

Chapter 4

Can non-native species explain patterns of convergence and deviation in the herbaceous layer of regenerating coastal dune forest?

Abstract

The successful restoration of disturbed habitat is influenced by many factors; not least of which is the introduction of non-native species in to the regional species pool. These species may preclude native colonisation and deflect regeneration trajectories away from restoration targets. The success of restoration (commonly measured against reference sites) may therefore be an unobtainable goal.

We determined if non-native species divert the regenerating trajectories of coastal dune forest. Specifically, using measures of ecological distance we first determined if successional trajectories of the herbaceous plant community in rehabilitating coastal dune forest sites were convergent. We then determined if rehabilitating coastal dune forest sites became more similar to an undisturbed reference site as they aged and which species contributed the most to dissimilarity between the reference site and rehabilitating sites.

The composition of herbaceous species in regenerating coastal dune forest plots became increasingly convergent as the time since disturbance increased. However, species composition appeared to deviate from that within an undisturbed reference site. Contrary to our expectations, non-native species did not contribute the most to dissimilarity, and thus not to the recorded

deviation. The deviation from the reference forest is attributable to the higher abundance of 1) a native forest specialist in the reference site, and 2) the higher abundances of native woodland adapted species in the rehabilitating sites. This deviation of the species composition in regenerating sites from that in the undisturbed reference site may therefore be indicative of successional changes and is not attributable to the presence of non-native species.

Keywords: Exotics plants, habitat restoration, herbaceous plants, regeneration trajectories, succession.

Introduction

Restoration success is typically measured against reference sites that represent the biological diversity characteristic of a region (for example, McLachlan & Bazely 2001; Wilkins et al. 2003; Redi et al. 2005; Wassenaar et al. 2005; Wong et al. 2010). These sites are usually high quality, minimally disturbed remnants of historic natural areas and constitute the desired endpoint of restoration (McLachlan & Bazely 2001; Wassenaar et al. 2005). If the species composition of rehabilitating sites becomes increasingly similar to that of the reference sites as the time since disturbance increases then restoration is considered successful (Wassenaar et al. 2005).

There are two linked assumptions that one makes when evoking reference sites within a restoration context. The first is that sites undergoing restoration represent early ecological stages of the reference habitat (SER 2004). The second is that sites undergoing restoration will become increasingly similar to the reference sites in terms of their species composition, abundance, and ecological processes (SER 2004; Wassenaar et al. 2005; 2007). However, these assumptions face several confounding factors, not least is that reference sites are a product of specific historic conditions that may no longer exist (Hobbs & Norton 1996; Jackson & Hobbs 2009). Changes in the disturbance regime, in landscape connectivity (which influences dispersal), and in the species pool (through local extinctions and by invasion of non-native species) may all hinder the reassembly of disturbed or destroyed communities (West et al. 2000; Suding et al. 2004; Jackson & Hobbs 2009; Matthews & Spyreas 2010; Grainger et al. 2011).

Here we investigate the regeneration of the herbaceous plant community in a post-mining restoration program on the east coast of South Africa. The mining company Richards Bay Minerals (RBM) aims to restore coastal dune vegetation to a third of its lease area (van Aarde et

al. 1996). This programme aims to recover the community composition of coastal dune forest through successional processes (see van Aarde et al. 1996 for a full account of the rehabilitation). In the past, we have assessed the trajectory of regeneration against “benchmark” values within undisturbed coastal dune forest sites (for example, van Aarde et al. 1996; Weiermans & van Aarde 2003; Kumssa et al. 2004; Redi et al. 2005; Wassenaar et al. 2005). Latterly, we have used the Sokhulu forest as our reference site. This forest is a relatively undisturbed patch of forest to the north of our study site, which covers approximately 500 hectares. It is contiguous with the Mapelane Nature Reserve making the effective size of this forest patch approximately 1500 hectares.

There is no doubt that our study region has undergone changes since the herbaceous plant community in the Sokhulu forest (our reference site) developed (see Weisser & Marques 1979). One of the most important changes is the introduction of non-native species into the regional species pool. The eastern coastal belt of South Africa is one of the most invaded areas (in terms of species number and abundance) within the Southern African region (Henderson 2007). Invasion of non-native species is known to cause the failure of regeneration trajectories to progress toward undisturbed reference sites (for example, Matthews & Spyreas 2010; Tognetti et al. 2010). Wassenaar et al. (2005) identified a slow rate of recovery in the herbaceous plant community of regenerating coastal dune forest sites when compared to the Sokhulu forest, but they did not offer any possible explanations for this. Here we identify whether the presence of non-native species in the regional pool does divert regenerating trajectories of coastal dune forest. If so, then the successful restoration of a coastal dune forest may be an unobtainable goal, or at least require increased management intervention to curb the establishment of non-native species.

