EFFECTS OF PINE INVASIONS ON GROUND-DWELLING ANTS ON THE SOUTHERN SLOPES OF THE SWARTBERG MOUNTAINS.

BY

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ABSTRACT

Ant and plant assemblages in patches of *Pinus* species trees in mountain fynbos and renosterbos *(Elytropappus rhinocerotis)* shrubland were investigated in order to determine whether there were differences in ant and plant species richness, abundance and cover between patches of pines and the surrounding indigenous vegetation. The study was carried out in the Matjiesrivier valley on the southern slopes of the Swartberg mountains in the Oudtshoorn district, South Africa. Ants were collected at three sites; one in an older (c. 70 years) pine patch in mesic mountain fynbos at about midslope and two in younger (c. 10 years) pine patches in closed and open remnant renosterbos shrublands respectively on lower slopes. On a per site basis, there were no major differences in ant and plant species richness between the pine and no-pine sites in renosterbos, or (with the exception of plants) the pine and no-pine site in mesic mountain fynbos.

A total of 2 539 ants belonging to 37 species, distributed among 15 genera, were collected during the study. *Camponotus* was most species-rich genus (13 species), followed by *Monomorium* (7 species), *Tetramorium* (4 species) and *Lepisiota* (2 species), with 11 of the 15 genera each represented by a single species. No non-indigenous species were observed during the duration of the study.

Camponotus sp.11, *Lepisiota* sp.1 and *Tetramorium quadrispinosum* were observed only in the open renosterbos site. *Camponotus klugii*, *Camponotus* sp.1, *Camponotus* sp. 6, *Cerapachys* sp.1, *Meranoplus peringueyi*, *Monomorium fridae*, *Monomorium* sp.3 and *Technomyrmex* albipes were observed only in the closed renosterbos. *Camponotus bayneii*, *Camponotus* sp.5, 7, 8 and 9, *Crematogaster peringueyi*, *Pachycondyla pumicoca*, *Solenopsis punctaticeps* and *Tetramorium regulare* were recorded only in mesic mountain fynbos.

The most abundant ant guild was the non-dominant generalist (17 species), particularly *Pheidole* sp. 1# (48 % of all individual ants) followed by nectar feeders (15 species), dominant generalists (2 species), specialist predators (2 species) and a seed harvester (1 species). In general, the non-dominant generalists preferred no-pine sites to sites invaded by pines.

There was very little undergrowth under the pines in mesic mountain fynbos, and *Clutia polygonoides*, *Cymbopogon* sp. 1, Erica sp. 1, *Metalasia cephalotes*, *Metalasia muricata*, *Pelagronium betulinum* sp. 1 and *Restio* sp. 1 were significantly more frequent outside the patch. The two renosterbos sites showed no significant difference in *Elytropappus rhinocerotis* cover in and out of pine patches, and only two species at the open renosterbos site, *Dodonea* sp. 1 and *Relhania squarrosa*, were more abundant under pines than in the surrounding renosterbos. The most abundant plant life form was the ericoids (37 species) followed by proteiods (11 species), grasses (11 species), forbs (9 species) and succulents (4 species). In general, the five life forms did not show any exclusive pattern of preference for either the pine or no-pine sites.

INTRODUCTION

Natural ecosystems throughout the world are increasingly subjected to major disturbances as they are being cleared for crop farming as well as the cultivation of economically important. The renosterbos (*Elytropappus rhinocerotis*) shrublands in the Western Cape Province are no exception and, because of their highly fertile soils (Rebelo 1996), approximately 32 % of these shrublands have been cleared and transformed into agricultural and grazing fields. Most of the remaining renosterbos shrublands are found as fragments in the matrix of cultivated lands and are therefore not protected from human-induced disturbances and may be subject to invasions by alien organisms. These fragments represent examples of a vegetation type that is rapidly disappearing, and are unlikely to be formally conserved and managed from a conservation perspective.

When there are changes in a community, either through habitat modification or the introduction of an alien species, local species diversity may decline and some species may even go extinct, resulting in cascading effects on other species in a community (Suarez *et. al.* 1998). These effects are often manifested in changes in ant (Hymenoptera: Formicidae) communities. Ants occur in most ecosystems and many plant and animal species rely on ants for seed dispersal and food (Majer 1983, 1990; Torres 1984; Keals & Majer 1991; Rossbach & Majer 1983; Andersen & Sparling 1997). Seeds of many plants in Mediterranean ecosystems, have fleshy, oily attachments called elaiosomes which ants utilise as food (Slingsby & Bond 1981). Foraging ants typically clasp the seeds by their elaiosomes and carry them into the nests where the elaiosomes are eaten and the seeds are discarded and buried, facilitating the dispersal of the seed. This ant-plant relationship, termed myrmecochory, is important in the fynbos biome in South Africa, but rare in the semi-arid Karoo and the nutrient rich soils of renosterbos shrublands (Bond & Slingsby 1983).

Pines trees (*Pinus* spp) were introduced to many areas of the Western Cape Province during the mid-nineteenth century and have now become widespread and invasive in many parts of the region (Richardson & Brown 1986; Richardson 1988; Richardson *et. al.* 1992). Pines were first introduced to South Africa for economic reasons such as timber or as garden plants or windbreaks. Species such as *Pinus radiata*, *Pinus pinaster* and *Pinus halepensis* are invasive species in the fynbos biome and can threaten indigenous plant and animal species, including ants. The cultivation of pines has resulted in major habitat changes threatening the persistence of both the indigenous animal and plant species (Richardson & Bond 1991; Van Wilgen & Richardson 1985). A number of studies have shown that invertebrate communities can change in an area invaded by alien plants, including pines (Donnelly and Giliomee 1985b; Richardson & Brown 1986; Samways and Moore 1991). As a result of their ability to invade and rapidly spread in any vegetation type, pines can affect the ant community structure and the interactions of the ants with other species in the ecosystem (Burbidge *et. al.* 1992). Ants play an important role in soil fertility and structure and these processes may be disrupted if appropriate ants are not present (Majer & de Kock 1992).

