THE PROTEA ATLAS of southern Africa

Anthony G Rebelo (Ed.)

South African National Biodiversity Institute, Kirstenbosch

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(Title Page)

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By whom?

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❧ Silver Tree Award for 1 000 Sight Record Sheets submitted.
❄ Golden Pagoda Award for 200 species atlassed.
✞ Deceased during the Protea Atlas Project (year in brackets).
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Charlie Ruiters, Heidelberg, 19, 77, 29
Gerhard Salvester, Bereaville, 1, 8, 8
Samuel Sampson, Kleinmond, 32, 228, 35
Clifford Sauls, Steenberg, 1, 5, 5
Rionaldi Saunders, Oudtshoorn, 91, 421, 29
Elsa Schaffer, Constantia, 7, 39, 20
Ann Scott, Gansbaai, 1, 4, 4
Gill Scott, Constantia, 4, 11, 11
Martin Scott, Oudtshoorn, 61, 263, 57
Jean Senogles, Westville, 3, 11, 6
Phyll Sephton, Maclear, 1, 3, 3
Sidney Shlomowitz, Parow, 40, 186, 39
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Ruth Smart, Wynberg, 1266 ☙, 5705, 276 ❄
Koos and Jenny Smit, Betty's Bay, 12, 67, 31
Anthony Smith, Rondebosch, 4, 14, 12
Brian Smith, Newton Park, 18, 107, 17
Tim Smulian, Wydgelee, 2, 6, 5
Larisa Smuts, Stellenbosch, 2, 3, 3
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Sandy Smuts, Rondebosch, 334, 1665, 157
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Craig Spencer, Kleinmond, 51, 188, 43
Jeff Spencer, Pinelands, 6, 21, 17
Sarel Spies, Tygerberg, 20, 81, 38
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Marc Stalmans, Nelspruit, 124, 203, 13
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Tommie Steyn, Lydenburg, 19, 39, 10
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Moira Truter, Tokai, 20, 131, 43
Roseanne Turner, Kirstenhof, 2, 7, 6
Ross Turner, Claremont, 13, 21, 5
Jason Valentyn, Robertson, 3, 17, 15
Michael Van Beinum, ***, 3, 9, 8
Eva Van Belle, Fish Hoek, 2, 2, 2
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Harry Van Den Berg, Malkerns, 5, 6, 3
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Cedras Van Der Merwe, Grabouw, 5, 31, 13
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Joseph Vena, Loerie, 1, 3, 3
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Willie Viljoen, Vryheid, 2, 3, 2
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Benjamin Walton, Muizenberg, 14, 35, 15
Paul Waterhouse, ***, 15, 18, 10
Karen Watkins, Newlands, 20, 72, 30
Denise Wedderburn, Rondebosch, 1, 4, 4
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Felicity Weir, Ugie, 2, 5, 3
Brian Wells, Port Elizabeth, 3, 6, 5
Chris and Jo Welman, Newlands, 744, 2544, 163
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Louise Williamson, Mossel Bay, 2, 8, 6
Crystelle Wilson, Durban, 2, 1, 1
Molly Wilson, Diepriver, 3, 24, 16
Jonas Witbooi, Uniondale, 34, 144, 23
Owen Wittridge, Simonstown, 3, 19, 15
Johannes Wolligter, Porterville, 2, 3, 3
Elmien Wolvaardt, Gardens, 6, 34, 15
Julia Wood, Tokai, 5, 6, 3
Steve Worth, Mowbray, 3, 5, 4
Peter Wright, Bredasdorp, 11, 54, 25
Ken Wynne-Dyke, Amanda Glen, 17, 105, 34
Mary Yates, Port Elizabeth, 2, 5, 3
Bonani Yekani, Scarborough, 1, 2, 2
Stefenie Yelenik, Rondebosch, 14, 41, 19
Marilyn Young, Knysna, 1, 3, 3
Gayle Youthed, Grahamstown, 6, 22, 8
Nana Zolbrod, Wynberg, 37, 108, 32

1. INTRODUCTION

Background

The Protea Atlas Project was styled on the successful Banksia Atlas project (Taylor and Hopper 1988), run from 1984-1986. The excellent background, history and evaluation of the Banksia Atlas gave the Protea Atlas a head start: this attention to detail is provided here so that future atlasses can learn can benefit from the experiences of these two projects.

Atlassing probably originated on a national scale with *the Atlas of the British Flora* (Perring and Walters 1962): about 2000 plant species were mapped on a 10 km grid. Since then national various atlas projects have been undertaken, the most popular being the bird atlasses such as those of Australia (Blakers et al. 1984) and South Africa (). Most atlasses focus on providing lists for grid squares. Resolution varies, but is typically of the order of squares of 10-50 km per side. It has been apparent for quite some time that the quarter-degree grid used in South Africa for nationally mapping the flora is inadequate (Rebelo, 1987?riversdale, 1989?vegbook-cow) for both understanding species distributions and conservation planning, especially in the species rich Cape Floral Region. Unlike animals, plants can be repeatedly visited over the order of decades, allowing the possibility of using a observer-based area for recording species present. Developments in computing have bridged the gap between simple compilation of raster lists to point sampling and compiling lists for any mappable unit of larger size. As the Banksia atlassed had pioneered this approach, it made sense to take a fine scale approach and see what sort of coverage volunteers could contribute to the mapping of the flora.

Rationale

<Take from web page and progress reports.>

Scope (objectives)

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Species

The entire Protea family was chosen.

Geographical extent

Southern Africa.

The Record Locality

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2. HISTORY

Background

,

How the Protea Atlas Project was organised and run

,

Recruiting and training

People were recruited by a variety of means. Records were only kept of those who completed an application form. Applicants were sent a recording kit and 2-years of Protea Atlas Newsletters. These included details of courses, and trips. Of the ??? who applied,

Recording kit

,

Data collection and validation

,

Historical data

,

Data processing

,

Data vetting

,

Feedback

Data summary
Newsletters
Web page
Interim Distribution Maps,

Data availability

,

Maintenance and accessibility

,

3. ASSESSING PROTEA ATLAS INFORMATION

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Biases

,

Geographical sampling biases

,

Seasonal biases

,

Current data biases

,

Coverage

,

Evaluation of problems experienced

Superbly guided by Banksia Atlas and its excellent "points to consider for future atlasses"

Identification

Field guide needed from start,

The Sight Record Sheet

,

Core data/optional data

,

Size of Record locality

,

Point versus raster locality references

co-ordinates versus grid squares

Map work problems

,

Locality and altitude resolution

,

Conservation status

,

Altitude

,

Landform

,

Aspect

,

Soils: type and colour

,

Vegetation structure

,

Extent of veld

,

Age of veld

,

Population size

,

Population distribution ,

Flowering ,

New Growth ,

Seedlings ,

Fire survival ,

Picking ,

Average Height ,

Pollinators ,

Recommendations for future Atlasses ,

4. ACHIEVEMENTS AND FINDINGS ,

New Taxonomic discoveries ,

Range Densification ,

Range Extensions ,

Conservation and Red Data List status ,

Taxonomical problem areas ,

Hybridization ,

Variation within populations ,

Atlas efficiency ,

Area ,

Season ,

5. GUIDE TO THE SPECIES ACCOUNTS

Guide to the Species Accounts: Interpreting Protea Atlas Data.

Please read this thoroughly!

Without understanding the definitions, assumptions and limitations of the Protea Atlas Project you cannot validly interpret the data. See "Data Collection and Validation" and "Assessing Protea Information" for further information on the background to the project. Herein we summarize information needed to interpret the data presented in this volume.

Scientific or Botanical Name:

This comprises the genus, species and author of the name and date of publication. Where the species was first described in another genus, the author of the first name is presented in brackets, followed by the author who assigned it to the current genus – in such cases both dates are given.

Technically the current valid name for any taxon (a genus, species, subspecies, variety or form) is the earliest published name containing the name, a brief Latin description of the species and reference to a herbarium specimen (or illustration) which becomes the "type". The Proteaceae were bedeviled by a feud between supporters of Richard Salisbury who published in 1809 and Robert Brown who published in 1810. Brown's supporters – comprising the professional scientists and gentry – claimed that Salisbury – a cantankerous *novo riche* – had sat in on a talk by Brown to the Linnaean Society and rushed into print a plagiarized work. However, Salisbury clearly had a manuscript prepared or in preparation by the time of Brown's talk. The rules clearly give Salisbury precedence, but this was only accepted in the 1930s, requiring extensive revision of names – especially since both Salisbury and Brown described all species then known. Today we use Robert Brown's generic names (which have been given a "conserved" status, despite not being first) and Richard Salisbury's species names. Some authors have argued that Brown's generic delimitation was better than Salisbury, but apart from *Leucadendron* it is Salisbury's generic concepts that are in use today for Cape Proteaceae.

Common English Name:

The most popular name in use: the official common name.

Common Afrikaans Name:

The most popular name in use, if any: the official Afrikaans common name

Other Common Names:

Other names encountered by atlassers or published in the literature. Many species have many different common names and these may vary from region to region or refer to different species in different regions. We have not discriminated between correct and inconsistently used names in the belief that local names arise spontaneously and often have charm and intimacy not found in the official names. We do not consider them less correct or legitimate than the official common name. We regard common names as proper nouns and not collective nouns and have therefore capitalized them appropriately. The are presented in the sequence English, Afrikaans, German, and other.

Other Scientific Names:

Older and invalid scientific names. These may be because an older name exists for the same taxon, or because of a technical fault with the publication (e.g. no type specimen, no Latin description, not validly published). Where the authors are in brackets they assigned the species to another genus. The dates are for the author who named the species.

Listings of names reassigned to older or current genera are not given (technically in Botany the two names are separate entities). For instance, *Protea lagopus* Thunberg 1781, *Paranomus lagopus* (Thunb.) Salisbury 1809 and *Nivenia lagopus* (Thunb.) R. Br. 1810 are all different names based on the same type and description. Because the species name is identical to the current name, none of these will be listed as synonyms.

Sample size

The sample size is the total number of record localities for the species, and is an index of both the abundance of the species and of recording effort. Sample sizes are repeated for data below, as they often include only subsets of the data. For instance, planted records were excluded for habitat descriptions, but were used for species specific information such as flowering, growth and height.

Note that atlas data are often highly pseudo-replicated: thus for a given area, month or habitat, the data may be highly temporally and spatially clumped. For example, most of the data for a month from a region could have arisen from a single weekend's hike on a trail. This is not optimal as local idiosyncrasies can bias results: the ideal would be if the records were scattered all over the region over the entire month. Bear this in mind when interpreting the data.

DEMOGRAPHY

The population size of a species has many implications for its biology. For example, species comprising very small populations may have inbreeding problems. This may result in the loss of genetic variability so that the species becomes very specific in its habitat requirements. This specialization may result in populations which are prone to extinction should the climate change or disease infect them. Species characterized by small populations are often very localized in their distribution and confined to a very few localities. Some more widespread species are also confined to small populations. These species often vary considerably in their habitat and floral or leaf morphology between populations. By contrast, species with dense populations comprising millions of plants, or with sparsely distributed plants in populations covering huge areas are probably relatively resistant to epidemics, climatic change and human interference. The density of plants in these species may reflect competition for water, space or the distribution of disease organisms in the areas.

Most species have a few relatively dense populations, covering a relatively large area (in the core or favoured habitat) and some sparser populations of smaller size (usually peripheral to its main distribution range).

Population:
Called "Population Number Code" on the SRS, or "Population size", this refers to the number of plants within the Record Locality. Seedlings were not included, but young plants were. The codes were defined as follows:

- A Abundant More than 10 000 plants.
- C Common 101 to 10 000 plants.
- F Frequent 10 to 100 plants.
- # Rare 1-9 plants (the actual number seen was recorded, or for those recorded as R, the default value of 5 was entered).
- X Extinct Known localities where plants were absent, or
  - Only dead plants or skeletons seen.

Data are presented as percentages in the order listed above for categories with data only. Only natural populations (see "Planted Records") are included. Repeat data are included.