Recently, Matthews & Spyreas (2010) developed a framework for monitoring ecological restoration projects, which assesses community convergence, and progression using measures of community dissimilarity and ordination distance (see Fig. 4-1). Here we use the terms “convergence” and “progression” with specific meanings. “Convergence” (the antonym of which is “divergence”) is the increased similarity, in terms of species composition, between regenerating sites within a region as the time since disturbance increases. “Progression” (the antonym of which is “deviation”) is the trend in the species composition in regenerating sites within a region to become increasingly similar to an undisturbed reference site as the time since disturbance increases.

We use the conceptual framework of Matthews & Spyreas (2010) to ask the following three questions (1) Are successional trajectories of the herbaceous plant community convergent in rehabilitating coastal dune forest sites? (2) Are rehabilitating coastal dune forest sites becoming more similar to a reference site as they increase in age? (3) Which species contribute the most to dissimilarity between reference sites and rehabilitating sites?

Methods

Study site

The coastal sand dunes north of Richards Bay (28°43’S and 32°12’E) have been mined since 1977 for the minerals rutile, zircon, and ilmenite (van Aarde et al. 1996). Here mining uses a dredging process that follows on the removal of all vegetation and topsoil in front of the dredge-pond, and the topsoil is stock-piled for use in the rehabilitation process. The rehabilitation process takes place immediately behind the dredge-pond, where sand dunes are re-

shaped and the previously stored topsoil returned to the dune. The topsoil is stabilised with drift-fencing (1.5 m high) and seeded with exotic annuals (sunflowers, sun-hemp, and millet). After this initial management intervention, the site regenerates naturally (van Aarde et al. 1996). The restoration process has led to the development of known-age (determined from mining records) regenerating coastal dune forest. Shortly after the initiation of rehabilitation, sites resemble grasslands; the exotic annuals have been replaced by species typical of grassland and the pioneer tree species *Acacia karroo* has established (Wassenaar et al. 2005). By 12 years of regeneration, trees typical of old-growth forest have colonized sites and dense undergrowth develops. By 22 years, a sub-canopy develops consisting of forest tree species and lianas, and by 30 years old *A. karroo* begins to senesce and secondary broadleaved species increase in abundance (Wassenaar et al. 2005).

The climate in the study area is humid and sub-tropical, with mean annual rainfall of 1488 ± 447.3 mm (mean \pm SD, $n = 34$ years between 1976 and 2009; data courtesy of Richards Bay Minerals). Rainfall peaks in February and the mean (\pm standard deviation) temperature is 23.8 ± 3.50 °C (monthly temperature between 2006 and 2009 [data courtesy of RBM]). Following the methodology of Wassenaar et al. (2005) all plant species below 1 m in height were identified and counted in 5 to 10 randomly located plots in six known-age sites regenerating after mining disturbance and rehabilitation (see Appendix 4-1). In addition, we surveyed the vegetation within an undisturbed coastal dune forest (Sokhulu Forest) which has been intact since at least 1937 according to aerial photographs. A plot consisted of 10 1 m^2 quadrats placed in a 2 x 5 pattern with 5 m separating each quadrat. Data were collected in 1995, 1999, 2003 and 2004 (see Appendix 4-1). In 1995, only five known-age sites were sampled, and in 2003, only five plots per site were sampled.

As taxonomic uncertainties abound in the identification of non-native species, only those species listed on the Conservation of Agricultural Resources Act – South Africa (1983) or the South African Plant Invaders Atlas (listed in Henderson 2007) were considered non-native. This yielded a species pool of 15 non-natives from 10 families; these are listed in Appendix 4-2.

To address our first question with regard to the convergence of herbaceous plant communities in rehabilitating coastal dune forest sites we grouped survey plots into five age categories: 3 to 5, 6 to 10, 11 to 15, 16 to 20, and 21 to 27 years old. We do not include data from the first two years of regeneration because this stage is influenced by the initiation of restoration and the exotic annual species deliberately seeded by management are present in the species community. After three years, these species are no longer present in the community. As the number of plots per age category varied, we randomly selected 100 pairs of plots in each age category and assessed the amount of compositional dissimilarity between them using the Bray-Curtis dissimilarity measure. Bray-Curtis returns a value between 0 and 1, where a value of 0 means that the two plots share the same species at the same abundance, and a value of 1 means that the two plots do not have any species in common. We used Analysis of Variance (ANOVA) with Tukey's multiple comparison post-hoc test to assess differences in the mean similarity between age categories.

We used Bray-Curtis dissimilarity to assess progression between regenerating sites and the regional reference site. We first calculated the mean abundance of all species recorded in the undisturbed Sokhulu forest. We then assessed dissimilarity between all plots in the regenerating sites and these mean abundance values. The relationship between site age and the Bray-Curtis dissimilarity was tested using the Spearman's rank correlation coefficient. The mean dissimilarity between plots within the regional reference site was also calculated to provide an

indication of the variation inherent in it. For a rehabilitating site to be considered successfully rehabilitated it must consistently fall within this range of dissimilarity (see Chapter 7 of this thesis).

