

THE POSSIBLE EFFECT OF FIRE ON THE STRUCTURAL AND FLORISTIC
COMPOSITION OF AFROMONTANE FOREST ON THE CAPE PENINSULA

BOTANY HONOURS PROJECT

(ECOLOGY)

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1989

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Diospyros whyteana resprouting from a central
charcoal stump, in the multi-stemmed forest.

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ABSTRACT

Adjacent single-stemmed and multi-stemmed forests were sampled to determine whether fire, as a form of catastrophic disturbance, played a role in the structural and floristic composition of the multi-stemmed forest. The data were subject^{ed} to structural and floristic statistical analyses to ascertain the differences between the two forests. The broad findings were that: i) there was more physical evidence of fire in the multi-stemmed forest. ii) *Podocarpus latifolius*, a fire sensitive species, was generally much bigger in terms of dbh, in the single-stemmed forest than in the multi-stemmed forest. iii) the basal areas of single-stemmed individuals in the multi-stemmed forest were on the whole smaller than the multi-stemmed individuals. iv) a greater percentage of trees in the multi-stemmed forest supported a liana species than in the single-stemmed forest. v) the two forests could be floristically discriminated by Discriminant Analysis with *Canthium inerme*, *Halleria lucida*, *Kiggelaria africana* and *Olea exasperata* as the discriminating species. Indications are that fire has had a role to play in determining structural and floristic composition of the multi-stemmed forest. It is proposed that a similar study be conducted at another site in order to validate the study by ascertaining whether similar trends are experienced in other examples of multistemmed forest.

INTRODUCTION

The effects of catastrophic disturbance on forest community dynamics had not received much attention until relatively recently. This is largely because disturbance, as an influence on community structure and dynamics, has not been incorporated into a theory of ecosystems and their dynamics (Pickett and White 1985). The result has been that researchers have concentrated on abiotic factors such as moisture or nutrient availability and geology as the determining factors in ecosystem dynamics (Moll 1978; Van Daalen 1984 ; Masson and Moll 1987).

More recently there has been a move towards understanding disturbance at a theoretical level (White 1979; Pickett and White 1985). It has been found that a better comprehension of the characteristics of various kinds of disturbance is needed in order to begin to develop theories and predictive models of the effects of disturbance at a community level.

This study relates specifically to the influence of fire as a type of catastrophic disturbance. It has been argued that fires have very marginal effects on Afromontane forests in Southern Africa (Edwards 1984; Huntley 1984; Van Wilgen, personal communication) and some researchers openly contend that 'forests do not burn' (Huntley 1984; McKenzie personal communication). As a result generalizations have been made to the effect that forests "are fundamentally an ecosystem of species intolerant to fire" (Edwards 1984). However, there is a growing body of evidence that indigenous forest can in fact burn (Granger 1984; Pammenter *et al* 1985). A small riverine forest at Jonkershoek

was burnt in 1988, and in 1986 a young emergent forest in the Vogelgat Private Nature Reserve, just outside Hermanus was also burnt (personal observation).

This has definite implications for the dynamics of small forest patches or forest fringes, depending on how different tree species respond to fire. Forest tree species may be classed as obligate reseeders, which tend to be killed by fire and so rely on seed establishment for regeneration, or , and this appears to be the majority, they may be classed as resprouters which tend to coppice after fire (Johnson and Lacey 1983; Granger 1984; Kruger 1984; Canham and Marks 1985), undergoing a process of 'reiteration' in relation to the disturbance (Hallé *et al* 1978). These responses would obviously affect community structure which would also be influenced by the frequency and intensity of the disturbance.

Floristic composition of the forest should also be affected by catastrophic disturbance as these change the availability of limiting resources. As a simple example: light availability on the forest floor can be greatly affected by catastrophic destruction of the canopy, and this would favour the growth of photophilic species.

The broad aim of this study ^{was} were to determine the possible effect of catastrophic disturbance, in this case fire, on the structural and floristic components of forests. A set of criteria could then be developed which would enable disturbed and undisturbed forest to be identified.

The two broad questions addressed are: 1) Do forest trees differ in their mechanism for surviving fire? 2) Does fire influence the structural and floristic composition of forests on the Cape Peninsula?

One assumption which was made, was that multi-stemmedness can be caused by fire. This was tested in an example of a forest that had been damaged by fire. Because forests on the Cape Peninsula appear to differ in the frequency of multi-stemmed individuals, the following hypothesis was proposed: Forests of low versus high frequency of multi-stemmed individuals had different disturbance histories, resulting in different structural and floristic composition.

1. If fire causes multi-stemmedness, then it is predicted that:
 - a) more physical evidence of fire (charcoal) will occur in the multi-stemmed forest.
 - b) single-stemmed individuals of any one species in the multi-stemmed forest should be smaller than the multi-stemmed individuals (in terms of their basal areas) since they would have recruited after the fire.
2. If multi-stemmedness is caused by fire, then:
 - a) species absent, or present only in small size classes, are sensitive to fire. *in multi-stemmed forests*
 - b) it is predicted that the single-stemmed and multi-stemmed forest will differ floristically in a predictable way and that positive and negative associates will be the same for other multi-stemmed forests, regardless of site conditions.

MATERIALS AND METHODS

All field work was conducted between 6 April and 20 May 1989. The initial task was to test the assumption that forest tree species tend to resprout from the base and so develop multi-stemmed trunks after a fire. A site for this purpose was selected in the Vogelgat Private Nature Reserve where, in January 1986, a fire occurred which completely destroyed an emerging forest. To determine how the individual trees regenerated after the fire, a randomly placed four metre wide transect was laid out and the first one hundred individual trees were sampled. For each individual the species was noted and it was recorded whether the individual was dead, resprouting from the base of the trunk, or resprouting epicormically.