Dispersion:
Called "Population Size Code" on the SRS, or "Population distribution," this refers to the density of plants within the Record Locality. The codes are defined as follows:

- E Even Uniformly distributed throughout the Record Locality but confined to the Record Locality.
- W Widespread Uniformly distributed throughout the Record Locality but extending well beyond the Record Locality (either into a different habitat or because the habitat exceeds the maximum Record Locality size of 25 ha).
- V Variable Varying conspicuously in density within the Record Locality.
- C Clumped Confined to one or a few localized patches within the Record Locality.

It was found that based on the above definition atlassers used "W" for "V" species when these extended beyond the Record Locality. Although regularly corrected, this bias persisted.
Data are presented as percentages in descending order by code. Only natural populations (see "Planted Records") are included. Repeat data are included.

PHENOLOGY

Due to repeat visits to the same site by certain atlassers, multiple visits to sites by different atlassers, and the volume of data received, it was hoped to be able to compile seasonal patterns of flowering and growth patterns and seedling emergence. These are presented here.

Flowering:
The state of flowering in a species is mainly determined by the time of year, water availability, plant resource levels, and the age of the plant. Different species flower at different times of the year. Whereas some species only flower at a specific season, other species may flower at different times of the year in different areas or at different altitudes. Whereas some species only flower after fires, others may require 1 - 15 years before they produce flowers.
In order to determine the flowering code atlassers first needed to check whether the species stores old flowerheads (infructescences or seedheads) for many years on the plant (serotiny) or discards them before flowering again. Seedheads are not to be considered for determining flowering code. They are easily recognized as they occur on the same branch below the current year's inflorescences.
The unit of flowering is the flowerhead: either conflorescences (flowerheads comprising many inflorescences e.g. *Mimetes, Paranomus, Serruria, Sorocephalus, Spatalla*) or inflorescences (flower heads e.g. *Leucadendron*, *Leucospermum*, *Protea*) on different plants. Atlassers had to determine whether the majority of the con/inflorescences in the population were:

in bud (flowerheads closed or open but no florets open)
open (some florets open, some closed) or
over (all florets open or finished).

Flowerheads may remain as "buds" for many months, stay open for several days to several weeks and remain as over for two to twelve months (any longer than a year and they are considered seedheads). However, it is possible to have a population in which half the flowerheads are in bud and one third are over and the remainder (one sixth) are open and yet the population may never have a larger proportion open. The flowering codes were defined as follows (flowerhead = conflorescence or inflorescence):

- B In Bud Majority of flowerheads in bud. A few may be open but fewer are over than are open.
- F Flowering Flowerheads either in bud or over predominate with some open. All three classes must be present.
- P Peak Flowering Some flowerheads in bud and over but with the majority open.
- O Over Majority of flowerheads over. A few may be open, but fewer are in bud than are open.
- C In Cone All of flowerheads over. None open or in bud. Seedheads with seeds present on plant.
- N Nothing No flowerheads visible either as in bud, open or over. Seedheads absent or having released all their seeds.

Note that the flowering code refers to the total number of flowerheads in the Record Locality. It does not refer to the numbers of bushes or plants in flower! It does not refer to the total number of individual florets! It does not refer to the florets within a flowerhead! Note that "In Cone" and "Nothing" only apply when there are no flowerheads. Note that "In Bud" includes states in which there many be no flowers or flowerheads open. Planted (see "Planted Records") and Repeat SRS are included.

Data are summarized textually and as a graph (see "Interpreting Flowering Graphs"). Sample sizes are presented for each month. Generally at least 10 records are required to have any confidence in the data (ideally these should also not be pseudoreplicates). For each category, the months with over 20% of records are listed. Peak levels are presented as the percentage of records, summed over Peak Flowering, Flowering, In Bud and Over, in the highest-scoring month. The previously published flowering period – usually the latest monograph - is presented for comparison.

Growth:

The period of shoot and leaf growth is a vulnerable period in the protea's annual cycle. Heat, lack of water and herbivores may destroy the young leaves and shoots before they may have had time to expand and harden. In order to protect the young growth, they are often covered by hairs or wax and may be a different colour to the hardened robust leaves and stem. Typically new growth on a stem lasts only a week or two, although plants may produce several growth flushes over the year, and not all branches will produce shoots. However, it was considered too complicated to ask atlassers record more than the presence of new growth. The new shoot growth codes are defined as follows:

- N None No new leaves or fewer than 5% of bushes with new leaves.
- R Rare New leaves on fewer than half the bushes.
- M Much New leaves on more than half the bushes.

Note that the code refers to bushes, not stems. Planted (see "Planted Records") and Repeat SRS are included.

Data are summarized textually and as a graph (see "Interpreting Growth Graphs"). Sample sizes are presented for each month. Generally at least 10 records are required to have any confidence in the data (ideally these should also not be pseudoreplicates). For each category, the months with over 20% of records are listed. Peak levels are presented as the percentage of records, summed over Peak Flowering, Flowering, In Bud and Over, in the highest-scoring month. There is no previously available data on growth phenology for comparison.

Seedlings:

Most protea seeds only germinate following a fire. Any seeds which might germinate at any other time are probably consumed by rodents. However, some species do recruit new plants into the population between fires. These exceptions are poorly known but are probably more common than currently thought. This information is crucial to reserve managers who must decide when to burn vegetation if it appears moribund.

For the Protea Atlas purposes, a seedling is a plant which still has conspicuous cotyledons present near the base of the stem. Cotyledons are the large, flat 'seed-leaves' that are the first to appear when a seed germinates. Note that most seedlings also have young leaves which are often hairy, more curved, smaller, and of a different colour to that of mature plants.

The identification of seedlings is not easy. Only atlassers who had germinated proteas from seeds, or who intimately knew the pre-fire proteas, would have been able to identify different species. The seedlings present codes are defined as follows:

- N None No seedlings of the protea species present.
- R Rare Seedlings fewer than number of parents or skeletons.
- M Many Seedlings more numerous than parents or skeletons.

If atlassers were uncertain as to the identification of any seedlings present then they recorded in the Additional Remarks Box that unidentified protea seedlings were present. The number of parents is the number of adult plants in a mature stand or the number of dead plants after a fire.

Very few records of seedlings were obtained. Seedlings excluded immature or juvenile plants that had lost their cotyledons but have not yet flowered: those atlassers wishing to present seedling to parent ratios for juvenile plants did so in the Additional Remarks Box. It was anticipated that useful seasonal data would be obtained by recording seedlings, but it transpires that many species retain cotyledons for an entire year, so that seasonal data are not particularly useful. Furthermore, few atlassers were able to identify seedlings and data are sparse. Thus seasonality of seedlings is not presented.

Nevertheless, some useful data on seedlings were obtained. These are presented as absent, and where present the seedling to parent ratios are presented. The month of seedling observations is also presented. Data include repeat SRS, but exclude planted (see "Planted Records") data.

ECOLOGY

Fire survival:

Fire is an important phenomenon in shaping vegetation communities and may determine which species are present in any Record Locality. Proteas differ in their response to fire.

Some species have dormant buds beneath a thick insulating bark. These buds start growing when the foliage has been killed by fire. These are the stem resprouters.

Other species have dormant buds below ground level either on a thick rounded bole or on thin underground stems. Following a fire which may kill all the above ground parts, the buds start growing from below ground. These are the ground resprouters.

Other species do not have dormant buds. When a fire occurs the plant may be killed. In these cases regeneration is by seeds only (obligate seed regenerators). These seeds may have been stored in a dormant state on the plant (waiting for the fire before being released) or stored dormant in the soil (waiting for fire to trigger off their germination).

Some obligate seed regenerating species may escape death by avoiding fires. They may grow too tall for the fire too affect them, or they may occur in habitats where fires usually cannot kill them (e.g. between big rocks).

This data was only recorded if there has been a fire recently and it was possible to determine the fire survival strategy. If atlassers were uncertain or if they could not determine a strategy then the field was to be left blank.

The fire survival codes are defined as follows:

- K Killed All adults killed by fire. No seedlings or young plants present.
- S Seedlings All adults killed by fire. Only seedlings or young plants present.
- E Escape A few adult plants survived escaping the fire by being too tall or growing among rocks. Few to many plants may have been killed.
- B Bole Most plants not killed by fire. Resprouting from below ground.
- T Trunk Most plants killed by fire. Resprouting from trunk.

Young plants are defined as those that have lost their cotyledons but have never flowered. They are thus intermediate between seedlings and adults.

The escape code "E" is not used plants that survived in swathes of unburnt vegetation where a fire burnt unevenly. All the above categories only apply in areas where a fire had burnt recently. If categories "E", "B" and "T" are accompanied by seedlings, or for category "S", the presence of seedlings must be added to the Seedlings Present code.

Data are presented as percentages in descending order by category. Only natural populations (see "Planted Records") are included. Repeat data are included.

Age to first Flowering

If the Record Locality was burnt within the last few years and the age of the vegetation could be worked out or ascertained from a local resident or forester, then the period since the last fire was recorded in decimal years (e.g. 4 months was recorded as 0.3).

If there were signs of a recent fire but it could not be found out when the fire occurred the field was to be left blank (the presence of fire was coded separately).

If there was no obvious sign of fire and a non-resprouting, serotinous female Leucadendron or Protea species was present, then the age of the Record Locality could be estimated as follows:

Select an average looking bush and select a branch tip on this bush. Starting at the branch tip and following the stem to the base, count the positions where old cones still occur, or used to occur, irrespective of whether they have opened or not. Add 2-4 years to this figure (to account for the time it took the plant to grow before flowering) and you have a rough age for the Record Locality. If there is another serotinous species in the Record Locality repeat the count and take the oldest age. This age should be accurate to within 5 to 20 years depending on the age of the vegetation.

Occasionally fires burn an area in patches, leaving swatches of vegetation unburnt. These two areas do not comprise two Record Localities. In such a case record the age of the most extensive area in the Age Veld box and in the Additional Remarks Box record the less frequent age. Code the Signs of Fire code as "P" for Patchy. Under such conditions atlassers could record in the Additional Remarks Box (ARB) whether species in the burnt area have begun flowering.

It was hoped that to use this data, together with the Age Veld, could be used to determine how long after a fire species flower for the first time.

Data are presented textually and graphically (see "Interpreting Age to Flowering Curves"). Three values are presented: the age at which the first records of flowering were obtained, an estimated age from the graph of when 50% of the localities had flowering plants, and the age at which all (100%) of the localities had flowered. The latter figure excluded young veld with only a single or 2 data points. Only natural populations (see "Planted Records") are included. Repeat data are included. Data for patchy fires and data in the ARB are excluded.

Height:

This is the distance from the ground level to the top of the bush. Take the average height of the live bushes in the stand. Ignore plants killed be fire or dead material on resprouting bushes (in which case record the height of the top-most living shoot). The average height codes are defined as follows:

- 1 < 0.2m Less than twice ankle height.
- 2 0.2m - 1m From 0.2m to waist height.
- 3 1m - 2m From 1m to between elbow and hand height when arms are held above head.
- 4 2m - 5m From 2m to about three times your height.
- 5 > 5m Taller than 5m.

Assigning height classes was often difficult. Most atlassers chose the modal height (that of most of the plants) as this made most sense. Although many proteas generally occur on cohorts (plants of the same age, dating from the last fire) of the same height, plants of some species may vary considerably in height within the Record Locality. However, the distribution of height classes usually occurs on one of two patterns:

- *Two or more distinct height classes*. Under these circumstances record the average height code of the most common height class in the Average Height field and in the Additional Remarks Box record the heights of other distinct classes.
- *No distinct height classes, merely a continuous range in heights*. Record the average height in the Additional Height field and in the Additional Remarks Box record that the height of the species varied over a wide range.

Data are presented as percentages in descending order by code.

Planted records and Repeat data (see "Planted Records") are included. ARB data are not included.

Pollinators:

Many species of insects, mites, birds and mammals visit protea flowerheads. These visitors are attracted by nectar, pollen and sometimes resins and waxes produced by the flowerheads. In addition, other visitors eat the floral parts. Flowerheads also provide shelter, warmth and protection. Yet other visitors feed on or hitch rides on these visitors.

