Title: The resilience of the medicinal plant community of rehabilitating coastal dune forests, KwaZulu-Natal, South Africa

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Introduction

There are many motivations for the ecological restoration of degraded habitat. These include the ecological and cultural benefits perceived to accrue from successful rehabilitation, for example, conservation of biological diversity, provision of ecosystem services, and the reinstatement of important cultural links with the local environment (Clewell & Aronson, 2006).

For many African people an important cultural link stems from the use of medicinal plants (Anyinam, 1995). Considering this importance, it is worth noting that one of the main threats to the diversity of medicinal plants comes from habitat loss (Shanley & Luz, 2003; McGeoch, Gordon, & Schmitt, 2008).

Our interest in medicinal plants stems from our work in the South African Province of KwaZulu-Natal, where an estimated 80% of the population uses traditional medicines (Taylor et al., 2001). This is corroborated by our recent survey where we asked local people how they utilised coastal dune forest, and most respondents (92.8%, n = 154; unpublished data) collected medicines from the forest. We have been assessing the recovery of coastal dune forest (an important habitat for medicinal plants; see Pooley 1993, 1998) after strip-mining for the last 18 years (see van Aarde, Coe & Niering, 1996). This paper evaluates how resilient the medicinal plant community has been to this large scale mining-induced disturbance and if it is recovering in response to rehabilitation.

Material and Methods

The coastal dune forests north of Richards Bay, KwaZulu-Natal, South Africa, are within the southern-most part of the Maputaland centre of plant endemism (van Wyk & Smith, 2001). The study site lies between Richards Bay Town (28°43’S, 32°12’E), and the Sokhulu forest

(28°27’S, 32°25’E). The strip-mining of these forests for sand minerals is a destructive process whereby all vegetation and topsoil is removed from the dune. During post-mining, the sand is re-shaped in to dunes and topsoil (seeded with annuals) is spread over them. From then on rehabilitation relies on natural successional process (van Aarde et al., 1996). Mining and subsequent rehabilitation is a continuous process leading to a known-aged sere of regenerating dune forest sites. We therefore assessed the recovery of medicinal plants after mining disturbance across a chronosequence consisting of seven mined sites, ranging between 5 and 28 years of age. The Sokhulu forest is the largest (500 hectares) undisturbed forest in the study region and this was used as a reference against which to measure the recovery of medicinal plants.

We assessed the woody plant and herbaceous plant community separately. We followed the methods described by Wassenaar et al. (2005) whereby self-supporting woody plants greater than 1.7 m in height were identified in at least seven 16 x 16 m quadrats per site. The exact number of quadrats was dependent on species accumulation curves reaching an asymptote. For the herbaceous plant community all plant species below 1 m in height were identified and counted in ten randomly (using the spatial analyst extension in ERSI ArcMap version 9.2) located plots in each site. A plot consisted of ten 1 m^2 quadrats placed in a 2 x 5 m pattern with 5 m separating each quadrat (Wassenaar et al., 2005). Data were collected in the winter of 2005. Medicinal plants were identified as such from published sources (Arnold & De Wet, 1993; Arnold et al., 2002). The age-related trends in the number and diversity (Shannon Index) of medicinal plants per quadrat were assessed using linear regression. Rather than assuming that the reference site was a static entity, we assessed the variation inherent in the medicinal community within the Sokhulu forest. Mean values (number and diversity of medicinal plants) and the

standard deviation about these values were considered the target for rehabilitation. Where plots in the rehabilitating sites were indistinguishable from those in the reference site (i.e. the plots within rehabilitating sites fall within the variation inherent in the reference site) we considered the structure of rehabilitating sites successfully restored. To assess compositional changes in medicinal plants over time we used Non-metric multidimensional scaling (NMDS) using the function 'metaMDS' of the package 'VEGAN' (v.1.15-3; Oksanen et al., 2008) in the R statistical software (v. 2.8.1; R Core Team Development, 2008).

Results and Discussion

As the sites in the chronosequence increased in age so too did the number and diversity of medicinal herbaceous and woody plants. The oldest site (28 years old) had a similar species number (woody plants ± standard deviation = 12.10 ± 4.76; herbaceous plants = 8.2 ± 1.55) and diversity of medicinal species as that found in the Sokhulu Forest (woody plants = 16.50 ± 5.90; herbaceous plants = 9.72 ± 2.84; see Fig.1). The species composition of medicinal woody plants changed with regeneration age and appeared to converge towards that of the Sokhulu Forest, suggesting that the medicinal woody plant community is highly resilient to mining disturbance and/or responds positively to rehabilitation (Fig 2). However, the composition of the medicinal herbaceous plant assemblage showed no age related trends (Fig 2).

