

### 3.3. Birds

Three line transects of approximately 500 metres were laid out in each of the known-aged stands referred to above. In addition one transect was also placed in the unmined seaward strip and two in unmined 30 year old forest. Each transect was sampled a number of times per day on between five and nine occasions during the period May 1993 to June 1994. Information was collected as described by Burnham et al. (1980) and densities estimated using the programme DISTANCE (Laake et al., 1993). Relative density of different species were calculated using  $rD = rN/rV$ , where  $rD$  is relative density,  $rN$  is relative number seen and  $rV$  is relative visibility, estimated from mean sighting distances for species.

Table 1  
Presence of millipede morphospecies in six coastal dune habitat types or stands in KwaZulu/Natal, South Africa

Species	Habitat type or Stand					
	Mature forest (n = 3)	30 years (n = 10)	12–14 years (n = 12)	8–11 years (n = 10)	5–7 years (n = 9)	2–4 years (n = 7)
<b>Juliformia</b>						
<i>Chersastus inscriptus / richardi</i>	x	x	x	x	x	
<i>Gymnostreptus flavilus</i>	x	x	x			x
<i>Spinotarsus anguliferus</i>	x	x	x	x	x	x
<i>Orthoporus</i>	x	x				
<i>Gymnostreptus pontifex</i>	x	x				
<i>Chersastus sanguinipes</i>	x					
<i>Alloporus</i>	x					
Juvenile D	x	x	x	x	x	
Juvenile E	x	x				
<b>Oniscomorpha</b>						
<i>Sphaerotherium rotundatum</i>	x	x	x			
<i>Sphaerotherium dorsale</i>	x	x	x			
<b>Polidesmoidea</b>						
Unidentified polydesmid	x	x				
<i>Uloidesmus biconus</i>		x				

n represents the number of transects surveyed.

## 4. Results and discussion

Successional changes of plant communities provide a useful framework for comparative studies of animal communities and create a temporal environmental gradient, which should also be revealed as a spatial gradient on locations where relative homogeneous areas are disturbed on successive occasions. Mentis and Ellery (1994) as well as Lubke et al. (1993) illustrated that ecological succession is taking place on both the mined and surrounding sand dunes disturbed through other human activities. Away from the mining path *A. karroo* is known for its ability to rapidly colonise areas of the Tongaland-Pondoland coastal forest when disturbed (see White, 1983) and the successional pathway resulting from the management programme used by Richards Bay Minerals seems to be representative of the area in general.

### 4.1. Millipedes

#### 4.1.1. Species composition

Thirteen morphospecies were distinguished, with eight of these identified to species level and two to the generic level. At least two of these morphospecies, which only occurred in soil samples, represent juveniles, possibly of other morphospecies. The millipede community comprised three different orders, with the order Juliformia represented by seven morphospecies, the order Oniscomorpha (pill millipedes) by two morphospecies, and the order

Polidesmoidea (keeled millipedes) by two morphospecies, probably consisting of a single species, *Ulodesmus biconus ramidens*. One of the morphospecies distinguished during the initial surveys on the structure of the community comprised two closely related species (*Chersastus inscriptus* and *Chersastus richardi*).

Total species richness increased with stand age, from two morphospecies in the 8–11 year old stand, to 13 morphospecies in the unmined areas. The different morphospecies recorded in the different stands are presented in Table 1. *Spinotarsus anguliferus* seems to be the first to colonise rehabilitating areas while *Orthoporus sp.*, *Alloporus sp.*, *Chersastus sanguinipes* and keeled millipedes were only recorded in unmined areas. All morphospecies found in younger stands also occurred in all older areas, with the exception of a single specimen of *Gymnostreptus flavilis* in the 2–4 year old stand (absent from stands of 5–11 years old) and *Ulodesmus biconus ramidens* which was recorded only twice in the 30 year old stands.