Many of these visitors are not pollinators. Others carry pollen and are therefore pollinators. To be in effective pollinator a visitor must brush against the stigma or the pollen presenter (the modified portion of the style which holds the pollen. Since the stigma and pollen presenter are very close together at the tip of the style (except in *Leucadendron* and *Aulax*) brushing against the one invariably means brushing against the other. If a visitor has pollen on its head or body then it is almost certainly a pollinator.

Not all visitors are diurnal, some are nocturnal. The only nocturnal visitors readily detected during the day are small mammals, as these leave signs of their visits (i.e. faeces, occasional foot spoor and pathways or runs between protea bushes, and nibbling of florets and bracts). If these signs are present in, or adjacent to, flowerheads, mammals were recorded as pollinators, as it is virtually impossible for mammals to take nectar without being dusted with pollen.

Any observations of animals visiting a flowerhead, or their signs, were recorded in the two pollinator code fields. Additional pollinators were recorded in the Additional Remarks Box. Where pollinators could be identified to spedies, these were recorded in the "Specify name of pollinator" section. The pollinator codes are as follows:

- W Wind.
  It is difficult to observe wind pollination. To determine if wind may pollinate a species, shake a branch with inflorescences. If pollen cascades down in considerable quantities (stand upwind if prone to hay fever) the species is both wind pollinated and ready to be pollinated.
- S Bird (Sunbirds or Sugarbirds or other species).
  Birds are obvious visitors and the easiest to identify: note the species in the "Specify name of pollinator" area.
- M Non-flying mammal (rats, mice and shrews).
  Most rodents are nocturnal so look for signs runs, faeces, spoor, nibbled bracts.
- H Hymenoptera (bees and wasps).
  Bees and wasps have pinched waists, two pairs of translucent wings and obvious antennae which are longer than their heads.
- D Diptera (Flies)
  Flies have only one pair of translucent wings, very short and inconspicuous (3 segmented) antennae and sucking mouth parts (either tube or mop like).
- L Lepidoptera (Butterflies and Moths)
  Butterflies and moths have colourful or camouflaged wings covered with fine scales and long thin coiled mouth parts.
- C Coleoptera (Beetles)
  Beetles have hard, dark front wings (elytra) which are horny or leathery, never veined and meet in a straight line on the back. These cover the membranous flying wings which are folded underneath the elytra when not in flight. Mouth parts are biting.
- A Acarinae (Mites).
  Although at first easily overlooked, close inspection of some *Protea* flowerheads with mites will reveal the thousands of mites present as a swirling mass on the heads, and subsequent itchiness on hands (and nose, if smelled). Tapping or breathing on the heads results in a drastic increase in activity and upwelling of these mites, in the expectation of a ride on the visitor to another flower.
- X Other (Bats, Bugs, etc.).
  Bugs (Hemiptera) have the upper half of the outer wings dark and translucent, the inner totally translucent. Mouth parts are sucking (tube like).
- N No pollinators seen.
  This was only supposed to be filled in after extensive checks when the species was flowering. Initially many atlassers filled this in as a matter of course, whether the species was flowering or not. These data were discarded and atlassers informed that at least 2 hours of observation were required to fill in code "N".

Ants were not considered pollinators and specifically excluded from "Hymenoptera" to this end. They do not move between plants (most proteas are self-infertile - pollen will not set seed in inflorescences on the same bush) and have powerful fungicidal secretions which kill pollen. Their presence could be recorded in the Additional Remarks Box.

Data are presented as percentages in decreasing order by category. All data were included, except that in ARB. Where sample sizes are unambiguous (all records for a single pollinator, or single observations), they have been omitted.

Detailed pollinators:

Atlassers volunteering more detailed information on pollinators did so here. These included common or Latin names of visitors, and sometimes just more information such as moths, Scarab or Monkey Beetle, or Carpenter Bee. Data were coded at the Protea Atlas office. Additional Remarks Box data were included here also if specific enough.

Data are presented in decreasing order with the sample size in parentheses. Unambiguous sample sizes (*i.e.* single records or where all records are for a single pollinator) are omitted. All data were included.

HABITAT

Distance to Ocean:

The sea has several major influences on plant life. It provides a spray of nutrients, but at the same time contains dehydrating salts. It provides a stabilizing effect on temperature and humidity, so that extremely hot or cold conditions occur very infrequently near the sea. It also provides mist and moisture. Consequently, plants nearer the sea live in a different habitat to those far inland. A distance of 2 km was arbitrarily chosen as the limit of the combined effects that the sea has on plants. Atlassers recorded a "Yes" if the Record Locality is within 2 km of the coast or a "No" if the Record Locality is not within 2 km of the coast.

Data are presented as the proportion of records within (coastal) or further than (inland) 2 km of the coast. Repeat data are not included.

Altitude:

Altitude determines the frequency of snow and frost, the amount of cloud and rainfall, and the amount of sunlight reaching a plant.

Altitude (in metres) is the height above sea level at the Record Locality, based on maps, preferably the 1:50 000 series topographical maps. Missing data were filled in by data checkers at the atlas office.

Data are presented textually and graphically (see "Interpreting Altitude Graphs"). The following syntheses are presented: Minimum and maximum altitude, followed by the lower quartile (lq), median (med) and upper quartile (uq): these are respectively the values of one-quarter, one-half and three-quarters of the sorted altitude, binned into 20m altitude classes. Repeat and planted (see "Planted Records") data are excluded.

Landform:
There are a great many potential landforms within a landscape. For simplicity the Protea Atlas Project defined the following Landforms:

- RV Riverine vegetation: on river banks or in river bed.
  Rivers (may) have water flowing in a clearly defined channel, with boulder beds or sand banks clearly visible. Typically riverine vegetation flanks the river and does not extend much inland.
- SW Swamps, dambos and seepages: permanent or seasonal.
  These are covered with vegetation. Most water movement (when present) occurs below ground-level or within the vegetation. There are no conspicuous channels of water movement. Swamps may also occur between rivers or on the edge of rivers and lakes.
- LE Lake or pan edge.
  These are devoid of vegetation, containing either expanses of water, salt or bare soil. Any vegetation present is strictly seasonal. Typically vegetation on the pan edge is restricted to a narrow belt of several meters and does not extend much inland.
- RO Rocky outcrops, boulder screes.
  Rocky outcrops are distinct localized piles of big or small rocks or boulders (> 1 m diameter), which intrude on the general landscape. It includes boulder screes. Typically there is very little soil within the outcrop, most of which is confined to crevices.
- DS Deep soils: no bedrock visible.
  Deep soil is used as a relative term to distinguish areas where there is no bedrock or half-buried boulders visible at the soil surface. The actual depth to which the soil may extend before encountering the bedrock is irrelevant to the definition.
- SS Shallow soils: bed rock clearly visible.
  Shallow soil is used as a relative term to distinguish areas where bed-rock is clearly visible and protrudes from the soil: at least quarter to half the area has to be bedrock. Large half buried boulders are considered to be part of the bed-rock. The actual depth to which the soil may occur between the boulders is irrelevant to the definition.
- TM Termite mound.
  Used when species are confined to termite mounds.

When recording landform codes proceed from top to bottom until correct category is reached. If two codes are equally applicable choose the uppermost. Soil depth is considered unimportant in the top three landforms.

Note that the plant species on the edge of rivers and lakes and pans", and in swamps, dambos and seepages, are usually totally different from those in the surrounding veld. These are quite different habitats as plants may have access to perennial water, or may be waterlogged - conditions for which plants must especially adapted. Thus separate Sight Record Sheets should be completed when a species occurs both next to a river or lake and in the veld beyond.
Data are presented as percentages in decreasing order by category. . Repeat and planted (see "Planted Records") data are excluded.

Slope:
Slope is important in determining species' distributions. Not only the angle of the slope, but also the position on the slope. However, codes were kept simple. The slope codes used for the Protea Atlas Project are defined as follows:
- CL Vertical slope or cliff (> 60^{o}).
- SI Steep incline or slope (> 20 ^{o} and < 60 ^{o}).
- GI Gentle incline or slope (> 5 ^{o} and < 20 ^{o}).
- DU A gentle undulating dune landscape.
  This caters for dune fields and fossil dunes. It refers to cases where the Record Locality comprises an undulating topography but the vegetation and soil are similar over the undulations (alternatively, record the different communities using other codes).
- HT Flat or level (< 5 ^{o}). Hill or mountain top.
- VB Flat or level (< 5 ^{o}). Valley bottom or bottomlands.
- PL Flat or level (< 5 ^{o}). A flat platform on a slope.

Data are presented as percentages in decreasing order by category. . Repeat and planted (see "Planted Records") data are excluded.

Aspect:
The aspect describes the direction that the entire Record Locality faces, when the slope is greater than 5 ^{o} (i.e. Slope codes CL, SI and GI). Fill in the box using the 16 compass points. For flat and level Record Localities aspect has no meaning, so leave blank. For highly variable aspects, without clear direction, leave blank.
The 16 compass points are as follows:
N, NNE, NE, ENE, E, ESE, SE, SSE, S, SSW, SW, WSW, W, WNW, NW, NNW.
In reality, atlassers tended to code aspect if any slope was detectable (a slope of 1-2^{o}). Also the primary compass points were coded more than the intermediates (see "Interpreting Aspect Pies").
Data are presented textually and graphically (see "Interpreting Aspect Pies"). Data are summarized into the 4 major compass points, presented as percentages in decreasing order by category. For summarizing the data, NE, SE, SW and NW were halved and this summed to the respective compass points. Repeat and planted (see "Planted Records") data are excluded.

Soil Type:
The simplified soil types used by the Protea Atlas Project are defined as follows:
- S Sand Comprising mainly course or fine sand. Loose when dry, crumbles even when wet, not sticky, water drains through.

- L Loam Comprising sand, clay and organic matter. Fragments into pieces when squeezed, malleable when wet, slightly sticky, porous to water.
- C Clay Comprising mainly clay. Hard when dry, moulds readily when wet without cracking, sticks to fingers when wet. Water tends not to sink into soil – may have cracks when dry.
- P Peat Often dark, comprising decomposed organic matter. Very little sand or clay present.
- G Gravel Mainly comprising pebbles between 2 and 75 mm in diameter, with some finer material between the pebbles.
- R Rocky Mainly comprising pebbles greater than 75 mm in diameter, with some finer material between the pebbles.

The categories were chosen for ease of use. To determine the soil type code, take some surface soil, crush and wet it. If a surface layer of leaf litter is present remove it (a kick should suffice) and take the underlying soil. Record the presence of the litter layer in the Additional Remarks Box (*This was never done*). Additional or more detailed soil types could be added to the ARB.

Data are presented as percentages in decreasing order by category. Repeat and planted (see "Planted Records") data are excluded.

Soil Colour:

Soil colour may reveal interesting things about the processes which are occurring in soil. Thus rain may wash certain minerals from the surface layers of soil into deeper layers, changing the colour of the soil with depth. By contrast, a waterlogged soil may have surface colours that normally occur very deep within the soil. Colour also indicates the oxygen content (essential for root growth) of the soil, and the origin of the soil.

Take a handful of soil from the surface (after kicking away the leaf litter), and determine its colour. Coloured blocks for this purpose were printed on the back of the Protea Atlas manual, but were too extreme to be of practical use. Atlassers were advised to use the colours relative to the soils that they know. The colours used were:

- K Black
- B Brown
- G Grey
- W White
- Y Yellow
- O Orange
- R Red
- X Other

Often soil colour may vary over remarkably short distances: this was not regarded as indicating a New Record Locality unless it was accompanied by changes in vegetation or soil type.

Data are presented as percentages in decreasing order by category. Repeat and planted (see "Planted Records") data are excluded.

Geology:

The geology code refers to the bedrock or boulders visible. At Record Localities where there are no bedrock or boulders visible, leave this field blank unless you know the geology or its decomposition products.

Where exposed bedrock differs from boulders, record the bedrock as the geology code, and record information on boulders in the Additional Remarks Box.

