

**BOTANY HONOURS**

**ECOLOGY PROJECT**

**PARENT DENSITY, TIME OF FIRE AND FLOWER HARVESTING AS  
DETERMINANTS OF SIZE OF FYNBOS PROTEACEAE POPULATIONS.**

**Submitted as partial requirement for the B. Sc. (Hons.) Degree.**

**IAIN GUTHRIE**

**October 1992**

The copyright of this thesis vests in the author. No quotation from it or information derived from it is to be published without full acknowledgement of the source. The thesis is to be used for private study or non-commercial research purposes only.

Published by the University of Cape Town (UCT) in terms of the non-exclusive license granted to UCT by the author.

**Abstract:**

Parent density, time of fire and flower harvesting and other factors were investigated as determinants of size of proteaceae populations in lowland fynbos on the Agulhas plain. Using generalised linear interactive modelling (GLIM) to analyse parent and seedling numbers, it was found that season of fire and parent densities were the major factors affecting post-fire seedling recruitment, fire being the most important factor. The species type, and the interactions between fire time and species type and fire time and pre-fire parent numbers were only minor factors in determining post fire seedling recruitment. Flower harvesting did not seem to have a significant effect on seedling recruitment, but this was attributed to the time of fire. Seedlings were found to be significantly different between the fire areas and this data suggests that seeds from the August fire did not germinate until the following winter.

**Introduction:**

In 1989 an area of fynbos in the Brandfontein Private Nature Reserve was burnt during a controlled fire break burning programme. These fires were used to burn an estimated area of 0.52 km<sup>2</sup> and occurred in areas adjacent to each other. The first fire took place on the 20 July and the second on the 10th August 1989. As these areas had 16 year old vegetation which contained an (almost) identical species composition, similar seedling regeneration was expected, however it became apparent that, despite the temporal closeness of these fires, regeneration after the July burn was more successful than regeneration after the August fire.

This situation causes many questions to arise concerning the nature of seedling regeneration, particularly of the overstorey proteaceae. The main problem that arises is why there is a noticeable difference in the regeneration of seedlings after the two fires. Some regard fire season as an important factor affecting the regeneration of fynbos, because fires in different seasons can have markedly varied

effects on the fynbos communities (van Wilgen, et al. 1990). Serotinous Proteaceae that are killed by fire have been shown to have maximum seedling recruitment after late summer and early autumn fires while burning outside this period produces fewer seedlings per parent in post fire recruitment (Bond et al. 1984; van Wilgen & Viviers 1985). Bond et al. (1984), show that winter and spring burns lead to very poor seedling establishment which are mostly well below replacement levels.

The fires investigated in this project took place in winter, perhaps explaining the poor seedling establishment in both fires, but the question of why there was such a marked difference in the recruitment successes is not answered satisfactorily. Hobbs & Atkins (1988) found that only in a very intense fire caused by heavy fuel loads was a uniform fire treatment experienced and have suggested that fire variability may be important in determining post-fire vegetation response, especially where temperature - dependent germination or cone-opening occurs.

If the difference in recruitment was due to differences in pre-fire parent densities, then can this be tested? Bond et al. (1984) found that the number of seedlings per pre-burn individual (parent) varied greatly from fire to fire. This variability was partially explained by pre-burn densities, but the explanation did not explain all the variance. Midgley (1988) found that parent density contributes minimally to seedling/parent ratios, but is sometimes significant, within season of burn.

An additional aspect that is considered in this project is the effect of harvesting of *Protea* inflorescences and *Leucadendron* infructescences for utilisation by the wild flower industry. While inflorescences and infructescences had been harvested for a number of years prior to the fires, in *Aulax* the inflorescences were not harvested. *Aulax* then may serve as a control to determine the effects of flower picking on seedling regeneration. This effect of harvesting inflorescences and infructescences is a factor that has been shown to affect the seed set of parent plants. Did this play a role in the poor regeneration after the fires at Brandfontein? Mustart & Cowling (in press), found that harvesting of inflorescences and infructescences reduced the following seasons inflorescence and infructescence production. Also they found that

harvesting caused increased insect predation levels in current year infructescences harvested and an unaltered or lower seed set relative to unharvested plants.

Whether success in the germination of seeds after the fires was linked to climatic factors needs to be considered. To a large extent the germination of seeds after a fire ties in with season of burn and may effect the subsequent seedling recruitment. Is the poor seedling recruitment due to poor germination? Mustart & Cowling (1991) tested the ability of proteaceae seeds to germinate at different temperatures, finding that current year seed had more than 90% germination at 10/20 °C and 10/10 °C while negligible germination was recorded for 15/30 °C.

The effects of rainfall on the germination of seeds after a fire need also be considered.

Bond (1984) has shown that the seedling stage is the most vulnerable to such factors as drought, predation and competition. It is thus necessary to attempt to consider if the poor seedling recruitment was due to post fire seedling mortality

This study thus investigates the effects of two winter fires (spatially adjacent, but temporally different) on the regeneration of *Protea compacta* R. Br., *Leucadendron laureolum* (Lam.) Fourc, and *Aulax umbellata* (Thunb.) R. Br. after the fires. These fires occurred in late winter and thus seedling recruitment was poor, however the 3 weeks gap between fires provides a good opportunity to test the significance of fire season on the regeneration of Proteaceae.

