

7 Coastal Dune Forest Rehabilitation: A Case Study on Rodent and Bird Assemblages in Northern Kwazulu-Natal, South Africa

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7.1 Introduction

Coastal dune forests in northern KwaZulu-Natal, South Africa, are continually exposed to natural and man-induced disturbances that usually initiate ecological succession (van Aarde et al. 1996a; Mentis and Ellery 1994). This succession is associated with temporal and spatial changes in vegetation structure that influence habitat suitability and ultimately the structure of vertebrate communities living there. For example, in the case of birds, we know from studies conducted elsewhere that species richness and diversity correlates with vegetation structural heterogeneity (see Kritzing and van Aarde 1998 for references). Vegetation succession is also known to affect small mammals (Foster and Gaines 1991), though the patterns recorded in coastal dune forests are less obvious than those for birds (see Ferreira and van Aarde 1999 for references).

Ecological rehabilitation programmes often aim at minimising the compositional, structural and functional differences between undisturbed reference sites and rehabilitating sites (see van Aarde et al. 1996a, b). In the present chapter, we aim to characterise species traits that affect a species' occurrence, abundance and persistence at particular stages of the regenerating sere of coastal dune forest. For rodents and birds, as with other taxa, we expect that rehabilitation would result in community characteristics converging towards those of benchmark sites. Species present in newly regenerating sites should be pioneers and r-selected, while those inhabiting later stages of the regeneration sere should be K-selected (Smith and MacMahon 1981). Based on earlier studies on vertebrates, we also expect mean species-specific reproductive output to decrease as a result of increasing environmental stability with increasing successional age (May 1984; Mönkkönen and Helle 1987). Furthermore,

habitats developing towards benchmarks in response to rehabilitation are transient. Generalists therefore, should inhabit developmental gradients for longer periods than specialists.

In the present contribution, we describe the development of rodent and bird communities in our study area north of Richards Bay (South Africa), where dune forest rehabilitation commenced in 1977. About 24 years of continued rehabilitation gave rise to the development of a range of known-aged transient habitats converging onto an undisturbed coastal dune forest (van Aarde et al. 1996a,b; Kritzinger and van Aarde 1998; Ferreira and van Aarde 1997). The questions we will be addressing here are as follows: Do the life history traits of early vertebrate colonisers differ from those of later colonisers? Do these life history variables follow the traditional r-K dichotomy?

7.2 Study Area

7.2.1 Indian Ocean Coastal Dunes

The Indian Ocean coastal belt supports a distinctive vegetation system with 40 % endemism among woody plants (Moll and White 1978). The coastal belt can be divided into four regions, namely the northern Swahili Centre of Endemism, the central Maputaland-Swahili Transitional Zone with little endemism, and the southern Maputaland and Pondoland Centres of Endemism (van Wyk 1996). Our study area is located within the southern Maputaland region. The Maputaland vegetation has been classified into 15–21 ecotypes, most of which include many endemic or localised plants usually associated with sandy soils (van Wyk 1996). One of these ecotypes includes dune forests, which occupy a narrow belt along the coastline (Moll and White 1978; Eeley et al. 1999) from Maputaland southwards where it becomes patchy and floristically impoverished (Moll and White 1978).

Coastal dunes support a relatively high diversity of vertebrates but limited endemism (McLachlan 1991). This may be ascribed to the relative narrowness of coastal dunes, allowing vertebrates from adjoining habitats free access in their search for additional food and shelter. Coastal dunes are also geologically relatively young and have thus had little time for the evolutionary development of unique species or subspecies (McLachlan 1991).

7.2.2 The Coastal Sand Dune Forests of KwaZulu-Natal

Tinley (1985) distinguished four vegetation zones in South African coastal dunes, one of these being forests. Coastal dune forests in a relatively undis-

turbed state form a narrow belt of potential habitat for vertebrates between the sea and the hinterland where it seldom extends further than 2 km from the coast in northern KwaZulu-Natal.