To visualise patterns of species composition in regenerating and the reference site we used Non-Metric Multidimensional Scaling (NMDS). We used the “MetaMDS” function in the “VEGAN” package (Oksanen et al. 2008) using the R statistical software (v. 2.8.1; R Core Team Development 2008). We used the mean species abundance values for each site per survey year for the NMDS and joined survey years for each regenerating site together with a line for ease of visual interpretation. Patterns of community composition shown in the NMDS were confirmed using ANOSIM, analysis of similarity (using the function ‘anosim’ in R’s VEGAN package).

In order to identify which species contribute the most to dissimilarity between regenerating sites and the regional reference site we used SIMPER analysis (Similarity percentages) in Primer version 5.0. This analysis determines the percentage contribution by each species to dissimilarity between samples. We wished to identify which species are contributing the most to the dissimilarity to determine if non-native species divert regenerating trajectories of coastal dune forest.

Results

We recorded 150 species in the herbaceous layer of regenerating coastal dune forest, 15 of which were non-natives.

Are successional trajectories convergent?

The herbaceous plant community within regenerating coastal dune forest appears to differ greatly at early stages of regeneration, but as sites age the composition becomes increasingly similar but is still approximately at 60 % dissimilarity in the oldest plots. Mean dissimilarity differed significantly between age categories (ANOVA, $P < 0.05$; Fig. 4-2). Plots in the youngest age category (3 to 5) shared on average 20 % of species in common. This did not differ significantly from the mean value in the 6 to 10 and 11 to 15 year categories, where plots shared 17 % and 24 % of species respectively (Tukey's post hoc test; $P > 0.05$; Fig. 4-2). Plots in the 16 to 20 year category shared 29 % of species, this was significantly different from all but the 11 to 15 year category (Tukey's post hoc test; $P < 0.05$; Fig. 4-2). In the oldest category (21 to 27 years old) plots shared 46 % of species and this was significantly different from all other age categories (Tukey's post hoc test; $P > 0.05$; Fig. 4-2).

The NMDS plot illustrates the convergence between rehabilitating sites (Fig. 4-3). The stress of the NMDS ordination was relatively high (> 20 %) with a two-dimensional ordination (i.e., $k = 2$) we therefore increased the number of axes to three ($k = 3$; Zuur et al. 2007; Fig. 4-3). Sites at younger stages of regeneration are found on the left-hand side of the plot and do not overlap with one another suggesting that they have few species in common. As the sites age (trend toward the right-hand side of the plot) they increasingly overlap suggesting species composition is similar and convergent.

Are rehabilitating sites progressing toward the reference site?

The species composition of all but the oldest rehabilitating site (Site 1) progressed towards that of the Sokhulu forest as sites increased in age (Fig. 4-4; Spearman's Rank Correlation test; Site 1: $r_s = 0.07$, $n = 35$, $p > 0.05$; Site 2: $r_s = -0.44$, $n = 34$, $p < 0.05$; Site 3: $r_s = -0.44$, $n = 35$, $p < 0.05$; Site 4: $r_s = -0.78$, $n = 35$, $p < 0.05$; Site 5: $r_s = -0.76$, $n = 35$, $p < 0.05$; Site 6: $r_s = -0.43$, $n = 24$, $p < 0.05$). However, none of the sites shared greater than 15 % of species that are found in plots in the Sokhulu forest, so whatever progression there was, appeared to be slow. The oldest sites (Site 1 and Site 2) become even more dissimilar in the last two surveys (i.e. they deviate from the reference site). The mean Bray-Curtis dissimilarity within the reference site was quite high at 0.57 ± 0.13 (\pm standard deviation, Fig 4-4). The NMDS plot (Fig. 4-3) confirmed the pattern of deviation away from the Sokhulu forest. The ANOSIM showed that there was a significant difference in composition between plots in the rehabilitating sites and the regional reference site ($R = 0.62$; $P < 0.001$).

Which species contributes the most to dissimilarity?

Species responsible for the greatest amount of dissimilarity between regenerating sites and the reference site appear to represent successional changes in the younger age categories (Table 4-1). Species adapted to high salt concentrations (such as *Dactyloctenium geminatum*) and grassland species were responsible for the greatest amount of dissimilarity in the youngest age categories.

As categories increased in age, the species that were responsible for the greatest amount of dissimilarity between regenerating plots and the Sokhulu forest reference site were those adapted to open woodland (such as *Asystasia gangetica* and *Ipomoea ficifolia*), then species

adapted to more closed woodland (*Pupalia lappacea* and *Laportea peduncularis*; Table 4-1). The lack of *Isoglossa woodii* in the regenerating coastal dune forest plots contributed the most or second most to dissimilarity between the undisturbed forest and all except the oldest age category (Table 4-1). Only three non-native species contributed to dissimilarity between rehabilitating sites and the Sokhulu forest reference site. These included *Commelina benghalensis*, which contributed 3.18 % of dissimilarity between the 3 to 5 year old age category and Sokhulu forest (Table 4-1). *Achyranthes aspera* contributed 9.88 and 10.09 % to dissimilarity in the 16 to 20 and 21 to 27 year categories, respectively (Table 4-1). *Chromolaena odorata* contributed 2.19 % to dissimilarity between the 21 to 27 year old category (Table 4-1).