I hypothesised that:

(i) The pines, by overtopping other (indigenous) vegetation, shade out some species of plants, resulting in a decrease in plant species richness.

(ii) The decrease in plant species richness results in ant communities in pine plantations/patches being species poor.

The following questions were addressed:

(i) Are there any differences in ant species assemblages (species and guilds) between patches of pines and indigenous vegetation?

(ii) Which of the ant guilds are absent or rare in pine patches?

(iii) Are there differences in indigenous plant life forms and species between pine patches and the matrix vegetation?

To provide some answers to these questions, I examined ant and plant assemblages under the pines and in adjacent indigenous vegetation at three sites in the Matjiesrivier valley in the Oudtshoorn district, Western Cape Province.

STUDY AREA

The Matjiesrivier valley, on the southern slopes of the Swartberg Mountains in the Western Cape Province region of South Africa ($33^0$36'S,$22^0$08'E), was chosen as a study area. The area has typical Karroid-type climate with hot dry summers and cold winters and the annual rainfall usually occurs during the spring and autumn months (Rebelo 1996). Fynbos vegetation dominates the northern slopes of the Swartberg mountain, while the southern slopes are mainly dominated by renosterbos shrublands. The plant species typically found on south slopes are *Elytropappus rhinocerotis* (renosterbos), *Anthospermum aethiopicum*, *Themeda triandra* (redgrass), *Hermannia flammea*, *Relhania squarrosa*, *Dodonea viscosa*, *Indigofera denudata* and *Helichrysum anomalum* (Rebelo 1996; Campbell 1985). Most of the renosterbos shrubland has been cleared and transformed into agricultural fields and pastures with only fragments of the original vegetation remaining in isolated patches.

Three sites were identified on the southern slopes. Site S was opposite the picnic spot on the Swartberg Pass and was mainly covered with mesic mountain fynbos vegetation. The other two sites were on the lower slopes in renosterbos shrubland on Botha's farm (site B) and Le Roux's farm (site L) respectively. These two sites were extensively used for agriculture (both pastoral and croplands) but remnants of the renosterbos shrubland still remain. Patches of renosterbos on site B were open and sparse whereas patches on site L were dense and bushy. The pine patches on the two renosterbos sites were quite dense but young (c. 10 years old) when compared to the plantation on the mesic mountain fynbos site. The pines at Site S were c. 70 years old, with little or no undergrowth and it was quite easy to walk through the plantation compared with moving through pine patches in the two renosterbos sites. All three sites were situated close to the firebreak on the Swartberg mountain.

Three sampling points were chosen at site S; S1 was inside the pine plantation, S2 was in an area that had been cleared of pines, and indigenous vegetation was re-establishing in the patch, and S3 was in the undisturbed mesic mountain fynbos vegetation adjacent to the plantation. Two sampling points were chosen at sites B and L. One point was within a pine patch and the second point was in the renosterbos shrubland adjacent to the pine patch at each of the sites. The sampling points at each of the three sites (S, B and L) were approximately 50 m away from each other.

METHODS

Ant sampling techniques

Pitfall trapping

A grid of 20 x 10 m was laid out at the sampling points at sites S, B and L. Each grid consisted of ten traps in two rows of five. The two rows in a grid were 10 m apart and the traps within the rows were set at 5m intervals. Pitfall traps used were plastic cups 9 cm deep and 7 cm in diameter, dug into the soil in such a way that the mouth of the cup was level with the surrounding soil.

The traps were laid out on 19 October 1998 and were left for three days to settle from the disturbance created by digging. After three days, the traps were set by opening them up and putting preservative into them. The pitfall traps were each half-filled with an ethylene glycol mixture on 22 October and were left open for the next ten days. The contents of the traps were taken out on 1 November, and the catch later sorted and identified in the laboratory.

Litter sampling

Since some species that reside in the leaf litter may have been missed by pitfall trapping, litter sampling was also done. Winkler bags (Belshaw and Bolton 1994) were used to examine the leaf litter from each site. Within each sampling point, places where ants could reside were identified and 1m^2 quadrats were randomly placed 2m away from the pitfall traps. All the leaf litter inside each quadrat was collected and sifted through a coarse sieve and left in the Winkler bags for three days. Each site was only sampled on one occasion.

Foliage sampling

In order to sample the ant species that are mainly found on the trees, a beating technique was used. A sheet was held and stretched below randomly selected branches, which were then beaten with a stick. The dislodged ants on the sheet were collected and preserved in 80 % ethanol. Each site was only sampled on one occasion. I also did general collecting of ants by searching for nests under the rocks and in dead wood, to find out if any other ant species had been missed by other collecting methods.

Plants

Plots of 5 x 5 m were set out in three rows of three at each of the sampling points. In each plot, percentage cover of each plant was estimated by using the Braun Blanquet method. The maximum height of each plant species, the soil type and the percentage bare ground were recorded in each plot.

Sorting and identification

The contents of each pitfall trap were washed through a fine mesh and preserved in 80% ethanol. Ants were sorted out from the other invertebrates captured. All ants were counted and most were identified to species level, but some specimens could only be identified to genus. These species were assigned a species code number, and voucher specimens under these code numbers have been deposited together with all ants collected during this study in the Entomology Collection of the South African Museum, Cape Town. Ants were classified into guilds according to their foraging, food and behaviour, and this classification was used to group guilds for subsequent analyses.

Data analysis

Statistical analyses were done using the program GENSTAT. Non-parametric Mann-Whitmey U tests were used to compare species composition between sites and Chi-squared tests were used to test differences between plant life forms in and out of pine patches.