The dune forests of KwaZulu-Natal are located on Pleistocene and Recent sands and are exposed to relatively high rainfall (Tinley 1985). High leaching of soil minerals may limit soil fertility. These dunes have been covered by forest for approximately 8000 years (see references in Eeley et al. 1999). Human activities in the region have had a major influence on coastal dune plant communities in KwaZulu-Natal since the early Iron Age (Conlong and van Wyk 1991). By 1939 most of the dunes in the area were covered with small scrub (Stephens 1939 in Conlong and van Wyk 1991), suggesting that agricultural and pastoral activities of semi-permanent settlers dramatically degraded coastal dune forests. By 1974 the protective policies adopted by the then Department of Forestry against fire, woodcutting, shifting cultivation and grazing resulted in the recovery of some of these indigenous forests (Weisser 1978). More recently, these forests have been fragmented through the establishment of commercial exotic plantations and by opencast dune mining followed by ecological rehabilitation. Here, the withdrawal of man-induced disturbances usually initiates habitat age-related changes in vegetation composition and structure through successional processes (see van Aarde et al. 1996b). Such development provides transient habitats for vertebrates and invertebrates typical of coastal dunes of the region, all of which are colonising such areas on their own accord (see van Aarde et al. 1996a, b; Kritzinger and van Aarde 1998; Ferreira and van Aarde 1997, 2000).

7.2.3 The Post-Mining Rehabilitation of Coastal Dunes

Most of the present discussion is based on information collected over a ten-year period from 1991 to 2000 along a 40-km stretch of regenerating and mature coastal dune forest between Richards Bay (28°43'S; 32°12'E) and the Mapelane Nature Reserve (32°25'S; 28°27'E) (see Fig. 7.1). Richards Bay Minerals has been extracting heavy metals (zircon, ilmenite and rutile) from some of the dunes northeast of Richards Bay since July 1977. During these operations, a 400-m-wide shoreline strip of dune vegetation is preserved to reduce slumping as well as to preserve a species pool from which potential colonisers of the regenerating habitats may originate.

Before dune mining commences, the surface vegetation is cleared away and the topsoil is collected for later use in rehabilitation. A floating dredger and separation plant collects sand and separates the heavy metals by a gravitational process, after which the minerals are pumped to a stockpile on land. The remaining sand (>94 %) is pumped to an area behind the dredging pond, where new dunes are formed and shaped to resemble the topography of the dunes prior to mining. Topsoil collected prior to mining, is then spread over