## **Methods:**

### **Species Studied**

To assess whether there is a significant effect of fire on the regeneration of Proteaceae at Brandfontein, three species of dominant overstorey proteoids in the community were selected. These were; *Protea compacta* R. Br., *Leucadendron*

laureolum (Lam.) Fourc, and *Aulax umbellata* (Thunb.) R. Br.. Adult plants of these species were present throughout the fire areas, but were destroyed in the two fires. Three years later the adult plants were still intact and counts of adult numbers could be taken.

### Study Area

The study area was situated in the Brandfontein Private Nature Reserve (34° 46'S, 19° 51'E) , which forms part of the coastal lowlands of the Agulhas Plain. In each of the two fire areas, three sample sites of 100m x 100m were selected and labelled as sites 1, 2, & 3 and sites 4, 5, & 6 respectively (See figure 1). The three sites in each fire area served as pseudo-replicates

Sampling was conducted in three year old proteoid fynbos in the following manner. In each site the pre-fire adult numbers were counted for the three species of Proteaceae being studied. Then 50 1m x 1m quadrats were taken randomly for the following conditions in each site:

- a) Under dead *A. umbellata* male parent plants.
- b) Under dead *A. umbellata* female parent plants.
- c) Under dead *P. compacta* parents plants.
- d) Under dead *L. laureolum* male parent plants.
- e) Under dead *L. laureolum* female parent plants.
- f) In open areas where parent plants are absent.

To test if there was a significant difference between seedlings in the two fire areas 60 seedlings of each of the three species being studied were harvested in march 1992. Only the above ground portions of the plants were harvested. The length, mass and number of leaves per harvested seedling were then taken for each seedling.

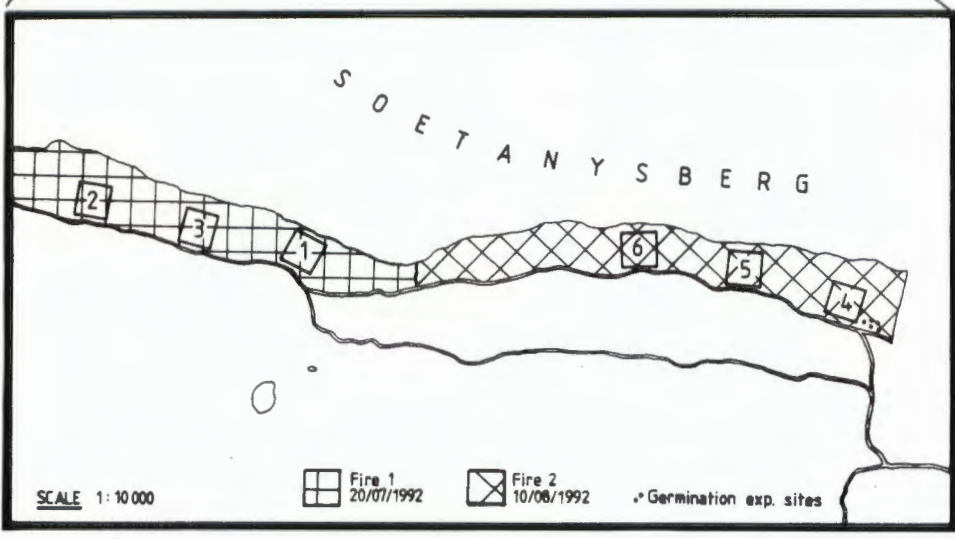
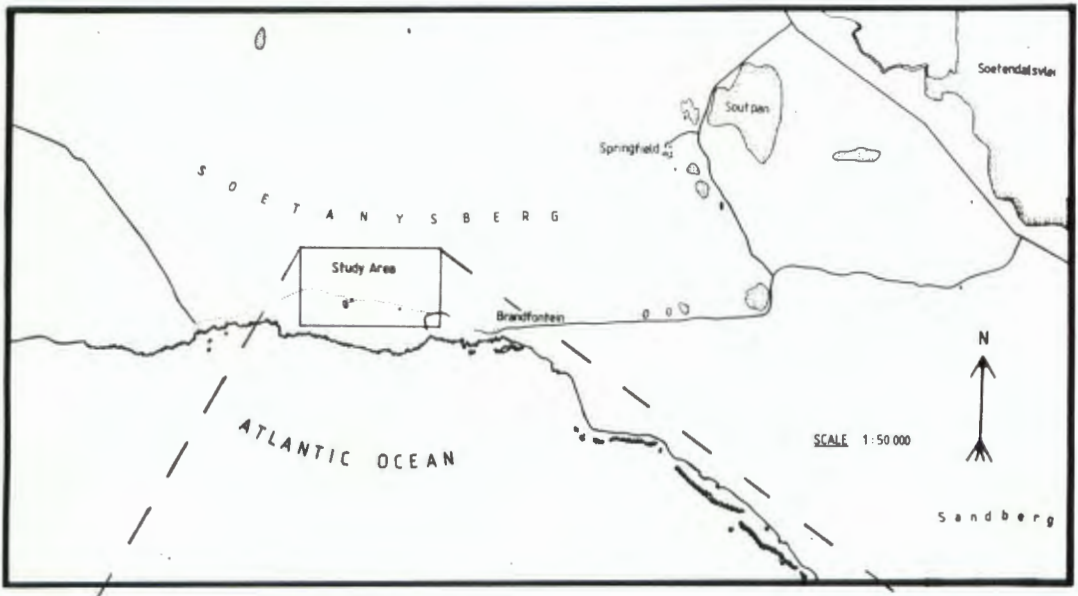


Figure 1: Maps showing the location of the study area and the study sites at Brandfontein Private Nature Reserve.