The number of species observed (Sobs) during sampling is usually an underestimate of the true species richness of the area. Those species that are rare may be missed thus leading to the underestimation of the total species representation of the area being sampled (Colwell and Coddington, 1994). The first order Jackknife (S_3^*) was computed to estimate and compare species diversity between sites using the formula :

$$S_3^* = S_{obs} + L\ (n - 1 / n)$$

where S_{obs} = number of observed species,

L = number of species occuring in only one sample and

n = number of samples.

The first order jackknife improves the estimate of species richness (S) and was calculated for each sampling site using the program Estimates by Colwell in 1997 (see Colwell and Coddington, 1994).

RESULTS

Ants

There were no significant differences in the data on ants collected by pitfall trapping, litter sampling, foliage sampling and searches for ants in likely nest sites. The data from these different sampling methods were therefore combined for the analyses.

Total observed ant species richness

A total of 2 539 ants belonging to 37 species were collected during the study. All the species collected were distributed among 15 genera, but 11 of the 15 genera were each represented by a single species. *Camponotus* was the most species-rich genus (13 species), followed by *Monomorium* (7 species), *Tetramorium* (4 species) and *Lepisiota* (2 species) (Table 1). The most abundant species was *Pheidole* sp.1 followed by *Monomorium fridae*, *Anoplolepis steingroeveri*, *Monomorium havilandi*, *Monomorium* sp. 2, *Lepisiota capensis* and *Ocymyrmex barbiger* (Table 1). No non-indigenous ant species were observed during the duration of the study.

Table 1: Composition of ant species collected in pitfall traps. Data are mean numbers of individuals per species at each sampling point. Frequency of occurrence of species at each sampling point is in brackets. Feeding guild classifications are: NG= Non-dominant Generalists, NF= Nectar Feeders, DG= Dominant Generalists, SP= Specialist Predators, SF= Seed feeders.

Species	Guild	Sampling point						
		B1	B2	L1	L2	S1	S2	S3
Anoplolepis steingroeveri	DG	---	6.1 (4)	0.3 (2)	8.1 (9)	---	0.2 (1)	3.0 (8)
Camponotus bayneii	NF	---	---	---	---	---	0.1 (1)	---
Camponotus klugii	NF	---	---	0.2 (1)	---	---	---	---
Camponotus niveosetosus	NF	0.4 (1)	---	0.1 (1)	---	---	0.1 (1)	0.8 (5)
Camponotus vestitus	NF	0.1 (1)	1.5 (6)	---	0.2 (1)	---	---	---
Camponotus sp. 1	NF	---	---	0.1 (1)	---	---	---	---
Camponotus sp. 3	NF	0.1 (1)	0.1 (1)	0.1 (1)	0.1 (1)	---	---	2.2 (7)
Camponotus sp. 5	NF	---	---	---	---	0.1 (1)	---	---
Camponotus sp. 6	NF	---	---	0.3 (3)	---	---	---	---
Camponotus sp. 7	NF	---	---	---	---	---	---	0.4 (4)
Camponotus sp. 8	NF	---	---	---	---	---	---	0.1 (2)
Camponotus sp. 9	NF	---	---	---	---	---	---	0.1 (1)
Camponotus sp. 11	NF	0.1 (1)	0.4 (3)	---	---	---	---	---
Camponotus sp. 13	NF	---	---	---	---	---	---	0.2 (2)
Cerapachys sp. 1	SP	---	---	---	0.1 (1)	---	---	---
Crematogaster sp. 1	DG	---	---	---	---	---	4.2 (9)	0.4 (1)
Lepisiota capensis	NF	0.1 (1)	3.8 (8)	0.1 (1)	---	2.6 (9)	0.3 (3)	0.2 (2)
Lepisiota sp. 1	NF	1.3 (6)	3.0 (9)	---	---	---	---	---
Meranoplus peringueyi	NG	---	---	2.1 (8)	2.7 (9)	---	---	---
Monomorium fridae	NG	---	---	14.4 (10)	26.0 (10)	---	---	---
Monomoriun havilandi	SF	9.3 (8)	4.0 (6)	---	0.1 (1)	---	---	---
Monomoriun sp. 2	NG	---	1.8 (4)	2.3 (6)	4.5 (7)	0.9 (1)	---	---
Monomorium sp. 3	NG	---	---	0.6 (3)	0.3 (2)	---	---	---
Monomorium sp. 5	NG	1.7 (3)	---	---	---	2.3 (9)	---	---
Monomorium sp. 6	NG	---	2.0 (3)	---	---	---	---	0.4 (2)
Monomorium sp. 7	NG	---	0.5 (2)	---	---	---	---	0.4 (2)
Ocymyrmex barbiger	NG	1.0 (5)	2.5 (9)	---	1.1 (5)	---	---	0.6 (5)
Pachycondyla pumicosa	SP	---	---	---	---	---	---	0.2 (1)
Pheidole sp. 1	NG	38.1 (10)	73.0 (10)	0.4 (4)	0.5 (1)	0.1 (1)	---	10.2 (8)
Plagiolepis sp. 1	NG	0.8 (4)	---	0.2 (1)	0.4 (3)	0.1 (1)	---	2.0 (6)
Solenopsis punctaticeps	NG	---	---	---	---	---	---	0.2 (1)
Tapinoma sp. 1	NG	---	---	0.2 (1)	0.5 (4)	---	0.1 (1)	0.2 (2)
Technomyrmex albipes	NG	---	---	---	0.9 (2)	---	---	---
Tetramorium argenteopilosum	NG	---	0.3 (1)	0.1 (1)	0.3 (1)	---	---	---
Tetramorium frigidum	NG	---	0.2 (1)	---	---	0.2 (2)	0.3 (1)	2.2 (8)
Tetramorium quadrispinosum	NG	1.4 (3)	0.1 (1)	---	---	---	---	---
Tetramorium regulare	NG	---	---	---	---	---	0.1 (1)	0.1 (1)

Differences in species richness between sites

Some species occurred exclusively in only one of the three sites. *Camponotus* sp. 11, *Lepisiota* sp.1 and *Tetramorium quadrispinosum* were observed only in the open renosterbos site (site B). *Camponotus klugii*, *Camponotus* sp.1, *Camponotus* sp.6, *Cerapachys* sp.1, *Meranoplus peringueyi*, *Monomorium fridae*, *Monomorium* sp.3 and *Technomyrmex albipes* were observed only in the closed renosterbos (site L). The species found exclusively in the mesic mountain fynbos site (site S) were *Camponotus bayneii*, *Camponotus* sp. 5, 7, 8 and 9, *Crematogaster peringueyi*, *Pachycondyla pumicosa*, *Solenopsis punctaticeps* and *Tetramorium regulare* (Table 1).