Discussion

The herbaceous plant community of rehabilitating coastal dune forest appeared to converge (i.e. become increasingly uniform as sites increased in age). Despite appearing to initially progress toward the undisturbed reference site, the trajectory of the rehabilitating sites was deviant (i.e. they did not progress toward the undisturbed reference site). This confirms the slow rate of progression found by Wassenaar et al. (2005) who used a chronosequence approach to assess the regeneration of the herbaceous layer in coastal forest. Patterns of convergence and deviation from progression as observed here are often attributed to the invasion and dominance of non-native species in regenerating sites (for example, Matthews & Spyreas 2010; Tognetti et al. 2010). In rehabilitating coastal dune forests, however, non-native species did not contribute the most to dissimilarity between plots in rehabilitating sites and the undisturbed Sokhulu forest. Although, the non-native species *Achyranthes aspera* did contribute second most to similarity in

the 21 to 27 year old category. We therefore, need to ascertain the plausible causes of convergence between rehabilitating sites and deviation away from the Sokhulu forest.

Causes of convergence

Convergence may occur where regional species pools are small because sites quickly exhaust the available species and therefore become increasingly similar in species composition (Cutler 2010). This is unlikely, however, to be contributing toward convergence in our study. The species pool of the coastal dune forest herbaceous plant community is not small (150 species) when compared to those in far northern latitudes, the number of species, for example, was three times that of volcanic primary successions in Iceland (Cutler 2010).

Convergence between rehabilitating sites may occur where the factors that determine species composition in the early stages of regeneration are stochastic and those that determine composition in the later stages of regeneration are homogeneous (Lepš & Rejmanek 1991). For example, the species composition in the early stages of succession may be determined by the proximity of seed sources (Lanta & Lepš 2009). Later in succession habitat factors (such as soil depth) may supersede the initial chance factors as determinants of species composition (Lepš & Rejmanek 1991). The pattern of convergence within rehabilitating sites matches this scenario. There were high levels of dissimilarity between plots in the youngest age categories. In the older categories dissimilarity decreased, meaning that the composition of plots in these later stages of succession were more uniform. The homogeneous factor is currently unknown, but we can assume that the canopy structure influences the composition of the herbaceous layer. After the first 5 years of succession the species responsible for similarity within age categories were similar in all the age categories. These species were *Digitaria diversinervis*, *Laportea*

peduncularis and *Asystasia gangetica*, which are all adapted to woodland or forest edge habitats (Pooley 1998). The canopy conditions across all sites may be similar, leading to homogenization of the species community and, therefore, convergence.

Dispersal and disturbance also may have attributed to the convergence of rehabilitating sites. Where there are few barriers to dispersal, convergence is likely as all sites can potentially share the same set of species (Lepš & Rejmanek 1991). The majority of species in the herbaceous layer of regenerating coastal dune forests are wind or bird dispersed, so one would expect that seeds would be spread across all sites. In addition, sites are in close proximity to one another and therefore, species that rely on relatively shorter distance dispersal, such as ballistic dehiscence (for example *Asystasia gangetica*), may reasonably be expected to have few barriers to dispersal. However, we still need to investigate the dispersal constraints of the herbaceous layer. Disturbance may also contribute to convergence, and one of the main forms of disturbance within rehabilitating sites is tree fall (see Chapter 5). Light gaps being created within the canopy in the later stages of rehabilitation may facilitate the persistence of the woodland or forest edge species and be the ultimate cause of convergence.

Causes of deviation

Deviation in the trajectory of rehabilitating sites from the Sokhulu forest can also be explained in terms of the habitat affinities. *Dactyloctenium geminatum* contributed to the most dissimilarity between the rehabilitating sites and the Sokhulu forest in the youngest plots (3 to 5 years old). This grass species is adapted to harsh environments such as those found on the seashore (Pooley 1998). It is, therefore, not surprising that this species is not found in mature forest. *Isoglossa woodii* contributed the most or second most to dissimilarity between all but the

oldest age category and the Sokhulu forest. This species was at higher abundance in the Sokhulu forest and is actually yet to establish within the regenerating sites. *Isoglossa woodii* is the dominant understorey plant species in coastal dune forest and plays an important role in forest dynamics (Griffiths et al. 2007). The reasons for the absence of this species in regenerating coastal dune forest needs to be investigated. The species may have not been able to disperse to the regenerating sites as it is a dehiscent only spreading its seed a small distance from the parent plants. The Sokhulu forest is far from the rehabilitating sites, but other populations of *Isoglossa woodii* are found in remnant forest adjacent to some of the rehabilitating sites, albeit at much lower abundances (Conservation Ecology Research Unit, University of Pretoria unpublished data). Additionally, conditions in the regenerating sites may not yet be suitable for its establishment. The higher abundances of *Digitaria diversinervis*, *Laportea peduncularis*, and *Asystasia gangetica* in the regenerating sites also contributed to the deviation from the Sokhulu forest. Canopy conditions in regenerating sites may be ideal for these woodland adapted species explaining their dominance, where as in the Sokhulu forest, canopy conditions suit forest adapted species.