To test if there had been differing germination successes due to climatic factors after each of the fires, germination tests were conducted. Perhaps there had been some sort of germination cue for seeds which had allowed the seeds from the first fire to germinate, but not those of the second fire. For the germination tests, five 1m x 1m plots were selected near site 4 and cleared of all vegetation. In each of these plots 20 seeds of each species studied were planted on the following dates:

- 1) 2 May 1992
- 2) 20 June 1992
- 3) 1 August 1992
- 4) 5 September 1992
- 5) 4 October 1992

Seeds collected for these germination tests came from adult Protea, Leucadendron and that were located in the same local population situated near site number 4.

The monitoring of germination of seeds started on the 20 June 1992 and occurred on the above planting dates. In this way cumulative germination data was obtained.

Rainfall figures for the Agulhas area were obtained from the Meteorological Office at D.F. Malan Airport for 1989/1990 and for 1992 so that the effects of rainfall on seedling germination might be considered. These data are presented in figure 1.1.

### Statistical Analysis

As count data often reflect a non-normal distribution, generalised linear interactive modelling (Baker and Nelder 1978) statistical package: GLIM, was used on the seedling and pre-fire parent data for the sites in each fire area. This method avoids the assumption of normality in parametric statistics. Log-linear models were fitted to the seedling and pre-fire parent data (count data) using Poisson error distributions and a log link function. The final model was selected by using partial and marginal effects. The effects of fire, pre-fire adult numbers, species type and

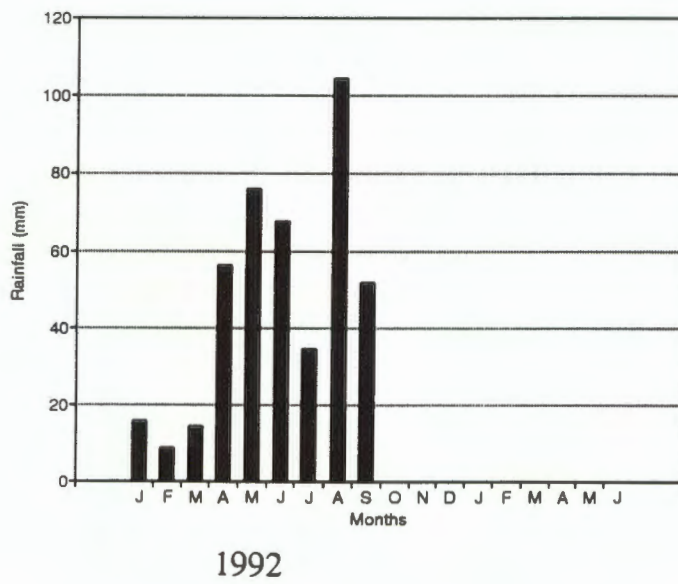
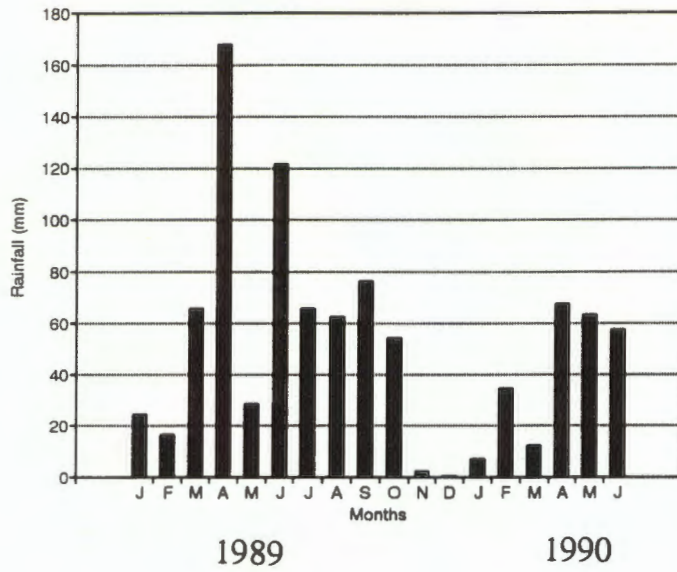


Figure 1.1: Graphs showing the rainfall at Agulhas for 1989/1990 and 1992.

interactions between species type and fire and species type and adult numbers were incorporated into the model. An overdispersion parameter was introduced where the variation in the data was more than that described by Poisson distributions.

In order to determine if there were significant differences in seedlings harvested from each fire area a two-way analysis of variance was used. This was used because of the unusually distributed data. Fire, species type and fire/species type interactions were used as factors for the independent variables; the number of leaves, length of shoots and mass of shoots.