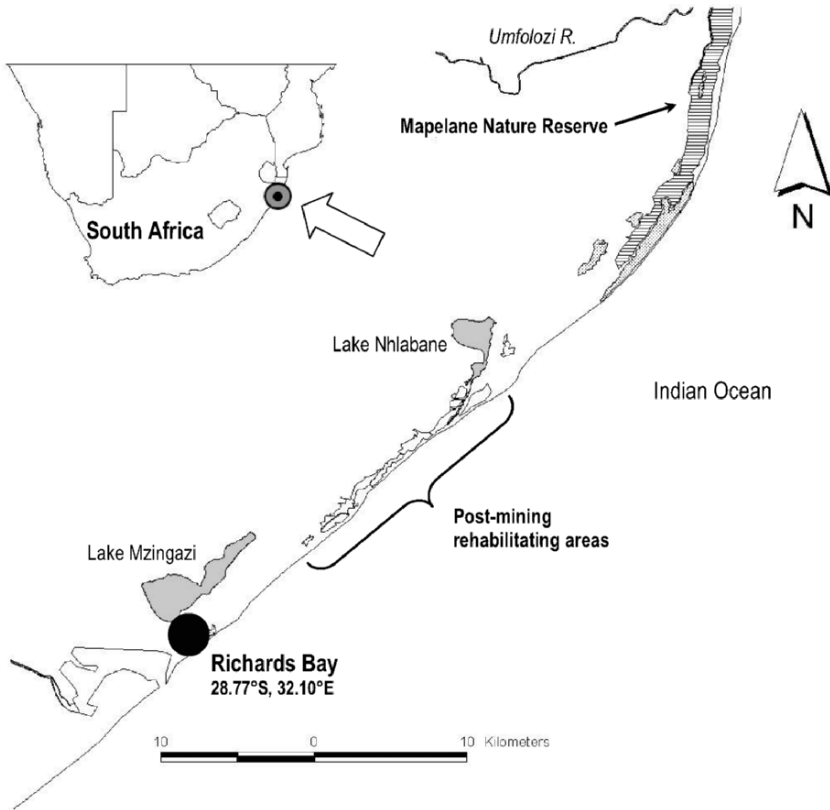


Fig. 7.1. A map of the study area showing the location of each particular regenerating site and the unmined mature coastal dune forest

the reshaped dunes. A seed mixture of annuals consisting of *Pennisetum americanum*, *Sorghum* sp. and *Crotalaria juncea* are incorporated in the topsoil. To reduce wind erosion and surface evaporation, 1.5-m-high hessian windbreaks are erected across the dunes. Within a month of the start of rehabilitation, this management programme gives rise to a dense plant cover that prevents erosion and apparently ameliorates the surface microclimate for the germination and subsequent establishment of indigenous species.

Within 3 to 6 months after the die-off of the annuals these areas are densely covered with grass and *Acacia kosiensis* seedlings, while at 2 years the canopy cover of low *A. kosiensis* trees is approaching 70–80%. Further successional development is associated with the self-thinning of *A. kosiensis* (van Dyk 1996) and unassisted colonisation by plant and animal species, typical of mature dune forests in the region (see van Aarde et al. 1996a, b). None of the rodent or bird species recorded here are endemic to coastal dune forests.

7.3 Materials and Methods

The collection of information and the reduction of data have been described elsewhere (for rodent studies see Ferreira and van Aarde 1996, 1997, 1999, 2000; Koekemoer and van Aarde 2000; for bird studies, see Kritzinger and van Aarde 1998; Niemand 2001). Rodent and bird community sampling occurred on the same regenerating sites of known age (1, 5, 13, 17, 20 and 23 years old at the time of the present study) and in a neighbouring mature coastal dune forest site (see Fig. 7.1).

7.3.1 Rodents

Trapping took place during summer (December–January) over a 10-year period from 1991 to 2001 on three to six permanent replicate trapping grids located on each of the six regenerating sites and an unmined dune forest site. Trapping grids consisted of 49 trapping stations arranged in a 7x7 configuration with 15 m between trapping stations. A single Sherman live trap (75x90x230 mm), baited with peanut butter and raisins, was placed at each station. Grids were placed at least 200 m apart to ensure independent sampling. Trapping on a grid continued for three nights and traps were checked and rebaited each day at dawn. Trapped animals were identified to species level, marked (by toe clipping), sexed and weighed prior to release. Abundance was calculated as the minimum number alive (MNA) per grid (Krebs 1999).

7.3.2 Birds

Data was collected during December and January of 1994, 1996, 1998 and 2000 using line transect surveys following the methods of Kritzinger and van Aarde (1998). The number of transects per site was affected by the size of the regenerating site and varied from two to four transects per site. Transect starting points were randomised, but transects did not overlap and were at least 200 m apart. Surveys continued for approximately four hours, beginning 30–60 min after sunrise when birds are most active and conspicuous. Transect lines ranged from 250–500 m in length and line length was incorporated in the calculation of density to correct for variable transect length.

Data for each transect was analysed separately using the programme DISTANCE (Laake et al. 1993). Mean and error values for total density per hectare for each sampled site are based on these individual estimates. Site-specific relative density (rD) for each species was calculated using the equation $rD=rN/rV$, where rN is the number of a given species relative to the total num-

ber seen on the transect and rV is relative visibility (Buckland et al. 1992). rV values were calculated according to Buckland et al. (1992).