#### 4.1.2. Density

Millipede densities for the different strata in the six stands are presented in Table 2. In spite of intra-stand variability, densities on the ground and tree strata differed significantly between the stands ( $F_{5,45} = 3.58$  and  $F_{4,39} = 6.15$ ;  $P < 0.05$  for ground and trees respectively, Mean  $\pm$  SD). Densities on the trees were higher in the mined than unmined areas,

Table 2

Stand and stratum specific densities for millipedes on rehabilitating and unmined areas. *n*, represents the number of transects surveyed

Ground	Rehabilitating areas				Unmined forests	
	(2–4 years)	(5–7 years)	(8–11 years)	(12–14 years)	(30 years)	Zulti North
Mean	2.0	33.7	105.4	22.7	24.1	3.3
CV	96.5	111.9	117.5	102.9	74.8	78.7
<i>n</i>	7.0	9.0	10.0	12.0	10.0	3.0
$F = 3.58$ ; $df = 5,45$ ; $P < 0.05$						
Trees	Rehabilitating areas				Unmined forests	
	(2–4 years)	(5–7 years)	(8–11 years)	(12–14 years)	(30 years)	Zulti North
Mean	0.0	22.89	15.80	11.06	55.20	44.33
CV	0.0	72.04	213.54	89.78	51.23	31.49
<i>n</i>	7.0	9.0	10.0	12.0	10.0	3.0
$F = 6.15$ ; $df = 4,39$ ; $P < 0.05$						

with the highest density recorded on the ground in the 8–11 year old stand ( $105.4 \pm 113.3$  (SD) individuals per transect). This value is significantly higher than that recorded in the pre and proceeding seral stages of the same stratum (Table 2). The value for the 12–14 year old stand ( $22.7 \pm 23.6$  individuals per transect) did not differ significantly from that of the unmined 30 year old seral stage ( $24.1 \pm 18.0$  individuals per transect) (Tukey multiple range test).

The *Chersastus inscriptus/richardi* category dominated in all stands and is to a large degree responsible for the recorded trends in the density of millipedes across successional stages. Tukey multiple range analysis for this category showed that the peak density recorded for this species on the 8–11 year old stand was significant ( $F_{4,49} = 2.82$ ,  $p = 0.025$ ), but that mean density here ( $119.2 \pm 164.3$  individuals per transect) did not differ significantly from that recorded in the unmined 30 year old stand ( $71.7 \pm 37.8$  individuals per transect). In terms of densities the *Chersastus inscriptus/richardi* category, though not the first to occur on these dunes, follows the trend expected for a pioneer species. Following the realisation that this category represents two distinct species, an analysis of data collected during September and December 1993 showed a distinct difference in the habitat preferences of these two species, with 99.83% ( $n = 1167$ ) and 35.79% ( $n = 299$ ) of the individuals in this category collected in the 8–11 and 12–14 year old stands respectively, identified as *Chersastus inscriptus*. In the 30 year old stand and at Zulti North *Chersastus richardi* comprised 56.97% ( $n = 244$ ) and 91.11% ( $n = 45$ ) of the category, respectively. This thus suggests that the successional development of the millipede community is characterised to some extent by species replacement, with *Chersastus inscriptus* dominating during the early stages (8–11 years old stands) and *Chersastus richardi* dominating during the later stages (12–14 years old stands) as well as in the unmined areas. Succession in the millipede community is thus characterised by species addition as well as numerical replacement of *Chersastus inscriptus*.

#### 4.1.3. Richness, diversity and similarity

Species composition changed with stand age and the differences in densities may thus be related to

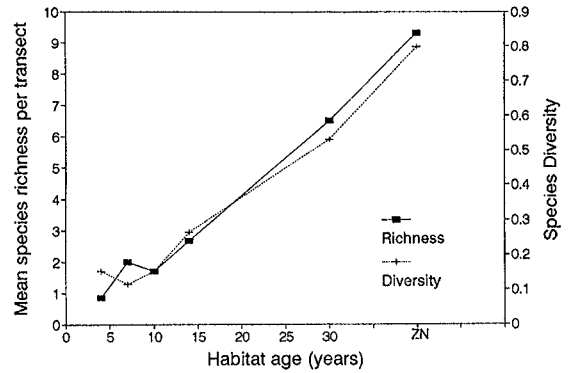


Fig. 2. Mean species richness per transect and diversity of millipedes as a function of stand or habitat age.

differences in species composition and richness. An analysis of mean species richness showed a near linear increase with stand age (Fig. 2). This trend is also reflected in the estimated mean diversity values.