The role of non-native species

The only non-native species to contribute any dissimilarity were *Commelina benghalensis*, *Achyranthes aspera*, and *Chromolaena odorata* (Henderson 2007). *Commelina benghalensis* contributed to dissimilarity between the youngest plots and the Sokhulu forest. This species occurs in disturbed areas, and is particularly associated with cultivated land but can be found along forest edges (Pooley 1998). *Commelina benghalensis* is shade tolerant so it is surprising that it does not continue to contribute to dissimilarity between the older regenerating

plots and the Sokhulu forest. The contribution of *A. aspera* to dissimilarity between regenerating plots and Sokhulu forest increased from 5 to 10 % in the two oldest age categories. This species has wide tolerances to shade, but prefers open woodland sites (Sager et al. 2008). Another species with wide shade tolerance is *C. odorata* which only contributed 2.19 % to dissimilarity between the oldest age category and the Sokhulu reference site. This species may be inhibited by closed canopies (De Rouw 1991). The oldest regenerating coastal dune forests resemble open woodland at this stage in their redevelopment, which may explain the high abundance of these species when compared to the Sokhulu forest reference site. The persistence of non-natives is not necessarily a precursor to a loss of native biological diversity and at present, non-natives do not appear to be the main drivers of deviation from progression between rehabilitating sites and the undisturbed Sokhulu forest. It is important, however, that we continue to monitor the situation.

The future of coastal dune forest rehabilitation

In answer to the three questions we originally posed, successional trajectories in the herbaceous plant community in rehabilitating coastal dune forest sites were convergent. Rehabilitating coastal dune forest sites, however, despite initially appearing to do so, did not progress towards the undisturbed reference site. Contrary to our expectations, non-native species did not contribute the most to dissimilarity. The deviation from the reference forest is attributable to the higher abundance of a native forest specialist in the Sokhulu forest and the higher abundances of native woodland or forest edge adapted species in the rehabilitating sites. Throughout a successional sere, one would expect that species' relative abundances would shift as the habitat conditions become optimal. The diversion from the undisturbed reference site may therefore be only temporary. Successional trajectories may be non-linear (Matthews & Spyreas

2010). We cannot be certain of the factors driving the convergence/deviation pattern we have observed here, but we continue to monitor the community composition of rehabilitating sites with reference to the Sokhulu forest. Using a process of adaptive management we can react to continued deviation through management action. Presently, we can initiate research initiatives to investigate questions of dispersal and habitat affinities of some key herbaceous plants.

Restoration managers must be aware that although idealized trajectories (as those indicated on Fig.4-1) are linear, changes in the abundance of species across successional time may cause non-linear trajectories to be a reality. It is therefore difficult to decide if and when to invoke more intensive management (such as restoration plantings), which aim to force regeneration trajectories back on course toward reference sites. Perhaps one way to decide if intensive management is required is to identify the species responsible for driving deviant trajectories as we have done here. Only if these species are new additions to the species pool (i.e. after the assembly of the reference community) should management be considered.

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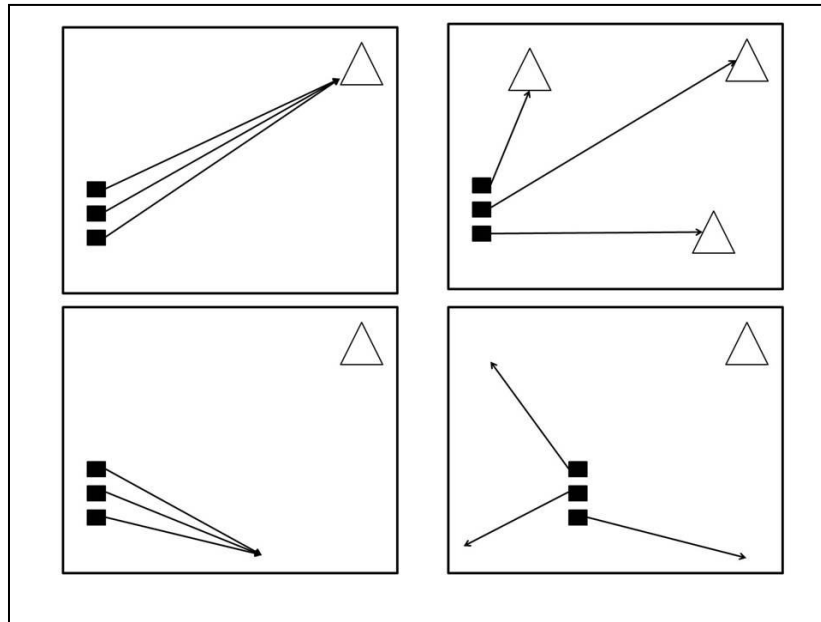