For each of the sites, typical species were identified as the most consistent species of a site, that is, those species contributing to the first 50 % of similarity within sites (Clarke and Warwick 1994). The present analysis is limited to the sets of typical species identified for the chronosequence of dune forest regeneration. Information on species body and clutch sizes was obtained from Maclean (1993).

The study was conducted over a ten-year period and most sites along the regenerating sere have been surveyed repetitively. A given site therefore contributed to more than one data point and data from sites of increasing age are not independent, thus not allowing for refined statistical analyses and curve fitting.

7.4 Results and Discussion

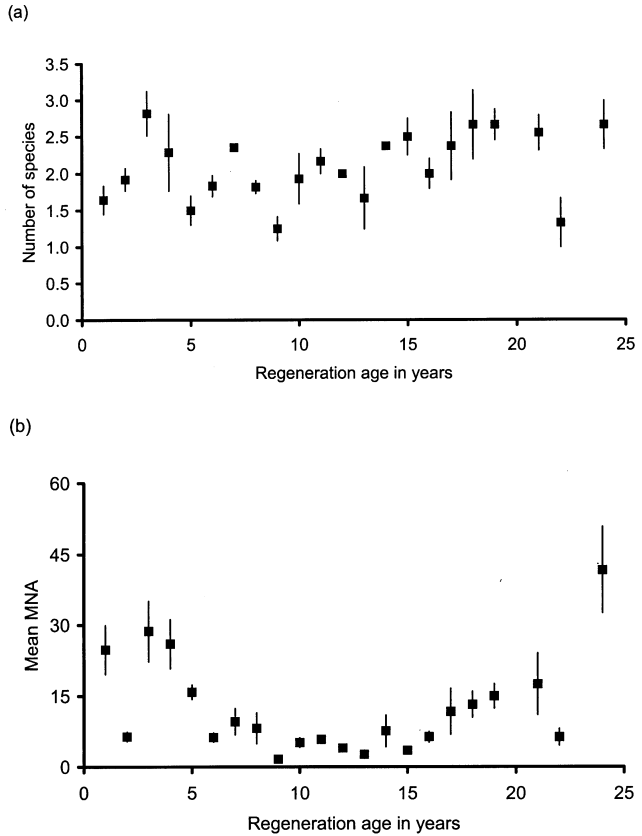
Coastal dunes in our study area are inhabited by vertebrates ranging in diet from granivores (rodents, birds) to frugivores (birds), insectivores (shrews, birds, reptiles, amphibians) and carnivores (reptiles, mammals). The presence of vertebrate species on specific sites or seral stages within such a successional sere conceivably depends on the presence of their resources, while the number of species and their absolute densities will depend on resource availability, area, and interspecific interactions.

7.4.1 Rodents

As mining of these dunes followed by dune rehabilitation may be considered a discrete disturbance event, the colonisation of such areas may be considered a recovery or regeneration of the relevant assemblages or communities. This implies that the undisturbed assemblage on stands of mature forest represents an entity towards which the disturbed assemblages can develop. Live-trapping (about 35,000 trap nights and 11,000 captures over a 10-year period of our study) on developing dune forests yielded eight rodent and three shrew species. All species recorded in unmined and relatively mature dune forests also occurred in regenerating dune forests with no clear change in the number of species inhabiting regenerating sites with increasing regeneration age (Fig. 7.2). Species inhabiting young regenerating stages were the same as those of mature forests and we may conclude that the post-disturbance recovery of rodent and shrew assemblages is not structured by habitat age-related factors.

Species richness at a given point along the chronosequence in our study, as in most habitats, is ultimately a consequence of the balance between local

Fig. 7.2. **a** The mean (\pm SE) number of rodent species and **b** mean (\pm SE) minimum number of rodents alive (MNA) as a function of regeneration age along a chronosequence of dune forest development



colonisation and extinction. The lack of a clear age-related pattern in species richness might thus reflect a lack of a clear pattern in colonisation and extinction. This may also be true for mature dune forests in the region where natural disturbances evoked, e.g. by tree-falls, create gaps within the forest (Ferreira and van Aarde 2000). Tree-falls at different times create patches at different stages of recovery, leading to a variety of habitats and rodent assemblages. It may thus be argued that these coastal dune forests are predisposed to disturbance events – a given patch may be colonised by whichever species are available in the surrounding areas. The pioneer species are probably always present at all sites and ready to exploit any opportunity.