The increase in species richness and diversity with an increase in stand age (Fig. 2) implies that rehabilitation through succession should result in the development of a community with characteristics similar to those of unmined areas. This is supported by the increase in similarity values of rehabilitating stands and the 30 year old forest with Zulti North with an increase in regeneration time (Fig. 3). The trends recorded for the millipede community variables are in agreement with those expected in a successional sequence, even though the 30 year old succession is on unmined land, while the younger areas represent mined, rehabilitating areas.

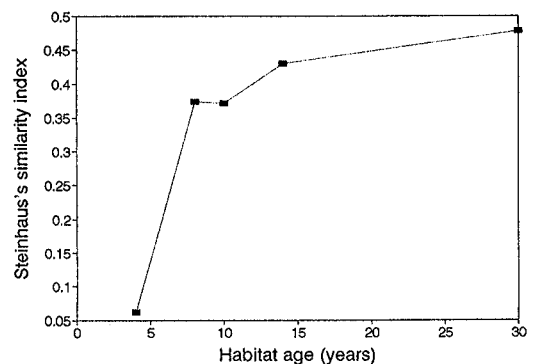


Fig. 3. Steinhaus's similarity indices for millipede communities on four rehabilitating stands and for a 30 year old unmined stand. The values referred to comparisons with Zulti North. Age of each stand is presented by its median age in years.

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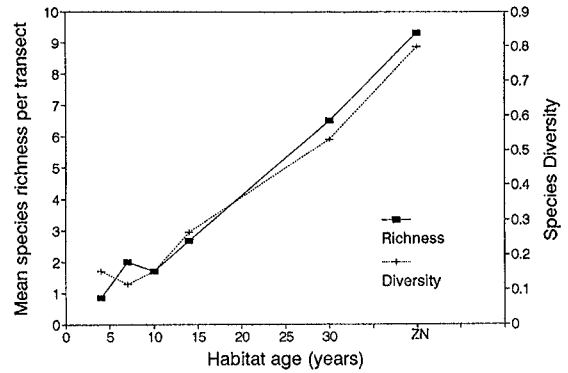


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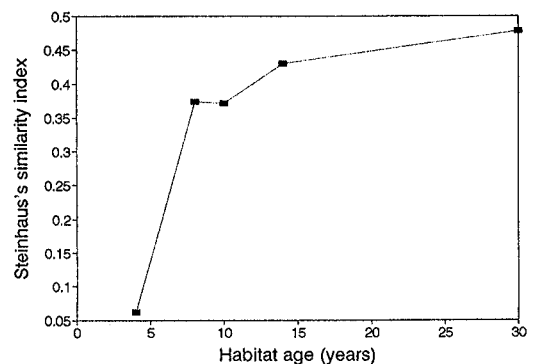


Fig. 3. Steinhaus's similarity indices for millipede communities on four rehabilitating stands and for a 30 year old unmined stand. The values referred to comparisons with Zulti North. Age of each stand is presented by its median age in years.

## 4.2. Rodents

### 4.2.1. Density and diversity

Rodent density peaked in the youngest areas and declined exponentially and significantly with an increase in stand age. The strong numerical response to habitat rehabilitation results from high immigration rates followed by a prolonged decline in numbers as the rehabilitating areas get older (Ferreira, 1993).

