# Cedars of the Cederberg



H. Peter Linder

Strelitzia 49



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# Cedars of the Cederberg

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# STRELITZIA

This series has replaced *Memoirs of the Botanical Survey of South Africa* and *Annals of the Kirstenbosch Botanic Gardens* which the South African National Biodiversity Institute (SANBI) inherited from its predecessor organisations.

The plant genus *Strelitzia* occurs naturally in the eastern parts of southern Africa. It comprises three arborescent species, known as wild bananas, and two acaulescent species, known as crane flowers or bird-of-paradise flowers. The logo of SANBI is partly based on the striking inflorescence of *Strelitzia reginae*, indigenous to the Eastern Cape and KwaZulu-Natal that has become a garden favourite worldwide. It symbolises the commitment of SANBI to champion the exploration, conservation, sustainable use, appreciation and enjoyment of South Africa's exceptionally rich biodiversity for all people.

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# Dedication

This book is dedicated to Humbaba, who died in defence of the cedar forests.

> And it befell that Gilgamesh uttered these words unto Enkidu, 'Then shall we journey unto the Forest of Cedars, unto the lair of Humbaba, the fearsome giant, Guardian of the Forest, and there shall we slay him, so his Evil will be no more. We shall defeat and destroy Humbaba and drive Evil forth from the land. Then will I cut down the Great Cedar Tree and then shall our names be remembered for all time.'
>
> —Gilgamesh, The New Translation, by Gerald J. Davis Insignia Publishing[1]

[1]Gilgamesh was King of Uruk in Mesopotamia, c. 2100 BC. Even then the bad consequences of the destruction of cedar forests were recognised.



# Preface

My father, Adolphe Linder, was a land surveyor. His first big contract, in 1950, was surveying the Cederberg. The months he spent walking through the Cederberg and meeting the farmers made a lasting impression on him. When he retired, he became a historian, and I convinced him to compile what is known about our exploitation of the cedars. He did a very thorough job, but after the severe fires at the beginning of the 21st Century destroyed so many of the trees he loved, he lost enthusiasm for the project. After his death, when clearing his office, I found all his notes, and picked up the project. I expanded it to include the biology of the cedars and was fascinated by the wonderful complexity. The resultant book is a compilation of what we know about the Clanwilliam cedars (*Widdringtonia cedarbergensis* J.A.Marsh), but it is also an exploration of the limitations of this knowledge and the difficulties of rescuing the magnificent cedars from extinction.



# Introduction: Why this book?

Cedars are charismatic trees (Figure 1). Already in the Gilgamesh Epic, 2000 years ago, cedars were special. In the Bible there are 79 references to cedars and cedarwood was used extensively to build Solomon's temple. When the first Dutch explorers found trees with aromatic wood in the mountains flanking the Olifants River, it was not surprising that they named them 'Cederboom' in reference to the lovely scent of the wood. Their association with the Cederberg, which became a spiritual home for the urban populations from the lowlands towards the end of the 20th Century, who regarded these mountains as an escape from the pressures of city life, added to the allure. The elegance of the trees, their aroma and the beauty of their open forests deepened the attraction. The apparently inexorable drift into extinction of these lovely trees adds to their mystique. It makes them emblematic of a world reeling under accelerating political, economic, social and climate change, and evokes a time when all was good and there were extensive groves of cedars in the Cederberg.

Mountaineers walking into the Cederberg from Algeria, up the hot and seemingly endlessly ascending, well-built path, first pass small dead cedar trees at the top of the zig-zag, then enter a lovely grove of tall cedars with scattered young trees. On Middelberg they pass two huts (one burnt down). Further

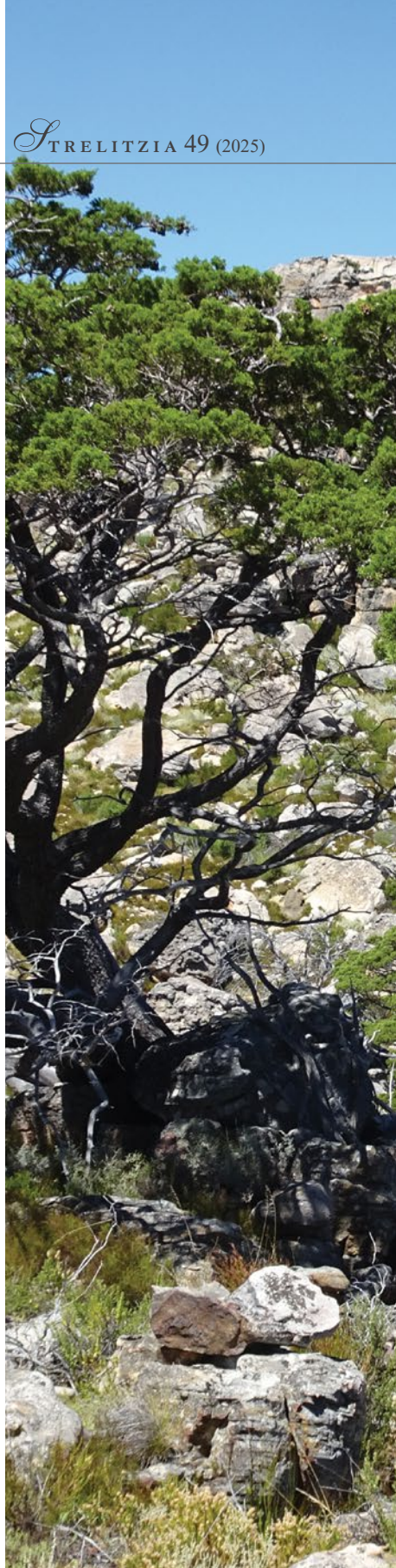
**Figure 1.** Sunrise behind a cedar near The Anvil.