Our results suggest that rodent communities in these forests are extremely flexible with temporal changes in the composition of assemblages not always being unidirectional (see Ferreira and van Aarde 1996, 2000). Ferreira and van Aarde (1999) also showed that for some rodents, habitat features, rather than inter-specific interactions, might explain species-specific densities. Spatial and temporal variability in habitat features such as vegetation height, area covered by shrubs, volume of shrubs and litter depth (Ferreira and van Aarde

1999) appear to determine the occurrence of rodents in coastal dune forests. Rodent assemblages should thus be seen as loose collections of species, rather than tightly structured communities.

Rodent numbers (minimum number alive), expressed as a function of habitat regeneration age, followed a pattern of high numbers on regenerating sites less than five years of age, after which numbers remained relatively low until a site regeneration age of 15 years, thereafter steadily increasing (Fig. 7.2). All assemblages along the successional sere were dominated by the multi-mammate mouse (*Mastomys natalensis*) and the pouched mouse (*Saccostomus campestris*) (Ferreira and van Aarde 1996), although numbers for both species varied considerably (see Fig. 7.3). Studies by Foster and Gaines (1991) and Ferreira and van Aarde (1996) had shown that successional changes in rodent communities are characterised by species additions as well as changes in abundance. However, long-term data, such as ours, is conceivably affected by inter-annual differences in rainfall that may affect productivity that may overshadow the influence of regeneration age on assemblage parameters. Yet, the present findings are in agreement with the successional sere noted earlier by Ferreira and van Aarde (1996, based on data collected

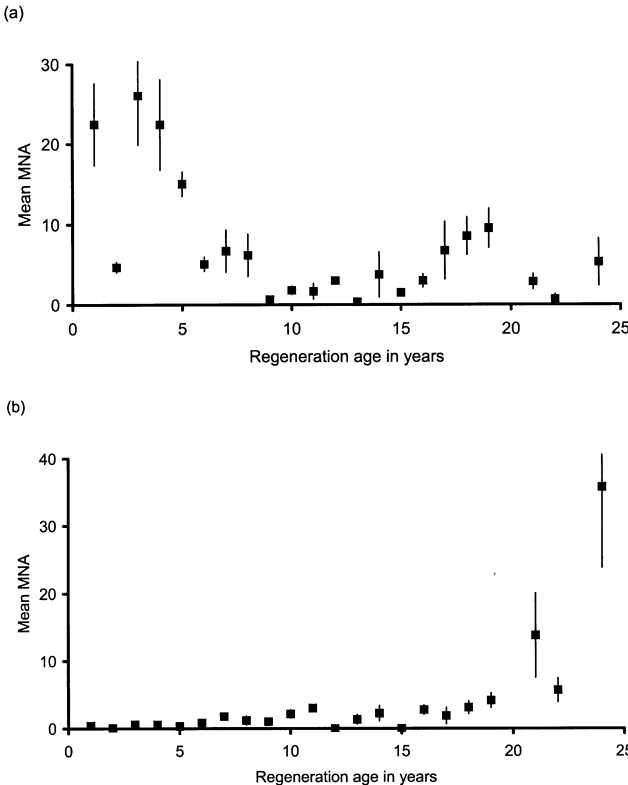


Fig. 7.3. The mean (\pm SE) minimum number alive (MNA) of a *Mastomys natalensis* and b *Saccostomus campestris* as a function of regeneration age along a chronosequence of dune forest development

between 1991 and 1993), where *M. natalensis* is replaced by *S. campestris* (Fig. 7.3). This pattern differed from that recorded later by Ferreira and van Aarde (2000), when between 1993 and 1995, *S. campestris* did not feature in the rodent successional sere. When considering all the data collected over a ten-year period from these dunes it is apparent that the pattern is determined by only two species. *Mastomys natalensis* is the most abundant species during the first few years of vegetation regeneration and *S. campestris* is dominant in sites older than 15 years of age (see Fig. 7.3).

