

**POPULATION ECOLOGY OF *ALOE Plicatilis*  
(LILIACEAE) IN RELATION TO DISTURBANCE**



*Aloe plicatilis* in Western Cape mountains

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**ABSTRACT**

A matrix model was used to simulate the effect of fire and baboon damage on the future population of *Aloe plicatilis* over a period of 150 years (10 fires). The study showed that excluding fires and mechanical damage caused by baboons from the population had a positive impact on the population growth shown by the capability of the population to increase rapidly ( $\lambda=1.2$ ) whereas the inclusion of these factors led to a general decline of the population shown by a  $\lambda$  of 0.7. Survival from fire and baboons was associated with height and the amount of rock surrounding the stem. Thus fire and baboons will tend to eliminate smaller individuals in the population and also those that are partially surrounded by rocks. The corky bark which is thicker in individuals >1m high could act as additional insulation and protection for the stem.

*A. plicatilis* faces serious reduction in population size under prevailing veld fires and baboon damage and this calls for some form of proactive management practices to be instigated. This means carrying out a rescue operation by planting more of this species outside its normal distributional area (ex-situ conservation). Studies on plant responses to disturbances in fynbos should be intensified as well because this will give a general picture of the future health of the plant community of the fynbos biome.

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## 1.0 INTRODUCTION

The Cape Floristic region hosts 8,600 plant species, 5,800 of which are endemic (Cowling and Richardson 1995). More than 1,400 plants from the Cape kingdom's vegetation feature in the Red Data list as being critically rare, endangered, or vulnerable- almost as many as the entire flora of the British Isles (Cowling and Richardson 1995). This region consists of a type of vegetation known as fynbos, vegetation that naturally burns at an interval of about 15 years (Brown et al. 1991). There are a number of plant demographic studies in the fire environment such as the fynbos, particularly of fire recruiting proteoid trees (e.g. *Protea lorifolia*, *P. nerifolia*, *P. repens*, and *Leucadendron sp.*) (Bond and van Wilgen 1996). However, no such studies have been done on non-proteoid species such as *Aloe plicatilis*.

In the fynbos biome, fire is the major disturbance and population studies of proteoid plants have shown that different plant populations respond in remarkably different ways to fire. Some essentially remain stable from one fire to the next while others fluctuate from explosive growth to extinction (Bond and Wilgen 1996). There is a need to determine fire behaviour of other taxa. In this report, I focus on demography of an Aloe.

West (1974) pointed out that aloes vary in fire sensitivity and are habitat specific in relation to incidence of fire. Tree aloes lack a continuous phellogen - the meristematic tissue-giving rise to bark in woody dicotyledons. This is why aloes have evolved various other ways of protecting themselves from fire such as by either maintaining a skirt of dead leaves (*A. ferox*), or by being habitat specific in relation to fire incidences (such as growing amongst rocks) (Bond 1983).

Transition probability matrices are very useful tools for analysing the present causes of population change and also in the prediction of the future structure of a population.

These models, unlike other models, incorporate size or age specific information on survival, growth and fecundity of plant populations with a mixed age structure. These models are appropriate where fires do not kill all individuals (sprouters) or where recruitment occurs between fires so that mixed age cohorts exists (Bond and van Wilgen 1996). Although they are simple to use on microcomputers, they have rarely been used for modelling populations exposed to fire (Bond and van Wilgen 1996).

Research on aloes has focused mainly on taxonomic studies (Hoffman 1988), pollination ecology (Stokes and Yeaton 1995), impact of dead leaves on the survival of aloes (Bond 1983), evolutionary biogeography (Holland 1978), and population ecology of a few non-fire species (*A. dichotoma* and *A. pillansi*), (Midgley et al. 1997). Research on the population dynamics of aloes in general is lacking and is important to note that no such study has been done in *A. plicatilis*. Osho (1991) remarked that it is scientifically sound to look backwards when one wants to search for explanations of the present in the past, to explain systems in relation to their history rather than their goals. He made this statement in the context of forest dynamics and implied that studies of the demography of long-lived tree populations should involve a search for the past influences that have contributed to their present structure. In the same context, on the other hand, 'ecology, if it is to gain maturity as a science, must become predictive ...' and matrix methods were suggested as one of the most promising approaches (Harper 1977). Matrix models were first developed by Lewis (1942) and Leslie (1945, 1948). They are quite simple and require a few assumptions, and they have had many interesting applications (Caswell 1996). They allow us to condense the complexities of age-specific schedules into a simply written but explicit form and are appropriate where fire does not kill all individuals or where recruitment occurs between fires so that mixed age cohorts coexist (Bond and van Wilgen 1996).

This project aims at answering some of the questions relating to the demography of *Aloe plicatilis* species. It uses real data on size classes collected in the field and matrix modelling to examine the effect of fire on the future population of this species.

## **2.0 STUDY TAXON**

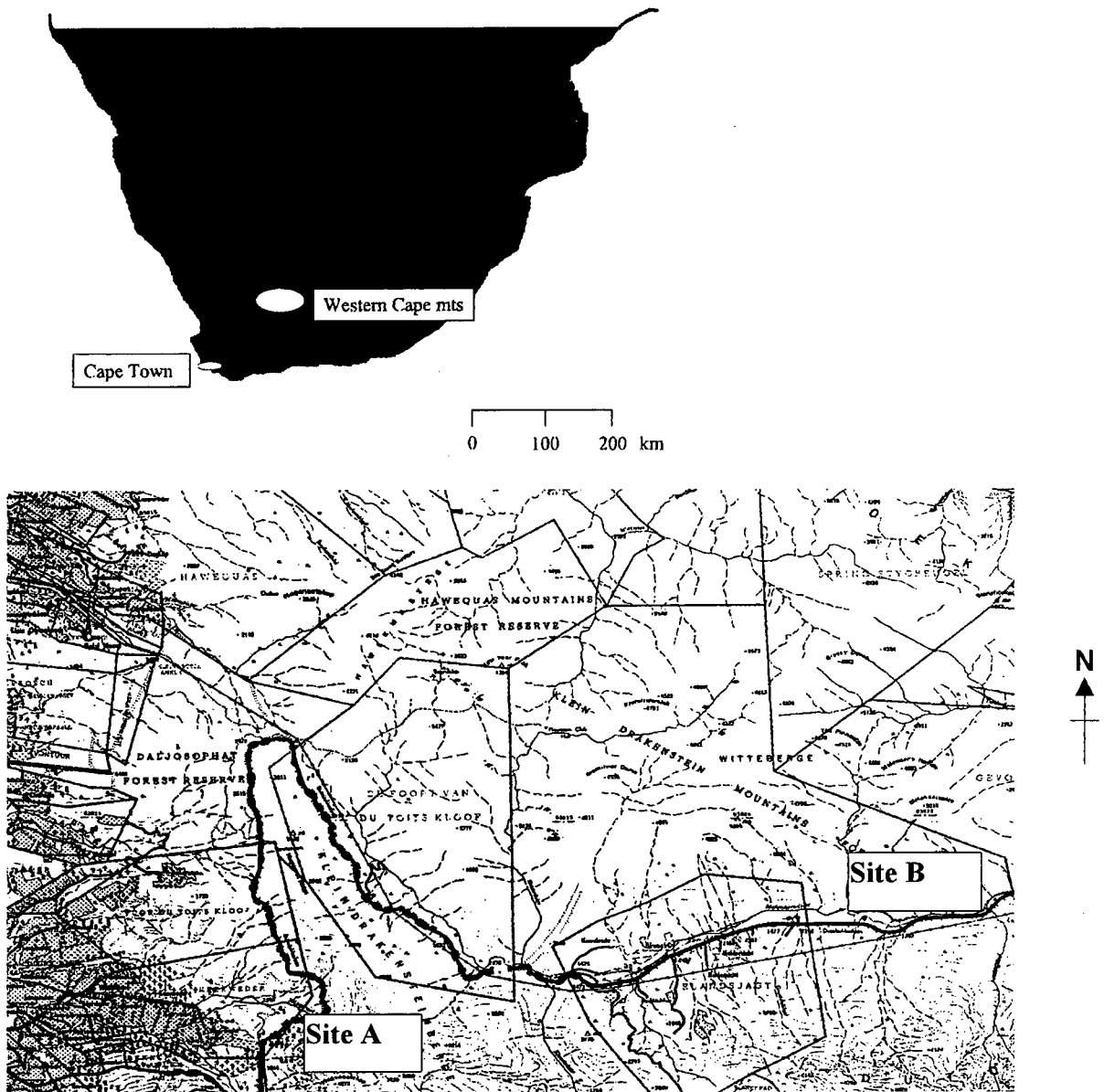
*Aloe plicatilis* (L.) Mill., is restricted to the Western Cape Mountains of South Africa from Franschhoek in the south to Elandskloof in the north (Reynolds 1950). It is endemic to the Western Cape Mountains and forms stands of more than 200 individuals/hectare (personal observation). The population at Du Toit Kloof consists of about 200 individuals while the one at Drakenstein Forest Reserve consists of more than 500 individuals per hectare (personal observation).