Geologists, engineers and gemmologists added additional geological codes, as required. Where species were known to have, or were suspected of having, highly specific geological preferences, atlassers were encouraged to record the geology as technically as they deemed necessary.

The primary geology codes used (those marked * where not originally defined and - with the exception of TS - were only used by a few atlassers) and their definitions, are as follows:

- BA Basalt (Igneous - deposited by volcanism).

  Crystals are not visible with the naked eye. Typically dark green or black in colour, basalts are not laminated. The top of the Drakensberg and Lebombo Mountains were deposited as huge basalt lava sheets.
- BC* Banded Chert
- CO Conglomerate (Sedimentary - deposited by water or wind).
  A rock of course fragments or pebbles, cemented together with finer particles. Formed by ancient fast flowing rivers, rock falls and glaciation. Most commonly occurs in ancient river valleys and adjacent old mountains.
- DI* Dibase
- DO Dolomite (Sedimentary - deposited by water or wind)
  Similar to limestone, but does not foam in acid unless heated. Typically, crystals are too small to see. Caves, blind rivers or sinkholes may be present in the area. Formed by the precipitation of calcium and magnesium in seawater by ancient algae, the largest expanses of dolomites occur on the Witwatersrand. These dolomites often have thin layers of hard chert within them.
- DR* Dolerite
- GR Granite (Igneous - deposited by volcanism)
  Consisting of clearly visible different kinds of crystals: sparkling flakes (mica), colourless pink rectangles (feldspar), and black biotite in a background of translucent milky quartz. Common as large granite domes, which formed deep in the earth as magma cooled slowly.
- HE* Haemitite
- HL Hardpan laterite / silcrete (Metamorphic - formed chemically)
  These hardpans (ouklip) are recognised by their dark colour, and their occurrence as thick sheets (crusts) on the tops of hills. They usually comprise spherical nodules (occasionally honeycombed) cemented in a reddish matrix. They were formed in deep waterlogged soils where iron, aluminium or silicon were leached from the upper soil and deposited as a dorbank, klipbank, or koffee-bank. With the removal of the upper soil, these hardpans have become the exposed rocks.

- LI Limestone (Sedimentary - deposited by water or wind)
  A pale rock containing more than 50% calcium carbonate (lime). It foams when a drop of acid is placed on it. It usually has crystals which are visible and may contain shell fragments. Caves, blind rivers or sinkholes may be present in the area. Formed from the shells of marine molluscs or by chemical deposition, limestones are mainly coastal in occurrence. This category includes calcium based hardpan formations, as it is not easy to tell whether limestones were formed by sedimentation or chemically.
- PY* Pyroxenite
- QU* Quartzites (Sedimentary/Metamorphic - deposited by water or wind)
  Sandstone with sand grains fused and not clearly visible.
- RY* Rhyolite
- SA Sandstone (Sedimentary - deposited by water or wind)
  A rock consisting of sand grains, clearly visible to the naked eye, cemented together with finer particles, but generally with a lot of space between the grains making them porous to water. They usually occur in beds from several centimetres to metres thick. Originally formed at beaches, deserts and deltas, they usually erode to form steep mountainous terrain, as in the Cape and Drakensberg.
- SC* Schists
- SE* Serpentine
- SH Shale (Sedimentary - deposited by water or wind)
  A rock consisting of fine grained particles, usually too fine to see by eye. Usually clearly layered, with beds several millimetres thick. Formed in lagoons lakes and flood plains, shales comprise 80% of sedimentary rocks. Typical of the Karoo and grain and fruit producing areas in the Cape.
- SO* Talk schists
- TS* Tertiary Sands (Sedimentary - deposited by water or wind)
  Loose, unconsolidated sand. Deep enough to prevent underlying geology from being determined.
- XX Other: This was usually coded up at the Protea Atlas office to one of the above categories, which includes any geological type recorded more than 5 times.

Data are presented as percentages in decreasing order by category. Repeat and planted (see "Planted Records") data are excluded.

<proposal: put in the correct geology based on GIS for Cape species. STILL TO DO>

Geology Types:
Only those > 5%, unless only 1 or 2 types
A short definition of terminology.

Vegetation:
This code records the characteristics of the vegetation at the Record Locality. The vegetation structure codes are defined as follows:

AL Agricultural Lands.

- DE Desert
  With a total plant cover of less than 30%. The landscape is dominated by the geology, rather than the plants (Synonyms: Arid Karoo).
- FO Forest
  Dominated by trees over 5m tall with canopies interlocked. Lianas and epiphytes common (Synonyms: Rainforest).
- GR Grassland
  Few tall shrubs or herbs (comprising less than 10% of the ground cover); dominated by perennial grasses and herbs.
- PL Plantations.
- SH Shrubland
  Dominated by shrubs less than 2m tall. Grasses may or may not be present, but shrubs dominate the projected canopy cover. (Synonyms: Alpine Scrub, Brokenveld, Fynbos, Heathland, Karoo, Macchia, Renosterveld).
- SU Suburban / urban.
- TH Thicket
  Dominated by shrubs and trees greater than 2m tall, but seldom more than 5m tall. These categories comprise more than 40% of the projected ground cover. Grasses may be present, or bushes may be so thick as to be impenetrable (Synonyms: Strandveld, Valley Bushveld).
- WG Wooded grassland
  Dominated by grasses and herbs, but with some trees or shrubs present. Trees and shrubs may comprise 10-40% of the projected ground cover (Synonyms: Kalahariveld, Thornveld).
- WO Woodland Dominated by trees (over 5m tall). Tree canopies comprise more than 40% of the projected ground cover, but never interlock. Grasses usually dominate the understorey (Synonyms: Savannah, Lowveld).
- XX Other.

Data are presented as percentages in decreasing order by category. Repeat and planted (see "Planted Records") data are excluded.

<proposal: put in the correct Vegetation type based on GIS for all species. STILL TO DO>

Vegetation Types:
Only those > 5%, unless only 1 or 2 types
A short summary of the vegetation map.

CONSERVATION STATUS AND THREAT

Red Data List Status:
This includes the current Red Data List status (see Rebelo et al. 2008). This comprises both the status and the justification for the status, in coded format. Thus "A" signifies loss of populations, "B" a small geographical range and threat, "C" a small population size and decline, and "D" a small or restricted population. Under "A" the numeral signifies past (2), future (3) or both (4) losses. Under "B" the numeral signifies a range determined by (1) occurrence or (2) occupancy. Under "C" the numerals (1) signify estimates of decline or (2) a continuing decline. Under "D" the numeral (1) refers to small number of individuals and (2) to the

area or number of locations. For "A" the small letters designate that the decline has been determined by: (a) – direct observation; (b) – an index of abundance; (c) a decline in occurrence, occupancy or habitat; (d) caused by exploitation; (e) caused by alien introductions. For "B" the letters signify that the threat is (a) fragmentation or few localities; (b) continuing decline; or, (c) fluctuations. For the latter two letters under "B" this can be measured by (i) occurrence; (ii) occupancy; (iii) habitat; (iv) locations or populations; or, (v) individuals. Different cut-offs for these categories determine whether a species is threatened (either Critically Endangered, Endangered or Vulnerable) Near-threatened or Least Concern. Details for each species, with reasons and current population status, can be found in the Red List.

This is followed by 2 sets of data estimating the geographical range and the conservation status and loss of habitat by occurrence and occupancy. These are computed from the Protea Atlas distribution data using GIS. Note that both conservation status and habitat loss vary considerably depending on what parameter is used to determine it. This is due to the effects of scale.

Occurrence:
Occurrence (short for "extent of occurrence") is the overall area in which the species occurs. It is accurately computed by mapping a "minimum convex hull" around all the localities. This is equivalent to placing pins at localities on a map and then putting an elastic band around all the pins: the area within the elastic band is the occurrence. However, in the Cape Flora many species are confined to Fynbos: For the majority of Fynbos proteas we only added up the area within the occurrence that contained Fynbos. Thus we distinguish between Fynbos Occurrence and Total Occurrence. Total occurrence is given for species that also occur in Renosterveld and species that occur outside of the Cape Flora.

Occupancy:
Occupancy (short of "area of occupancy") is the actual area in which plants occur. Ideally the area covered by each plant should be summed to give occupancy. However, this is impossible and usually an electronic grid is used, and the number of occupied grid cells is the occupancy. Potentially a grid of 500m across could be used for atlas data, but because Protea Atlas Data are not grid based (the atlassers chose the centres of their plots), this would result in too many unatlassed cells. Because other data exist (climate, topography, etc.) at a minute by minute grid scale (1.6 X .8 km) this scale was used. Thus the unit area of occupancy is 3 km^2.

In very rare species estimates of occupancy exceed that of occurrence. This occurs because occupancy is measured in cell units when occurrence is less than this, occupancy should be measured at a finer scale. However, for consistency and comparison all occupancy units are the same grid size.

Fragmentation ratio:
The proportion of the Occupancy to the Total Occurrence, expressed as a percent. This is strictly a continuity ratio – the higher the value the less fragmented the distribution. Values below 5% are considered significantly fragmented.

Nature Reserves:
Atlassers recorded when they were in conservation areas or not. Data were extensively checked at the office by volunteers, and also verified against current (2002) available conservation area boundaries.

Atlas data were not collected uniformly across the landscape, and Nature Reserves – with their easy access, hiking trails and accommodation were visited preferentially to private land. However, this data does give a value for comparison with the figures presented above. Note that all three measures of conservation extent are valid and none are perfect: the best solution would be to model the species' distribution and then calculate the area inside nature reserves.

The proportion (as a percent) of records within nature reserves is given. Where this figure is high or low, a note on the conservation status in terms of targets of 80% (well conserved) or 20% (poorly conserved) is given.

Habitat Destruction:
Atlassers recorded a "Vegetation Island Code" to note the effects of man on the landscape. Where formerly extensive veld was converted into small patches of vegetation, or otherwise impacted, notes were made. However, it soon became apparent that habitats could be naturally fragmented and a few new codes (marked *) were added at the request of atlassers:

- E Extensive
  Site surrounded by extensive natural veld. This was the default condition.
- I Islands
  Confined by agriculture, forestry or urbanization. Initially this was confined to patches smaller than the record locality, but this condition was soon relaxed to include patches that were bordered by agriculture.
- V Verges
  Confined by agriculture, forestry or urbanization to the edges of roads or railways.
- P Power Lines
  Confined by agriculture, forestry or urbanization to under power lines.
- C Corridors
  Confined by agriculture, forestry or urbanization to strips such as along rivers, or the coast or between houses and fields.
- L Linear
  Naturally occurring in corridors (not confined by agriculture, forestry or urbanization) such as riverine thickets, shale band vegetation and ecotones.
- F Fragmented
  Naturally occurring in small patches, such as rocky outcrops in a sandy region, or sand patches within a rocky area. This code was only used if the patches were smaller than a record locality and the species differed between the patches and the interpatch zones.

Data are presented as percentages in decreasing order by category.

Alien Invasive Species:
No less of a threat than agriculture and urbanization, alien plant species may surreptitiously eliminate indigenous vegetation. Alien plants compete for

water, minerals, light and space. Because they no longer have their natural pests to control them, alien plants can outcompete the indigenous species. The alien invasion codes are defined as follows:

- N None None: no aliens noted on Record Locality.
- F Fabaceae Any member of the Pea Family: *Acacia, Albizia, Sesbania.*
- P Pinus Includes any other invasive Gymnosperm.
- H Hakea Any invasive *Hakea* species.
- M Myrtaceae Any member of the Blue Gum Family: *Eucalyptus, Leptospermum*
- A Asteraceae *Chromalaena*: Triffid Weed; Cosmos
- B Brambles Brambles
- C Cactaceae Cactaceae: *Opuntia* Cactus
- E Meliaceae Meliaceae: *Melia* Syringa
- G Grasses Any alien grasses
- J Jakaranda Jakaranda
- K Oaks Oaks *Quercus*
- L Poplars Poplars *Populus*
- O Apocyanaceae Apocyanaceae: *Nerium* Oleander
- S Solanaceae *Solanum* bugweed, *Nicotiana* Wild Tobacco
- V Verbenaceae Verbenacae: *Lantana* Cherrypie

Data are presented as percentages in decreasing order by category. Repeat and planted (see "Planted Records") data are excluded.