Figure 4-1. The conceptual model of convergence and progression of Matthews & Spyreas (2010). The top-left panel illustrates the convergence of the rehabilitating sites (black squares) and progression toward an undisturbed reference site (open triangles). The top-right panel illustrates divergence between the rehabilitating sites but progression toward a series of acceptable reference sites. The bottom-left panel illustrates convergence between rehabilitating sites but progression away from the reference site to an entirely novel species composition. Finally, the bottom-right panel which shows divergence between rehabilitating sites each of which heads away from the reference site. Reproduced with permission from John Wiley and Sons (License Number 2758771123540, 30th September).

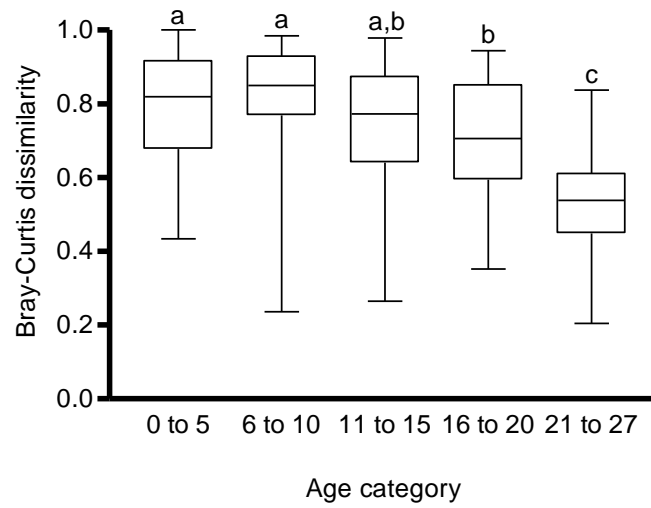


Figure 4-2. Box and whisker plot showing the mean Bray-Curtis dissimilarity between plots within age categories. Letters indicate the results of a Tukey's post hoc test, the same letter indicates age categories whose means do not differ significantly.