## **3.0 MATERIALS AND METHODS**

### **3.1 Study area**

The study was conducted at two sites of the two biggest populations in the Western Cape Mountains. Two populations one the South-west-facing slope of Du Toits Kloof (33° 44' S, 19° 04' E) at an elevation of about 1600ft and on the Drakenstein mountain Forest Reserve (40° 43' 30" S, 19° 10' 30" E) were studied (Fig. 1). The population at Site A (Du Toit Kloof) was studied for relationship between baboon and fire damage with plant height. This area experienced a veld fire about three years, previously, which led to the death of most stems. The whole population was sampled.

The population at Site B (Drakenstein mountains Forest Reserve) was also used as a comparison. Here baboon damage was minimal and previous fire was about 8 years. No dead individuals were found in this area. The population has not been subjected to veld fires for some time ( $\pm 8$  years) demonstrated by the node counts on Proteaceae. At both sites, the population of *Aloe plicatilis* occurs on rocky, open and gently sloping ground with thin stony soils (personal observation).



Scale: 1:50000

Fig. 1 Locality of study sites. Site A, Du Toit Kloof, Site B, Drakenstein Forest Reserve.

### 3.2 Age estimation

A full understanding of the demography of a species requires a diversity of information on parameters such as dispersal, growth, reproduction, seed-bank and adult persistence (Midgley et al. 1997). Since information on age of this aloe was not available for this study, it was necessary to infer this on the basis of height increment and number of leaves between inflorescences. In many cases individuals were found which retained previous years dried inflorescence, as well as producing a new inflorescence. In *Aloe plicatilis*, when a leaf wilts and falls off, it leaves a ring type scar on the stem (Plate 1). Since on average three leaves were produced between inflorescences, it means that the length of stem of three rings on the stem could give a rough idea of height increment per year. To complement this method, the amount of growth since last fire at Site A was recorded. This site experienced some veld fires three years ago and the height increment since stem blackening of last fire would give us the amount of growth for a 3-year interval that would give us a rough idea of how much growth occurs in one year. To estimate the age of each individual, total height (H) of each individual was divided by the estimated height increment per year.

### 3.3 Plant height and basal diameter measurements

Plant height was measured from ground level to the base of the tallest leaf cluster using a metre rule. For each plant, basal diameter was also recorded. In cases where it was difficult to determine plant height (in dead individuals), inferences were made from a regression equation (1) below;

$$y = 7.8061 + 6.1562x \quad (r^2 = 0.83994, n = 140) \quad (1)$$

Where  $y$  = height of the plant

$x$  = basal diameter

For each area, height –frequency histograms were plotted.

### **3.4 Assessment of death from baboon damage and fire**

In order to assess the effects of baboons and fire on this species, dead stems were visually examined to elucidate causes of its death, and categorized as below;

1. Fire- when the dead stem was charred
2. Baboons- any observable mechanical damage on the stem
3. A combination of the above two factors.

#### **3.4.1 Rock protection from fire**

In order to assess the degree of protection offered by surrounding rocks, the following categories were used;

1. rocks on all sides- if the stem was completely surrounded by rocks
2. rocks on three sides
3. rocks on two sides
4. rocks on 1 side

### **3.5 Plant height and flowering**

In order to find the height at which individuals begin start to flower, the presence of an inflorescence in the current flowering season was recorded.

For ease of computation, individuals were allocated into 5 height classes;



**Plate 1.** *Aloe plicatilis* stem showing rings used in the estimation of annual growth

<u>Class</u>	<u>Height (m)</u>
1.	0 – 0.5
2.	0.5 – 1
3.	1 – 1.5
4.	1.5 - 2
5.	>2

The above size classes were chosen in order to minimize gaps in the data. The demographic datasets used in this study are summarized as appendices 1, 2, and 3.

### **3.6 Model development**

In order to examine the effect of fire and baboons on the future population of this species, an excel spreadsheet model was used. The demographic data set of growth, mortality and fecundity that was used to build this model was obtained from the field. Since it was not possible to study the population for the whole period between fires i.e. 15 years, estimates on fecundities and transitions from one size class to the next had to be done based on the demographic data set which was collected.

A population projection matrix was constructed by pooling all the data for all the stems sampled. Five size classes were used: these are 0-.5m (class 1), .5-1m (class 2), 1-1.5m (class 3), 1.5-2m (class 4) and over 2m (class 5). To construct the following general matrix state vector was first set up with the elements using the numbers of individuals censused in each size class at site B as below;

$$\begin{bmatrix} 113 \\ 86 \\ 34 \\ 11 \\ 25 \end{bmatrix} \quad (2)$$

The above population growth was then represented by a square matrix **A** (5x5) whose rows and columns represented the five height classes:

$$\mathbf{A} = \begin{array}{|c|c|} \hline a_{11} & c_{12} \dots c_{15} \\ \hline a_{21} & a_{22} \dots a_{25} \\ \hline a_{31} & a_{32} \dots a_{35} \\ \hline a_{41} & a_{42} \dots a_{45} \\ \hline a_{51} & a_{52} \dots a_{55} \\ \hline \end{array} \quad (3)$$

where  $a_{ij}$  is the contribution over a unit time interval of stems in size class  $i$  ( $i, j = 1, 2, \dots, 5$ ), and  $c_{ij}$  is the average recruitment per individual aloe in class  $j$ . Assumptions of the matrix model are that any aloe in the population could make one and only one of these moves, that is move to a higher size class  $i$ , remain in size class  $i$  or die in class  $i$ ; that no aloe would regress, that is no resprouting from the base would be allowed during the growth period

### 3.6.1 Calculation of transition probability

The probability of changing from one stage to each of the others was based on growth rates determined from leaf scars. Since the mean for each size class was 25cm, there was a need to promote individuals, which measured 25cm or more to the next size class. In order for individuals to grow to the next size class before the next fire (15 years), they needed to have a growth rate of;

$$25\text{cm}/15\text{years} = 1.67\text{cm/year.}$$

Since the sample mean growth for an individual aloe in a year was  $1.2 \pm 0.25\text{cm}$ ; their probability of growing at the rate of 1.67cm/year was calculated using the normal distribution formula as below;

$$Z = \frac{X_i - \mu}{\sigma} \quad (4)$$

Where

$X_i$ , is a random variable

$\mu$ , is the sample mean

$\sigma$ , is the sample standard deviation

$$Z = \frac{1.67\text{cm} - 1.2\text{cm}}{0.25\text{cm}} = 1.88$$

The Z-value of 1.88 corresponding to a value of 0.45. This value was used as the probability for the aloes in the first four size classes to move to the next class. The fifth size class will have no individuals moving up to class 1 (shrinkage of class five elements to the smallest size class is impossible). The complements of these proportions automatically represent the proportions of aloes that were not promoted during the simulated growth period. Thus  $(a_{ij}) = (1-p_j)$  are the diagonal elements of the matrix A; and  $p_j$  is the probability of the aloes moving from class  $j$  to class  $j+1$  at the end of the growth period;  $1-p_j$  is the probability of aloes remaining in  $j$  at the end of the growth period.

### 3.6.2 Fecundity

Fecundity was estimated from the percentages of flowering in each size class. It was observed in the field that the tallest individuals produces more flowers and that the number of individuals flowering increased with an increase in height. Since absolute fecundity could not be recorded during the short period of the study, it was necessary to estimate it from the flowering data. Thus, a size factor to represent fecundity was assigned to each class as presented in Table1 below;

**Table 1. Summary of values used to determine number of flowering units in each size class**

Class	% flowering	Numbers flowering	Size factor	Flowering units
1	0	0	0	0
2	21	3	.4	1.2
3	50	18	.6	10.8
4	64	21	.8	16.8
5	76	35	1	35
Total no. of units				63.8

To determine the number of flowering units in each size class (Table1), the number of aloes flowering in that class was multiplied by the size factor for that particular class; for example, for class 2 = 3 x .4 = 1.2. This value gives an indication of how many flowering “units” existed. In order to determine the number of recruits from the population, it was necessary to determine how much an aloe could grow for a period of 15year. This was done by multiplying the rate of growth per year (1.2cm/year) with the number of years the plant had to grow, ie;

$$1.2\text{cm/year} \times 15 \text{ years} = 18\text{cm}.$$

This means that in the population sampled, all individuals which measured 18cm or less were considered to be recent recruits, of which there were 35. To allocate recruits to size classes, the total number was divided by the total number of flowering units i.e. 35recruits/63.8 flowering units = .55 recruits per flowering unit. The next step was to determine fecundity in each size class, which was obtained by using the following formula;

Proportion flowering x Size factor x Number of babies

(5)

Fecundity values for each size class are summarised in table 2.

**Table 2. Determination of fecundity for each size class**

Proportion flowering	Size factor	Number of babies	Fecundity
0	0	0.55	0
0.21	0.4	0.55	0.05
0.5	0.6	0.55	0.17
0.64	0.8	0.55	0.28
0.76	1	0.55	0.418

### 3.6.3 Estimation of survival rate

Calculations of survival rates were based on the proportions, which had survived fire at site A. The final matrix **A** was constructed from the data shown in Table 3.