Mean species diversity increased with age and attained a peak in the 8–11 year old stand, after which it declined (Ferreira, 1993). This increase in species diversity was generally much slower than those recorded in other similar studies (see Kirkland, 1974; Kirkland, 1977; Kirkland, 1990; Kirkland et al., 1985; Clough, 1987), where species diversity were measured to attain a peak 3 to 5 years after clearcutting. However, the slower rate recorded during our study is expected, since clearcutting does not result in total destruction as in dune mining. In our study area all species are driven out of the areas exposed to dune mining. Colonisation then occurs from older rehabilitating areas or unmined areas, which could lead to slower colonisation rates and subsequent slower increase in species diversity than in areas exposed to clearcutting. Substantial differences can also be expected between temperate and subtropical climates.

### 4.2.2. Colonisation, extinction and species richness

Mean monthly species richness declined from  $3.8 \pm 1.39$  ( $n = 9$ ) species in the 2–4 year old stand to  $2.1 \pm 1.05$  ( $n = 9$ ) species per month in the 12–14 year old stand, but statistically this decline was not significant. The number of species within a given area is a product of the difference between the rates of colonisation and extinction (Petraitis et al., 1989). Petraitis et al. (1989) developed three models which describe patterns in which colonisation and extinction rates changes with stand age and which lead to specific patterns of species richness. One of their models suggests a decline in colonisation rate but never to zero, with a simultaneous increase in extinction rate until extinction is higher than colonisation rate. Subsequently extinction rate declines until extinction and colonisation rates are equal. This leads to an initial increase in species richness followed by a decline when extinction rate is higher than coloni-

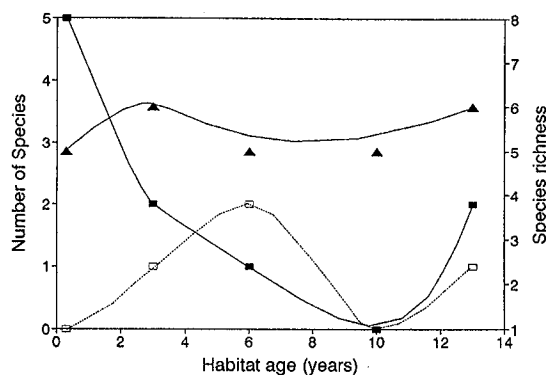


Fig. 4. Small mammal colonisation (■) and extinction rates (□) between successive rehabilitating stands and species richness (▲) as a function of stand or habitat age. Age of each stand is presented by its median age in years.

sation rate. Species richness attains a constant value when these rates are equal and the turnover of species results from the rates not being zero (Petraitis et al., 1989).

During the present study, colonisation and extinction rates followed the trends expected with an increase in stand age (Fig. 4). Colonisation rate was higher than extinction rate in the youngest stand (0–8 weeks old) and declined with age. Extinction rate increased with age and attained a peaked after 5–7 years old which was higher than the colonisation rate here. Older rehabilitating areas were characterised by these rates being about the same. Changes in colonisation and extinction rates as well as species richness thus are in agreement with the model of Petraitis et al. (1989). The changes in small mammal community structure referred to here follow patterns similar to those described in other studies (Parker, 1989; Kirkland, 1990).

### 4.2.3. Species replacement

Relative density of some rodent species captured in rehabilitating areas as a function of regeneration age is illustrated in Fig. 5. Due to seasonal changes in abundance (Ferreira, 1993), the maximum annual value for each species in each of the stands was used to investigate species specific changes.

In our study rodent succession after disturbance follows a pattern similar to that recorded after mining in Australia (see Fox and Fox, 1984). In our area highest densities of *Mastomys natalensis* were