The species accumulation curves for observed species (Sobs) and predicted number of species (S_3^*) do not level off and appear to be still increasing at all sites except for site L2 (Figs. 1a and b).

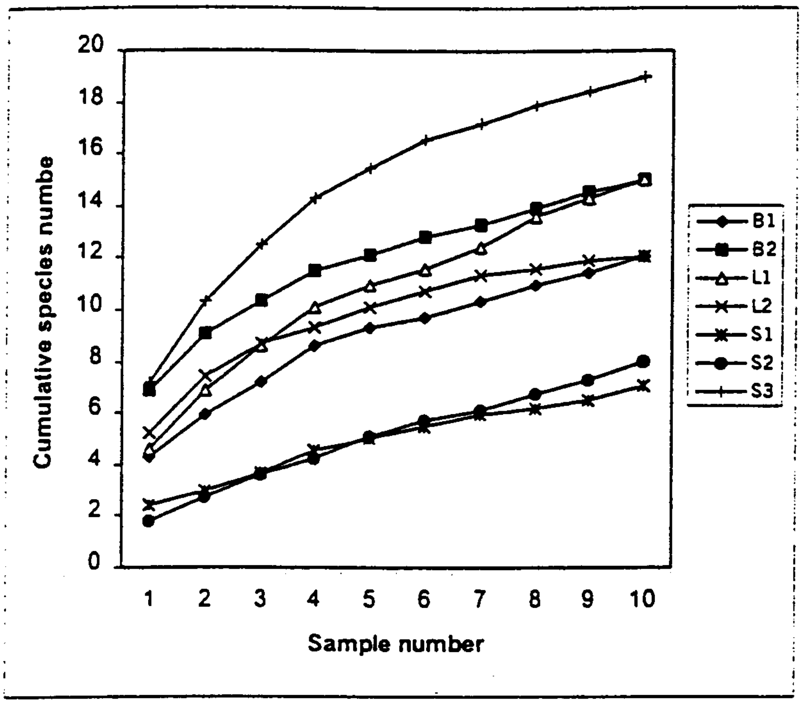

Figure 1a: Species accumulation curves showing observed number of ant species per sampling plot.

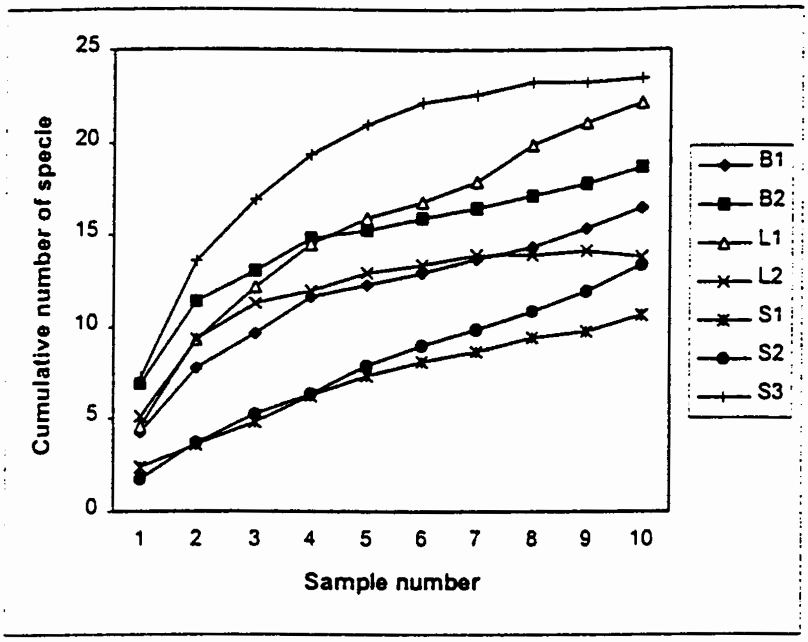

Figure 1b: Species accumulation curves showing the predicted number of ant species per sampling point (first order jacknife)

<u>Species richness in the pine versus no pine areas</u>

There were species which favoured the pine and no-pine sites in each of the three sites (Table 2). The clear distinction suggests that there are some species that might be specific in their habitat selection. Of the 8 species exclusively found in the closed renosterbos, only *Monomorium fridae* showed significant differences between pine and no-pine ($U = 2.08$, $p < 0.05$). The remainder did not show any significant differences between the pine and no-pine site (Table 3).

Table 2: The number of ant species that significantly favour pine and no-pine sites. Symbols are as follows: F1= number of species favouring pine, F2= number of species favouring no- pine.

	Site			
	B	L	S1 vs. S2	S1 vs. S3
F1	4	2	5	4
F2	6	3	9	9

Of the nine species found exclusively in the mesic mountain fynbos site, *Camponotus* sp. 7 showed similar significant differences between pine versus no-pine and cleared pine versus no-pine sites ($U = 2.18$, $p < 0.05$). *Monomorium* sp. 5 was found exclusively under pines at both the open renosterbos and mesic mountain fynbos sites while *Monomorium* sp. 6 and 7 were found exclusively in the no-pine areas of both sites. *Crematogaster peringueyi* on the other hand, was much more abundant in the cleared pine site than the no-pine site ($U = 3.36$, $p < 0.001$) in the mesic mountain fynbos site. *Anoplolepis steingroeveri* and *Ocymyrmex barbiger* showed significant differences between pine and no-pine areas at all three sites (Table 3).