**Table 3. Life table for *Aloe plicatilis***

	<u>Height class</u>				
	1	2	3	4	5
Live aloes	113	86	34	11	25
Proportion moving	.45	.45	.45	.45	0
Proportion remaining	.55	.55	.55	.55	.95
Fecundity	0	.05	.17	.28	.42
Survival rate <sup>1</sup>	.57	.67	.76	.83	.89

<sup>1</sup>Survival rate was determined with the population at Site A

$$\mathbf{A} = \begin{bmatrix} 0.55 & 0.05 & 0.17 & 0.28 & 0.42 \\ 0.45 & 0.55 & 0 & 0 & 0 \\ 0 & 0.45 & 0.55 & 0 & 0 \\ 0 & 0 & 0.45 & 0.55 & 0 \\ 0 & 0 & 0 & 0.45 & 0.95 \end{bmatrix} \quad (6)$$

A second matrix **B** was constructed to incorporate information on the survival from both fire and baboon damage by multiplying matrix **A** by the vector containing survival values as below;

$$\mathbf{A} = \begin{bmatrix} 0.55 & 0.05 & 0.17 & 0.28 & 0.42 \\ 0.45 & 0.55 & 0 & 0 & 0 \\ 0 & 0.45 & 0.55 & 0 & 0 \\ 0 & 0 & 0.45 & 0.55 & 0 \\ 0 & 0 & 0 & 0.45 & 0.95 \end{bmatrix} \times \begin{bmatrix} 0.57 \\ 0.67 \\ 0.76 \\ 0.83 \\ 0.89 \end{bmatrix}$$

$$= \mathbf{B} \begin{bmatrix} 0.31 & 0.03 & 0.13 & 0.23 & 0.37 \\ 0.26 & 0.37 & 0 & 0 & 0 \\ 0 & 0.3 & 0.42 & 0 & 0 \\ 0 & 0 & 0.41 & 0.46 & 0 \\ 0 & 0 & 0 & 0.37 & 0.84 \end{bmatrix} \quad (7)$$

#### **3.6.4 Predictions with the model**

With the above model, the evolution of the stand could now be projected over some period say, 10 fires with  $N_0$ , and the population structure at Site B. The time step for the matrix for this study was equal to 15 years, which is the minimum time period between two fires. A computer model was then used to predict the population over a period of 150 years (10 fires).

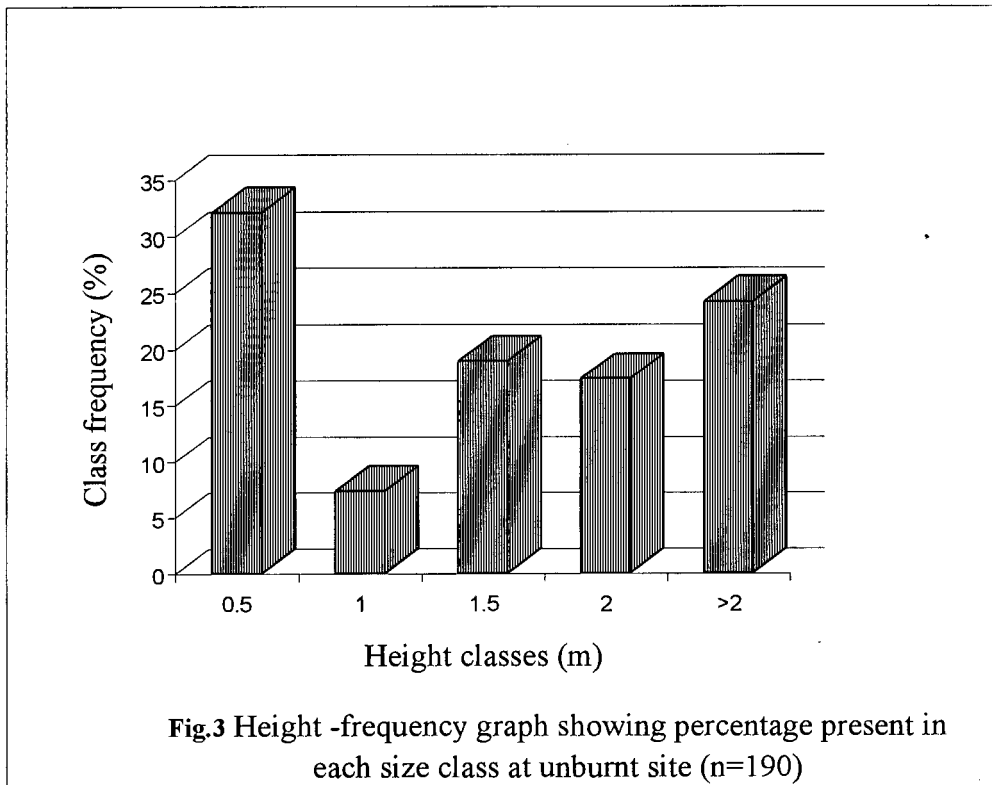
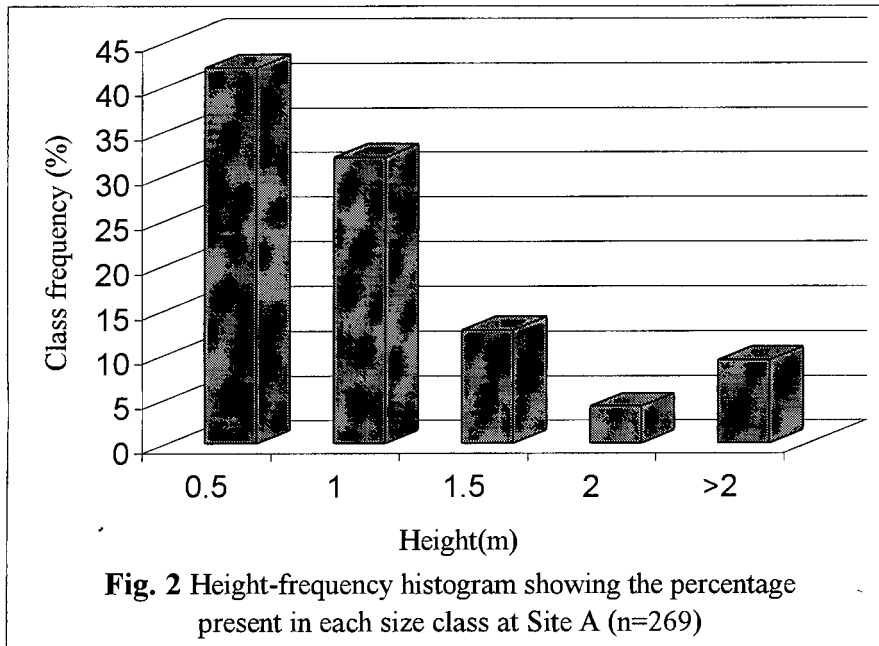
### **4.0 RESULTS**

#### **4.1 Age estimation**

The annual height increment for this species was estimated using two separate methods. In the first method, 3 scars were measured and in the second method, the amount of new growth since last fire on stand A was measured. An estimate of growth from the three scars gave an average growth value of  $1.2 \pm 0.25$  cm/year ( $n=50$ ) while the second method gave a mean value of  $1.23 \pm 1.43$  cm/year. These two methods of estimating the amount of growth per year complemented each other. Assuming that this data gave a fair account of annual height increment of this species, it follows that this species takes about 83 years to grow 1m tall, 167 years to reach 2m ie. they have generally a very slow growth rate.

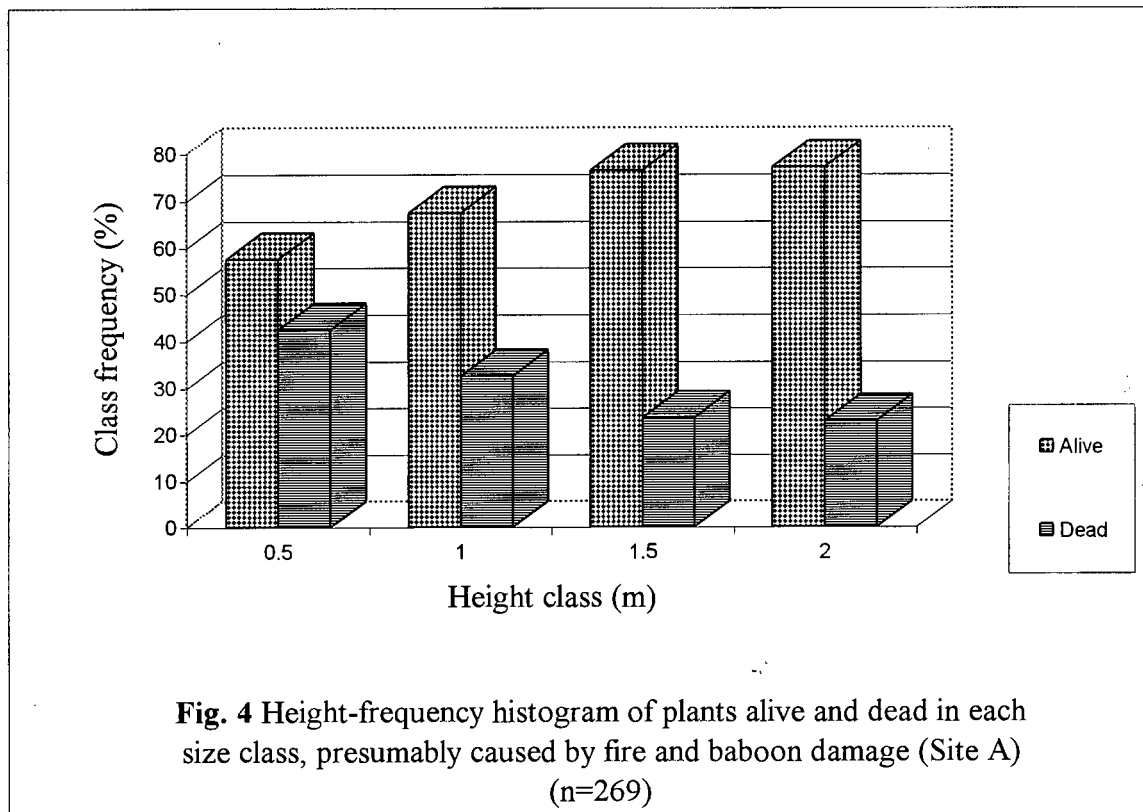
#### **4.2 Plant height and Basal Diameter Measurements**

Plants less than 1m high dominate the Du Toit Kloof population (Fig. 2). The same applies to site B, which also has the largest percentage of plants in the smallest size class (Fig. 3). Plants taller than 1m make up less than 50% of the population at Site A while at Site B it is greater than 50% (Fig. 3).