along, towards Jurie se Berg, are several small groves of trees on the sand plain, while the rocky ridges and horizon are dotted with dead trees. They will start wondering what is going on in the Cederberg and with the cedars. Why so few living trees? Why such a superb path? Why the dilapidated huts? This book will provide answers to some of these questions.

The cedars raise major conservation questions. Were the mountains once covered in a cedar forest? Are the cedars really going extinct? Why is the massive effort to conserve the species over the last 150 years failing? Was the wrong action taken? Is this yet another consequence of climate change? The Clanwilliam cedar is probably the best researched species in the fynbos (Richardson 1993), but did we nonetheless ask the wrong questions? What does this mean for efforts to conserve the rich botanical heritage of the Cape flora?

The cedars also suggest difficult ethical questions. Where do we humans fit in? How much are our past actions to blame for the plight of the cedars? Is our current behaviour contributing to the problems which the species faces? And if so, how do we balance our desires against the survival of other species? Can we construct win-win situations, and when that is no longer possible, can we put the survival of other species before our desires and needs?

In this book we explore what we know, or think we know, about cedars and what the road forward could look like. We conclude that possibly the central problem for the cedars is anthropogenic climate change, but that our past actions significantly damaged the species. Cedars are very visible, whereas much of the wonderful rich diversity of the Cape flora is cryptic: could this mean that there are more species sharing the plight of the cedars? Are we absolutely incapable of stopping climate change and its impact, helplessly (like the fabled sorcerer's apprentice) watching the world spin out of control?







1

# Setting the question

Scattered in the Cederberg, among the mighty sandstone rocks, are gnarled cedar trees. They fit visually to the fantastic rock formations, stone and tree mimicking each other, tangled up to create a dance of trolls and trees. Together they create a landscape of sublime beauty that fills the heart of the weary mountaineer with joy (Figures 2–4). These iconic trees of the Cederberg have attracted the attention of Europeans for more than two centuries.

These trees look incongruous in the fine, much-branched, low fynbos vegetation, which is otherwise almost treeless. Fynbos rarely exceeds 2 m in height, with the few taller species being mostly proteas with their larger leaves, or occasional evergreen large-leaved trees. Cedars are 5–7 m tall and can grow up to 20 m high, with a trunk diameter of more than 1 m and horizontally spreading branches. Manning and Goldblatt (2012) regard the Clanwilliam cedar as the only true fynbos tree. Sometimes you are lucky and find a family group of trees: old gnarled spreading trees along with young, slender, pencil-shaped or conical trees with a strong main shoot driving upwards and side branches down to the ground, almost inviting to be cut as walking sticks. More looking around reveals dead trees, skeletons among the rocks, often quite distant from any living trees (Figure 5). Some of these scarred tree-trunks are substantial in size, bigger than any living trees. In some places there are even relicts of forests, all dead. The depressing possibility that we may be looking at

**Figure 2.** A rock *koppie* near Van Zyls Klip, with an open stand of living cedars and a few dead trees.



**Figure 3.** A superb tree in a typical habitat, among large rocks, near Vogelsang.

a very small number of survivors of a species that may well have been much more common in past slowly sinks in. That, maybe, there had been something approaching a cedar forest in the Cederberg. This impression is not new. Leipoldt[2], the amazing journalist, medical doctor, botanist, cook and poet, who was remarkably competent in both Afrikaans and English, already thought a century ago that the species was on the brink of extinction (Leipoldt 1899a). He described seeing trees 70 foot (21 m) tall, with a girth of 18 feet (5.5 m), with the first branches 5 m above the ground. He thought these were dwarfed by some trees of which he could see only the dead trunks. Indeed, some old photographs reveal massive trees with long straight trunks and spreading branches with a sparse foliage high above the ground.

There is much evidence of change in the Cederberg. The large number of dead cedar trees, contrasting with the few living trees (Figure 6), suggests that these charismatic trees are

[2]C. Louis Leipoldt was a well-known author, medical doctor and botanist. He was the grandson of Johann Gottlieb Leipoldt who founded the mission station at Wupperthal. Louis Leipoldt grew up in Clanwilliam.

becoming rare in the landscape. The abandoned and dilapidated huts indicate that human use of the mountains has changed. This impression is reinforced by the beautifully built, but overgrown, paths.

Presented with the current picture, a number of questions arise: What is going on in the Cederberg and what are the ruined huts at Middelberg about? Why are there so many more dead than living trees; were they really more common in the past and thus on the brink of extinction? And if so, why have they become so rare? Is the current decline the result of over-exploitation in the past, or perhaps of more recent mismanagement, of too many fires? Or are we seeing the consequences of global climate change? Attempts to conserve them have been ongoing for more than a century, why are these failing? Above all, can we still save the cedars of the Cederberg?