Once this assumption was tested, further fieldwork was carried out in two forests, situated at Noordhoek, on the Cape Peninsula at latitude $34^{\circ}05'S$ and longitude $18^{\circ}22'E$ (Figure 1). Two adjacent forests were sampled for floristic and structural data. In each forest, ten randomly placed plots were sampled. In the single-stemmed (SS) FOREST, which is characterized by large, tall single-stemmed trees, the plots were ten metres by twenty metres in size, while in the multi-stemmed (MS) FOREST, which is characterized by a more dense forest with shorter multi-stemmed trees, the plots were ten metres by ten metres in size. An approximately equal number of trees were sampled from each site for statistical reasons; a Student's t-test shows that the average plot density for each forest was not significantly different, even though the area of the plots in the MS FOREST were twice the area of plots in the SS FOREST.

In each plot the following data was collected: i) a species list was drawn up of all individual trees within the plot; ii) it was ascertained whether the crown of each individual tree reached the forest canopy or not; iii) whether each individual had a single or multi-stemmed trunk at breast height (1,3 metres from the forest floor [Geldenhuys *et al* 1988]); iv) the diameter at breast height (dbh) was recorded for each tree - in the case of multi-stemmed individuals the dbh of each trunk was recorded and acknowledged as belonging to a single individual tree; v) it was also noted whether each tree supported a liana species or not. Further, vi) the area of each plot covered by rock was recorded as was vii) any physical evidence of fire in the form of charcoal remains on tree stumps.

Size class (dbh) frequencies of *Podocarpus latifolius* were determined for each forest by means of the Wandering Quarter Method (WQM) (Catana 1963) in order to test the prediction that fire sensitive species would be absent or present only in small size classes in multi-stemmed forest. The proportion of multi-stemmed to single-stemmed individuals for each forest area was also determined by means of the WQM. The latter was used to validate data from the plots.

These data were then subject to various statistical analyses. Discriminant Analysis was used to ascertain whether floristic differences occurred between the two forests. Only species which were represented in at least three of the ten plots in either forest were considered; the others were deemed part of a "sink population" (Ellner and Shmida 1984). The Student's t-test/Mann

Whitney-U test and Fisher's Exact test were used to ascertain on what grounds the two forests could be discriminated, quantitatively or qualitatively, respectively.

In order to quantify the observed structural differences between the two forest areas, differences between the proportion of multi-stemmed to single-stemmed individuals for each forest were determined. Only overstorey individuals were used as it is argued that understorey individuals could possibly have recruited after the fire and would thus have a better chance of being single-stemmed.

The density of *Canthium inerme* in each forest was calculated and used as an indicator species on the basis of Granger's (1984) observation that burnt forest areas tends to have a higher density of *C. inerme* than unburnt forest areas. Because of the differences in plot size, each plot's density was brought to a common denominator (the number of individuals per m²). Liana density (the percentage of trees supporting any species of liana) was also determined. Statistical significance of differences between forests was tested by means of the non-parametric Mann Whitney-U test.

Basal areas (the transverse sectional area of the trunk at breast height), were calculated using the simple equation, $area = \pi r^2$.

All statistical analyses were carried out on *Statgraphics* using a micro-computer. Significance levels for all tests were standardized to 95%.

RESULTS

Evidence from the burnt forest at the Vogelgat Private Nature Reserve, showed clearly that forest tree species tend to resprout from the base after fire (Figure 2). It is assumed henceforth that multi-stemmedness may be an indicator of fire.

The data from Noordhoek shows that the SS FOREST, which occurs on a more rocky substrate than the MS FOREST (54,8% rock cover compared to 7,4%), has less physical evidence of fire than the MS FOREST. ie. out of ten plots in the SS FOREST one had physical evidence of fire, while five out of ten plots in the MS FOREST had this physical evidence. In three of the plots in the MS FOREST there were a number of burnt stumps. It is suggested that the more rocky the substrate the greater the protection from fire is afforded to the trees which exist on it.

Structural composition:

In a burnt forest, it is predicted that there would be a higher number of multi-stemmed individuals than in the unburnt forest. A Chi-squared Goodness of Fit test shows that there is a significant difference between the two forests with respect to the percentage of multi-stemmed overstorey individuals in the plots with 14,1% in the SS FOREST and 47,9% in the MS FOREST (Chi-squared=53.64, one degree of freedom, significance level=1.8E-14)(Figure 3). This finding is supported by data collected using the WQM (Table 1). In this instance, both understorey and overstorey trees were included.

One would expect in a multi-stemmed forest, if it had been burnt, that the single-stemmed individuals of a species would be smaller in terms of their basal areas than the multi-stemmed individuals because they would have recruited after the fire. The within species basal area comparisons of six species are illustrated in Figure 4 (a-f).

Diospyros whyteana (Figure 4a), *Olinia ventosa* (Figure 4b) and *Cassine peragua* (Figure 4d) all adhere very closely to the above stated prediction. In addition, in the single-stemmed forest, where it is assumed that no fire has occurred, no multi-stemmed individuals of the latter two species were encountered.

However, the prediction does not hold for *Olea capensis capensis* (Figure 4c), *Rapanea melanophloeos* (Figure 4e) and *Maurocenia frangularis* (Figure 4f).

In multi-stemmed forest it is predicted that fire sensitive species would be absent or present only in small dbh size class as they would either have been killed by the fire or would have recruited after the fire. Size class frequencies of *Podocarpus latifolius*, thought to be a fire sensitive species, fit the prediction (Figure 5).

Floristic composition:

In a forest that has been damaged by fire, it is expected that liana species would be more abundant than in unburnt forest because an increase in light and nutrients (Canham and Marks 1985) as well as an increased availability of trellises (Putz

1980) stimulates liana growth. The percentage of trees which support a species of liana in each forest was not significantly different (Mann Whitney-U test, $Z=0.126$). However, when only overstorey individuals of each forest were considered, a significant difference between the two forests did exist with 49.5% of the MS FOREST trees supporting lianas and only 18.34% of the SS FOREST trees supporting lianas (Mann Whitney-U test, $Z=0.024$). This phenomenon is characteristic of a disturbed forest (Leigh 1975, cited in Brokaw 1985).