### 4.3 Assessment of death from baboon and fire damage.

The number of dead individuals decreased with an increase in height (Fig. 5). This reflects the greater susceptibility of young plants to both mechanical and fire damage. As plants grow in height from 0.5m to over 2m, their stems are increasingly protected against fire by a corky bark, which increases linearly with an increase in plant diameter (Fig. 5). When the number of plants that died in each size class was plotted against their corresponding heights (m), a linear relationship between the two variables was found (Fig. 6). The fitted line was computed from the numbers that had died in each size class at site A and it indicates that death of plants decreases with increase in plant height.



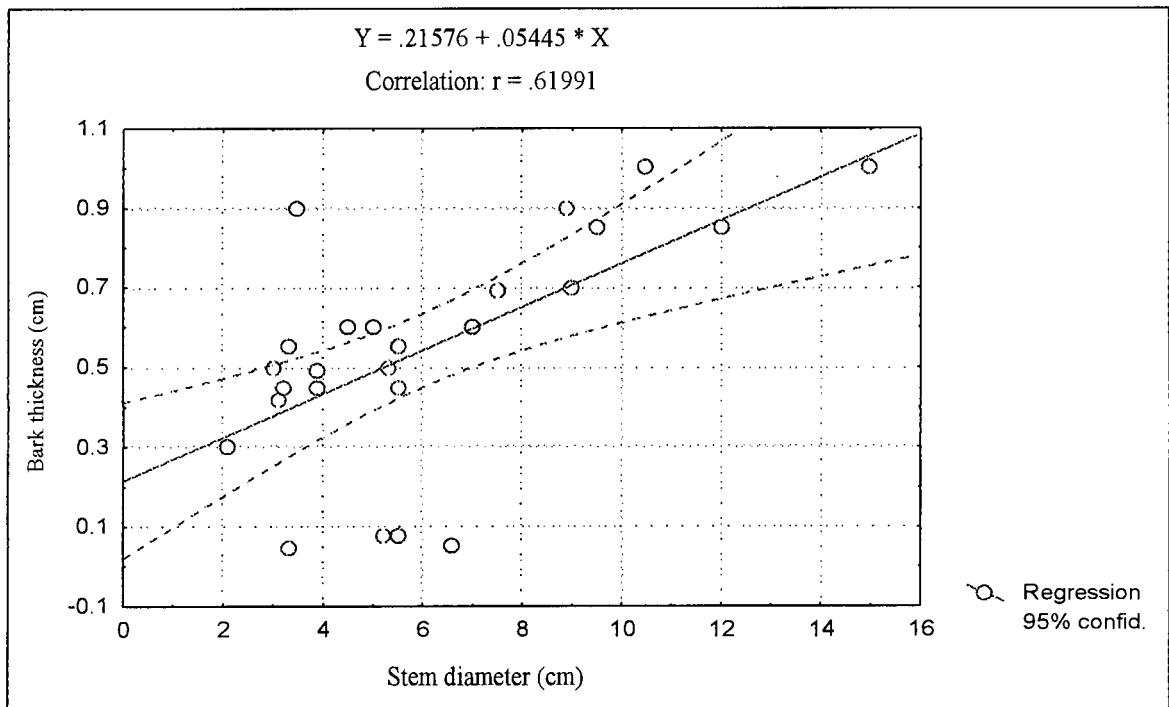


Fig. 5 Stem diameter versus bark thickness for 25 plants at Site A (n=25)

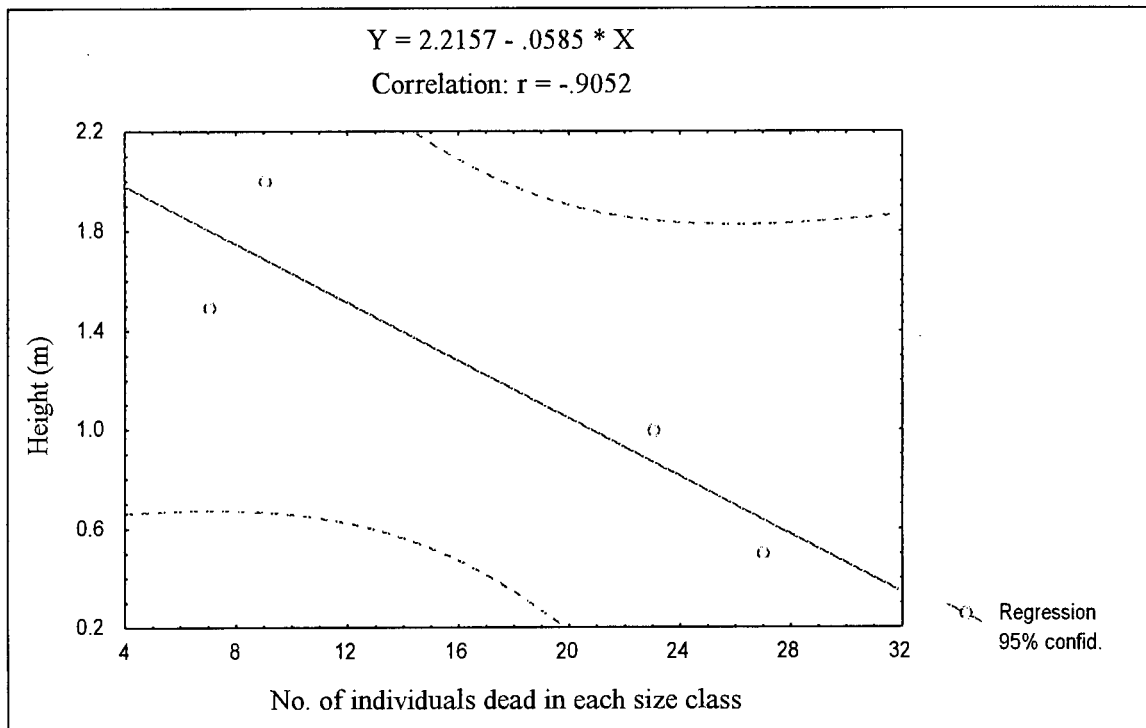
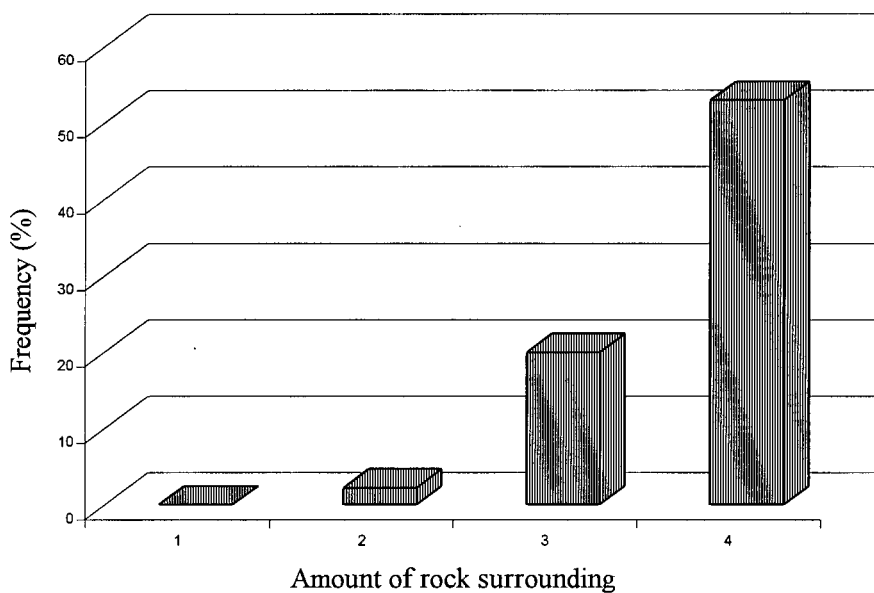


Fig 6. Relationship between plant height (m) and the percentage of individuals dead in each size class (n =4).