The Clanwilliam cedar is restricted to the Cederberg. This rugged mountain range forms the northern-most high mountains in the north-trending sandstone Cape fold mountains that run from Worcester and the Hex River Valley northwards to Vanrhynsdorp and the



**Figure 4.** Two big cedars (see person for scale) below Mied se Kop.



**Figure 5.** Dead cedars on the skyline, a common sight in the Cederberg.

Matsikamma. To the south of the Cederberg is the large plateau of the Koue Bokkeveld with its scattered mountains; to the north the mountains rapidly become lower, dropping down to the Doorn River; to the east the arid plain of the Ceres Karoo (also known as the Tankwa Karoo); and to the west the Olifants River Valley (Figures 7, 8).



**Figure 6.** Small patches of trees on the pass below Jurie se Berg, with the path leading through underneath the trees. The even age shows that they are remnants of plantations.

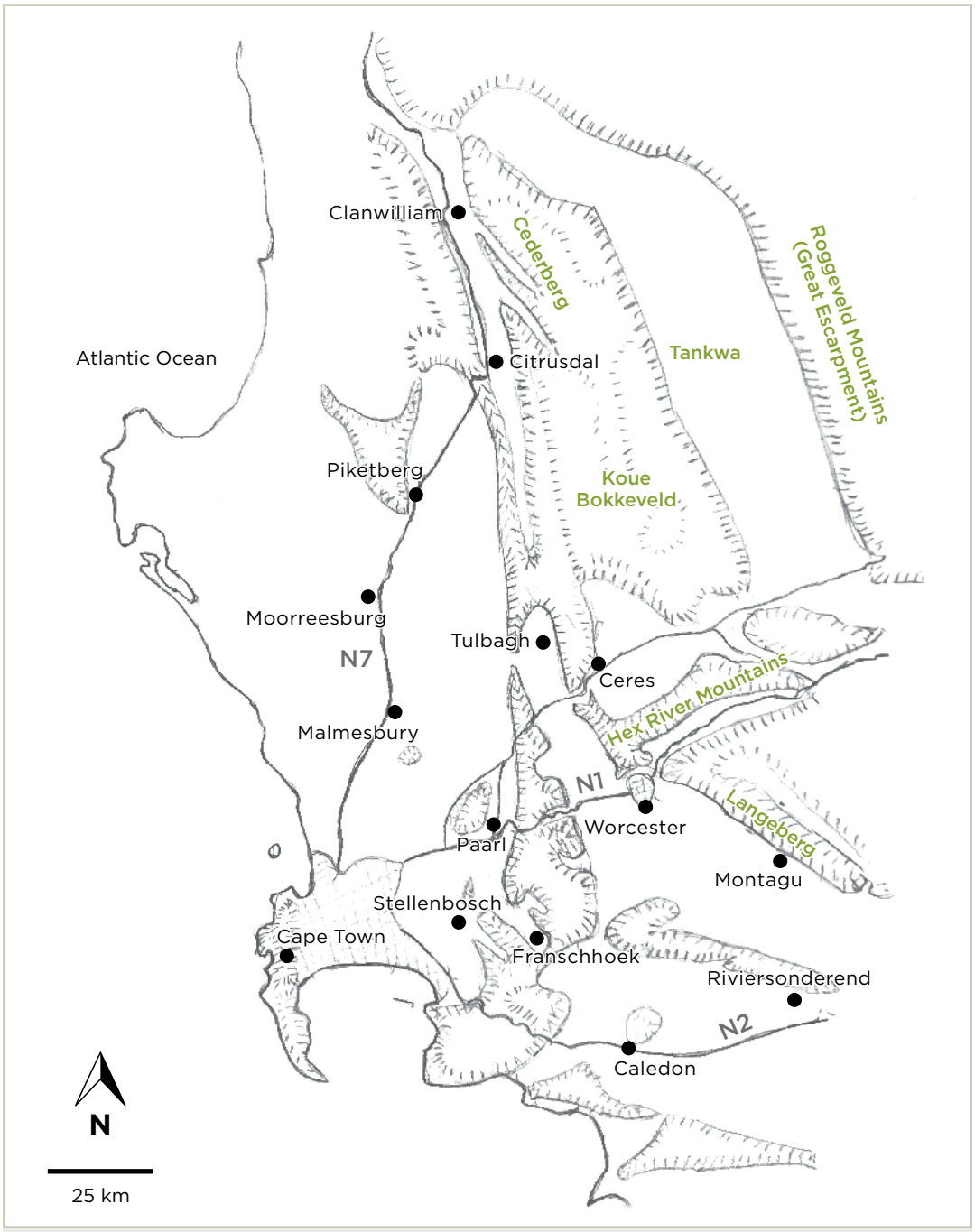