Canthium inerme, which was observed by Granger (1984) to be denser in previously burnt forest, had significantly different densities in each forest with the SS FOREST having a density of $0.001/m^2$ and MS FOREST having a density of $0.035/m^2$ (Mann Whitney-U test, $Z=0.00915$).

Discriminant Analysis of the species in each forest showed that the two forests could be discriminated (Table 2). Each of the plots was classified in terms of their discriminant function score (Figure 6), which shows that almost all the plots could be classified as belonging to either the the SS FOREST or the MS FOREST. All MS FOREST plots have discriminant function scores which classify them as being taken from the MS FOREST. Six of the ten SS FOREST plots are classified as being taken from the SS FOREST with four having characteristics of the MS FOREST. Fisher's Exact tests, Student's t-tests, and Mann Whitney-U tests showed which species of those used in the Discriminant Analysis were influential in floristically discriminating between the two forests (Table 3).

DISCUSSION:

The finding that forest tree species tend to resprout in areas of forest previously burnt is in sharp contrast to Edward's (1984) contention that forests are "fundamentally an ecosystem of species intolerant to fire". It is the outward appearance of forest, a compact, evergreen mass of trees, which lends itself to the idea that it does not burn.

The two forests at Noordhoek which lie adjacent to one another are in fact continuous; yet there are structural differences between the two. In the MS FOREST, where there is a high proportion of multi-stemmed individuals when compared to the SS FOREST, there is a correspondingly frequent occurrence of physical evidence of fire (charcoal), suggesting that fire may have had an influence on the dynamics of the MS FOREST.

The intraspecific basal area comparisons also give insights into the effect of disturbance on the MS FOREST. *Diospyros whyteana*, *Olinia ventosa* and *Cassine peragua* (Figure 4a b d) are all consistent with the idea that in forest which has suffered fire damage, the single-stemmed individuals would tend to be smaller than the multi-stemmed individuals because they should have recruited after the fire. *Olea capensis capensis*, *Rapanea melanophloeos* and *Maurocena frangularis* (Figure 4c e f) do not reflect what is expected. What we do see in the MS FOREST, however, is that both multi-stemmed and single-stemmed individuals of these species tend to have small basal areas with generally more of them being single-stemmed individuals. This implies that they may have all recruited after the fire; this

might have been a possibility as a large number of these species occur in the adjacent SS FOREST. The presence of multi-stemmed individuals in the SS FOREST is negligible and could be attributed to other causes.

It is acknowledged, however, that multi-stemmedness can also result from other agents; for example browsing which destroys the apical meristem of the plant and so releases the plant from apical dominance (Frost 1984; Philips 1931 cited in Kruger 1984). Multi-stemmedness may also result from other types of catastrophic disturbance such as tree fall (Picket and White 1985). It should also be noted that fire sensitive species, like *Podocarpus latifolius*, tend not to resprout after fire - only a single *P. latifolius* individual had a multi-stem, out of 329 individuals sampled - so that where they are dominant in a forest, they will influence the observations of multi-stemmedness as being an indicator of fire.

Fire sensitive species can also be important indicators of fire history. The results of the ^{size of} size class frequencies of *P. latifolius* in each forest is consistent with the idea that the fire in the MS FOREST killed all the individuals of this species and that the high concentration of small podocarps in this area has resulted from recruitment after the fire.

With respect to Granger's (1984) observation that *Canthium inerme* was (13X) more dense in forest that has suffered fire damage than in unburnt forest, the significantly higher density of *C. inerme*

in the MS FOREST compared to the SS FOREST, provides further evidence that fire has had a role to play in the dynamics of the MS FOREST.

The significantly higher proportion of trees in the MS FOREST supporting lianas, serves to confirm the idea that fire has played a role in the dynamics of the MS FOREST. A significant result is only forthcoming when overstorey individuals are considered because they would have been burnt down to the ground by the fire, and so would have supported the lianas from the ground up as they regrew. The added factor of low resource levels and lack of suitable trellises (Putz 1980) in the SS FOREST, could also have reduced the proportion of lianas in the SS FOREST. This is further evidence which is consistent with the idea that the MS FOREST has been disturbed by fire.

Much of the evidence supports the hypothesis that fire has had an effect on the MS FOREST. Fire can thus be considered as a mechanism which may alter the floristics and structure of Afromontane forest regions.

In other forest types (particularly tropical), cyclones and the often accompanying floods, are often deemed responsible for tree fall^s, especially of structurally weak plants. For Afromontane forests in the Southern African sub-region, such conditions are rare. It is therefore suggested here that catastrophic disturbances such as fire play a similar role in the dynamics of forest areas. As Whitmore (1982) maintains, fire can be considered the cause of gap forming process which would, like any

other of these processes, "drive the forest growth cycle and determine forest floristics" and forest structure (White and Pickett 1985). ✓

It has been suggested by MacKenzie (1978) that the species diversity of Afromontane forests in South Africa tends to decline as one moves from east to west. He proposes that the Knysna forest is the 'sea' from which tree species disperse and that, consistent with Island Biogeography Theory (MacArthur and Wilson 1967), there is a reduction in species number as one moves further from the source of dispersal. However, it is suggested here that perhaps fire is a determinant of species composition and therefore diversity. As one moves west from the Knysna forest, the patches become smaller and thus there is a greater chance of fire being able to burn a large portion of a patch of forest, eliminating the fire sensitive species. ✓

A floristic difference exists between the two forests considered. *Canthium inerme*, *Halleria lucida*, *Kiggelaria africana*, and *Olea exasperata* are the four species by which the two forests may be discriminated on a quantitative basis, and in the case of three of them, on a qualitative basis as well (Table 3). The occurrence of *C.inerme* and *O.exasperata* is a good indicator of MS FOREST as are the low numbers of *K.africana* and *H.lucida*.