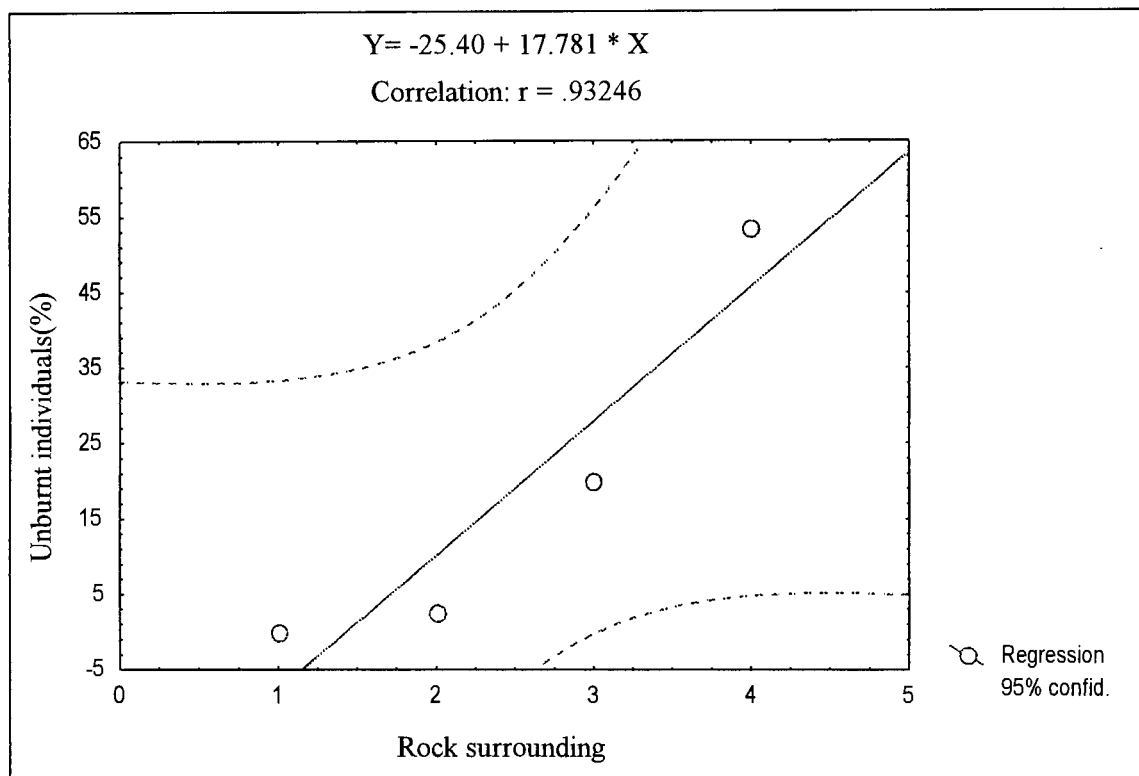
Fire survival appears to be related to the degree to which stems were protected by rocks (Fig. 7). Fifty-three percent of the total number of plants, which were totally surrounded by rocks, were not burnt and this percentage decreased with the amount of rock surrounding (Table 4). All the 17 individuals that were surrounded by rocks on one side had been burnt by fire (Table 4). This can also be supported by the results in Fig. 8, which shows a positive linear relationship between the numbers of unburnt which increases as the amount of rock surrounding.



**Fig. 7** Histogram showing frequency of unburnt stems increasing with an increase in the amount of rock surrounding the stem (n=276) .

**Table 4.** Protection from fire by varying rock surroundings at Site A. (n=276)

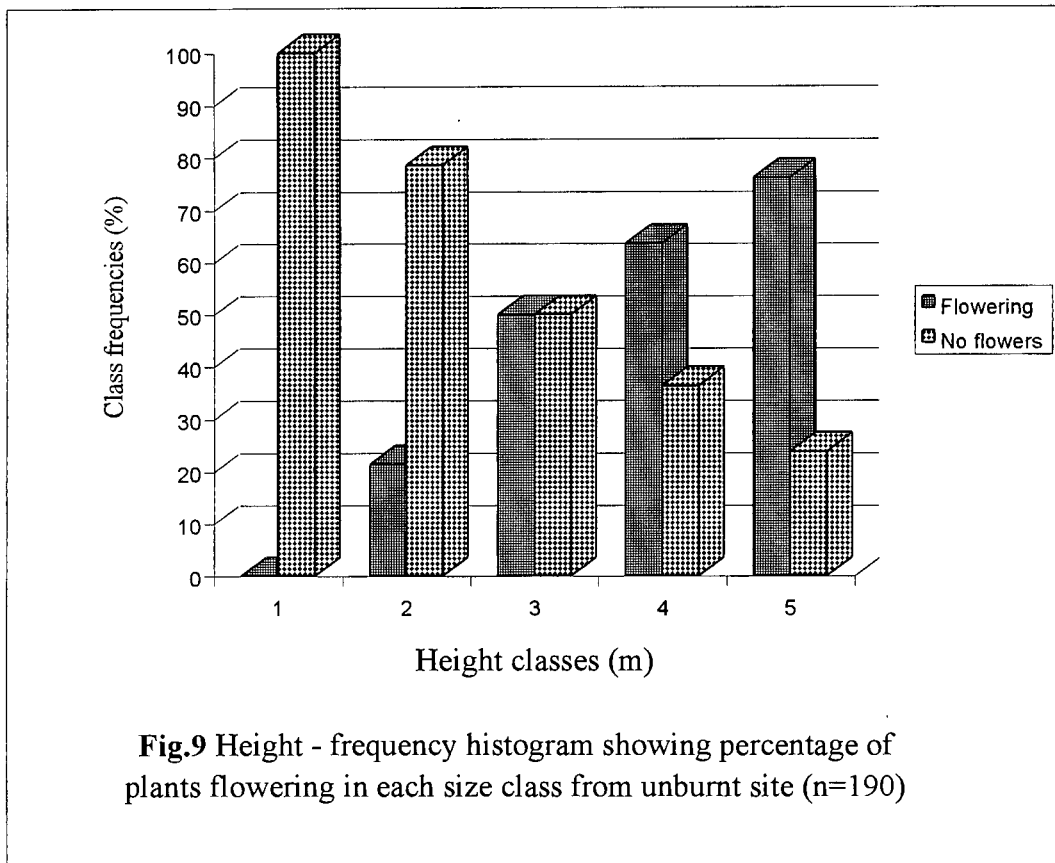
Rock surrounding	Unburnt individuals	Burnt individuals	Total	Percentage of unburnt individuals
4	84	73	157	53.5
3	13	52	65	20
2	1	36	37	2.7
1	0	17	17	0



**Fig. 8.** Relationship between rock surrounding and protection of plants from fire .

#### 4.4 Plant height and flowering

Flowering in *Aloe plicatilis* only starts when the plants are about 1m tall (Fig. 9). Seventy-seven of the 267 observed individuals at site B flowered during the study (Table 5). The shortest individuals to flower were 1m tall (Fig. 9) and only 3 individuals out of 17 in this class managed to flower (Table 5). The number of individuals flowering in this population increased with an increase in plant height (Fig. 9)



**Table 5.** *Aloe plicatilis* flowering at Site B (unburnt site) in relation to height.

Totals	Height classes (m)					
	0.5	1	1.5	2	>2	
No. of plants flowering	0	3	18	21	35	77
No. of plants not flowering	61	14	36	33	46	190
<b>Total</b>	<b>61</b>	<b>17</b>	<b>54</b>	<b>54</b>	<b>81</b>	<b>267</b>