The germination data was recorded in graph form showing germination success in percentages after the number of days since planting.

## **Results:**

The total numbers of adult plants counted in each site ( $10\,000\text{m}^2$ ) and the numbers of seedlings counted for the  $300\text{m}^2$  sampled within each site are given in table 1. The  $300\text{m}^2$  was derived by adding together the 50  $1\text{m} \times 1\text{m}$  quadrats sampled for the following condition:

- a) Under dead *A. umbellata* male parent plants.
- b) Under dead *A. umbellata* female parent plants.
- c) Under dead *P. compacta* parents plants.
- d) Under dead *L. laureolum* male parent plants.
- e) Under dead *L. laureolum* female parent plants.
- f) In open areas where parent plants are absent

Estimated pre-fire parent/post-fire seedling ratios have then been derived by scaling up the seedling data by 33.3. The table provides a means to compare pre-fire adult numbers with post-fire seedling recruitment.

TABLE 1: A COMPARISON OF ADULT AND SEEDLING NUMBERS

(Adult numbers are per 10 000m<sup>2</sup>, seedling numbers are per 300m<sup>2</sup>)

		<i>Aulax umbellata</i>			
	Site	parents	seedlings	estimated seedlings	estimated parent/
	Number	per 10 000m <sup>2</sup>	per 300m <sup>2</sup>	per 10 000m <sup>2</sup>	seedling ratios
July Fire	1	1848	649	21611.7	1:11.7
	2	1422	559	18614.7	1:13.1
	3	791	329	10955.7	1:13.9
August Fire	4	2250	309	10289.7	1:4.6
	5	2335	183	6093.9	1:2.6
	6	1632	211	7026.3	1:4.3
		<i>Protea compacta</i>			
	Site	parents	seedlings	estimated seedlings	estimated parent/
	Number	per 10 000m <sup>2</sup>	per 300m <sup>2</sup>	per 10 000m <sup>2</sup>	seedling ratios
July Fire	1	320	284	9457.2	1:29.6
	2	188	261	8691.3	1:46.2
	3	508	211	7026.3	1:13.8
August Fire	4	743	104	3463.2	1:4.7
	5	334	102	3396.6	1:10.2
	6	583	74	2464.2	1:4.2
		<i>Leucadendron lauratum</i>			
	Site	parents	seedlings	estimated seedlings	estimated parent/
	Number	per 10 000m <sup>2</sup>	per 300m <sup>2</sup>	per 10 000m <sup>2</sup>	seedling ratios
July Fire	1	604	117	3896.1	1:6.5
	2	471	311	10356.3	1:22
	3	724	330	10989	1:15.2
August Fire	4	260	164	5461.2	1:21
	5	265	199	6626.7	1:25
	6	426	139	4628.7	1:10.9

A clear difference was found between estimated pre-fire parent numbers and post fire seedling ratios for *A. umbellata* and *P. compacta*. For the sites in the July fire area *A. umbellata* had estimated parent/seedling ratios of 1:11.7, 1:13.1 and 1:13.9 compared to sites in the August fire area which had estimated parent/seedling ratios of 1:4.6, 1:2.6 and 1:4.3 which represents a large drop in seedling recruitment. For the sites in the July fire area *P. compacta* had estimated parent/seedling ratios of 1:29.6, 1:46.2 and 1:13.8 compared to sites in the August fire area which had estimated parent/seedling ratios of 1:4.7, 1:10.2 and 1:4.2 which also represents a large drop in seedling recruitment. Although there were less seedlings recruited in the August fire area than in the July fire area for *L. laureolum* the parent/seedling ratios rose for the August fire area. It must be noted that the pre-fire parent densities in the August fire area were lower than those in the July fire area and thus the parent seedling ratios showed a net rise from 1:6.5, 1:22 and 1:15.2 in the July fire area to 1:21, 1:25 and 1:10.9 in the August fire area.

The effects of fire, pre-fire adult numbers and species type as well as the interactions between species type and fire and species type and pre-fire adult numbers were determined using a generalised linear interactive model (GLIM) with a Poisson error distribution. These results are given in table 2.

It is evident that fire was the most significant factor which can be used to explain post fire seedling numbers. When fire was incorporated in the model there was a change in deviance of 776.6 from the initial deviance of 1418.4 which explained 54.75% of the variance in the model. This is a clear indication of the importance of fire time. The second most significant factor which can be used to explain post fire seedling numbers was the pre-fire adult (parent) numbers. This brought a change in deviance of 302 which explained 21.29% of the variance in the model.