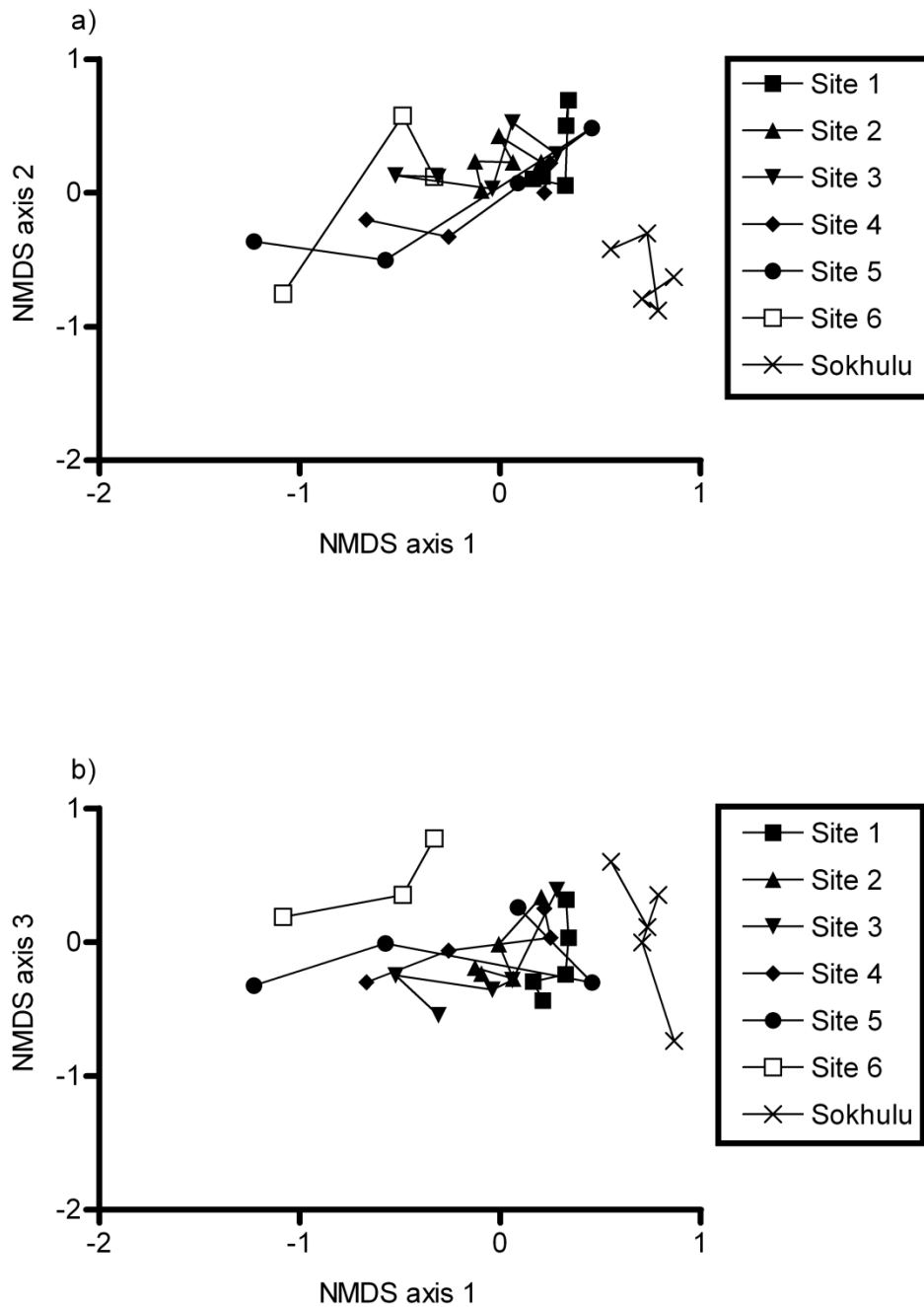


Figure 4-3. Non-metric Multidimensional Scaling (NMDS; stress = 11.70; non-metric fit $r^2 = 0.99$; linear fit $r^2 = 0.95$) plot (showing axis 1 versus 2 (a) and axis 1 versus axis 3 (b)). Survey events are linked within sites using a line.

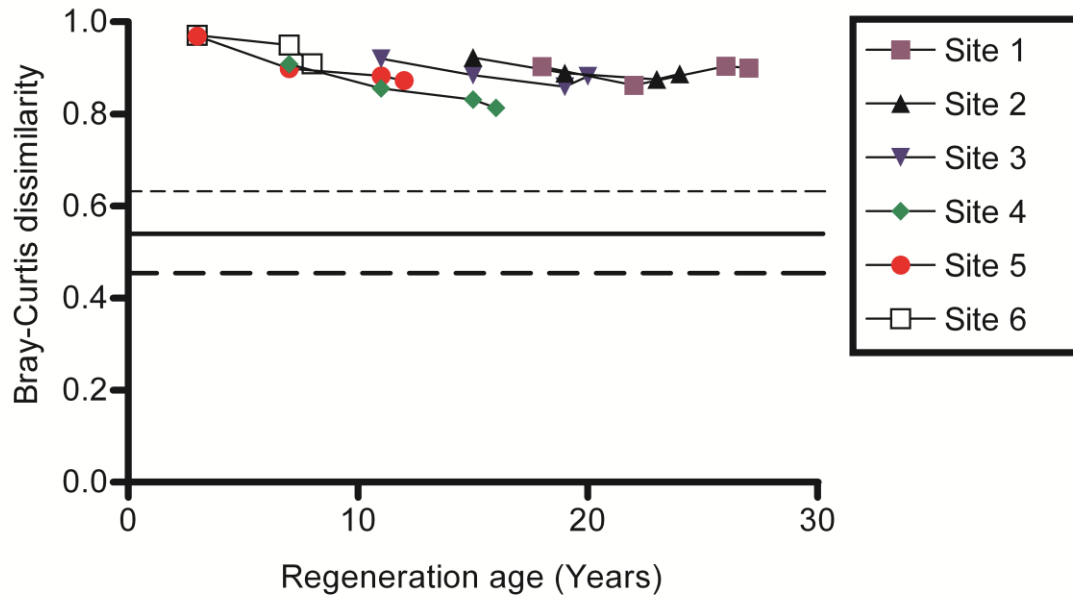


Figure 4-4. Bray-Curtis dissimilarity between regenerating sites and the reference site (Sokhulu forest). The points shown are the mean dissimilarity values per survey year for each site (for clarity of visual interpretation). The solid horizontal line indicates the mean dissimilarity within the regional reference site and the dotted horizontal lines indicate the variation about this mean.

Table 4-1. Results of a SIMPER analysis showing the 10 species with the highest contribution to Bray Curtis dissimilarity between each age category and the undisturbed Sokhulu forest.