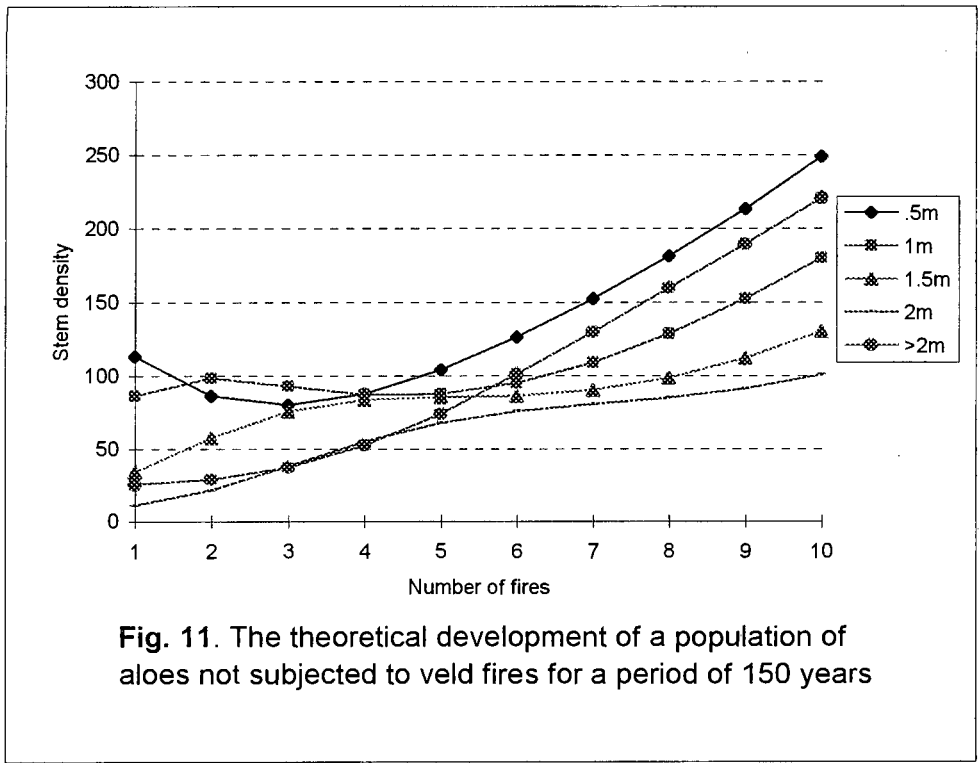
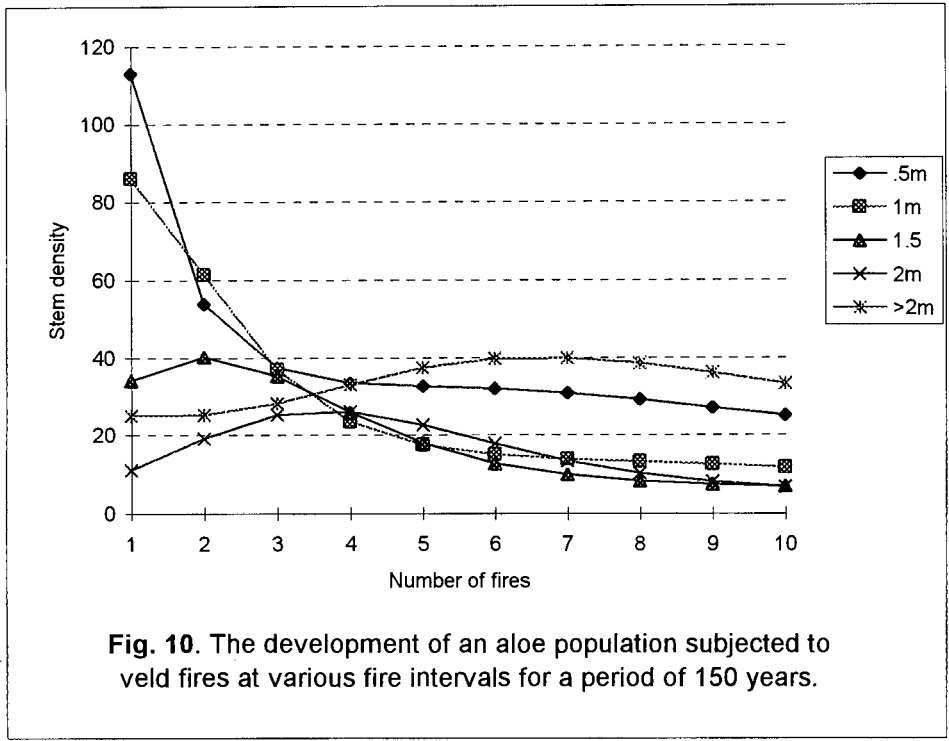
#### 4.5 Results of population projection

##### Stability analysis

The single most important parameter in the determination of population size stability is the dominant eigenvalue ( $\lambda$ ) associated with population projection matrix. A value of  $\lambda = 1$  would imply a stable population;  $\lambda < 1$  would imply that population size was declining and  $\lambda > 1$  would indicate an increase in population size (Osho 1991). The

projected population structures for the two stands are summarized in Figs. 10 and 11. Exclusion of fire and baboon damage has a dramatic effect on the population of *A. plicatilis* in that it leads to an increase in the population size. The dominant eigen value ( $\lambda$ ) associated with the population projection matrix was 1.1. A value of  $\lambda=1$  implies a stable population. Fig. 11 shows the same population exposed to a combination of 10 fires and baboon damage. The population size responds by decreasing in numbers with an increase in fire and baboon damage. The dominant eigenvalue associated with the projection matrix **B** was 0.7., which implies that the population size was declining. Thus, the aloe population represented by the projection matrix **B** would be expected to decline drastically to local extinction 150 years from the present (Fig. 11).

Comparison of the two matrices (6, and 7) also reveals differences in almost every transition in the life cycle. It is evident from these matrices that size classes 4 and 5 make the largest contributions to population growth, where as the smaller size classes contribute very little.



## 5.0 GENERAL DISCUSSION

The lack of basic knowledge of the non-proteoid populations responses to fire and other related mechanical damages such as those caused by baboons makes it difficult to study the dynamics of these species. This study used demographic datasets to feed a theoretical transition probability matrix model in order to contrast the demographic properties of *A. plicatilis* in habitats subjected to veld fires. Eliminating fire from the model results in a rapid growth of the population, while introduction of fire and baboon damage to the model to local extinction by eliminating the smaller size classes. These have shown in this study and also in other species such as *A. ferox* (Bond, 1983), to be more vulnerable to fire and mechanical damage. Although the study showed that classes 4 and 5 are the most important determinants of population growth in either environment, the young produced are more vulnerable to fire evidenced by large numbers of dead individuals censured in the smallest size class. Mortality in the small size classes will strongly influence future survival of the aloe population. Since *Aloe plicatilis* is a slow growing species, most plants are killed by fire before the of about 1m when they acquire a corky bark which like a skirt of dead leaves in *A. ferox*, insulate the stems from heat. Bond and van Wilgen (1996), emphasized the importance of bark thickness to plant survival in fire prone environments. Bark thickness increase with stem diameter, which depends primarily on the age of a species. Thus, fire will tend to prey selectively on younger or smaller individuals and thinner-barked plants within a population (Bond and Wilgen, 1996). In this way, it is analogous to herbivory in selectively killing suppressed individuals (Crawley, 1983). This explains why damage was more prevalent in young stems than in older individuals during the period of the study. Microhabitat factors such as the amount of rock surrounding also appeared to play a role by insulating the stem from fierce veld fires. This property is well supported

in this study by results, which show a negative linear relationship between the number of burnt individuals and rock protection. Bond (1983) reported that heat distribution in fire prone environments is not uniform but rather it varies with height from above the soil surface. Studies in fire prone areas have also shown that fire temperatures are greatest between 0.2m to 1m above the ground. This gives an explanation as to why the small height classes have greater mortality rates than individuals whose above ground heights were more than 1m. According to the model, a minimum fire free period of 83 years is unlikely to enable seedlings to reach an above ground height of 1 m during which they acquire a corky bark for protection against veld fires. In a related study of *Aloe ferox*, Holland and Fuggle (1982) reported that grazing animals and veld fires exert a profound impact on relic population of this species. This seems to be a general feature in the genus *Aloe*, in that in this study of *A. plicatilis*, recruits were also found to be more susceptible to fire and mechanical damage from baboons. In both species, the impact on mature plants is however, less. In concluding their findings, Holland and Fuggle (1982) warned that if such pressures were permitted to persist, entire populations of *A. ferox* could disappear from western Cape Province. As Mason (1936) showed, there is a critical phase in the life history of every plant species when it is particularly susceptible to disturbance. In the instance of *A. plicatilis*, that stage extends from germination until the age of 83 years when the plants acquire a corky bark which has been to protect the stem from fire. In *A. ferox*, this period is shorter i.e. from germination to 10-12 years (Holland and Fuggle 1982). In their study, Holland and Fuggle concluded that *A. ferox* is in danger of local extinction (in spite of it being a wide spread species). Unlike *A. ferox*, *A. plicatilis* has very limited distribution and hence it faces more danger of local extinction and hence a call for its urgent rescue. This model has further demonstrated how some vital information on plant demography

could be obtained rather simply and cheaply. The model has one immediate benefit, which is; a quick estimate of the future health of a standing *A. plicatilis* population and also how fire and baboons can contribute to its extinction in the near future.

## **6.0 CONCLUSIONS**

In conclusion, the study has shown that the future of this species is greatly threatened by further veld fires and mechanical damage. Owing to the uniqueness of this population; as it is an endemic species to this fire prone region, some form of proactive forest management strategies have to be instigated. This means carrying out a rescue operation by planting more of this species in areas outside its normal distributional area (ex-situ conservation) and also by baboon control. The results also suggest several avenues of research. First, studies on plant responses to fire should be intensified and more especially in non-proteoid plants whose up-to-date demographics are lacking. Secondly, this study does not permit other sources of environmental variability such as temperature, and rainfall, which might have pronounced effects on the population as well. The importance of density -dependant issues and competitive effects, which could be important as well, was also not incorporated in this study.