**Figure 7.** Map showing the placement of the Cederberg in the Western Cape.

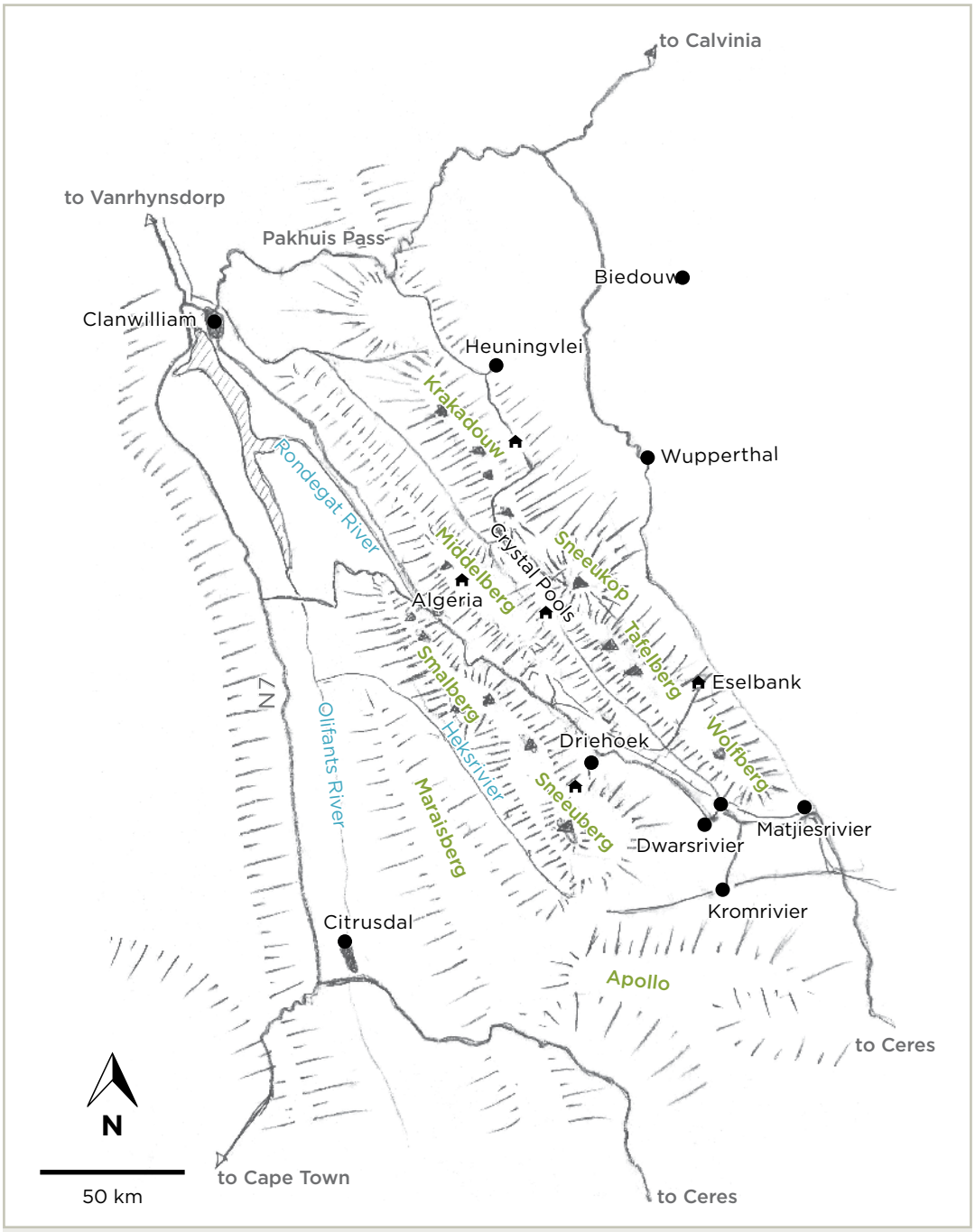



**Figure 8.** Main geographical features of the Cederberg.

How widespread are the cedars in the Cederberg? The current distribution, frequency and number of trees in the field are difficult to determine. The trees mostly grow in wild, inaccessible places. These can be difficult to reach and a complete search on foot would take a very long time. Two quite different approaches have been used to map the trees: modelling the potential range and abundance, and using satellite imagery to count the number of trees.

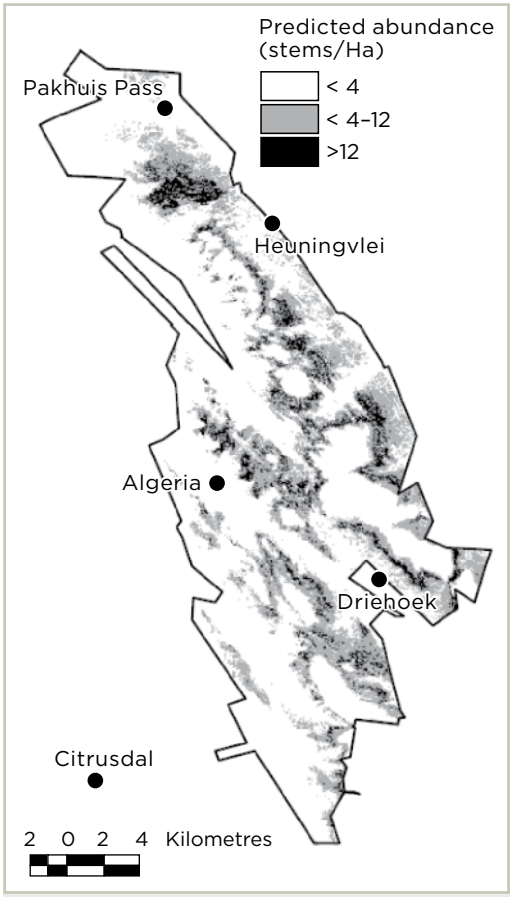



**Figure 9.** Modelled distribution of the Clanwilliam cedar, with an indication of how abundant the trees are expected to be (from Farjon [2001]).