Table 3: The Mann-Whitney U tests and p-values of ant species that showed significant differences between the pine and no-pine sites.

Species	Site B		Site L		Site S1 vs S3		Site S2 vs. S3	
	U	P	U	P	U	P	U	P
Anoplolepis steingroeveri	2.16	*	2.72	**	3.42	***	3.07	***
Camponotus niveosetosus					2.49	**	2.01	*
Camponotus sp. 3					3.11	***	3.11	***
Camponotus sp. 7					2.18	*	2.18	*
Camponotus vestitus	2.36	*						
Crematogaster sp. 1							3.36	***
Lepisiota capensis	3.15	***			3.43	***		
Monomorium fridae			2.08	*				
Monomoriun sp. 2	2.16	*						
Monomorium sp. 5					3.40	***		
Ocymyrmex barbiger	2.10	*	2.49	**	2.50	**	2.50	**
Pheidole sp. 1	2.31	*			3.07	***	3.45	***
Plagiolepis sp. 1	2.16	*			2.40	*	2.79	**
Tetramorium frigidum					2.85	***	2.82	***

* p = < 0.05, ** p = < 0.01, *** p = < 0.001

There were highly significant differences in the number of ant species found per trap between pine and no-pine sites at all sites except for the closed renosterveld. The open renosterbos site (B1 and B2) showed highly significant differences ($U = 3.12$, $p < 0.001$). The tests also showed differences in sites S1 versus S3 as $U = 3.64$, $p < 0.001$ and S2 versus S3 as $U = 3.81$, $p < 0.001$.

<u>The guild composition in pine versus no-pine sites.</u>

The most abundant guild was the non-dominant generalist (17 species), particularly generalist *Pheidole* sp.1 (48 % of all individual ants) followed by nectar feeders (15 species), dominant generalists (2 species), specialist predators (2 species) and a seed harvester (1 species) (Fig. 2). In general, the non-dominant generalists preferred no-pine sites to sites invaded by pines. The pine patches and the surrounding vegetation did not differ significantly in the ant guild types ($\chi^2 = 19.6$, df = 24, p = 0.719).

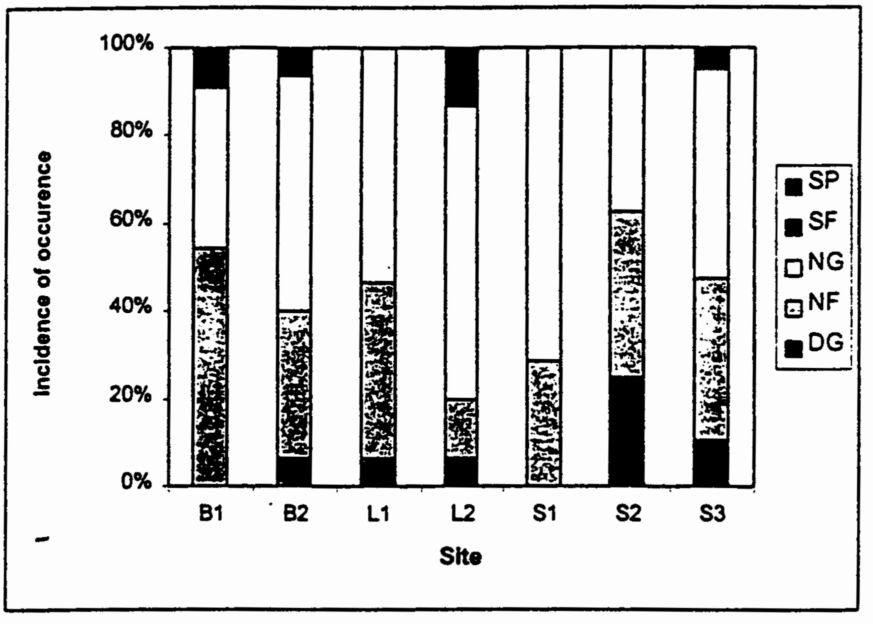

Figure 2: Guild composition in pitfall traps (based on incidence of occurrence data). Guilds are as follows: SP= Specialist Predator, SF= Seed Feeder, NG= Non-dominant Generalist, NF= Nectar Feeder, DG= Dominant Generalist.

Plants

<u>Total species richness in pine versus no-pine sites</u>

A total of 72 plant species were observed during the study. Although there was an overlap in plant species occurence at all the sampling points, many species did not show any significant preference for either the pine or no-pine sites (Tables 4 and 5). *Anthospermum aethiopicum* was the most abundant species, even though it only showed significant differences in mesic mountain fynbos site (site S) between pine versus no-pine sites (U = 2.28, $p < 0.05$) and cleared pine versus no-pine sites (U = 2.79, $p < 0.01$) (Table 6).

Table 4: Composition of plant species collected from sampling quadrats. Data are mean numbers of plants per species for each sampling point. Frequency of occurrence data per species for each sampling point is in brackets. Life form classification is as follows: E= Ericoid, F= Forb, G= Grass, P= Proteoid, S= Succulent.