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## 9.0 APPENDICES

### Appendix 1. *Aloe plicatilis* data from Site A. Du toits Klof

Length of stem(cm)	Basal diameter(cm)	Alive/Dead	Baboon damage	Fire Damage	Other (rock surrounding)
12	4.7	A	<50%,	burnt	all
55.21	7.7	D	uk	burnt	3 sides
67.82	9.7	D	uk	burnt	3 sides
42.9	5.7	D	uk	burnt	2 sides
80	11.7	D	>50%	burnt	2 sides
10	4.9	A	nd	burnt	all sides
39	11.5	A	<50%	burnt	2 sides
59	11	A	>50%	burnt	1 side
35	12.5	A	nd	burnt	2 sides
28	7.5	A	nd	burnt	2 sides
29	7.1	D	>50%	burnt	3 sides
45	8.7	A	nd	b	1 sides
9	4	A	nd	b	3 sides
135	34	A	<50%	b	3 sides
37	6	D	>50%	b	3 sides
20	4	D	>50%	b	1 sides
149	36	D	>50%	b	3 sides
29	7.1	A	nd	b	2 sides
150	33	A	<50%	nb	all
74	13.3	A	nd	nb	3 sides
41	5.5	D	>50%	b	
35	6.5	D	>50%	b	2 sides
41	8.7	A	<50%	b	2 sides
92	12	A	<50%	b	1 side
54	11.5	D	<50%	b	1 side
31	6.1	D	nd	b	1 side
62	14	D	<50%	b	2 sides
41	4	D	<50%	b	1 side
41	9.1	A	<50%	b	1 side
46	9.5	D	>50%	b	2 sides
190	28	D	>50%	b	all
15	4.1	D	>50%	b	1 side
73	12.9	D	>50%	b	3 sides
93	15.5	D	>50%	b	3 sides
210	32	A	>50%	b	2 sides
36	4.6	D	>50%	b	2 sides
73	11.5	A	<50%	b	3 sides
31	7.5	D	>50%	b	1 side
18	6	D	>50%	b	3 sides
80	9.9	A	<50%	b	all
73	9.5	A	>50%	b	all
98	21	A	>50%	b	3 sides
195	47	A	<50%	b	all, part of scree
280	45	A	<50%	nb	all, part of scree
290	48	A	<50%	nb	all, part of scree

450	65 A	<50%	nb	all, part of scree
250	15.5 A	<50%	nb	all, part of scree
260	33 A	<50%	nb	all, part of scree
210	31 A	<50%	nb	all, part of scree
220	28 A	<50%	nb	all, part of scree
280	27 A	<50%	nb	all, part of scree
125	21 A	<50%	nb	all, part of scree
13	3.5 A	<50%	nb	all, part of scree
135	20 A	<50%	nb	all, part of scree
280	23 A	<50%	nb	all, part of scree
280	30 A	<50%	nb	all, part of scree
265	31 A	<50%	nb	all, part of scree
220	30 A	<50%	b	3 sides
28	5 A	<50%	b	1 side
40	8.5 D	>50%	nb	3 sides
74	6.5 A	<50%	b	2 sides
57	9 A	<50%	b	all
70	12 A	<50%	b	all
48	8.2 A	>50%	b	all
110	20 A	<50%	nb	3 sides
280	40 A	<50%	nb	3 sides
5	3 A	nd	nb	all
5	3 A	nd	nb	all
5	3 A	nd	nb	all
5	3 A	nd	nb	all
13	5 A	nd	nb	all
145	19 A	>50%	nb	all
210	18 A	>50%	nb	all
190	38 A	<50%	nb	all
135	19 A	<50%	b	all
100	15 A	<50%	b	all
76	12.2 A	>50%	b	3 sides
40	10.8 A	<50%	nb	3 sides
180	14 D	>50%	b	2 sides
110	15 D	>50%	b	3 sides
145	27 A	<50%	b	all
80	10.5 A	>50%	nb	3 sides
155	18 A	<50%	nb	all
90	16 A	<50%	nb	all
320	31 D	>50%	b	all
55	9 A	<50%	b	all
95	14 A	<50%	b	all
38	9.5 A	<50%	b	all
21	7 A	nd	b	all
85	9 A	>50%	b	all
61	6.5 A	<50%	b	2 sides
135	11 A	>50%	nb	3 sides
5	3 A	<50%	nb	all
20	5 A	nd	nb	all
95	11.5 A	<50%	nb	all
145	15 A	<50%	nb	all
150	15 A	<50%	nb	all

245	26 A	<50%	nb	all
150	26 D	>50%	b	all
150	24 D	>50%	b	3 sides
25	2.5 A	<50%	nb	all
115	18 A	<50%	nb	all
95	12 A	<50%	b	3 sides
115	22 A	<50%	nb	all
220	32 A	<50%	nb	all
39	6 A	<50%	nb	all
110	15 A	<50%	nb	all
110	15 A	<50%	nb	all
85	14 A	<50%	nb	all
85	14 A	<50%	nb	all
10	3.5 A	nd	nb	all
5	2 A	nd	nb	all
5	2 A	nd	nb	all
72	15 A	nd	b	all
30	8.5 A	<50%	nb	all
38	6.5 A	<50%	nb	all
100	15 D	>50%	b	all
62	8 A	>50%	b	2 sides
25	5.5 A	<50%	nb	all
41	5.5 D	>50%	b	3 sides
41	5.5 D	>50%	b	all
41	5.5 D	>50%	b	all
40	6.6 D	>50%	b	all
45	10 D	>50%	b	all
50	7 D	>50%	b	all
55	9 A	>50%	b	all
65	10 A	>50%	b	2 sides
125	20 A	>50%	b	all
70	13 A	>50%	b	all
105	14.5 A	<50%	b	2 sides
20	5.5 A	nd	b	all
16	2 A	>50%	b	all
38	5 D	>50%	b	2 sides
5	2.5 A	>50%	nb	all
32	4 D	>50%	b	1 side
70	11 A	>50%	nb	3 sides
70	11.5 A	>50%	b	2 sides
85	7.5 D	>50%	b	all
40	7.5 D	>50%	b	all
110	20 D	>50%	b	all
155	33 D	>50%	b	all
240	22 D	>50%	b	3 sides
240	22 D	>50%	b	3 sides
45	8 D	>50%	b	2 sides
95	11.5 D	>50%	b	3 sides
210	26 A	<50%	b	3 sides
28	5 A	<50%	nb	all
60	15 A	>50%	b	all
75	8 A	<50%	b	3 sides

71	19 A	<50%	b	3 sides
65	12 A	>50%	nb	3 sides
64	8 A	<50%	nb	all
50	10.5 A	<50%	nb	all
12	4 A	nd	nb	all
43	6.8 A	<50%	nb	all
80	9 A	<50%	nb	all
84	12.5 D		100% b	all
225	28 A	<50%	nb	all
130	28 A	<50%	nb	all
40	7.6 A	<50%	nb	2 sides
150	15.5 A	nd	nb	3 sides
5	3 A	nd	nb	all
95	10.5 A	<50%	nb	all
65	8 A	<50%	nb	all
160	42 A	<50%	nb	all
30	6.5 D	>50%	b	3 sides
85	18 D	>50%	b	3 sides
47	10.5 D	>50%	b	all
230	23 D	>50%	b	3 sides
150	27 D	>50%	b	all
175	19 A	<50%	b	all
20	5 A	<50%	nb	all
40	5.5 A	nd	b	all
225	35 A	<50%	b	all
25	6 D	>50%	b	all
45	7.5 A	nd	nb	all
45	7.5 A	nd	nb	all
45	7.5 A	nd	nb	all
45	7.5 A	<50%	nb	all
38	5 D	>50%	b	all
38	5 D	>50%	b	all
38	5 D	>50%	b	all
38	5 D	>50%	b	all
38	5 D	>50%	b	all
38	5 D	>50%	b	all
35	6.5 A	nd	b	2 sides
47	6.5 D	nd	b	3 sides
40	6.5 A	<50%	b	2 sides
40	6.5 A	<50%	b	2 sides
25	5.5 D	>50%	b	all
15	3.5 A	<50%	nb	all
75	8.5 A	nd	nb	3 sides
15	6.5 D	>50%	b	3 sides
15	6.5 D	>50%	b	3 sides
85	13 A	<50%	b	2 sides
41	11 A	nd	b	2 sides
55	12 D	>50%	b	3 sides
55	12 D	>50%	b	3 sides
55	12 D	>50%	b	3 sides
55	12 D	>50%	b	3 sides
55	12 D	>50%	b	3 sides

55	12 D	>50%	b	3 sides
55	12 D	>50%	b	3 sides
15	4.5 A	nd	nb	all
15	4.5 A	nd	nb	all
15	4.5 A	nd	nb	all
50	7 D	>50%	b	3 sides
50	7 D	>50%	b	3 sides
50	7 D	>50%	b	3 sides
80	10.5 A	nd	nb	all
60	9 A	nd	b	3 sides
25	6 A	<50%	b	2 sides
75	10.5 A	<50%	nb	all
75	10.5 A	<50%	nb	all
5	2.5 A	nd	nb	3 sides
50	10 A	<50%	nb	3 sides
82	10 A	<50%	nb	3 sides
85	9.5 A	<50%	b	3 sides
52	8.3 D	<50%	b	1 side
125	20 A	>50%	b	all
261	33 D	<50%	b	all
95	14 D	<50%	b	3 sides
110	18 A	<50%	b	all
25	6.5 D	>50%	b	2 sides
25	6 A	<50%	b	3 sides
130	22 A	>50%	b	3 sides
35	9 D	>50%	b	3 sides
95	19 A	<50%	b	all
55	7.5 D	>50%	b	3 sides
35	5.5 D	>50%	b	all
90	19 D		100% b	all
90	9.5 D	>50%	b	all
90	7.5 D	<50%	b	all
10	3 A	nd	nb	all
124	20 A	<50%	b	3 sides
100	12 A	<50%	b	3 sides
35	5.5 A	nd	b	all
125	25 A	<50%	b	all
200	26 A	<50%	b	all
85	10 A	>50%	b	all
90	11 A	<50%	b	all
27	4 A	nd	nb	all
90	15 A	<50%	b	all
55	15 A	nd	nb	all
80	12 A	nd	b	all
80	12 A	nd	b	all
80	11 A	<50%	b	all
110	14 A	<50%	b	2 sides
90	12 A	>50%	b	2 sides
94	13.5 D	>50%	b	all
34	6 D	>50%	b	2 sides
192	30 A	<50%	b	3 sides
35.4	5.5 D	>50%	b	2 sides