The modelling approach to determine the potential range and abundance of cedars is to build what is known as a species distribution model. Using this methodology, a large number of locations within the potential distribution range are investigated for environmental variables and these are correlated to the occurrence of cedars. Steve Higgins, Ed February[3] and Andrew Skowno (Higgins et al. 2001) sampled 50 × 50 m plots placed randomly along routes that traverse the cedar distribution area. For each plot they recorded the elevation, aspect, slope, distance from streams, estimated evapo-transpiration rates and Landsat spectral (satellite) images, as well as the presence/absence of cedars and some measures of their size. These were used to build a model of the environmental conditions under which cedars are found and this model was used to determine the area of suitable cedar habitat across the mountains (Figure 9).

[3]Ed February, Emeritus Professor at the Botany Department of the University of Cape Town, and superb mountaineer and rock climber, worked extensively on cedar biology from c. 1990 to 2020. He collaborated with Willie Stock and Steve Higgins and supervised several M.Sc. degree projects on the cedars (including projects by Sarah-Jane Fox, Leila Mitrani, Fiona Ballantyne and Joe White).

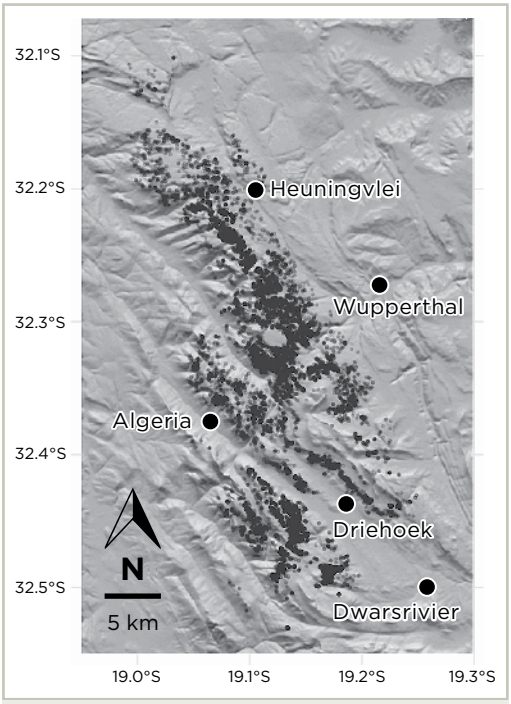



**Figure 10.** Current distribution of cedars, according to Peter and Jasper Slingsby. Map generated by Jasper Slingsby.

The more direct plant count approach was developed by a father–son combination, Peter and Jasper Slingsby (2019). They spent a month studying Google Earth images from 2013, identifying and marking the trees. Then they spent a considerable amount of time doing targeted fieldwork to check on the accuracy of the Google Earth mapping – and found it to be very high. There were almost no errors of commission (i.e., marking trees which are not there) and few errors of omission (missing out trees which are there). Live trees or tree-clusters with a canopy diameter of less than 4 $m^2$ were below the resolution of the images. In total, they mapped 13 419 localities with a live tree or cluster of live trees, ranging from just north of Pakhuis Pass south to Dwarsrivier (Figure 10). The western-most outliers are on Maraisberg above Brakfontein, just east of the Olifants River, and the eastern margin of the distribution range is a straight line from Heuningvlei in the north to Gabriël's Pass in the south.[4]

So, what is the fuss about? There are still thousands of cedars in the Cederberg, indeed they are very widespread in the range. One may argue that the large number of dead trees could simply be the result of the dry climate where old, dead trees take centuries to rot away and disappear from the environment. These results appear very optimistic. However, their fieldwork showed that recently dead trees, some with leaves still on them, outnumbered living trees by a ratio of 2:1. Is there any evidence that numbers of cedars have become reduced, that their range has become restricted, and that they are heading to extinction? We explore this evidence in the next chapter.

[4]These are marked on the publicly available *Slingsby Maps: Hike the Cederberg*.





# 2 Decline of the cedars

We generally tend to believe that things were better in the past than at present and that the future looks dismal. This bias is further confounded by our short memories: we can remember back a few decades, at most, and usually we compare the current year with the previous one. In this chapter we explore the evidence that cedar populations have been much reduced during the last two centuries. Digging into the past is tricky. The evidence is often ambiguous and, consequently, we are exposed to the danger of interpreting it to fit our preconceptions. To minimise this risk, we present both the evidence and our interpretations, so allowing the reader to travel into the past and re-interpret the sparse evidence. We divided the chapter into three sections: the first deals with the 'pre-European' era, from before any written records. The second deals with the period from 1800 to 1870, consisting mostly of comments from travellers. After 1870 the nature of the comments changes, they are mostly (but not always) from foresters, and from 1960 onwards are increasingly supported by numbers.