Species	Life form	Sampling point						
		B1	B2	L1	L2	S1	S2	S3
Anthospermum aethiopicum	E	18.3 (4)	21.7 (1)	5.6 (8)	21.7 (7)	---	9.2 (6)	6.3 (3)
Arctopus sp. 1	F	---	---	---	0.1 (1)	---	---	---
Aspalathus sp. 1	E	0.4 (4)	1.0 (7)	0.1 (1)	0.1 (1)	---	0.2 (1)	0.6 (4)
Asparagus sp. 1	E	0.3 (3)	0.1 (1)	---	---	---	---	---
Athanasia sp. 1	E	0.1 (1)	---	0.6 (5)	0.2 (2)	---	---	---
Chasmophytum sp. 1	S	---	---	---	0.1 (1)	---	---	---
Chrysanthemoides sp. 1	P	---	---	---	---	---	---	0.2 (0)
Chrysocoma ciliaris	E	0.1 (1)	0.1 (1)	---	0.1 (1)	---	---	---
Cliffortia sp. 1	E	0.3 (3)	0.3 (3)	---	---	---	1.7 (5)	---
Cliffortia ruscifolia	E	---	---	---	---	---	---	0.5 (3)
Clutia polygoinoides	E	0.3 (3)	---	0.1 (1)	0.4 (4)	---	0.3 (2)	0.8 (5)
Crassula sp. 1	S	0.2 (2)	0.1 (1)	0.1 (1)	0.1 (1)	---	---	---
Cullumia sp. 1	E	---	0.1 (1)	---	---	---	---	---
Cymbopogon sp. 1	G	---	---	0.1 (1)	---	---	0.3 (2)	0.6 (5)
Diosma sp. 1	E	0.2 (2)	0.6 (4)	2.1 (9)	1.1 (9)	---	---	0.7 (5)
Disparago sp. 1	E	---	---	0.2 (2)	0.2 (2)	---	---	---
Dodonaea sp. 1	P	1.3 (8)	0.3 (3)	---	0.1 (1)	---	---	---
Ehrharta sp. 1	G	0.2 (2)	0.4 (4)	1.6 (6)	3.2 (9)	---	0.8 (2)	---
Elytropappus rhinocerotis	E	2.2 (9)	2.8 (9)	0.3 (3)	0.7 (6)	---	---	---
Eragrostis africana	G	0.1 (1)	---	0.6 (3)	0.1 (1)	---	---	---
Erica sp. 1	E	---	---	---	---	---	0.3 (2)	2.1 (6)
Euryops latifolius	E	---	---	0.3 (3)	---	--	---	---
Exomis sp. 1	F	---	---	0.2 (2)	0.3 (3)	---	---	---
Felicia filifolia	E	0.7 (6)	1.1 (8)	---	0.1 (1)	---	---	---
Facinia sp. 1	G	0.2 (1)	---	---	---	---	0.5 (2)	0.2 (1)
Gnidia sp. 1	E	0.1 (1)	0.3 (3)	0.1 (1)	0.4 (4)	---	---	---
Grass (bulbous)	G	---	---	0.4 (4)	0.1 (1)	---	---	---
Grass (unidentified)	G	0.1 (1)	0.3 (3)	---	0.1 (1)	---	0.5 (3)	---
Helichrysum crispum	F	---	---	0.1 (1)	0.6 (5)	---	---	0.7 (4)
Helichrysum rosum	E	---	---	0.1 (1)	0.1 (1)	---	---	---
Helichrysum sp. 1	E	1.3 (7)	0.9 (7)	---	0.6 (5)	---	---	---
Helichrysum sp. 2	E	---	---	0.2 (2)	0.4 (3)	---	---	---
Helichrysum sp. 3	E	---	---	---	0.2 (1)	---	0.2 (1)	---
Helichrysum sp. 4	E	---	---	---	---	---	0.8 (2)	---
Helichrysum sp. 5	E	---	---	---	---	---	---	0.2 (1)
Hermannia sp. 1	E	0.3 (3)	0.2 (2)	0.1 (1)	---	---	---	---
Indigofera sp. 1	E	---	---	0.1 (1)	0.2 (2)	---	---	---
Leucadendron rubrum	P	---	---	---	---	---	0.2 (2)	0.3 (2)
Leucadendron salignum	P	---	---	---	---	---	---	0.3 (2)
Lightfootia sp. 1	E	0.4 (4)	0.8 (7)	---	0.4 (4)	---	---	---
Lobostemon fruticosus	P	---	---	---	---	---	---	0.1 (1)
Merxmuellera sp. 1	G	---	---	0.1 (1)	0.7 (6)	---	---	---
Mesembryanthemum sp. 1	S	---	---	0.1 (1)	---	---	---	0.2 (1)
Metalasia cephalotes	E	---	---	---	---	---	---	1.1 (6)

Metalasia muricata	E	0.3 (3)	0.3 (3)	0.1 (1)	---	---	---	1.3 (6)
Muraltia heisteria	E	0.7 (6)	0.9 (8)	0.2 (2)	---	---	---	0.5 (3)
Othonna quinquedentata	P	---	---	---	---	0.1 (1)	1.0 (4)	0.2 (1)
Pelargonium betulinum	F	---	---	---	---	---	1.2 (6)	---
Pelargonium myrrhifolium	F	---	---	---	0.2 (2)	---	---	---
Pelargonium sp. 1	F	0.3 (3)	---	0.1 (1)	0.2 (2)	---	---	0.7 (5)
Pentaschistis sp. 1	G	---	---	---	---	0.1 (1)	---	0.2 (1)
Phylica sp. 1	E	---	0.1 (1)	---	---	---	---	---
Plagiochloa sp. 1	G	---	---	2.2 (8)	---	---	---	0.1 (1)
Polygala sp. 1	E	---	0.2 (2)	---	---	---	---	---
Protea laurifolia	P	---	---	---	---	---	---	0.5 (3)
Psoralea pinnata	E	---	---	---	---	---	1.7 (5)	0.7 (3)
Pteronia incana	E	---	---	0.1 (1)	0.1 (1)	---	---	---
Putterlickia pyracantha	P	0.1 (1)	---	0.2 (2)	0.1 (1)	---	---	---
Relhania squarrosa	E	1.2 (9)	0.8 (7)	0.1 (1)	---	---	---	---
Restio sp. 1	G	0.3 (3)	0.6 (4)	0.3 (3)	1.3 (8)	---	1.7 (5)	2.8 (6)
Rhus lucida	P	0.1 (1)	---	---	---	---	---	---
Rhus mucronata	P	0.2 (1)	---	---	---	---	---	---
Rhus undulata	P	0.2 (1)	---	0.1 (1)	0.3 (3)	---	---	---
Ruschia sp. 1	S	---	---	0.1 (1)	---	---	---	---
Selago sp. 1	F	0.2 (2)	---	---	---	---	---	---
Senecio sp. 1	F	---	---	---	0.1 (1)	---	0.2 (1)	---
Stoebe sp. 1	E	---	---	0.1 (1)	---	---	1.8 (6)	0.2 (1)
Struthiola sp. 1	E	---	---	---	---	---	---	0.1 (1)
Themeda triandra	G	0.3 (2)	0.1 (1)	0.9 (5)	0.1 (1)	---	---	---
Thesium sp. 1	E	---	---	1.6 (9)	0.3 (3)	---	---	0.3 (2)
Ursinia sp. 1	F	---	---	---	---	---	---	0.2 (1)
Walafrida sp. 1	E	---	---	0.1 (1)	---	---	---	---