35.4	5.5 D	>50%	b	2 sides
151	25 D	>50%	b	all
112	10.5 A	<50%	b	3 sides
55	6.5 D	<50%	b	2 sides
37	6 D	>50%	b	2 sides
50	9.5 A	>50%	b	1 side
95	14 A	<50%	b	all
55	8.5 A	>50%	b	3 sides
45	6.5 A	nd	b	all
125	25 A	>50%	b	all
38	12 A	<50%	b	1 side
100	10 A	<50%	b	3 sides
15	5.5 A	nd	b	1 side
110	13 D	<50%	b	2 sides
50	7.5 D	<50%	b	all
60	15 D	>50%	b	1side

**Appendix 2** *Aloe plicatilis* data from Site B, Drakestein Forest Reserve

Stem length	Basal diameter	Alive/dead	baboon damage	other	Flowering/not flowering
43	5.7 A		<50%		4 nf
5	1 A		no		4 nf
190	32 A		no		4 f
5	1 A		no		4 nf
5	1 A		no		4 nf
5	1 A		no		4 nf
5	1 A		no		4 nf
5	1 A		no		4 nf
335	20 A		<50%		4 f
175	13 A		no		4 f
150	35 A		no		4 f
8	2 A		no		4 nf
195	27 A		no		4 n,
5	1 A		no	4, 1 sprouter	nf
190	35 A		no		4 f
2	1 A		no		4 nf
55	10 A		no		4 nf
190	55 A		no		4 f
350	50 A		<50%		4 f
250	45 A		no		4 f
290	35 A		<50%		4 f
2	35 A		<50%		4 f
160	11 A		no		4 f
245	45 A		no		4 f
350	53 A		<50%		4 f
220	26 A		<50%		4 f
250	42 A		no		4 f
220	40 A		no		4 f

23	7 A	no		4 nf
26	8.9 A	no		4 nf
12	3.8 A	no		4 nf
350	22 A	<50%		4 f
180	23 A	no	4, 1 sprouting	n
140	38 A	no		f
170	23 A	no		f
150	28 A	<50%		f
150	25 A	no		nf
35	9 A	no		nf
25	9 A	no		nf
25	9 A	no		nf
25	9 A	no		nf
220	49 A	<50%		f
10	2 A	no	4, sprouter	nf
45	10.5 A	no		4 n
135	25 A	no		4 f
220	45 A	no		4 f
250	25 A	no		4 nf
250	25 A	no		4 nf
1	1 A	no		4 nf
300	35 A	no		4 f
350	25 A	no		4 f
110	19 A	no		4 nf
150	20 A	no		4 f
155	40 A	no		4 f
155	40 A	no		4 f
130	30 A	no		4 nf
80	14 A	no		4 nf
45	8 A	no		4 nf
180	35 A	no		4 f
140	40 A	no		4 nf
100	15 A	no		4 f
130	30	no	4, 2 sprouters	f
140	32	<50%		4 nf
140	32	<50%		4 nf
175	25	no		4 nf
140	15	no		4 f
210	25	no		4 f
400	45	no		4 f
130	15	no		4 nf
130	15	no		4 nf
25	5.5	no		4 nf
300	50	no		4 f
200	27	no		4 f
200	25	no		4 f
185	25	no		4 f
200	22	no		4 nf
194	24	no		4 nf
200	40	no		4 nf
20	6.5	no		4 nf
200	40	no		4 f

5	3	no		4 nf
220	31	no		4 nf
35	5	no		4 nf
200	20	no		4 nf
95	17	no	4, 1 sprouter	nf
15	13	no		4 nf
220	33	no		4 f
130	20	no		4 f
252	41	no		4 f
252	30	no		4 f
40	8	no		4 nf
40	2	no		4 nf
2	17	no		4
115	31	no		4 nf
320	30	no		4 f
210	26	>50%		4 f
160	25	no		4 nf
250	30	no		4 f
250	30	no		4 nf
300	40	no		4 nf
230	30	no	4, 2 sprouters	nf
200	30	no		4 f
110	15	no		4 nf
175	25	no		4 nf
40	10	no		4 nf
90	15	no		4 nf
250	25	no		4 f
120	18	no		4 f
250	30	no		4 f
350	30	no		4 f
120	27	no		4 nf
250	30	no		4 f
250	30	no		4 nf
5	3	no		4 nf
180	27	no		4 f
180	20	no		4 nf
180	20	no	2 sprouters	nf
300	45	<50%		4 f
110	23	no		4 nf
100	11	no		4 nf
25	7.5	no		4 nf
45	10	no		4 nf
40	9	no		4 nf
12	3.5	no		4 nf
145	28	no		4 nf
200	25	no	1 sprouter	nf
250	45	no		4 nf
40	8	no		4 nf
20	5.5	no		4 nf
90	12	no		4 nf
105	16	no	2 sprouters	nf
115	17	no		4 nf

100	13	no	4 nf
140	10	no	4 nf
125	25	no	4 nf
130	11	no	4 nf
150	22	no	4 f
30	6	no	4 f
10	5	no	4 f
300	45	no	4 f
200	21	no	4 nf
175	22	no	4 f
9	5	no	4 nf
5	2	no	4 nf
5	2	no	4 nf
5	2	no	4 nf
5	2	no	4 nf
85	9	no	4 nf
220	38	no	4 f
110	13	no	4 nf
180	30	no	4 f
200	31	no	4 f
175	31	no	4 f
10	3	no	4 nf
85	19	no	4 nf
275	50	no	4 f
15	5	no	4 nf
350	35	no	4 nf
250	40	no	4 nf
5	2	no	4 nf
5	2	no	4 nf
120	17	no	4 f
120	25	no	4 f
25	10	no	4 nf
65	14	no	4 nf
45	9	no	4 nf
150	14	no	4 f
145	15	no	4 f
400	50	no	4 f
300	35	no	4 f
130	22	no	4 f
110	15	no	4 nf
120	16	no	4 f
100	15	no	2, sprouters nf
300	35	no	4 f
90	15	no	4 f
90	15	no	4 f
170	33	no	4 f
50	9	no	4 nf
8	5	no	4 nf
250	55	no	4 f
5	5	no	4 nf
5	5	no	4 nf
5	5	no	4 nf

5	5	no	4 Nf
5	5	no	4 Nf
40	6	no	4 Nf
30	8	No	4 Nf
35	10	No	4 Nf
300	35	No	4 F

**Appendix 3.** Data used the estimation of growth per year and also in elucidating the relationship between stem diameter and bark thickness

Length of 3 scars (cm)	Newgrowth since last fire(cm)	No of leaves since lastyears inflorescence	Stem diameter (cm)	Bark thickness (cm)
1.5	2.2	3	3.2	4.5
1.1	4.6	3	3.5	9
1	8	3	10.5	10
0.95	4.7	3	5	6
1.1	2.9	3	7.5	6.9
1.05	4	3	15	10
0.95	4.7	3	3.9	4.9
0.75	5.6	3	5.2	0.75
1.2	5	3	3.3	5.5
1.1	2.7	3	6.6	5.5
1.5	1.9	3	3.3	5.5
1.2	4	3	9.5	8.5
1.1	5	3	3.1	4.2
1.5	3.2	3	7	6
1.2	2	3	5.5	4.5
1.1	2.8	3	4.5	6
0.8	2	3	3	5
1.8	1.8	3	5.5	0.75
1.5	4.1	3	9	7

1.1	3.5	3	12	8.5
0.7	3.1	3	3.9	4.5
0.7	2.6	3	5.5	5.5
0.75	3.1	3	3.2	4.5
1.2	2.6	3	2.1	3
1	3.1	3	8.9	9
1.1	2.6	3	5.3	5
0.9	3.1	3		
0.8	2.4	3		
1.2	3.2	3		
1.1	2.6	3		
1.4	6	3		
1.3	3.1	3		
1.4	6	3		
1.2	4.1	3		
1.2	3.6	3		
1.2	3.4	3		
1.1		3		
1.3		3		
1.4		3		
1.6		3		
1.3		3		
1.3		3		
1.6		3		
1.4		3		
1.5		3		
1.2		2,2,2,2,2,2,2,2		
1.3		2,2,2		

1.1	4,4,4,4,4,4,4,4
1	4
1.3	5,5,5,5,5.
1.6	
1.4	
1.3	