## Prehistoric evidence of cedar distribution (before 1780)

If we could travel in a time capsule into the Cederberg's past, before the first words were written about

the cedars, we would have answers to many questions. We would, for example, know the size of their distribution range, and whether or not they were always restricted to rocky habitats and if they formed closed forests there. We would also know if they occurred on the sand plains and, if so, whether they formed closed forests there. We have surprisingly much evidence on the vegetation of the Cederberg from prehistoric times, but it needs to be interpreted very carefully, as it is all too easy to interpret the data to fit our assumptions.

The large number of plant species currently restricted to the Cederberg suggests that these species have most likely evolved and persisted there. This would only be possible if fynbos has been the dominant vegetation type throughout the Pleistocene, so during the last 2.5 million years. This, in turn, implies that there were no dramatic changes, as happened for example in Europe during this epoch. During this time the Arctic ice cap reached northern Germany, the central European forests were replaced by tundra and mammoths roamed this bleak landscape. However, the persistence of fynbos tells us little about the fate of individual species, such as the Clanwilliam cedar.

From the Last Glacial Maximum (LGM), about 20 000 years ago, to the present we have a surprisingly good fossil pollen record for cedars from the Cederberg. Pollen walls are immensely durable, being constructed of a chemical called sporopollenin[5]. Especially in conditions where there is no oxygen, they are preserved for millions of years. This provides a wonderful record of variation in the relative importance of different parts of the flora.

For the last 25 000 years there are two such preservation conditions. The first is in bogs and wetlands. Exploring the pollen record preserved in bogs was pioneered almost a century ago in Sweden by Gunnar Erdtman. The pollen is preserved in anoxic organic sediments of the bogs, with the oldest at the bottom of the deposit and the most recent at the top. Carbon dating approaches are used to date some of the layers and the ages of the rest are then filled in. Usually, a core is drilled out of the wetland, carefully kept intact, and sampled every few centimetres for charcoal, pollen, organic material, or whatever is being researched. Recently another pollen preservation material was found and developed for South Africa: dassie (rock hyrax, *Procavia capensis*) middens (Scott & Woodborne 2007). These middens have a wonderful name, hyraceum, but the more descriptive Afrikaans name for them is *klipsweet*. They are usually found in caves or under rock overhangs, where they are protected from rain (Figure 11) and are formed from the consolidated and dried faeces and urine of the dassies. Because dassies keep using the same toilet site for thousands of years, these middens can

[5]Sporopollenin is one of the most chemically inert biological polymers, with a complex chemical composition.



**Figure 11.** Dassie hyraceum at De Rif in the Cederberg. Photograph: L. Quicke.

grow into massive structures. This mass often contains plant and animal remains, and huge numbers of pollen grains. Often the middens 'grow' at a fairly constant rate and can be dated with carbon-dating approaches. This is a superb source of dated fossil pollen samples in regions too dry for bogs.

However, the interpretation of the fossil pollen record comes with several caveats. First, each site is biased towards the species which grew immediately around the area. For bogs, these are wetland species (often sedges), for hyrax middens these are species that grow around rocks. Thus, neither preservation method samples well-drained sand plains. The second bias is that the pollen has to reach the bog or midden, thus wind-pollinated species with long flight distances are over-represented, and animal-dispersed pollen is largely absent. Confusion can also arise from occasional other means of transport, such as streams flowing into bogs. In the case of middens, if the pollen in the dassie manure is used, it must have been carried in by the dassies. Fortunately, cedars are wind-pollinated, so their pollen can be assumed to always be represented in the deposits if the trees grew nearby. However, amazingly, we do not know how far cedar pollen can travel by wind. The pollen walls are, compared to most other plant species, thin, and it is therefore likely that transport distances are short, possibly less than 100 m, before the pollen grains dry out and collapse. The third caveat is that, although the minute pollen grains are rich in surface ornamentation, they can usually only be identified to family or at best to a tribe (thus groups of genera). Here, again, we are lucky: the Clanwilliam

cedar is the only member of the family Cupressaceae in the Cederberg, so the species can be unambiguously identified.

There are seven relevant fossil sites in the greater Cederberg area that reach back to the beginning of the Holocene, with some into the LGM. The Holocene, which started 10 000 years ago, had a more or less modern climate, sharply distinct from the climate of the glacial periods and possibly comparable to earlier interglacial climates. The coldest, and for the Western Cape probably the wettest, time of the last glacial is referred to as the LGM, about 26 000 to 19 000 years ago. Between the LGM and the start of the Holocene, Western Cape climates probably gradually became drier and warmer. The seven fossil sites are summarised in Table 1 and the map in Figure 12.

Of these sites, Pakhuis (Scott & Woodborne 2007) is on the northeastern end of the range, on the much drier inland side of the mountains and at a much lower elevation, although only 3.5 km from the nearest extant cedars. Katbakkies (Meadows et al. 2010) is far to the south,

**Table 1.** Plant fossil pollen sites in the greater Cederberg area

| Locality name | Preservation type | Elevation (m a.s.l) | Oldest age (years) | Habitat | Cedars recorded in the record |
|---|---|---|---|---|---|
| Pakhuis | Midden | 460 | 23 000 | Rock | Never |
| De Rif (Quick) | Midden | 1 200 | 15 000 | Rock | Continuous, rare |
| De Rif (Valsecchi) | Midden | 1 200 | 15 000 | Rock | Continuous, rare |
| Driehoek Vlei | Bog | 900 | 14 000 | Sand | Continuous and common until 3 000 years ago, then declining and becoming almost absent in the last centuries |
| Sneeuberg Vlei | Bog | 1 320 | 14 000 | Sand | Continuous, rare |
| Truitjieskraal | Midden | 890 | 10 000 | Rock | Never |
| Katbakkies | Midden | 1 190 | 8 000 | Rock | Never |