Alien Density:

The release of biocontrol agents promises some spectacular changes in patterns of alien plant invasions. Previously dense thickets should become minor infestations over the next decade. Our indigenous seed and leaf feeding insects, fungi and pathogens are also getting in on the act, and are seriously impacting certain *Acacia* and *Hakea* species.

The density codes for aliens are defined as follows:

- N None No plants visible.
- S Scattered A few plants visible here and there.
- A Abundant Many plants, but canopies not touching.
- D Dense A dominant plant in numbers or foliage cover.
- I Impenetrable Making entry difficult, except along cleared paths.

Data are presented as percentages in decreasing order by category. Repeat and planted (see "Planted Records") data are excluded.

CULTIVATION AND UTILIZATION

Picking:

Many proteas are utilized for the cut flower trade, both locally and internationally, although the international market generally requires orchard-grown, cultivar material. Veld harvesting is widespread but we do not know which species are harvested where, both because farmers sell material under old or incorrect names, and because farmers do not want to trade in threatened species and use alternative names. Any signs of plucking (cut stems, uprooted plants, cut material, discarded material, pickers in action) were recorded. The signs of picking codes are defined as follows:

N	None	No evidence of plucking.
R	Rare	Some plucking evident - not obvious, plants unaffected.
S	Severe	Plucking obvious, bushes badly stunted or stripped of all blossoms.

Data are presented as percentages in decreasing order by category. Repeat and planted (see "Planted Records") data are included.

Cultivation Status:

A planted code was not provided for, but it soon became apparent that atlassers were recording plants from outside of their known range from protea orchards and from both orchards that had reverted to being wild and from plants that had escaped from orchards. In addition, some farmers seed plants into burned or ploughed fields and allow the veld to return to a semi-natural state. Many atlassers were astute and picked up such occurrences, but many had to be investigated to determine if they were genuine range extensions or plantings. Atlassers were requested to note instances of plantings and escapes in the Additional Remarks Box, and this was coded at the office.

The planted codes were defined as follows:

- A Augmented
  Planted (or escaped) within naturally occurring populations of the proteas.
- E Escaped
  Escaped plants from plantings nearby, or in a previous fire cycle that have now become locally naturalized outside of the natural range or habitat of the species.
- P Planted
  Species planted outside of the natural range or habitat of the species.
- Q Probably Planted
  Species probably planted outside of the natural range or habitat of the species.
- C Control
  Records for checking. All instances were checked and this code is currently redundant.

Data are presented as records in decreasing order by category. Percentages are only noted if greater than 1% or if sample sizes are not around 100.

Witches Broom:

Atlassers recoded incidences of Witches Broom – a plasmolemma causing fasciation (or, more informatively, a bit of parasitic DNA that causes cancer) in the Additional Remarks Box. Here we present the proportion (as a per cent) of the total records noted as containing Witches Broom. These are probably major under-estimates of the true extent of the disease, but should be consistent between species. Because reported incidences are low (typically 0.01-0.5%), the proportion is always noted.

ATLASSERS NOTES:

This contains information about the species volunteered by atlassers while collecting the data. Most of the data were coded in the Additional Remarks Box (ARB). These included any

observations, interesting facts or problems concerning the Record Locality.
It varies from scientific to anecdotal, from mundane to hilarious. In many cases it has been summarized and redrafted for readability. Data specific to certain contexts and dealing with numerical or qualifying data have been omitted. Data relevant to regeneration, identification, morphological variation, pollination and so forth are included. Included in parenthesis are the references to allow GIS users to track down the geographical location of the records in question: the first three letters refers to the author of the information – codes to atlassers can be found in the "Acknowledgements", the next six numerals are the date in year, month and day, followed by the Record Locality number for the atlasser for that day. Additional data are provided on the electronic version.

CONFUSING SPECIES:
<Add>

VARIATION AND TAXONOMY:
<Add>

DISTRIBUTION:
<Distribution Map>
<Data resolution>

6. INTERPRETING THE GRAPHS

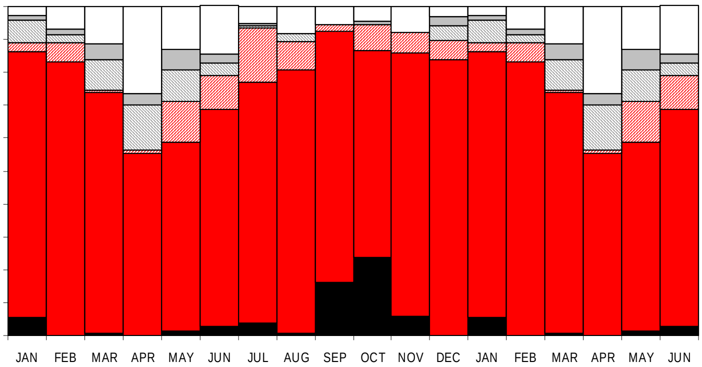
Interpreting Flowering Graphs

Flowering is presented over 18 months from January to June. This allows easier comparison of both summer and winter peaks, in that the graph does not split one or the other.

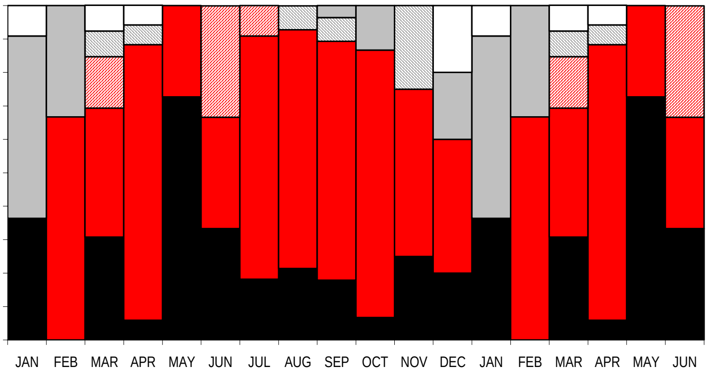
The unlabelled y-axis on the graph is a proportion (out of 1.0 or 100%, with tick marks at 0.2 intervals) of the total data (sample sizes are in the textual account). Data are the proportion for each month of the flowering categories (see definitions above) in ascending order:

Peak Flowering = Black;
Flowering = Red; Bud = diagonal up red; Over = diagonal down grey;
Cone = Grey; and, Nothing <change throughout document to “No Flowers ?”>= White.

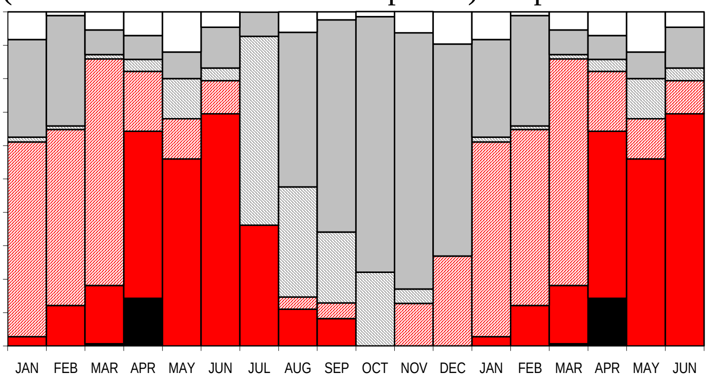
Note that data are for populations (or record localities), and not plants per population. No attempt has been made to restrict data to mature plants, so records for young veld are included. The following examples illustrate the most important patterns:



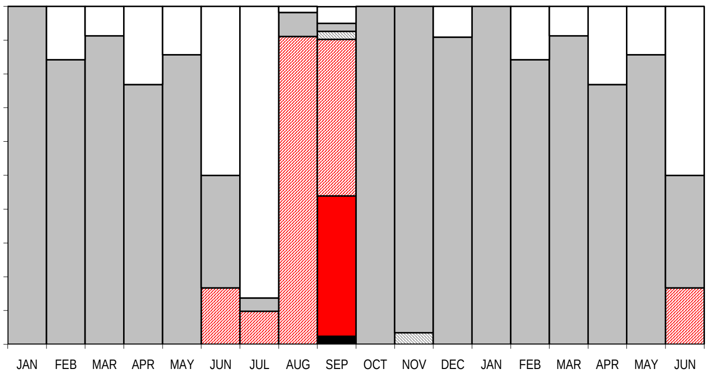
No season: *D. divaricata* has no proper flowering season, generally found in flower all year round. Peak Flowers occurs mainly in Sep to Oct, and Buds and Over occur at low levels all year round, as do Cones – in this non-serotinous species this means seeds. A low number of records have No Flowering.



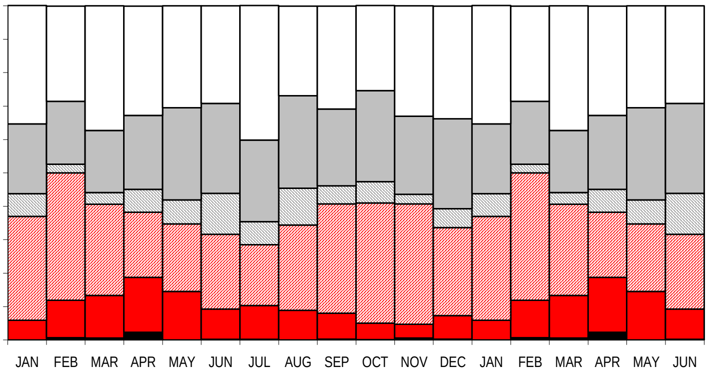
High Peak: *S. mollis* is unusual in having a high incidence of Peak Flowering. Flowers are found in most months, but lowest in Dec to Feb, when Cones (seeds in this non-serotinous species) are prominent.



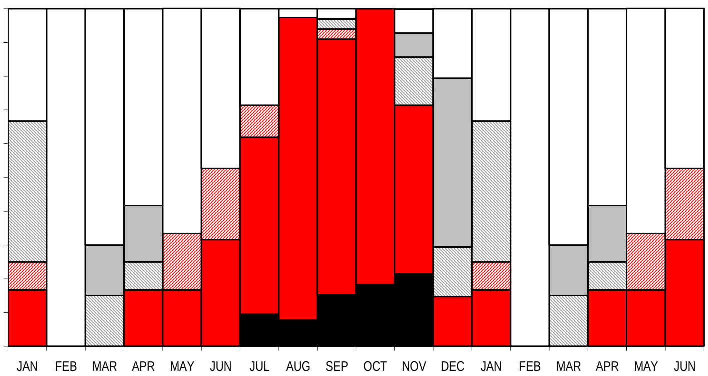
Broad season: *P. susannae* has a broad flowering season centred on Apr to Jul, but extending from Jan to Sep. Prior to Jun it is in Bud, and post Jun it is Over. During the non-flowering season the serotinous cones are prominent, with very few records of No Flowering (probably from young veld).



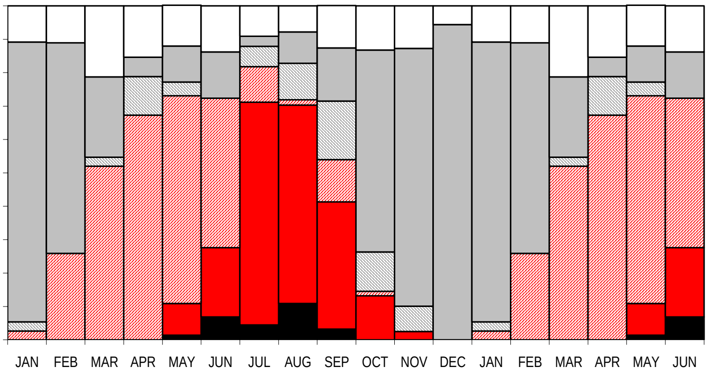
Narrow season: *L. laxum* has a very narrow flowering season (Sep), with Buds from Jun to Sep, and almost no detectable Over (Sep and Nov). Seeds (Cones) are stored on the plant until Jun, when they are dropped prior to the plants going into bud.