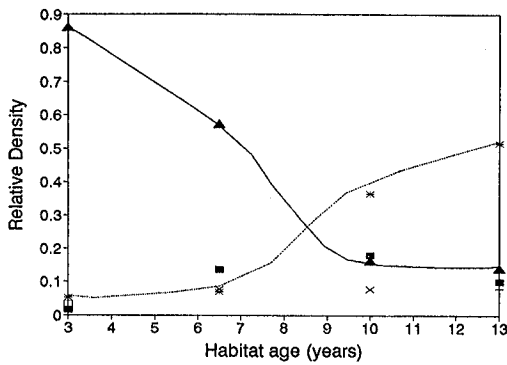


Fig. 5. Density as a function of stand or habitat age of six rodent species captured in rehabilitating areas. (■ *M. minutoides*; + *D. melanotis*; \*- *S. campestris*; □ *O. angolensis*; X *A. chrysophilus*; △ *M. natalensis*). Changes in the densities of the two most abundant species are highlighted using lines.

recorded on the young stands ( $69.8 \pm 6.85$  animals  $\text{ha}^{-1}$  in the 2–4 year old stand) and declined to  $2.2 \pm 6.48$  animals  $\text{ha}^{-1}$  in the oldest mined stands. It is followed by *Mus minutoides* which reaches its highest density when the habitat is about 5 years old, followed by *Saccostomys campestris* which dominates the oldest stand (Fig. 5). Van Aarde and Ferreira (1992) reported unmined forests thought to be 50 years old to be dominated by *Aethomys chrysophilus*. This suggests that *S. campestris* will be replaced by *A. chrysophilus* during later stages of succession.

Rodent succession after dune mining follows a similar pattern but on a different time scale to small mammal successions reported after fire (Fox and McKay, 1981; Rowe-Rowe and Lowry, 1982) and clearcuttings (Parker, 1989; Kirkland, 1990). Rodent

succession at Richards Bay also appears to be slower than that reported after mining in Australia (Fox and Fox, 1984). This probably results from habitat requirements of the species in communities after dune mining at Richards Bay being different to those in the other studies. It may also stem from differences in the intensity of disturbance as the disturbance created by dune mining is totally destructive. The mining by Richards Bay Minerals results in bare dunes that appear similar to dunes created by natural processes i.e. wind. Natural newly formed dunes would take longer to be colonised than mined dunes, as these have never been vegetated (no seedbank available in the topsoil) and subsequently never inhabited. Therefore, it would appear that small mammal succession in rehabilitating areas closely approximates primary succession, while the existence of seed in the topsoil replaced during initiation of rehabilitation, classifies the vegetation succession as secondary (Barbour et al., 1980).

#### 4.3. Birds

##### 4.3.1. Species composition

The two most common species recorded in order of prevalence in each stand are as follows: 0–1 year old stand: fantailed cisticola (*Cisticola juncidis*) and yellow weaver (*Ploceus subaureus*); 2–4 year old stand: rattling cisticola (*C. chiniana*) and yellow weaver (*P. subaureus*); 5–7 year old stand: rattling cisticola (*C. chiniana*) and yellowbreasted apalis (*Apalis flavida*); 8–11 year old stand: yellowbreasted apalis (*A. flavida*) and bleating warbler (*Camaroptera brachyura*); and in the 12–14 year old

Table 3

Habitat specific densities, total and mean species richness, species diversity, number of species exclusive to the area and species turnover of bird communities on rehabilitating and unmined areas.

Stand	<i>n</i>	Density	Total richness	Mean richness	Total diversity	Exclusive species	Percentage turnover
0–1 year	9.0	4.8	25.0	7.3	2.6	5.0	
2–4 years	29.0	8.7	36.0	7.9	3.0	3.0	37.7%
5–7 years	26.0	14.0	51.0	13.6	3.8	6.0	40.2%
8–11 years	25.0	6.7	54.0	13.1	3.8	7.0	27.6%
12–14 years	25.0	6.3	47.0	14.6	3.8	3.0	14.9%
Unmined	19.0	17.6	54.0	20.5	4.4	13.0	

*n* refers to the number of occasions transects were surveyed in each stand.

stand: yellowbreasted apalis (*A. flavida*) and bleating warbler (*C. brachyura*). On the unmined areas bleating warbler (*C. brachyura*) and yellowbreasted apalis (*A. flavida*) were also the most frequently seen species.