While the effects of species type and the interactions between species type and fire and species type and pre-fire adult numbers do not have such a large effect upon the post fire seedling recruitment as the effects of fire and pre-fire adult numbers had, their effect was still significant and thus must be included in the model. Together their effect brings a change in deviance of 142.92 which explains 10.08% of the

TABLE 2: ANALYSIS OF DEVIANCE TABLE SHOWING THE EFFECTS OF FIRE, PRE-FIRE ADULT NUMBER AND SPECIES TYPE IN EXPLAINING SEEDLING NUMBERS

Model	Deviance	df	Change in Deviance	Change in df	$X^2$	df
Mean	1418.40	17				
Mean + Fire	641.80	16	776.60	1	682.40	16
Mean + Fire + Adult	339.80	15	302.00	1	323.90	15
Mean + Fire + Adult + Species	283.61	13	56.19	2	256.00	13
Mean + Fire + Adult + Species + Species x Fire	225.24	11	58.37	2	208.00	11
Mean + Fire + Adult + Species + Species x Fire + Species x Adult	196.88	9	28.36	2	179.00	9
	Scale parameter = 19.90			New Scale:	9.899	9

variance in the model. Separately species type brings a change in deviance of 56.19 or 3.9% of the variance, species type and fire interactions bring a change in deviance of 58.37 or 4.1% of the variance and species type and pre-fire adult number interactions bring a change in deviance of 28.36 or 1.9% of the variance.

The final model included all of the above effects and accounted for 86.11% of the variance of the data, leaving 13.89% unexplained. A scale factor of 19.9 was used to make the model fit completely and brought the final  $X^2$  from 179 to 9.899 with 9 degrees of freedom.

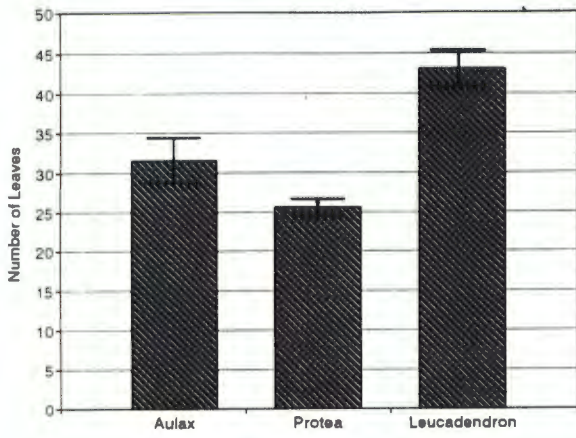
The mean number of leaves, mean length and mean shoot mass for the seedlings harvested in each fire area were calculated with the standard errors and plotted in graph form in figure 2.

The mean number of leaves of seedlings of all species were significantly more for the July fire area than the August fire area. *L. laureolum* always had the most leaves per seedling irrespective of fire time. The length of the shoots of seedlings of all species were significantly more for the July fire area than the August fire area. *P. compacta* always had the tallest seedlings and *A. umbellata* always the shortest irrespective of fire time. Mean shoot masses of seedlings of all species were significantly larger for the July fire area than the August fire area. *P. compacta* seedlings were always the largest and *A. umbellata* always the smallest regardless of fire time. *P. compacta* were disproportionately larger after the July fire.

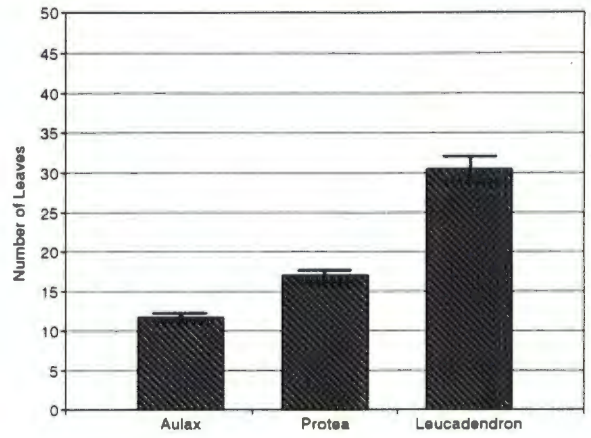
The two-way analysis of variance conducted on to test if there was a significant difference between seedlings harvested in the July fire area and the August fire area showed that there was a significant difference. The results of the analysis of variance are given in table 3. The variation between masses from the July fire area and the August fire area are greater than the variation within the fire areas. This pattern is also true for species type and the species type and fire season interactions. The same patterns are observed for the numbers of leaves and the lengths of seedling shoots.

JULY FIRE

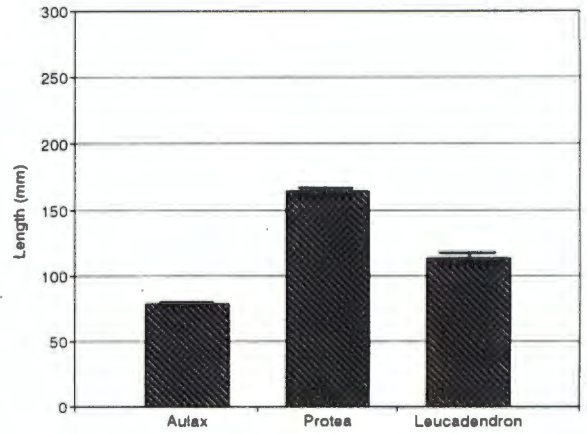
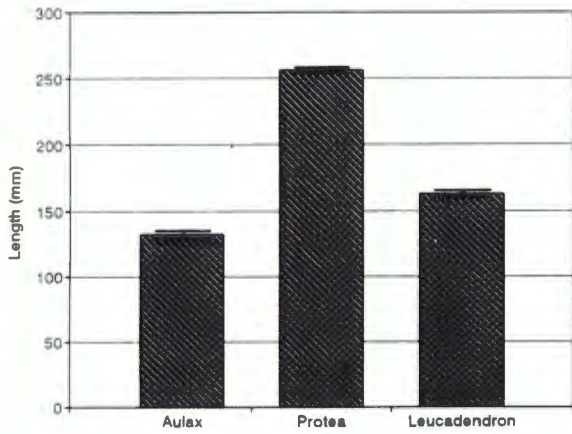
MEAN NUMBER OF LEAVES