During the first few years of forest regeneration, the vegetation is dominated by grasses and sedges (Conlong and van Wyk 1991). These conditions favour colonisation by a generalist pioneer such as *M. natalensis*, known to flourish in disturbed environments (Meester et al. 1979). *Saccostomus campestris*, a more specialised hoarder, especially of *Acacia* species seeds (Swanepoel 1972), could conceivably thrive on the 12-year and older regenerating sites where the dominant mature *A. kosiensis* trees are producing seed. These sites are, however, also characterised by disturbance caused by natural tree-falls that create patches ideal for pioneers, such as *M. natalensis*, thus explaining the continuing occurrence of this species along our successional sere.

Our studies suggest that the composition of rodent assemblages may be best explained by movement of animals between disturbed and undisturbed patches (see Ferreira and van Aarde 1996). High community dominance (only a few species dominating community structure) may also be due to limited interspecific competition and selective resource advantages at specific stages during forest regeneration. For instance, by experimentally manipulating food availability for rodents in early post-mining habitats, we have previously shown that community dominance increases (Shannon diversity decreases) with an increase in food availability (Koekemoer and van Aarde 2000). This was the result of an increase in the absolute numbers of the pioneer species rather than a change in the abundance of other species (Koekemoer and van Aarde 2000). It is thus fair to say that in our study area, the unstable environmental conditions that give rise to habitat changes, rather than interspecific interactions, result in temporal trends in rodent species richness and diversity (Koekemoer and van Aarde 2000).

How do these results reflect on our questions? Most species are present at the onset of rehabilitation, but typical pioneer species, such as *M. natalensis*, with high reproductive output and generalist feeding requirements (Meester et al. 1979) numerically dominates. In contrast, *S. campestris* (most prevalent on later stages) exhibits variable reproductive output (Westlin and Ferreira 2000) and more specialised feeding requirements (Swanepoel 1972). Early rodent dominants have different life history traits than those of later dominants, while these traits appear to follow the traditional r-K dichotomy.

7.4.2 Birds

We recorded 105 bird species during the four annual transect surveys completed between 1994 and 2000. Most (42%) of the species on mature dunes also occurred on dunes regenerating in response to dune rehabilitation. The species (33%) noted on regenerating sites but not in the mature forests were all grassland species typical of the region, e.g. the Rattling Cisticola (*Cisticola juncidis*), Grassveld Pipit (*Anthus cinnamomeus*) and Common Waxbill (*Estrilda astrid*). For birds, the rehabilitating habitats were similar to those typical of the region, with the result that regenerating habitats did not support any unique species (see Niemand 2001). This is to be expected, as local assemblages are probably dependent on regional species pools.

By reducing our data base and concentrating on species typical of known-aged and mature sites along the chronosequence of developing dune forest, it became clear that the number of typical species increases with regeneration age (Fig. 7.4). This increase coincided with a decrease in the contribution of each species to each of the site assemblages, as well as a decrease in their abundance and variability in abundance (Fig. 7.4). Successional development was further associated by an increase in body size, particularly after 10 years