The fact that some of the SS FOREST plots have floristic affinities with the MS FOREST in terms of their discriminant function score (Figure 6) suggests that fire is not the sole determinant of floristic composition. ✓

It is also important to recognize the topographical implications of this study. As Pickett and White (1985) have pointed out the heterogeneity of a landscape's topography may have a major influence in defining disturbance regimes. For example, where a forest exists in a kloof one may expect to find the central regions of the forest untouched by fire, and thus structurally and floristically different from the exposed outer margins of the forest which may have a greater chance of being affected by fire.

In order to validate this study, one needs to conduct a similar study at another site where the structural differences of two forests become an indicator that fire has had an affect on the forest. If fire has been influential in other forests, then regardless of the influence of geology and soil similar differences would be forthcoming in these forests. Fire is then, proposed as possibly having an overriding influence on the structural and floristic dynamics of forests on the Cape Peninsula.

ACKNOWLEDGEMENTS

There are a number of people I would like to thank:

* Mr Ion Williams of the Vogelgat Private Nature Reserve near Hermanus, for permission to work in his reserve.

* Mr Sharpe, the manager of De Goede Hoop Estate, for the opportunity of working in the forests above Noordhoek, which was a truly unique experience.

* Dr Richard Knight for his valuable comments in the initial stages of the project.

* Alan and Susha for their assistance in the field.

* Dave Freer and Dave Balfour for painfully valuable comments on an earlier draft.

* Andy at the COMPUTER ROOM for helping with the editing and printing of the project.

* And finally and especially Dr William Bond for his inspiration and valuable "who dunnit" guidance throughout the duration of the project.

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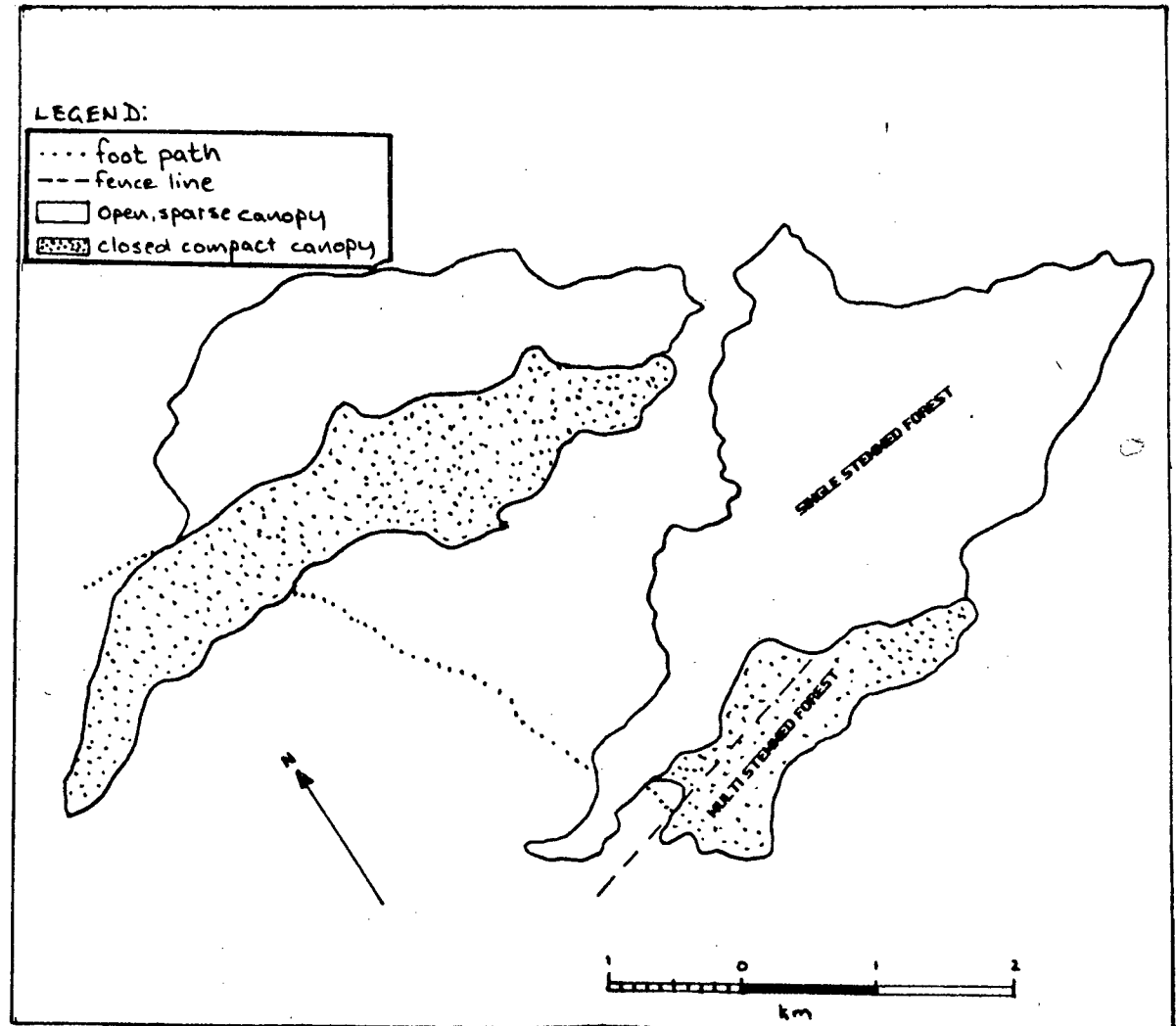
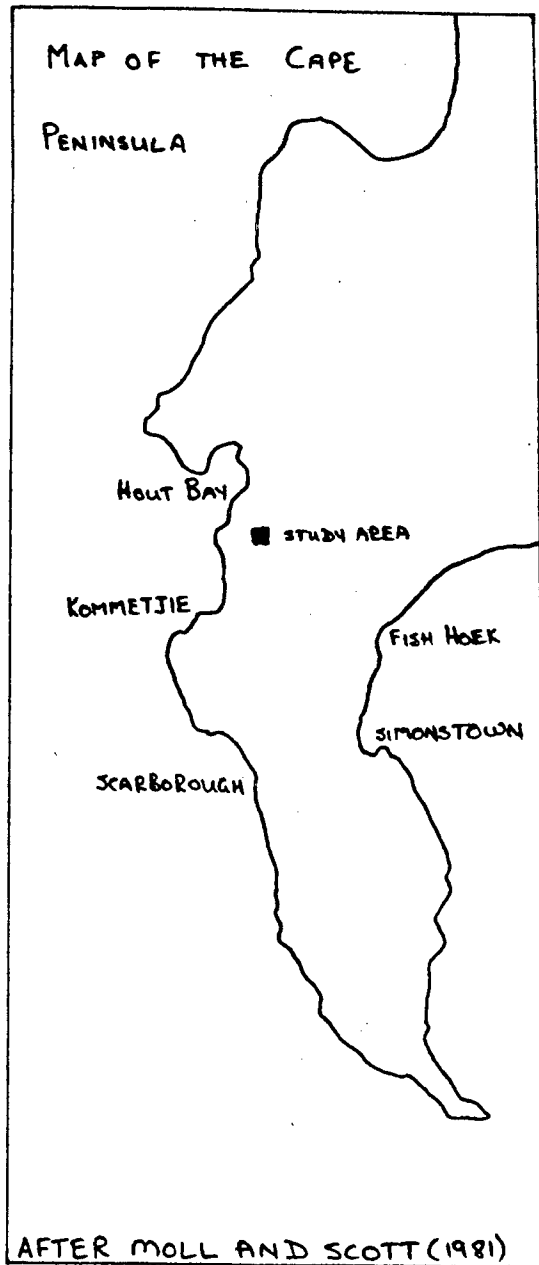