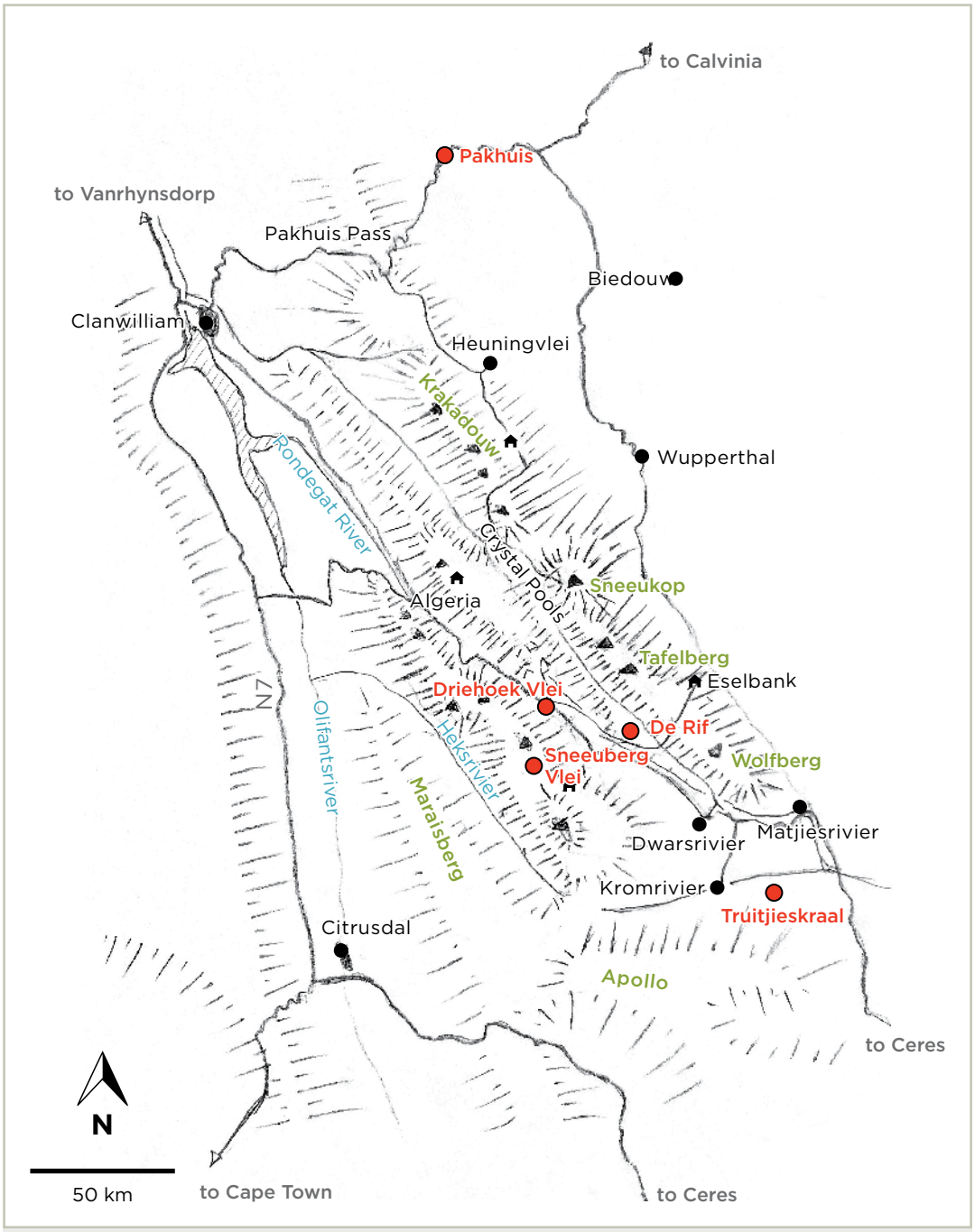



**Figure 12.** Map of Cederberg showing positions of fossil sites (except Katbakkies).

on the eastern, inland edge of the Koue Bokkeveld, 60 km beyond the current range of the cedars and also much drier. Truitjieskraal (Meadows et al. 2010) is directly south of the main cedar range, also in a much drier habitat and only about 10 km from the nearest living cedars. The two De Rif sites are within the range of the cedars, each less than 1 km from living plants, as are the two bog sites. Driehoek Vlei is just below the lower margin of the current elevation range, about 1 km from the nearest cedars on Mied se Kop, with Sneeuberg Vlei in the middle of that range (near Sneeuberg Hut).