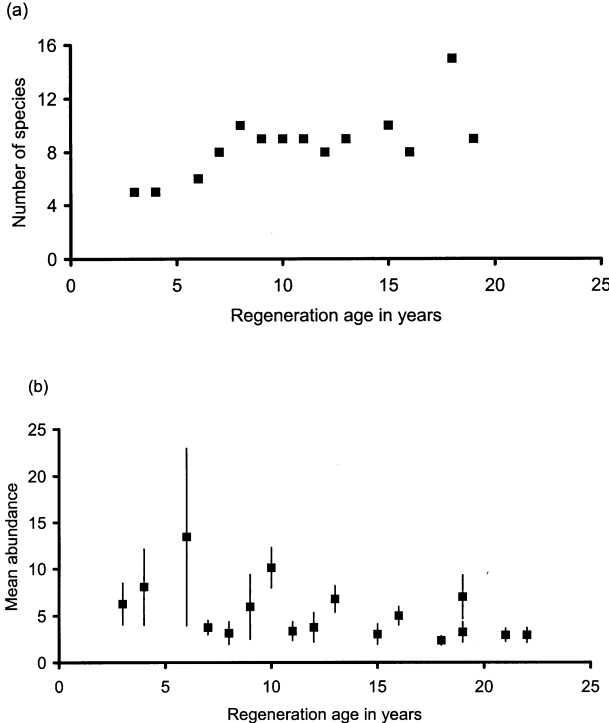
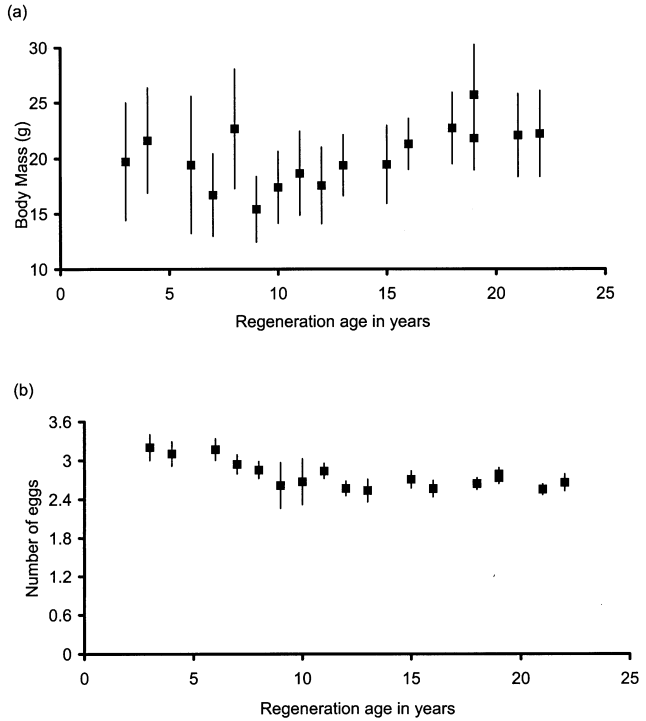


Fig. 7.4. a The total number of typical bird species along a known-aged chronosequence of dune forest development. b Mean (\pm SE) abundance for typical bird species based on summer censuses conducted along transect lines surveyed during 1994, 1996, 1998 and 2000

Fig. 7.5. a Mean (\pm SE) body mass in grams for birds identified as typical of a chronosequence of coastal dune forest development. **b** Mean (\pm SE) clutch size for birds identified as typical of a chronosequence of coastal dune forest development



of regeneration, and a decrease in clutch size, especially during the first 10 years of regeneration (Fig. 7.5). Therefore, the bird community of the regenerating sites followed developmental patterns typical of ecological succession (May 1984; Mönkkönen and Helle 1987).

In our studies, changes in the species composition of birds were closely associated with succession-induced changes in vegetation composition and structure (see also Kritzing and van Aarde 1998). As expected (May 1984; Mönkkönen and Helle 1987), species typical of later successional stages were more K-selected (relatively large-bodied with relatively smaller clutches and occurring at relatively lower densities), than the r-strategists of earlier successional stages.

7.5 Conclusion

In response to the questions asked at the onset of the study we conclude that the life history traits of early colonisers differ from those of later colonisers for birds but not for rodents as all species colonise early. However, for rodents, life history traits of early dominants differed from those of later dominants.

Changes in these life history variables for birds appear to follow the classic r-K dichotomy associated with successional changes, but do not imply that rehabilitation has been successful or will succeed in the future. Trends in both bird and rodent communities do, however, indicate that rehabilitation is at least a management tool that could potentially reverse the ubiquitous trends of habitat loss and fragmentation that threatens the viability of species populations.

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