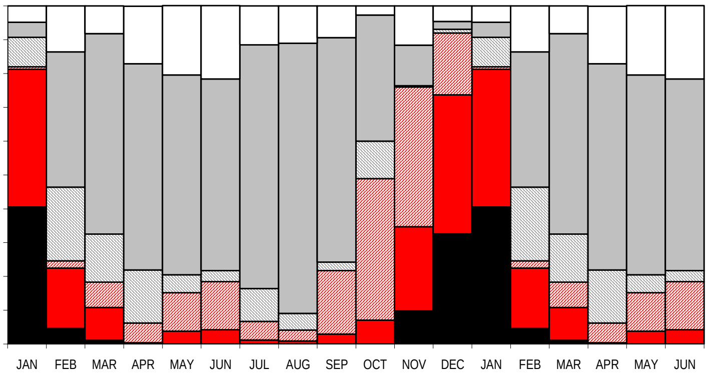
Low flowering: *P. cynaroides* does not produce much flowers, although there is a barely detectable autumn-winter peak. Note that the proportion of Buds is high all year round and that this exceeds the Flowers, suggesting that many buds produce new growth rather than flowerheads. Although serotinous, about an equal proportion have No Flowering, suggesting either a long period to flowering after a fire, or – more realistically – that flowers are not produced in older veld.



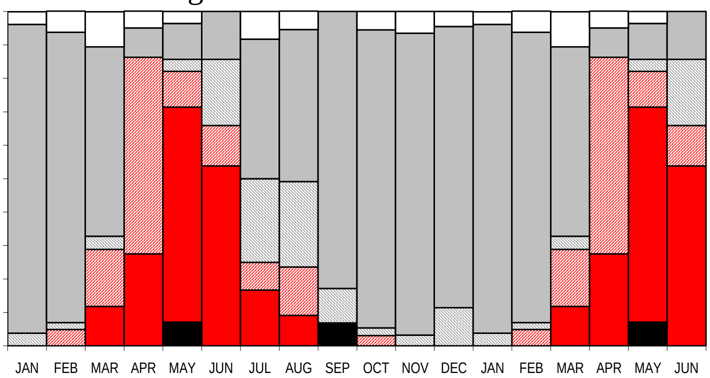
Skewed season: *M. pauciflorus* has a gradual increase in flowering from Apr to Jul, before reaching maximum levels (in both Flowering and Peak Flowering) from Jul to Nov. Post flowering there is a sudden decline with Over and Cone, with a lull prior to producing new flowers in Autumn.



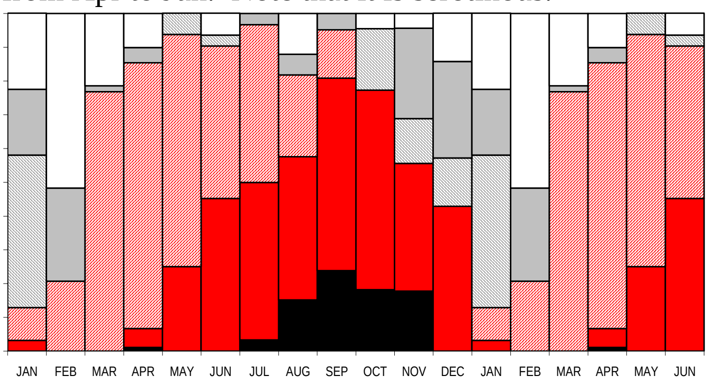
Winter Peak: *P. burchellii* has a winter peak, centred on Jul and Aug. Note that it is serotinous.



Summer Peak: *A. umbellata* has a summer peak, centred on Nov to Feb, with a strong component of Peak Flowering. Note that it is serotinous.

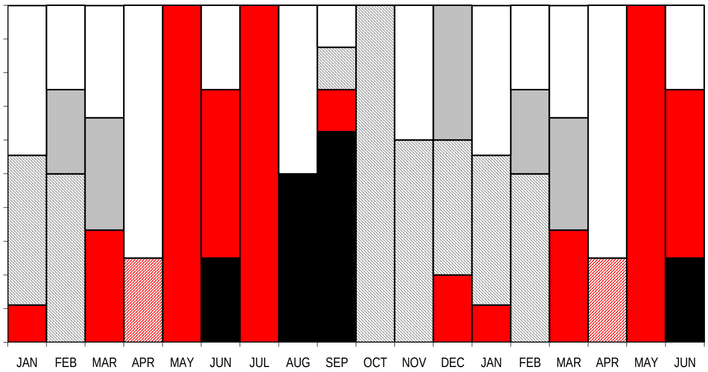


Autumn Peak: *P. canaliculata* has an autumn peak from Apr to Jun. Note that it is serotinous.

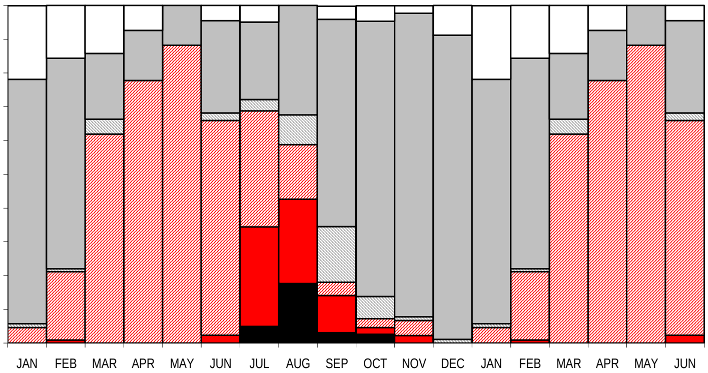


Spring Peak: *L. nitidum* has a broad spring peak, with most flowers in Sep to Oct. Note that it is not serotinous with Cones (seeds) on the plant from Nov to Jan (the “ant” season), and a brief spell of No Flowering before Buds start in Autumn.

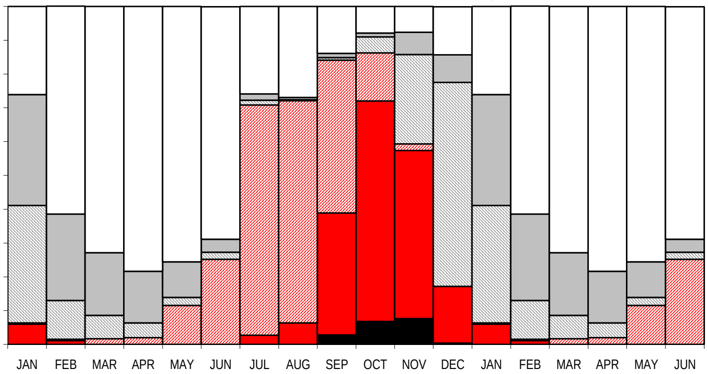
Bimodal Peaks: No examples of bimodal flowering (two peaks within a year) were found in our data.



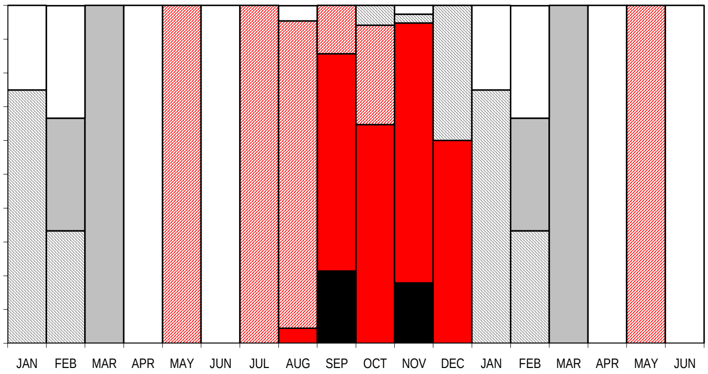
Short buds: *O. zeyherii* is unusual in only producing Buds for a very short period (Apr). By contrast plants are Over from Oct to Feb, with fruit (Cones) from Dec to Mar.



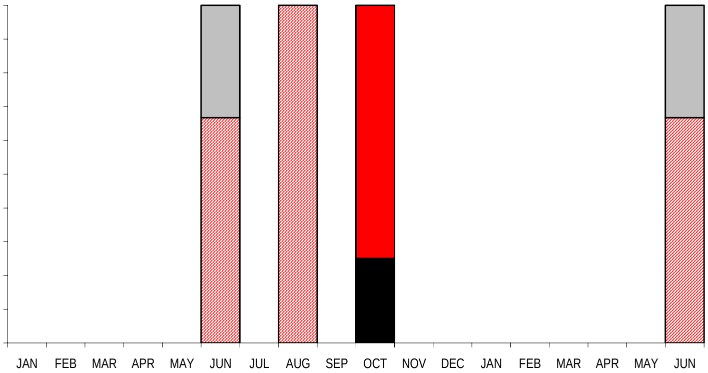
Long buds: *L. microcephalum* has buds from Feb to Jun, and flowers from Jul to Sep. Only Sep has prominent Over. The species is clearly serotinous.



Long cone: *L. conocarpodendron* is non-serotinous, and has an almost symmetrical Bud to Over pattern around the flowering period. Although fruit (Cone) peak in Jan to Feb, some can be found all year.

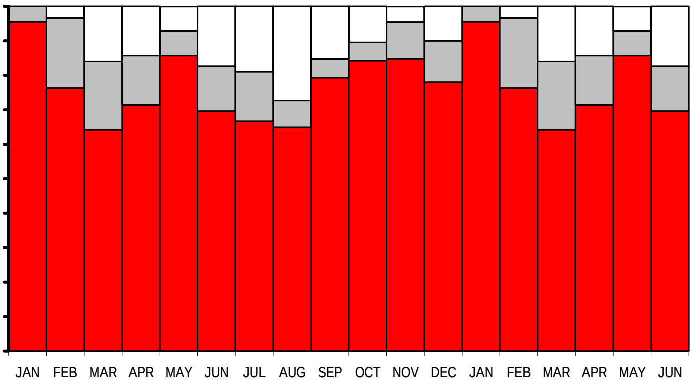


Short cone: *L. catherinae* flowers from Sep to Dec, with Over from Dec to Deb. However, fruit (Cones) are only found in Feb to Mar. The broad obvious steps in the bars suggest that data is limited and the graph should be interpreted cautiously.

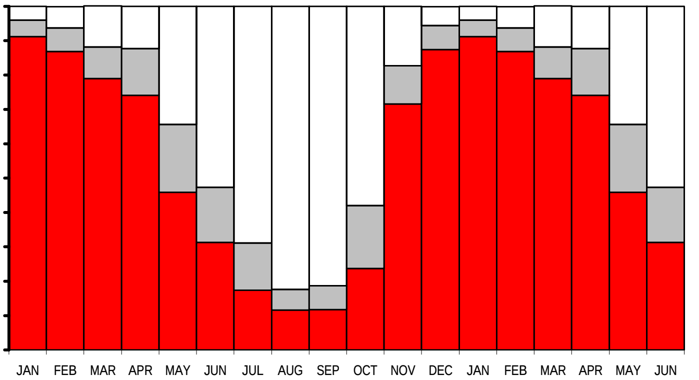


Insufficient data: *L. harpoganatum* is so rare that it was visited only infrequently – in four months. Although a pattern is evident, the sample sizes are too small to allow confidence in an Oct flowering peak, and do not allow the duration of the flowering season to be deduced, although the Cones from Jun suggest it might perhaps be as long as 6 months or more.