AUGUST FIRE



MEAN LENGTH



MEAN SHOOT MASS

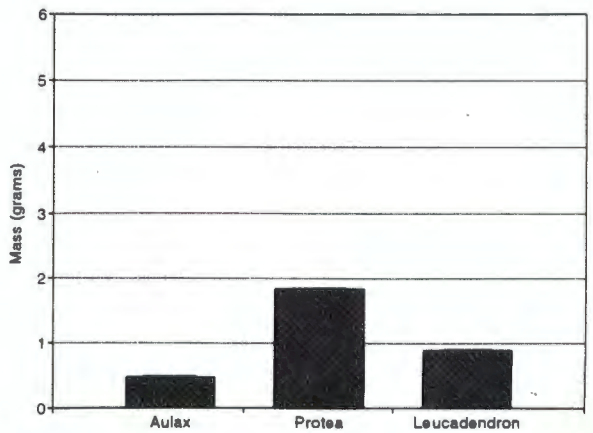
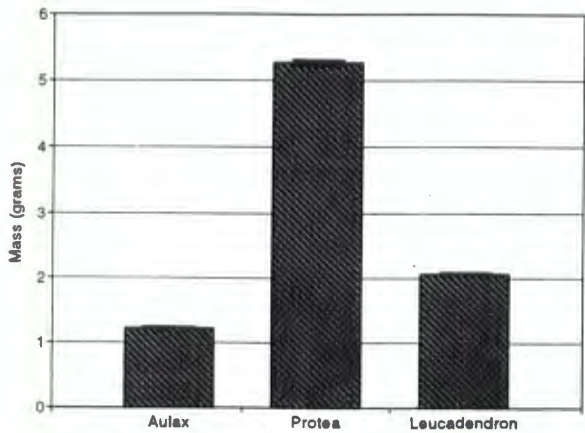


Figure 2: Graphs showing the mean number of leaves, the mean lengths and mean shoot masses (with standard errors indicated on the graphs) for seedlings harvest in the July and August fire areas.

**Table 3: Summary of Two-way analysis of variance testing for significance of differences between seedlings harvested in the July fire area and the August fire area.**


	Fire Season	Species Type	Species Type x Fire Season
<b>Variables</b>			
<b>Leaf Number:</b>	*** 85.71	*** 47.70	* 4.97
<b>Length:</b>	*** 266.69	*** 284.09	*** 257.99
<b>Mass:</b>	*** 95.99	*** 107.35	*** 90.31

\*\*\*  $p < 0.0001$  (Highly Significant)

\*  $p < 0.0075$  (Significant)

The germination results have been graphed from date of first planting to include each observation of germination. These graphs are shown in figure 3. These results are inconclusive as more time is required to test when germination ceases. As the rainfall figures for the 1989 period after the fires are different to those for the same period in 1992, this may have affected the germination results for the germination experiment.

### Discussion:

In attempting to understand  what has caused the differing patterns of seedling recruitment, it has become clear that season of fire is the major and most important factor determining the post-fire regeneration of the overstorey proteaceae in the Agulhas plains. A large and significant difference was clearly demonstrated for the recruitment of seedlings between the July and August fire areas.

Also the GLIM modelling clearly demonstrated that the time of fire in the areas burnt at Brandfontein was the most significant factor affecting the subsequent seedling recruitment after the fires. This was confirmed in the two-way analysis of the data obtained from seedlings harvested in each fire area. Here the results showed that the season of fire was highly significant in affecting the size of seedlings that were recruited after the separated fires.

However while season of fire is seen to be the most significant factor, the GLIM model that was finally accepted was complex and many other factors were also responsible for affecting the subsequent seedling recruitment after the fires. The pre-fire adult number was also a major factor (not as great as that of fire) which accounted for much of the variance in the data analysed in GLIM. This means that the number of parents before the fire is to a large extent responsible for the number of seedlings recruited after the fire. This factor however is in a sense fire dependent as a 'bad' fire which results in poor seedling recruitment will to a large extent negate the benefit that might have been gained from high parent numbers. This