The mesic mountain fynbos site showed the most conspicuous differences in species composition between grids. This site had 18 species that showed the significant differences between S1 versus S3 and S2 versus S3. The species that showed the highest significant values, i.e. $p < 0.001$, were *Clutia polygonoides*, *Cymbopogon* sp. 1, *Diosma* sp. 1, *Erica* sp. 1, *Metalasia cephalotes*, *Metalasia muricata*, *Pelargonium betulinum*, *Pelargonium* sp. 1 and *Restio* sp. 1 (Table 6).

The two renosterbos sites showed some differences in terms of the plant cover and also had some species that showed significant differences between pine patches and surrounding no-pine vegetation. *Elytropappus rhinocerotis* was commonly found in both the open and dense renosterbos sites, but there were no significant differences in its occurrence in cover between the pine and no-pine sites.

Table 5: The number of plant species that occurred more frequently in pine, or in no-pine sites. Symbols are as follows: F1= number of species more frequent in pine patches, F2= number of species more frequent in no-pine patches.

	Site			
	B	**L**	S1 vs. S2	S1 vs. S3
F1	2	8	0	5
F2	2	9	15	8

In general, only two species at the open renosterbos site (site B), *Dodonea* sp.1 and *Relhania squarrosa*, showed significant differences between the pine and no-pine sites. These two species were much more abundant under the pines than in the surrounding no-pine site. The grids in the open renosterbos had more bare ground in comparison with the dense renosterbos site. Ten species at this site showed highly significant differences between the pine and no-pine sites (Table 6).

Table 6: The Mann-Whitney U Tests and p-values of plant species that showed significant differences between pine and no-pine sites.

Species	Site B		Site L		Site S1 vs S3		Site S2 vs. S3	
	U	P	U	P	U	P	U	P
Anthospermum aethiopicum					2.28	*	2.79	**
Aspalathus sp. 1					2.74	**		
Cliffortia sp. 1							2.80	**
Cliffortia ruscifolia					2.29	*		
Clutia polygoinoides					3.24	***		
Cymbopogon sp. 1					3.17	***		
Diosma sp. 1			2.80	**	3.19	***	2.74	**
Dodonaea sp. 1	2.69	**						
Ehrharta sp. 1			2.79	**				
Erica sp. 1					3.18	***	2.47	**
Helichrysum crispum			1.94	*	2.76	**	2.35	*
Helichrysum sp. 1			2.56	**				
Lightfootia sp. 1			2.20	*				
Merxmuellera sp. 1			2.35	*				
Metalasia cephalotes					3.18	***	2.88	***
Metalasia muricata					3.18	***	2.88	***
Muraltia heisteria					2.29	*		
Pelagronium betulinum							2.88	***
Pelargonium sp. 1					3.19	***	2.74	**
Plagiochloa sp. 1			2.53	***				
Protea laurifolia					2.29	*		
Psoralea pinnata					2.28	*		
Relhania squarrosa	1.94	*						
Restio sp. 1			2.69	**	3.18	***	2.08	*
Stoebe sp. 1							2.87	***
Themeda triandra			2.06	*				
Thesium sp. 1			3.12	***				

* p = < 0.05, ** p = < 0.01, *** p = < 0.001

Plant life form composition in pine versus no-pine sites

The most abundant life form was the ericoids (37 species) followed by proteiods (11 species), grasses (11 species), forbs (9 species) and succulents (4 species). In general, the five life forms did not show any exclusive pattern of preference for either the pine or no-pine sites (Fig. 3) and there was no significant differences between the various plant life forms ($\chi^2 = 22.55$, df = 24, p = 0.546). The ericoids, for an example, favoured no-pine sites at open renosterbos and mesic mountain fynbos sites but favoured being under pines in the dense renosterbos site. The data used for comparison of life forms are frequency of occurrence data (total number of species in each guild per sampling point).

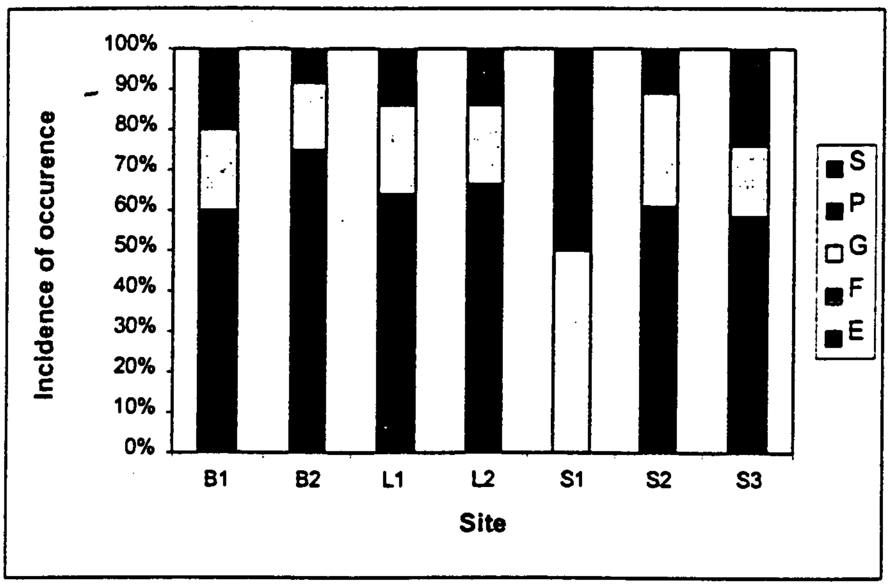

Figure 3: Plant life form composition per plot (based on incidence of occurrence data). The plant life forms are as follows: S= Succulents, P= Proteoids, G= Grass, F= Forbs, E= Ericoids.