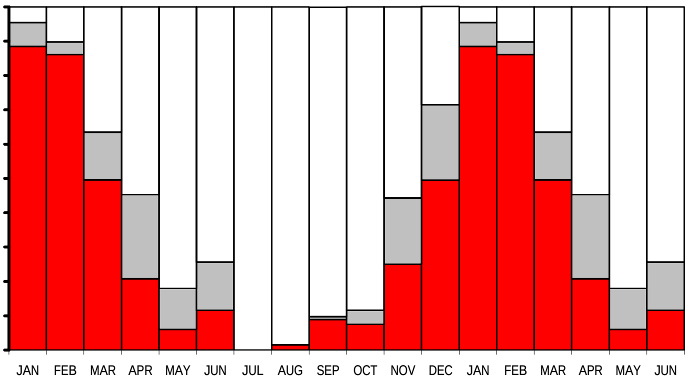
Interpreting Growth Graphs
Like the flowering graphs, the growth graphs extend over 18 months from January to June. The unlabelled y-axis on the graph is a proportion (out of 1.0 or 100%). Data are summarized as the proportion for each month, in ascending order, of the growth categories:
"Much" in black; "Rare" in red; and, "None <change throughout in text to "No Growth"?>" as white.
Note that data are for populations (or record localities) and not plants per population.
Interpretation of the graphs is relatively simple, but for maximum benefit should be considered in tandem with the flowering data. Specifically, do species flower at, before, or after peak growth, or does growth cease for flowering? Do species with narrow flowering periods have narrow growth periods? There is a surprising wealth of strategies presented here for the first time.
The following examples illustrate the most important growth patterns:



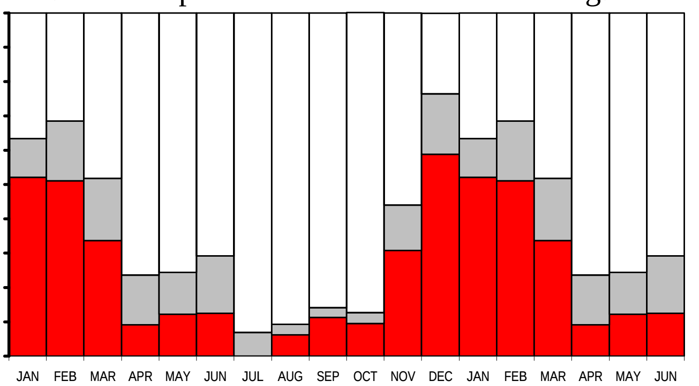
No season: *P. subulifolia* shows no seasonal pattern in new growth, producing growth throughout the year.



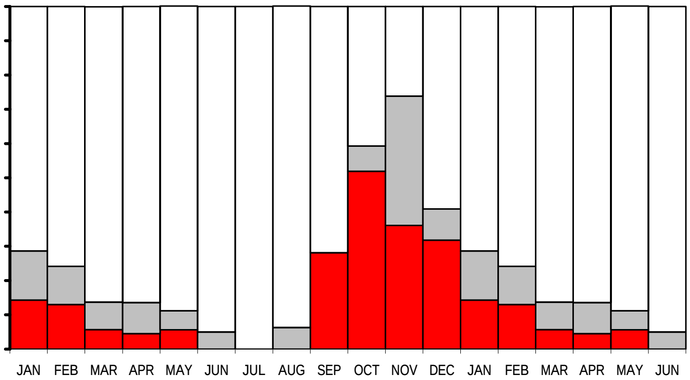
Broad season: *L. xanthoconus* produces growth from Nov to Apr, although there is some growth all year round.



Narrow season: *L. microcephalum* produces growth mainly from Dec to Mar, but peaks strongly in Jan to Feb. There is peak of No Growth in Jul to Aug.

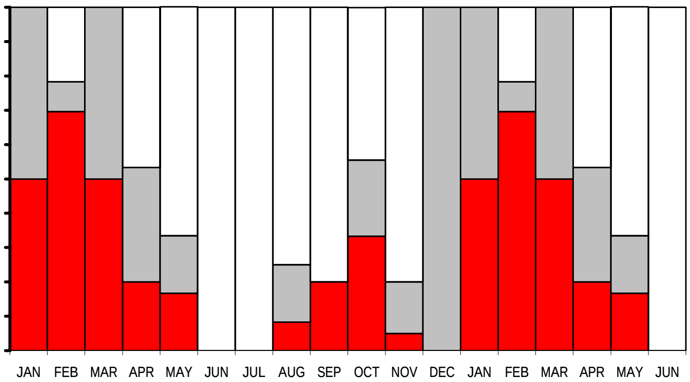


Low season: *A. pallasia* produces some new growth all year round, with a Dec to Feb peak, but even during this period only about 60% of populations are active.

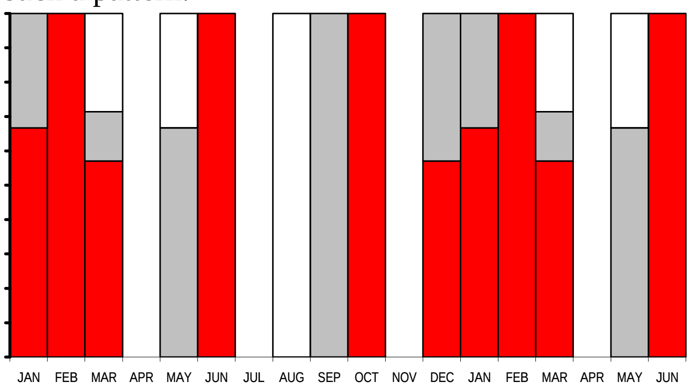


Skew season: *P. acuminata* has a sharp initial rise in growth from Aug to Oct, followed by a long decline from Oct to May. Although Much Growth peaks in Oct, most populations have growth in Nov.

Winter Peak: No examples of a winter peak were found in our data. Proteas don't grow in winther!



Bimodal Peak: *P. montana* appears to have two peak growth periods: a minor peak in Sep to Oct and a major peak in Jan to Mar. Not many species exhibit such a pattern.



No data: *D. myrtifolia* clearly grows from Dec to Mar, but the Jun and Oct peaks might be spurious based on too little data. Note the large column blocks, suggestive of few records per month, even though 9 of the 12 months have data.

Interpreting Age to Flowering Curves

The age to flowering curves have been calculated from data in which atlassers provided both the veld age and data on flowering. Veld coded as "Patchy" for fire age have been excluded, as have planted records. For each age class from 1 to 20 years old the proportion of records containing "None" for flowering *versus* the remaining categories for flowering has been calculated. These are presented as points on the graph with the vertical axis being the proportion of flowering records (from 0 to 1) per age class, and the horizontal axis the age of the veld (and by implication the age of the plants) from 1 to 12 years old (the data for 1-20 years are available electronically).

The error bars are calculated simply as $1/\sqrt{n}$: thus a big error bar of 1.0 implies a single record, an error bar of 0.5 above and 0.5 below would imply 4 records, and progressively smaller bars imply a greater and greater reliability of the data. Although not strictly accurate, it is useful to regard the data as being somewhere along the error bar and not necessarily at the shown point.

The curve connecting the points is calculated as a trinomial (ax^3+bx^2+dx+c). It is not constrained to pass through the axis (thus we do not assume that populations cannot flower within the year following a fire, or that populations cannot have null flowers in much older veld, *i.e.* we do not assume that $c = 0$). The curves do not incorporate the sample sizes and consequently we have not presented estimates of accuracy (*e.g.* R^2) of the curves.

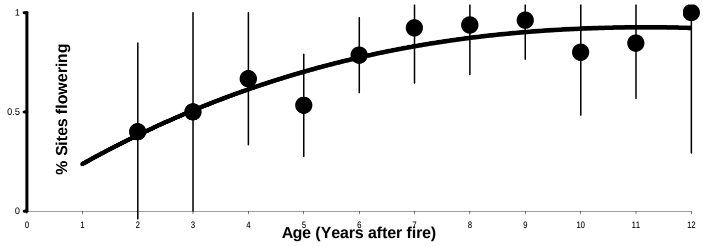
Note that these data are proportion of populations (or record localities) containing plants that have flowered, and are not proportion of plants within the population. No attempt has been made to check that these patterns are uniform across the species' distributional range. Note that sample sizes are usually small.

Strictly, age to flowering is only useful for serotinous species. These species store the fruit on the plant allowing plants that have flowered in the past to be coded as "In Cone" and not as "None". For these species the age to 100% flowering is valid. For non-serotinous species, records from the non-flowering period will be coded as "No Flowering" so that values of 100% will rarely be achieved. Non-serotinous species flowering for long periods will attain higher values than those flowering briefly. However, species that are cryptic and overlooked when not flowering (e.g. some *Spatalla*) may have the proportions overestimated.

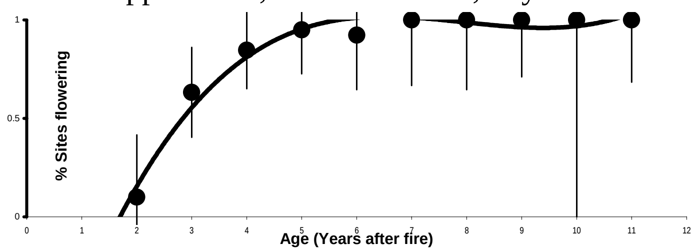
However, age to first flowering is useful for all species, and so curves are presented for all species. It must be noted though that only a single plant is required for the population to be coded as "Flowering" so that age to first flowering does not necessarily imply an ecological ability to cope with a fire at this age, although it strongly suggests that some plants will survive.

The assumption that the age of the plants is the same as the veld age does not apply to resprouters, which may be hundreds of years old. However, the utility of the graphs in determining post-fire flowering patterns is equally useful, and reflects a species ability to recover from the fire. Interestingly, many species exhibit the same patterns of recovery as species killed by fire.

Note that the descriptive accounts of the age to flowering included planted or escaped populations for which veld age is known, and thus include marginally more data, resulting in apparent conflict between the descriptive and graphed data.



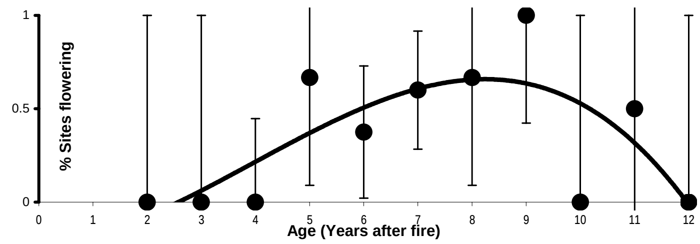
Typical: *A. cancellata* produces its first flowers at 2 years, but note the high error bars for veld of 2 to 3 years age, and the lack of data for veld one-year old. Small error bars at years 6-9 indicate good estimates. About 50% flowering is reached in year 4-5 and 100% is approached, but not reached, in years 7-13.



Early flowering: *A. pallasia* is a resprouter and flowers in the second year after fire, reaching 50% at 2-3 years and 100% by year 5, which is maintained thereafter.

Late flowering: *P. stokoei* is a late flowerer, with the first data for flowering in 9-year old veld. Even at 13 years 50% flowering has not been attained.

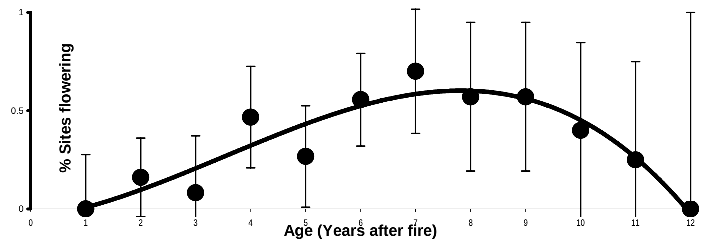
Non-serotinous resembling serotinous: *O. zeyheri*, although myrmecochorous and thus expected to never peak flowering, in fact starts flowering in year 4, reaches 50% in year 7, and attains 100% from 8-9 years. The tails on the curve are extrapolation errors.



Non serotinous: *P. sceptrum-gustavianus* yields a curve expected for non-serotinous species, in that 100% flowering is not achieved because of records outside of the flowering season. Species with shorter flowering seasons will have lower peaks: in this case, flowering peaks at about 50% of populations, and suggests that after 9 years flower production declines. However, the error bars are too large to have much confidence in this interpretation.

Resprouter early flowering: *S. lineare* flowers at 100% after flowering. This is more likely to be a function of the populations not being detected when the plants are not in flower, than a true 100% flowering.