All of the medicinal herbs present in the reference site (Sokhulu forest) were recorded in the rehabilitating sites. The apparent divergence stems from additional species in the rehabilitating sites. The youngest rehabilitating sites were more similar in community composition to the Sokhulu forest than the older sites (Fig 2a & b). Species may have established

from the topsoil or have dispersed to the youngest sites more easily as these sites are closer to remnant forest patches.

Habitat loss is a major threat to medicinal plants in Africa (McGeoch et al., 2008) and habitat restoration has the potential to redress this. We have shown here that the medicinal plant community of a coastal dune forest is resilient to disturbances and can be restored through rehabilitation. Further to this, the creation of a sere of regenerating sites of different seral stages has allowed the colonisation of non-forest species that also have medicinal value. Future work will focus on which species are most valued by the local community and if current rates of harvesting are sustainable in these regenerating forests.

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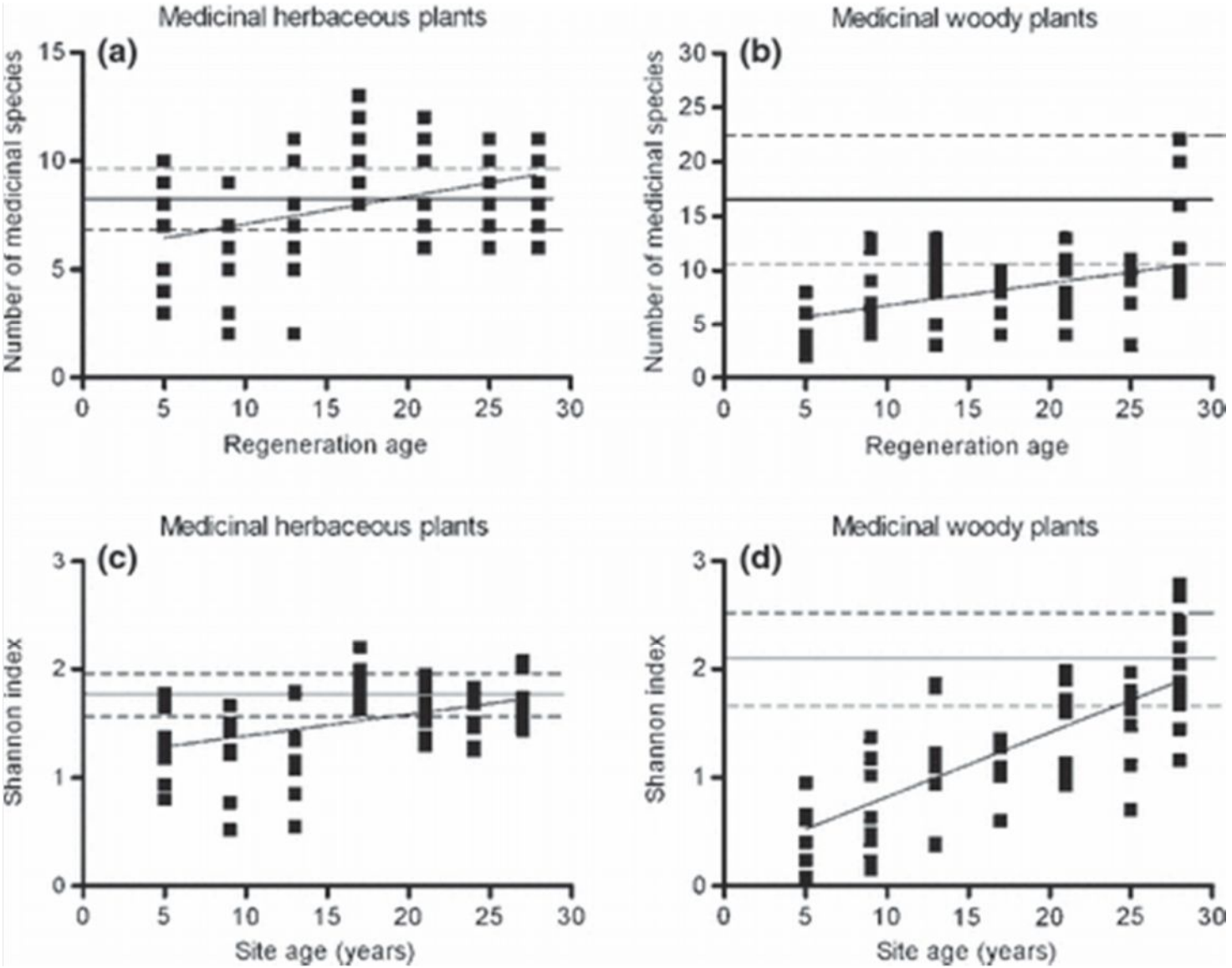

Figure 1. The number (a and b) and diversity (c and d) of medicinal species as a function of regeneration age for herbaceous (a and c) and woody (b and d) plants in the rehabilitating coastal dune forest. A regression line indicates significant non-zero trends (as assessed using linear regression). The mean number of medicinal species and diversity of species per plot and the variation about this mean (standard deviation) in the undisturbed Sokhulu forest is indicated by the horizontal solid (mean) and dotted (standard deviation) lines