Figure 1: Map of the study area showing the two forests which were sampled. Also illustrated is the recurrent pattern observed in a forest nearby (the left forest area) detected on an aerial photograph taken in 1983.

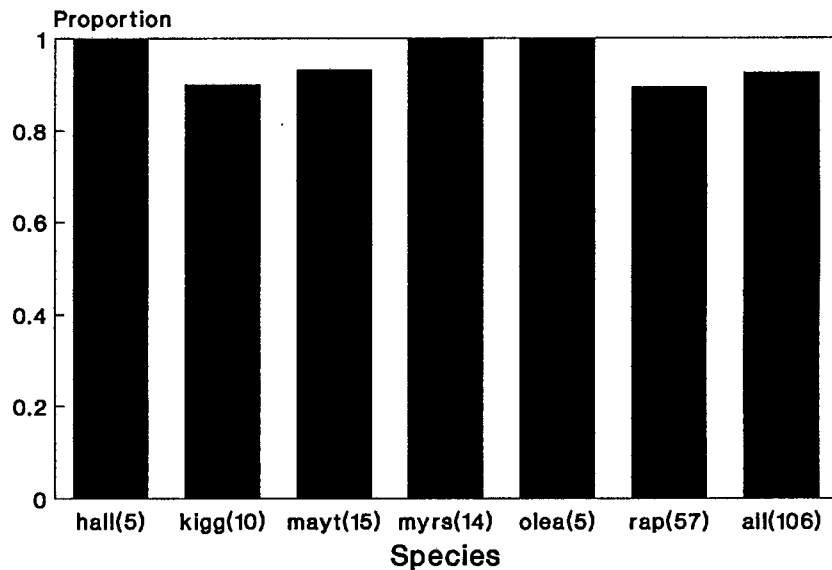


Figure 2: Regeneration after fire at the Vogelgat Private Nature Reserve, Hermanus shown as the proportion of base resproaters. Figures in the brackets indicate the number of individuals of each species sampled. [hall=Halleria lucida; kigg=Kiggelaria africana; mayt=Maytenus acuminata; myrs=Myrsine africana; olea=Olea capensis capensis; rap=Rapanea melanophleoes; all=average proportion of all base resproaters sampled].

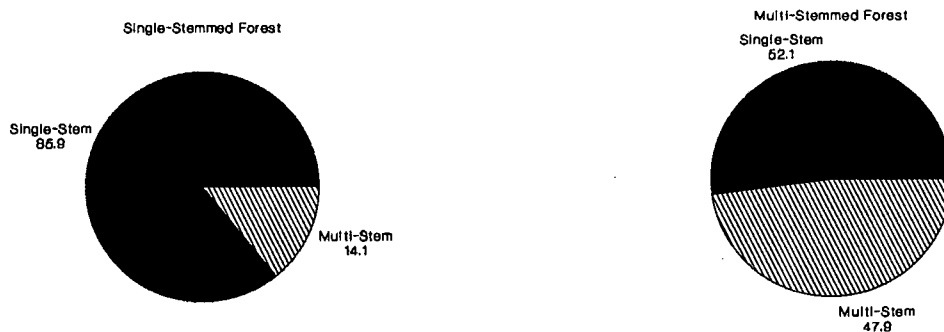


Figure 3: Pie charts showing the proportion of single-stemmed to multi-stemmed canopy individuals in each forest. (Chi-square = 58.6452 with one degree of freedom; Significance level = 1.88738E-14).

Architecture	Observed frequency	Expected frequency	Chi-Square
Single stem	36	27	3.00
Multi stem	14	23	3.52

Chi-square = 6.52 with one degree of freedom
 Sig. level = 0.0106

Table 1: Statistical information for the proportion of single-stemmed to multi-stemmed individuals in each forest, using the Wandering Quarter method.