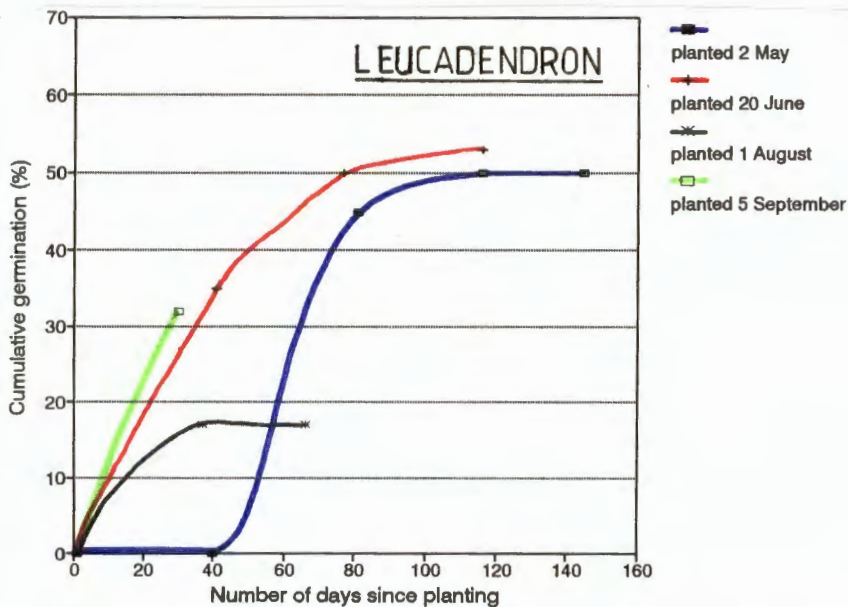
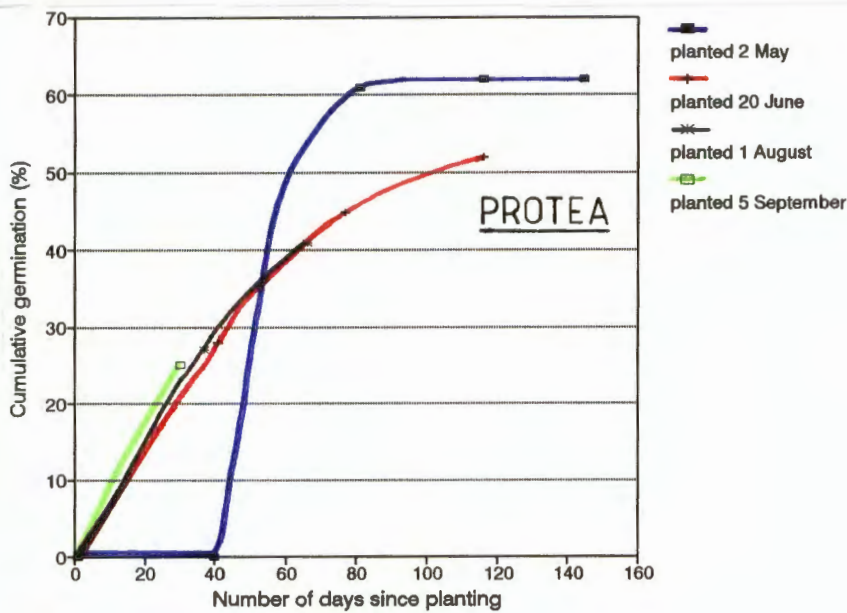
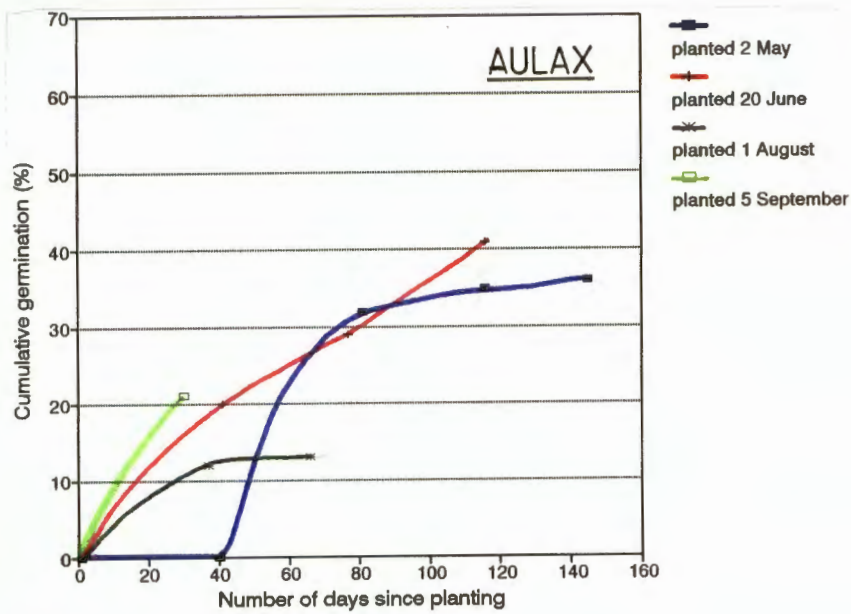


Figure 3: Germination results for *Aulax umbellata*, *Protea compacta* and *Leucadendron laureolum*, showing cumulative germination from dates planted.

seems to be the situation with *A. umbellata* which had the highest pre-fire adult numbers, but the lowest estimated parent/seedling ratios.