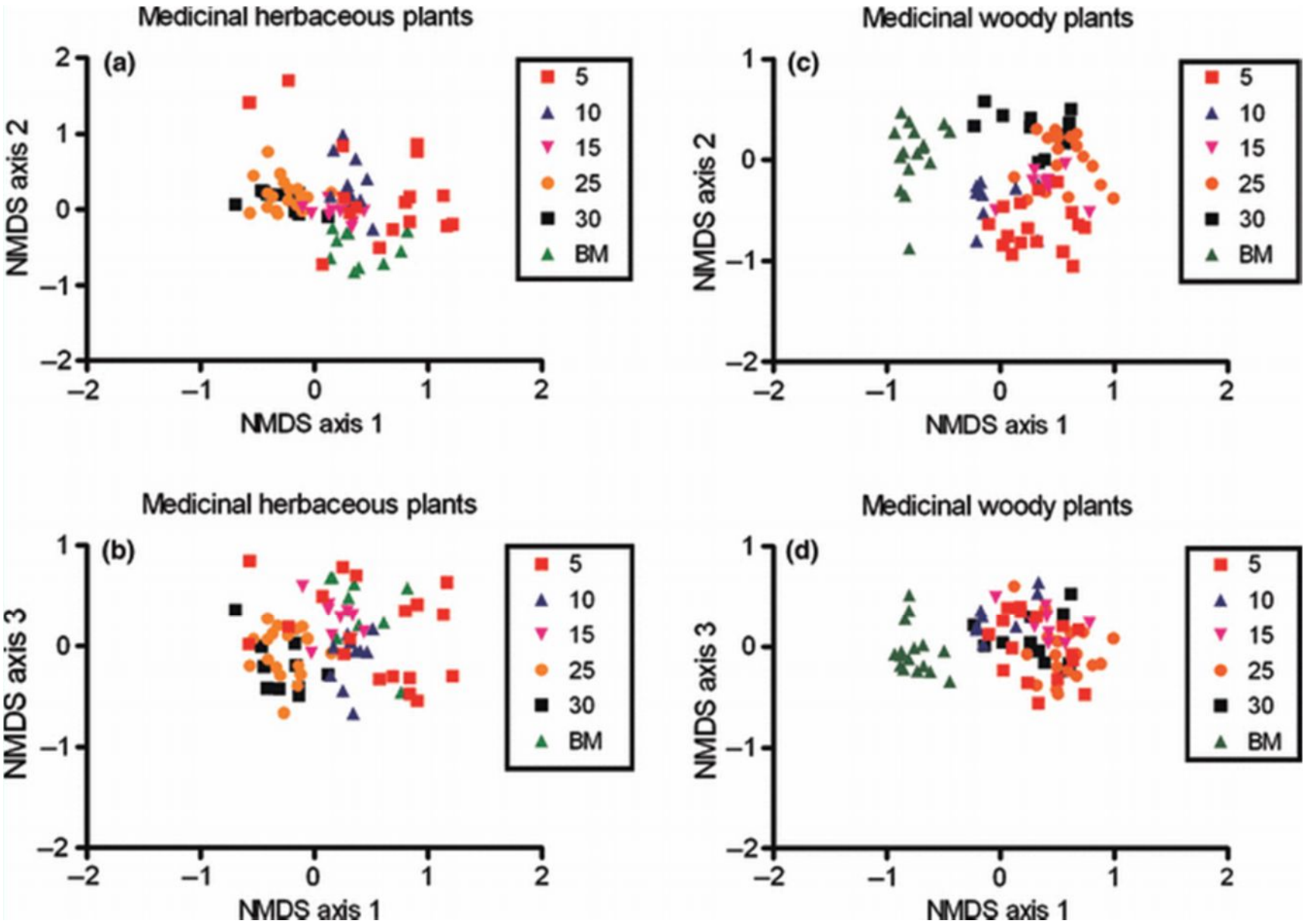

Figure 2. For the medicinal herbaceous plant community (a and b) there was no apparent age related pattern for rehabilitating sites. Some of the younger rehabilitating sites appear to have a similar composition of medicinal herbaceous plants to that in the Sokhulu Forest (BM). For the medicinal woody plant community (c and d) of the rehabilitating coastal dune forest sites (post-mining disturbance) as sites increased in age they appeared to become increasingly similar to the undisturbed Sokhulu forest (BM) in terms of their medicinal tree composition. The stress of the NMDS ordinations was relatively high (>20%) with a two-dimensional ordination (i.e., $k = 2$) we therefore increased the number of axes to three for both taxa ($k = 3$; Zuur, Ieono & Smith, 2007). Sampling plots are grouped in to 5 year age categories for ease of visual interpretation