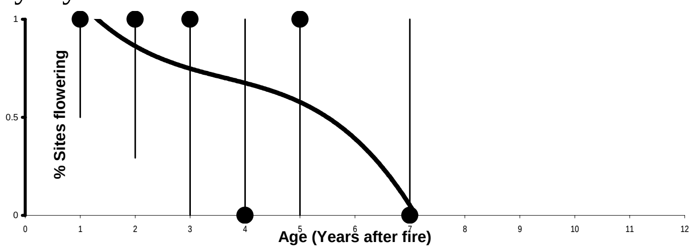
Resprouter resembling reseeder: *P. nitida* (note the nice short error bars indicative of plenty of data) appears to behave as a reseeder, except that in year 1 above 20% of the populations have flowered. However, the maximum attained is only 80% of populations – as we would expect for a non-serotinous species.



Resprouter with decline: *B. stellatifolium* displays the same pattern as *P. nitida* up until 7 years, but then declines to zero in year 13. The large error bars indicate the small sample sizes, and the last point is based on a single record which is thus of high uncertainty. Interpretaion of this curve is complicated by the flowers and fruit only being visible for a few months.

Resprouter with decline: *F. saligna* is a tree in grassland and should be largely immune to fire cycles. The data suggest though that most of the plants flower in the first 3 years following a fire, and then declines dramatically. Since most grasslands burn regularly, this might hint that keeping fires out of grasslands results in reduced flowering – however the high variance (error bars) suggests that such a hypothesis might be premature. On the other hand grasslands older than 3 years are relatively rare, and this may explain the lack of data for older veld.

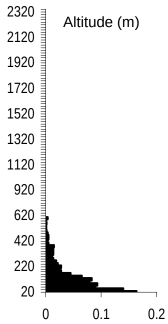
Poor data: *D. buekii* has only two records of veld age, both of which are supported by only a single data point. It is thus difficult to deduce anything from this data other than that some populations have flowered by 3 years.



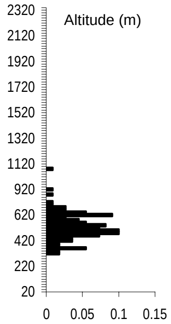
Poor data: *F. galpinii* has much more records, but most of these are based only on spurious data, as evidence by the large error bars. Little can be inferred other than that it can flower the year following a fire: perhaps not unexpected from a forest margin species.

Interpreting Altitude Graphs

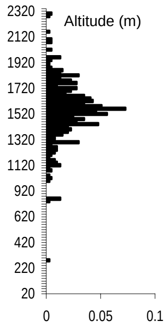
Altitude graphs are presented for all species. The vertical axis is the altitude range, which is resolved into 20 m intervals. The Fynbos altitude range of sea level up to 2400 m is used for all species – records from elsewhere higher than 2400 m are binned into the 2400 m class. The horizontal axis is the proportion of records from each altitude class – obviously species with many records from many altitudinal classes will have a low maximum value, whereas species that are poorly atlassed or with narrow altitudinal ranges will have a high maximum value. Planted records are excluded. <check if so – why do the textual and graphs sometimes differ: tie up the y axis to be more meaningful> Some patterns are:



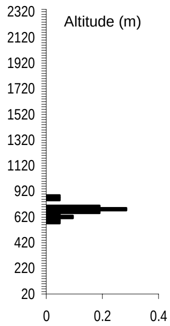
Low altitude: *L. coniferum* occurs mostly at very low altitudes from sea level to 100 m, but with outliers at higher altitudes.



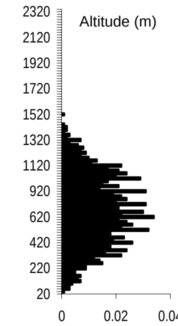
Medium altitude: *S. triternata* occurs mainly between 400 and 600 m



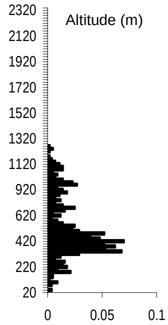
High altitude: *S. lanatus* is primarily a high altitude species, occurring above 1000 m, but with a peak at about 1500 m.



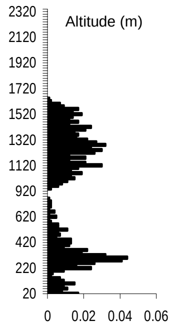
Narrow altitudinal range: *P. inopina* occurs over a very narrow altitudinal range, at about 600 m.



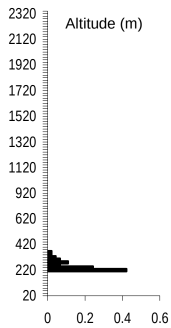
Broad altitudinal range: *P. nitida* occurs over a broad altitudinal range from sea level to 1300 m.



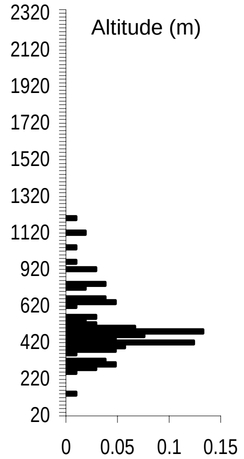
Double Peak: *L. procerum* shows two peaks: a sharp peak at about 400 m, and a lower, broader peak at about 800 m.



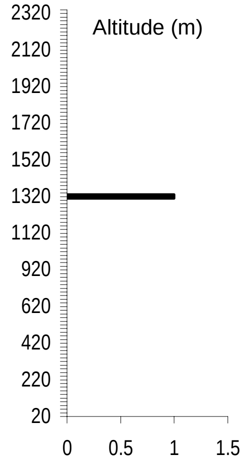
Triple Peak: *L. teretifolium* displays three peaks, corresponding to its three disjunct areas, viz. Agulhas Plain at 50 m, the Ruens with a sharp peak at 220 m, and the Little Karoo with a broad peak between 1000 and 1500 m.



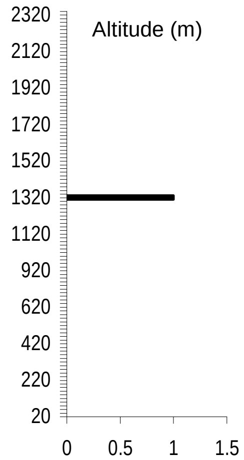
Poor data: *Di parile* has poor data, but this reflects its rarity rather than poor atlas data. Note though that the species is confined to a narrow altitudinal range.



Poor data: *D. thymaeloiodes* appears to have poor data, as the upper data is sparsely scattered over a wide 600 to 1200 m range. However, this is due to poor sporadic “sampling” of its habitat by the species, rather than lack of atlas data.



Profile of Cape Flora data: <dummy graph – data still to be compiled>



Profile of South African data: <dummy graph – data still to be compiled>

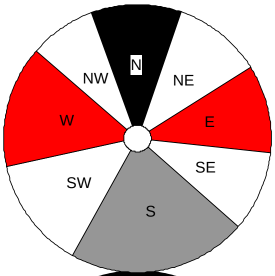
Interpreting Aspect Pies

Data were coded by Atlassers into 16 compass points. These are summarized as the four major compass points in the text summary. The Aspect Pies summarize these data in 8 compass points. The categories NNE, ENE, ESE, SSE, SSW, WSW, WNW and NNW were halved and the value added to the 8 principal compass points. These are coloured as black for North, grey for South, red for East and West, and white for the four intermediate compass points.

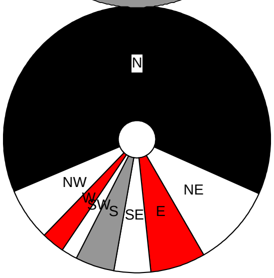
The proportions of records are coded as the angle of the pies. Thus a bigger slice implies a larger proportion. This has the disadvantage that the position of the compass points is lost, but is does have advantages. The North slice (when present) is constrained to be centred at 0^o.

However, aspect is not always relevant. Especially where the landscape is flat aspect may not a major environmental factor to the species. Consequently, the proportion of records from flat landscapes (Valley Bottom, Hill Top, Plateau) has been included as a doughnut. The size of the doughnut varies from < 10% for species that are confined to slopes, to 90% (the limit of legibility of the pie) for those that only occur in flat landscapes. The scale between 10 and 90% is linear by radius and equal to the proportion of flat areas.

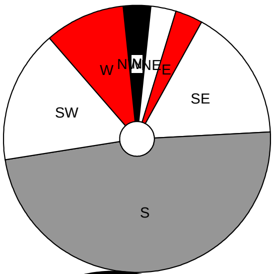
Even
Protea lepidocarpodendron has a fairly even distribution of aspect, with a very slight bias to the south and south-west. Almost all the records are from slopes.



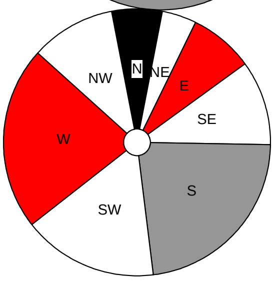
North bias
Leucospermum erubescens has a strong north bias, with over half of records from the north slope, and a good proportion of the rest from the NW and NE slopes.



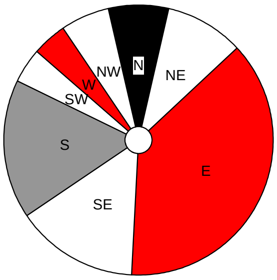
South bias
Leucospermum formosum has a strong south bias, with a good proportion from the SW and SE slopes as well. West slopes are slightly better represented than eastern slopes.



West bias
Leucadendron sessile has half of its records from the west, SW and NW sector. By contrast, only one quarter of its records are from the equivalent eastern sectors.

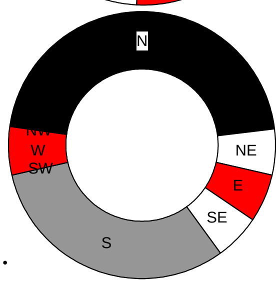


East bias
Leucadendron argenteum has a third of its records from the East, and over half from NE to SE.

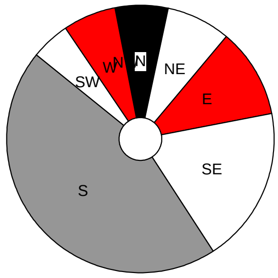


North-South bias

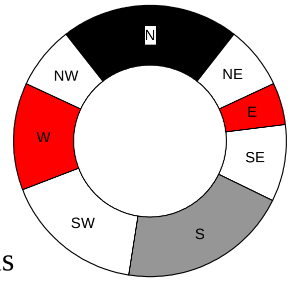
Mimetes saxatile has most of its records from the North and South slopes, and very few from any other aspect. About half of the records (57%) are from flat areas, as shown by the size of the doughnut in the centre.



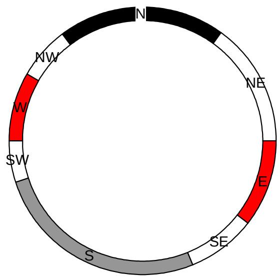
South and East bias
Protea stokoei occurs predominantly on south and SE slopes, but also on east and NE slopes. As a consequence the larger south wedge is displaced clockwise.



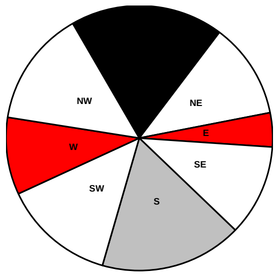
Largely flat landscapes
Leucospermum hypophyllocarpodendron occurs predominantly (56%) on flats and low-lying areas, with relatively few records from slopes. This is indicated by the relatively large doughnut.



Exclusively flat landscapes
Leucospermum heterophyllum occurs almost exclusively (> 90%) on low-lying areas and although aspect data give a good aspect distribution (slightly biased to S and NE), the size of the doughnut suggests that aspect is largely irrelevant for this species.



Sampling domain in the Cape.
The distribution of aspect types in the Cape Flora is not symmetrical and is shown opposite. Note the bias of north and south slopes (due to the Swartberg and Langeberg-Outeniqua- Tsitsikamma mountains ranges) compared to east and west. This is the pattern expected for species that are not affected by aspect. Flat areas are ignored in this summary.



Interpreting Distribution Maps
More to come here.

7. SPECIES ACCOUNTS

6 files to come here!

References
Appendices
Abbreviations, Symbols and Glossary
Index: Common Names and synonyms
Index: Scientific Names and synonyms

CD of atlas data.