The GLIM model highlights other still significant, but less important factor which play smaller roles in determining the recruitment of seedlings after fire. It is evident that species type plays a role in affecting recruitment. The different species (or in fact the different genera) dealt with in this project **do** react in different ways to fire. *A. umbellata* had the lowest estimated parent/seedling ratios, even when there were more pre-fire adults than the other species studied. It would then seem that *P. compacta* and *L. laureolum* are better able to recruit seedlings after winter fires than is *A. umbellata*

Also the interactions that occur between species type and fire time and between species type and number of pre-fire adults affect the subsequent recruitment of seedlings after the fires. These factor are small and to an extent overridden by the season of fire.

When considering the question of the effects of harvesting on the recruitment of the different species after the fires, it becomes evident that, although *A. umbellata* was not subject to harvesting as was *P. compacta* and *L. laureolum*, *A. umbellata* had the lowest parent/seedling ratios. Where *A. umbellata* should have had a distinct advantage over *P. compacta* and *L. laureolum* because of higher pre-fire adult numbers the opposite is observed. It then seems that the effects of harvesting of *P. compacta* and *L. laureolum* inflorescences and infructescences cannot be determined by the results obtained in this project. This may be the result of the ability of *P. compacta* and *L. laureolum* to recruit more seedlings per parent after a winter fire than can *A. umbellata*

As the germination results were still outstanding at the time this project was written up, it was not possible to see definite trends in the data. What was expected was that germination would drop off during spring and completely stop over the summer period and resume again when the next winter approached. This seems likely in view of the significant differences in the masses, numbers of leaves and lengths of the harvested seedlings from each fire area, many if not most of the seeds in the

August fire did not germinate immediately after the fire, but waited till the following year before germinating. This seems to be the most likely explanation which complete germination results might suggest.

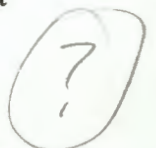
Also the differing rainfall figures for the 1989 and 1992 period may have cause different results to be obtained in the germination experiment and thus make it difficult to suggest that the germination patterns in 1992 would have been similar to those after the fires. What has not been considered is if the germination success after the fire was not affected by the maximum and minimum temperatures experienced after the fires.

That 13.89% of the variance in the data analyses with GLIM was not explained, even though the model did explain such a high percentage of the variance in the data, means that there were other factors not accounted for in the methods of this projects that influence seedling recruitment after fire.

The predation of seeds and seedlings by rodents and the effects of hot, dry summer periods on the seedling survival in the years subsequent to the fires has not been investigated in this project. These factors could explain some of the variance unaccounted for in the GLIM model, but could not be tested. It certainly seems that the poor seedling recruitment in the August fire could be the result of seedling mortality during the hot dry summer subsequent to the fires. The July seedlings may have had an advantage over the August seedlings

### **Conclusion:**

Thus time of fire and parent density are the major determinants of the size of proteaceae populations, fire being the most important factor. The species type, and the interactions between fire time and species type and fire time and pre-fire parent numbers were only minor factors in determining post fire seedling recruitment. Other factors such as rodent herbivory and seedling mortality in the hot dry/need further investigation. Flower harvesting did not seem to have a significant effect on seedling recruitment, as the fire season seems to negate any effect that harvesting



might have had. Seedlings were significantly different between the fire areas and that it seems that seeds from the August fire did not germinate for 6 months until the approach of the following winter, this giving the seeds which germinated after the July fire a 6 month head start.

**Acknowledgements:**

I would like to thank my supervisor Prof. R.M. Cowling for his help with the project design, for helping out with various problems and for commenting in the draft manuscript.

Many thanks to Mr Johan Albertyn on whose farm the project was conducted, Ms Karen Esler who greatly helped me with the GLIM modelling.

I would also like to thank Miss Emma Lee who faithfully assisted with the data collection and the planting of seeds for the germination experiments. Your help and support with this project is greatly appreciated.

**Literature Cited:**

- Bond, W.J.** 1984. Fire survival of Cape Proteaceae - influence of fire season and seed predators. *Vegetatio* 56:65-74.
- Bond, W.J., Vlok, J. & Viviers, M.** 1984. Variation in seedling recruitment of Cape Proteaceae after fire. *Journal of Ecology* 72:209-221.
- Cowling, R.M., Campbell, B.M., Minstart, P.J., McDonald, D.J., Jarman, M.L. & Moll, E.J.** 1988. Vegetation classification in a floristically complex area: the Agulhas Plain. *South African Journal of Botany* 54:290-300.
- Hobbs, R.J. & Atkins, L.,** 1988. Spatial variability of experimental fires in south-west Western Australia. *Australian Journal of Ecology*, 13: 295-999.
- Midgley, J.J.** 1989. Season of burn of serotinous fynbos Proteaceae: A critical review and further data. *South African Journal of Botany* 55:165-170.
- Mustart, P.J. & Cowling, R.M.** (in press). Impact of flower and cone harvesting on the seed banks of serotinous Proteaceae. *South African Journal of Botany*.
- van Wilgen, B.W., Bond, W.J. & Richardson, D.M.** 1990. Ecosystem management. In: *Fynbos Ecology*. ed **Cowling, R.M.** pp. 345-371, Oxford University Press, Cape Town.
- van Wilgen, B.W. & Viviers, M.** 1985. The effect of season of fire on serotinous Proteaceae in the western Cape and the implications for fynbos management. *South African Forestry Journal* 133:49-53.