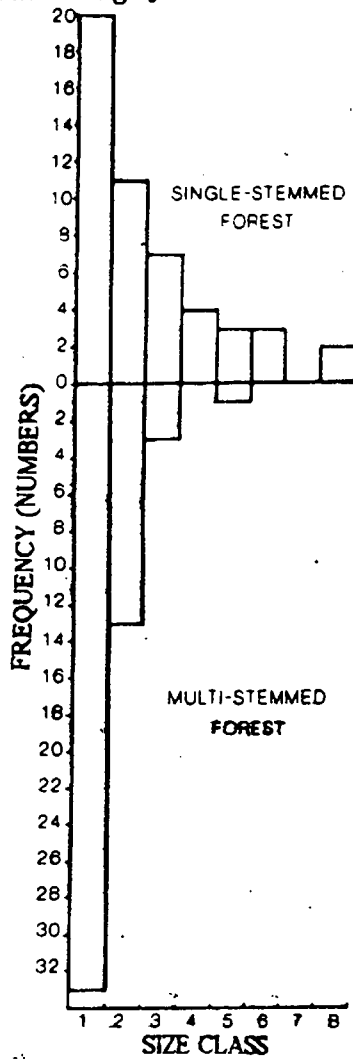


Figure 5: Podocarpus latifolius size class frequencies for SS FOREST and MS FOREST using the Wandering Quarter Method.

(Size Class: 1 = 1-10cm; 2 = 11-20cm; 3 = 21-30 etc).

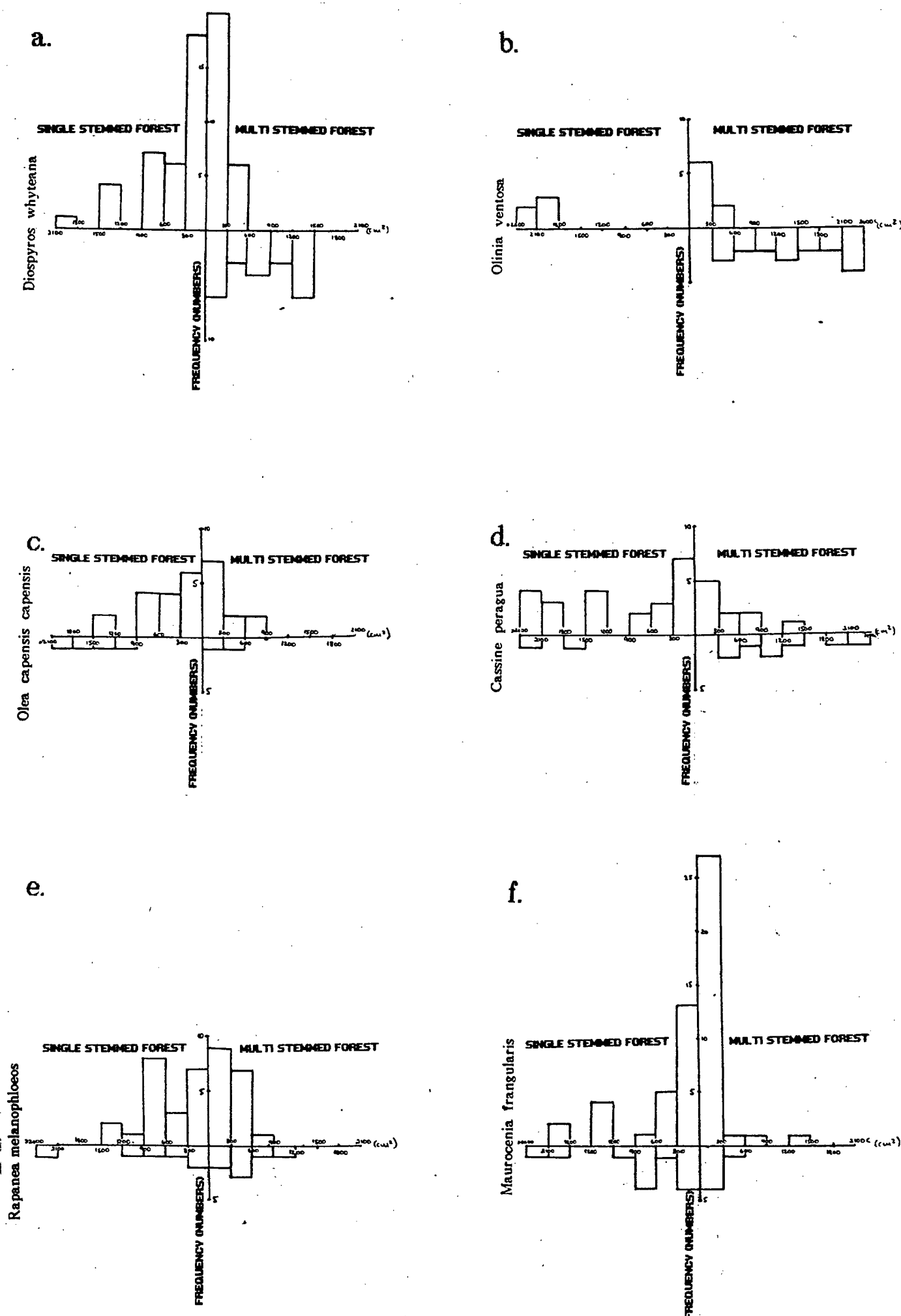


Figure 4: Within species basal area comparisons. The X-axis represents basal area classes at 300cm² intervals. The Y-axis is the frequency and is quoted as the number of individual trees in a defined basal area class. The basal areas of single-stemmed individuals are shown above the X-axis and the basal areas of multi-stemmed individuals are shown below the X-axis.