Age category (years)	Species	Mean Abundance	Reference		Standard deviation	Percentage	
			site abundance	mean Dissimilarity		contribution to dissimilarity	Cumulative percentage
3 to 5	<i>Dactyloctenium geminatum</i>	38.82	0	10.01	0.95	10.39	10.39
	<i>Isoglossa woodii</i>	0	7.78	9.09	0.98	9.44	19.83
	<i>Panicum maximum</i>	21.85	0	5.4	0.76	5.61	25.44
	<i>Pupalia lappacea</i>	0.68	6.87	3.9	1.07	4.05	29.49
	<i>Senecio sp.</i>	13.62	0	3.27	0.79	3.4	32.89
	<i>Digitaria diversinervis</i>	12.91	0.93	3.1	0.55	3.21	36.1
	<i>Commelina benghalensis</i>	11.79	2.35	3.06	0.67	3.18	39.28
	<i>Pyrenacantha scandens</i>	0	1.65	2.84	1.09	2.94	42.22
	<i>Cyphostemma woodii</i>	0	0.74	2.78	0.68	2.88	45.1
	<i>Conyza albida</i>	10.53	0.02	2.63	0.59	2.73	47.83
6 to 10	<i>Isoglossa woodii</i>	0	7.78	10.55	0.86	11.11	11.11
	<i>Digitaria diversinervis</i>	28.23	0.93	6.23	0.89	6.56	17.67
	<i>Pupalia lappacea</i>	3.56	6.87	4.75	0.99	5	22.67
	<i>Asystasia gangetica</i>	22	0.76	4.34	0.73	4.57	27.24
	<i>Pyrenacantha scandens</i>	0.1	1.65	3.31	0.92	3.49	30.73

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	<i>Cyphostemma woodii</i>	0.23	0.74	3.31	0.61	3.48	34.21
	<i>Ipomoea ficifolia</i>	11.49	2.22	3.2	0.69	3.36	37.57
	<i>Dactyloctenium australe</i>	7.41	3.02	2.85	0.54	3	40.57
	<i>Mariscus dregeanus</i>	9.95	0	2.81	0.55	2.96	43.53
	<i>Aneilema aequinoctiale</i>	10.15	0.7	2.65	0.63	2.79	46.32
	<i>Isoglossa woodii</i>	0	7.78	9.98	0.88	10.77	10.77
	<i>Laportea peduncularis</i>	37.1	8.44	8.46	1.05	9.14	19.91
	<i>Dactyloctenium australe</i>	33.5	3.02	8.08	0.94	8.72	28.63
	<i>Digitaria diversinervis</i>	29.13	0.93	7.17	0.83	7.74	36.37
11 to 15	<i>Pupalia lappacea</i>	4.23	6.87	4.21	0.98	4.55	40.92
	<i>Pyrenacantha scandens</i>	0.11	1.65	3.12	0.94	3.37	44.29
	<i>Cyphostemma woodii</i>	0.47	0.74	3.11	0.62	3.35	47.64
	<i>Panicum maximum</i>	10.24	0	2.8	0.48	3.02	50.66
	<i>Ipomoea ficifolia</i>	10.13	2.22	2.57	0.7	2.77	53.43
	<i>Asystasia gangetica</i>	10.41	0.76	2.53	0.55	2.73	56.16
	<i>Isoglossa woodii</i>	0	7.78	9.32	0.82	10.2	10.2
	<i>Digitaria diversinervis</i>	46.07	0.93	9.03	1.22	9.88	20.08
	<i>Laportea peduncularis</i>	43.73	8.44	8.24	1.27	9.01	29.09
16 to 20	<i>Achyranthes aspera</i>	26.36	0.39	5.38	0.95	5.89	34.98
	<i>Dactyloctenium australe</i>	24.36	3.02	5.03	0.77	5.51	40.49
	<i>Asystasia gangetica</i>	25.16	0.76	4.93	0.8	5.39	45.88
	<i>Pupalia lappacea</i>	15.42	6.87	4.47	1.02	4.89	50.77

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	<i>Pyrenacantha scandens</i>	0.11	1.65	2.93	0.87	3.2	53.97
	<i>Cyphostemma woodii</i>	0.2	0.74	2.9	0.58	3.18	57.15
	<i>Secamone filiformis</i>	12.11	0.52	2.52	0.87	2.76	59.91
	<i>Digitaria diversinervis</i>	70.63	0.93	12.05	2.36	13.13	13.13
	<i>Asystasia gangetica</i>	53.29	0.76	9.49	1.3	10.34	23.47
	<i>Achyranthes aspera</i>	53.27	0.39	9.26	1.58	10.09	33.56
	<i>Laportea peduncularis</i>	51.86	8.44	8.14	1.51	8.87	42.43
21 to 27	<i>Isoglossa woodii</i>	0	7.78	6.42	1	6.99	49.42
	<i>Dactyloctenium australe</i>	22.33	3.02	3.94	0.83	4.29	53.71
	<i>Aneilema aequinoctiale</i>	20.69	0.7	3.6	0.95	3.93	57.64
	<i>Pupalia lappacea</i>	22.14	6.87	3.6	1.08	3.92	61.56
	<i>Chromolaena odorata</i>	11.22	0	2.01	0.53	2.19	63.75
	<i>Pyrenacantha scandens</i>	0	1.65	1.99	1.11	2.17	65.92