Of the 101 species (excluding birds of prey) recorded during the study period, 47 were seen only in the rehabilitating areas, 13 in the unmined areas only and the rest in both areas. The species turnover rates of 15–40% between adjacent seral rehabilitating stands reflect the response of the avian community to habitat regeneration following disturbance resulting from mining. The species turnover between the oldest rehabilitating stand and the unmined areas (38.6%) was considerably less than that (61.2%) during the 16 year time span of habitat rehabilitation following mining.

#### 4.3.2. Density, species richness and species diversity

Both mean species richness and species diversity increased with stand age but stand specific density did not follow a clear trend (Table 3). However, total density in the unmined area was higher than in the rehabilitating areas. The increase in species richness with stand age (species addition) also was associated with a turnover of species (species replacement). The trends of both species richness and diversity with stand age lead us to expect that rehabilitation may eventually result in a community with properties (richness and diversity) similar to those of the unmined areas.

The recorded species replacement is also associated with an increase with age in the similarity of species composition between mined areas and the unmined areas (Fig. 6). In terms of species densities, rehabilitating areas older than nine years are already more similar to the unmined areas than 2–4 year old stands (not illustrated), and areas older than 5 years were more similar to unmined areas than to the less than 1 year old stand. The decreasing slope of the similarity curve results from a decrease in species turnover rates with age, which is a trend typically expected during succession. Although this does not imply that the community in the mined areas will eventually become identical to that of unmined areas, it does support the idea of bird community composition of the mined areas developing towards that in the unmined forest.

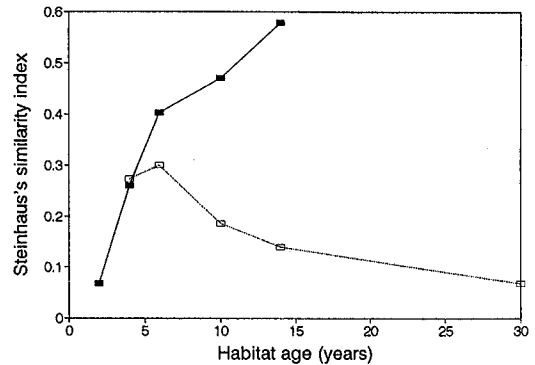


Fig. 6. Steinhaus's similarity indices of bird communities on rehabilitating stands or habitats of different ages. Age of each stand is presented by its median age in years. The dotted line represents similarity with the youngest rehabilitating stand (less than one year old) and the solid line denotes similarity with the unmined areas.

## 5. Synthesis

Succession is here regarded as the process of community establishment following severe disturbance as well as the subsequent development of communities characterised by continuing non-seasonal and directional local colonisation by and extinction of species populations. This process depends on the availability of species pools from where such colonisation can take place. In the case of the Richards Bay mining operation the lay-out of the mining path results in such refuges being present in the form of a relatively narrow unmined seaward strip all along the mining path, as well as fragments of relatively undisturbed forests ahead of the mining path. In addition to this some species may colonise early successional stages from surrounding disturbed areas as well as older rehabilitating areas. Topsoil collected prior to mining from abutting dunes, may serve as another source through which some communities may become established. Colonisation of the taxa considered in the present paper is not assisted through artificial manipulation and thus relies on the abilities of such species to colonise rehabilitating areas on their own.

All our studies show a progressive increase in species richness with time, as well as definite sequences of species replacement, thereby supporting the notion that changes on the rehabilitating dunes

represent successional change. The areas investigated by us do not represent a complete series of seral stages, but are rather representative of relatively early seral stages of coastal dune forest succession. In spite of this it is exciting to note that most of the small mammals, birds and millipedes recorded in unmined areas have also been recorded on the rehabilitating mined path.

The rates of succession in the different communities differ and is slower for the millipedes than those recorded for the rodent and bird communities. This probably results from differences in dispersal abilities, generation intervals and other size and taxon specific life history variables.

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