Discriminant function:	1
Canonical correlation:	0.9612
Functions derived:	0
Wilks Lambda:	0.0762
Chi-square:	27.034
Degrees of freedom:	15
Significance level:	0.02846

Table 2: Statistical information with regards to the Discriminant Analysis done on the forests

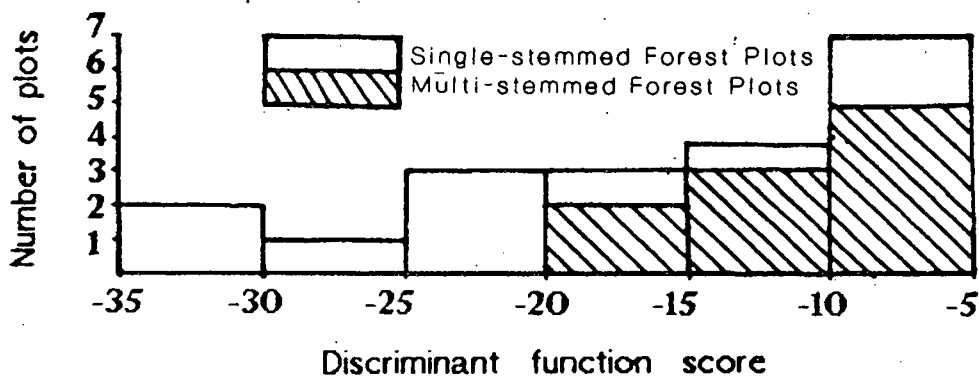


Figure 6: Graphic illustration of the assigned discriminant functions scores of each plot in each forest.

SPECIES	QUALITATIVE Fisher's Exact	QUANTITATIVE	
		Student T-test	Mann Whitney-U test
Canthium inerme			Z=0.0142
Halleria lucida	p=0.005	t=3.16 p=5.408E-3	
Kiggelaria africana	p=0.005	t=4.02 p=7.94E-4	
Olea exasperata	p=0.005		Z=0.024

Table 3: Statistical information for the indicator species which discriminate the two forests

APPENDIX



Single-stemmed forest at Noordhoek (April 1989).



Multi-stemmed forest at Noordhoek (April 1989).



Charcoal remains on tree stumps which occurred in the Multi-stemmed forest at Noordhoek.



ADDENDUM

A small validation study was carried out at Orankekloof, the back table of Table Mountain. This was to determine whether the trends recorded in the SS FOREST and MS FOREST at Noordhoek also occurred in ~~structurally different~~ ^{on different topography} forests at another site.

Two structurally different forests were chosen subjectively at Orankekloof. Sampling was carried out in the same way as at Noordhoek with one exception. Instead of defined plots, the first thirty trees in an approximately ten metre wide strip were sampled.

Four questions were asked about the Orankekloof forests:

1. Are *Podocarpus latifolius* individuals smaller in the MS FOREST than in the SS FOREST?
2. Are the multi-stemmed individuals of *Diospyros whyteana*, *Olinia ventosa* and *Cassine peragua*, in the MS FOREST, bigger than the single-stemmed individuals in terms of their basal areas? ie Do these species reflect the pattern evident at Noordhoek?
3. Can the two structurally different forests be floristically discriminated using the same coefficients used in the Noordhoek Discriminant Analysis?
4. Is *Canthium inerme* more abundant in the MS Forest than in the SS FOREST?

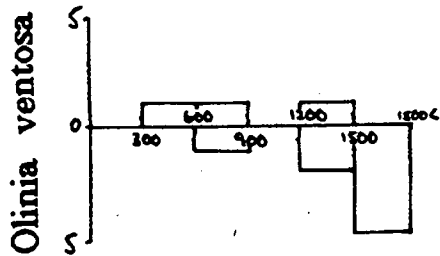
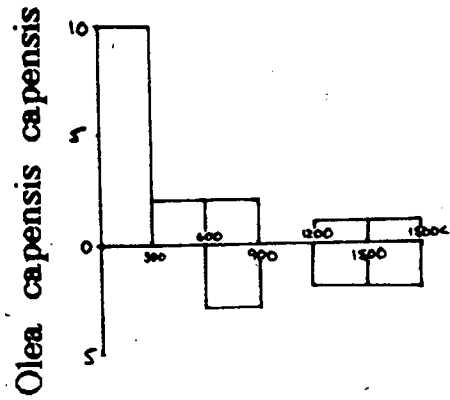
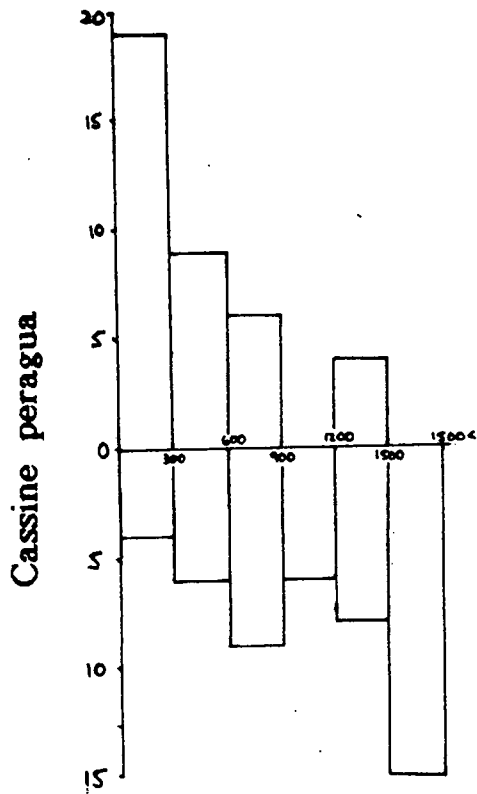


Figure 2: Within species basal area comparisons. The X-axis represents the basal area classes at 300cm² intervals. The Y-axis is the frequency and is quoted as the number of individual trees in a defined basal area class. The basal areas of the single-stemmed individuals are shown above the X-axis and those of the multi-stemmed individuals are shown below the X-axis.