DISCUSSION

PINES AND THE ENVIRONMENT

Results from this study suggest that pines can negatively impact the environment including the fauna and flora that reside there. The negative effects of pines on the environment can be through changing the soil structure, shading of indigenous vegetation, with concomitant lowering of plant diversity, and changing the leaf litter composition. This is likely to decrease the resources available to animals. The effects of pines on the environment was most noticeable at Site S on the Swartberg pass, where the mesic mountain fynbos site (S3) was more species-rich in terms of ants and plants than the pine plantation (S1) and the cleared site (S2). This mature, solid stand of pines had extensive bare ground and little undergrowth.

EFFECTS OF PINES ON ANT AND PLANT SPECIES DIVERSITY

Vegetation plays a major role in structuring ant communities, and any changes in plant composition and structure are likely to bring changes in ant species diversity (Andersen 1983). Vegetation has an influence on ant communities through its effects on microclimate (Greenslade & Greenslade 1977). The microclimate changes (changes in moisture and insolation levels) by plants have previously been shown to have significant impact on insect diversity and ant activities (Burbidge *et. al.* 1992; Levings 1983; Lynch, Johnson & Balinsky 1988; Postle *et. al.* 1991). Although not measured in the present study, it is possible that changes in the microclimate under the mature stand of pines (site S1) are another factor impacting plant and animal communities. This aspect requires further investigation.

The results suggest that the age of the pine plantation may also be a significant factor. The older the pine patch, the more the threat it poses to the survival of the ant and plant species. This statement is further supported by Whitford and Gentry (1981), who suggested that mature pine plantations tend to have lower ant species richness. In another study, Donnelly and Giliomee (1985b), also found out that ants occurred in fewer numbers in pine plantations, but that there was little difference in ant species richness.

ANT HABITAT PREFERENCES

Crematogaster peringueyi was common under the cleared pine site and presumably can outcompete other species. The other non-dominant generalists such as *Tapinoma* sp. 1, *Tetramorium frigidum* and *Tetramorium regulare* also occured in the cleared pine site but in very low numbers, and it may be suggested that *Crematogaster peringueyi* excluded them from establishing in this site. However, no evidence of competitive interaction between ant species was collected during this study, so this suggestion is purely speculative.

The pine patches were preferred by some ant species possibly because of the resources available to them. For example, *Tetramorium quadrispinosum* was found only at the open renosterbos site and mainly under the pines. The genus *Tetramorium* has very unspecialised diets, poor competitive ability and usually found in sites that are highly disturbed (Andersen 1997; Burbidge *et. al.* 1992), and this may explain the high abundance of *T. quadrispinosum* in pine patches. -

Ocymyrmex barbiger was more frequently trapped and observed in the surrounding natural vegetation than under the pines, suggesting that even though the surrounding vegetation had more plant undergrowth, there was still enough suitable bare ground for the movement of these ants. *Ocymyrmex* species generally forage on bare ground, and have a high heat tolerance, feeding on heat stressed invertebrates (Marsh 1985). Although there may have been more bare ground under the pines, *Ocymyrmex barbiger* seems to be one species that prefers indigenous vegetation to being under the pines.

ANT AND PLANT SPECIES RICHNESS IN AN AGRICULTURAL MATRIX

Disturbance by agriculture facilitates the invasion of non-indigenous plants (Harper 1977). In general, pine patches on the two farms in renosterbos were as species-rich (in terms of ants and plants) as the adjacent indigenous vegetation. More than 70% of the plant species were common to both the pine patches and the surrounding indigenous vegetation. The pine patch on Botha's farm (B1) had a more diverse number of plant species when compared with the surrounding renosterbos. The explanation for this could be that the surrounding vegetation was subjected to disturbance in the form of cultivation and grazing before it was abandoned (based on personal observations in the area).

The use of fertilisers or other forms of agricultural disturbance such as ploughing may thus have negatively impacted on the plant diversity of the surrounding vegetation. Additionally, the livestock normally trample the soil during grazing thus completely changing the soil structure of that environment (Scougall *et. al.* 1993). The relatively high ant and plant species richness under the pine plantations on the farms suggests that pines may be acting as sinks to the plants and ants and are therefore likely to lose their high species diversity in time when conditions change. This subject requires further investigation.

CONCLUSIONS

The present study has shown that the invasion of renosterbos by pines does affect ant abundance, and, to a lesser degree, ant species assemblages. As a result, the impact of pine invasions on ant communities may have some important consequences for the conservation and management of renosterbos shrublands, including disruptions to the dispersal of seeds, disruptions to nutrient and decomposition cycles and cascade effects on organisms preyed on by ants.

The remnants of pristine patches of the renosterbos should be regarded as important insect reserves within a generally unfavourable agricultural matrix. Results from the present study suggest that the impact of pines on ant species assemblages increases with the age of the pines. It is clear that, in order to maintain ant species richness within the pine patches, control measures should be applied to the young pines before the remnant renosterbos within them disappears. It would be worthwhile to investigate the stage at which pine patches become major threats to the biodiversity of renosterbos shrublands. It would also be worthwhile to find out the rate at which patches that have been cleared of pines are recolonised by indigenous plants and their associated invertebrate fauna.

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