RESULTS

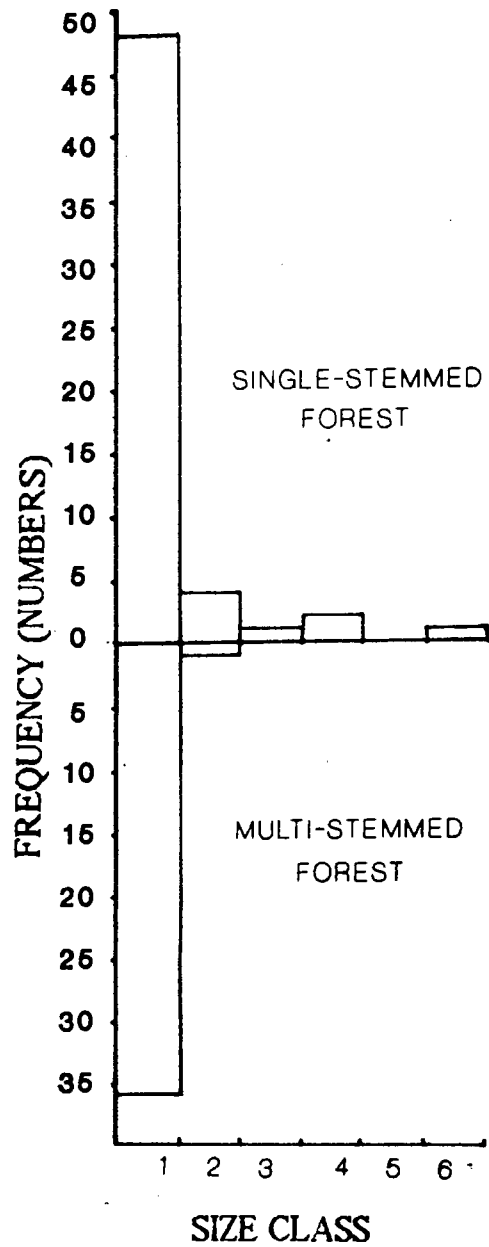


Figure 1: *Podocarpus latifolius* size class frequencies for the SS FOREST and MS FOREST at Orangekloof. (Size class=1-10cm; 11-20cm; 21-30cm etc).

With reference to Figure 3, the two structurally different forests can be discriminated floristically with no overlap in discriminant function scores. This implies that just on the basis of structural differences between the two forests the two forests are floristically different. If one accepts that fire has caused the change in forest structure it follows that this has resulted in a floristic effect on the disturbed forest. It should be noted that not all the species at Orangekloof were included because of the lack of ^{discriminant function} coefficients.

There is no significant difference between the densities of *Canthium inerme* in each forest according to a Student's t-test. This could be an indication that in the time since the fire, competition has played a role in eliminating the difference between the two forests in terms of *C. inerme* densities.

It is therefore suggested that the following criteria can be used to assess whether a patch of Afromontane Forest has been disturbed by fire:

- i. the size in terms of dbh of *P. latifolius* or other fire sensitive species.
- ii. the basal area distribution of *C. peragua*, *Olinia ventosa*, *Olea capensis capensis* and *D. whyteana* if they were present at the time of a fire.
- iii. the fact that two structurally different forests can be floristically discriminated.

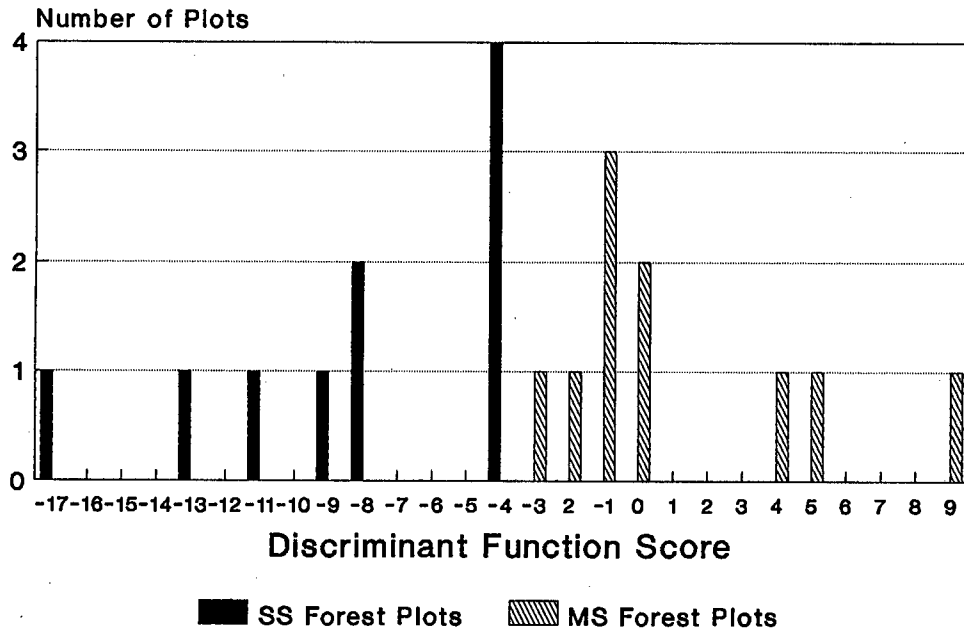


Figure 3: Graphic illustration of the assigned discriminant function scores for each plot in each forest at Orangekloof. (The clear blocks represent the SS FOREST plots and the hatched blocks represent the MS FOREST plots).

There are no large *Podocarpus latifolius* individuals present in the MS FOREST, whereas a few relatively big ones do occur in the SS FOREST (Figure 1).

Diospyros whyteana does not reflect a basal area frequency distribution which exists at Noordhoek. However, many small single-stemmed recruits were evident suggesting that colonization took place post fire. *Cassine peragua* and *Olinia ventosa* have patterns which suggest that fire has played a role in the MS FOREST structure. This is also supported by the basal area distributions of *Olea capensis capensis* (Figure 2).