These data give a partial answer to the question of whether the geographical distribution range of the cedars was larger during the colder and wetter glacial periods. Probably not. The Pakhuis dassie midden that Scott and Woodborne (2007) investigated did not have any cedar pollen. This despite the fact that it is only a few kilometres from the nearest extant plants and reaches back to the LGM at 23 000 years ago. It is, however, at a much lower elevation and currently much drier. The other expansion direction could have been to the south, into the Koue Bokkeveld. The midden from the Katbakkies Pass, which is 60 km south of the nearest extant stand and currently drier although at the correct elevation, also had no cedar pollen (Meadows et al. 2010). This record does not reach back to the LGM, but it does suggest a moister climate near its base, so possibly cedars may have occurred there during the LGM. More interesting is the midden from Truitjieskraal, which Mike Meadows and Brian Chase (2010) investigated. This site is only 10 km south of the nearest living plants, at the same elevation, but drier. This record dates back to the beginning of the Holocene, but not to the LGM. It also has no cedar pollen. Frustratingly, the available data cannot exclude the possibility that, during the colder and wetter LGM, the distribution range of the cedars extended further south.

As to the question of whether there were forests of cedars in the rocky outcrops, the two middens at De Rif give a clear answer. The one De Rif site is assembled of two middens, one in a rocky hill with cedars on it, the other 140 m away. These sites reach back to 20 000 years ago (Quick et al. 2011), to the LGM. Cedar pollen is present throughout this period and at the same low proportion as it is now. There is no evidence of large stands or closed forests of cedars. This is corroborated by the other pollen types present, such as Restionaceae, *Stoebe* type and *Anthospermum*, all of which are from lineages of light-demanding species, which will not be found under a closed canopy forest. This suggests that much denser stands were unlikely – and closed forests definitely not the case – along the path from Driehoek to De Rif. These results were corroborated by the study of a midden 400 m to the northwest, on the same slope, but in a currently drier habitat (Valsecchi et al. 2013) without any extant cedars. At this site, cedar pollen occurred sporadically and was completely missing during the probably hotter and drier early Holocene.

As to the question of whether cedar stands ever occurred on sand plains, the pollen record from the Driehoek Vlei site is informative (Meadows & Sugden 1991). The vlei (a marshy area or shallow lake) is a large, flat, sandy plain through which the Driehoeksrivier meanders. Although the rocky ridges around the vlei (Mied se Kop, Hoogvertoon) still have cedars among the rocks, there are none on this sand plain. Possibly the elevation is too low (900 m a.s.l.), fires sweeping uninhibited across the vlei removed the cedars, or the soils are too dry or too wet. Mike Meadows and Jean Sugden (1991) took cores from this vlei and obtained a record reaching back to 17 000 years ago. Cedars were a common element until 3 500 years ago, after which they became more rare. The proportional contribution gradually declined from just under 10% at the end of the LGM, with further steps down at several points in the Holocene, and then a dramatic decline in the last 3 500 years, finally disappearing quite recently. As can be expected from a wetland, sedges consistently contribute about 15% to the pollen and restios some 10%. The decline in cedar pollen is compensated by an increase in erica and Proteaceae pollen. The site is 600 m from the nearest rock outcrops and cliffs on both Mied se Kop and Hoogvertoon. It seems that the only possible explanation is that there was an open forest on the sand plain, that this decreased gradually in density throughout the Holocene, and then rather rapidly in the last 3 500 years. As the forest opened up, Ericaceae and Proteaceae became more important. The consistently high percentage of sedges suggests that the wet part of the wetland remained an open sedge bog (as it is now), with the forest or woodland some tens of metres away. If this interpretation is correct, then there were cedars on the sand plain and they did form almost closed canopies. This does not accord with Mike Meadows and Jean Sugden's (1991) interpretation, when they note, '...nor are they indicative of a cedar "forest" on the Cederberg vlakte...', although it is not clear whether they include open forest as a forest type. They do accept that, 'Open, perhaps even savanna-like, cedar communities formerly extended to lower altitudes than they do in the present day.'

This is corroborated by the second core Mike Meadows and Jean Sugden (1991) investigated. This came from the Sneeuberg Vlei site, situated at the headwaters of the stream flowing down the Cederhoutkloof. This consists of relatively narrow sand plains (100 m or less) containing the vlei, flanked by rocky ridges and plains with occasional cedar trees. This record reaches back to 11 000 years ago and also shows a gradual decline in cedar pollen, with pollen still present at the top of core (thus, the present). In the early Holocene the cedars were interpreted by Meadows and Sugden (1991) to form an open woodland with proteas on the sand plain, whereas by the late Holocene the cedars were interpreted to be gone from the sand plain, but to be persisting on the rocky outcrops. Possibly the increase in restio pollen through the Holocene reflects the sand plain becoming a tree-free restio plain. As in the De Rift middens, there is a persistence through time, but the cedars were more common in the early Holocene than the Late Holocene.

The final question is how far cedar pollen travels. This is important in being able to establish whether a fossil pollen site means that the trees grew there, or whether the pollen could have travelled in, and it also impacts the breeding system of the cedars (see Chapter 4). Cedar pollen seems to travel less than 300 m. Fiona Ballantyne (2010) studied the bog at De Rif and, although the core was some 300 m from the plantation at De Rif, she found no cedar pollen in the deposit. This short distance dispersal is corroborated by the sporadic presence or even complete absence of cedar pollen from the Valsecchi midden, which is less than 400 m from a rocky outcrop with several cedars on it, as well as a midden showing continuous occurrence of cedar pollen from the LGM (Valsecchi et al. 2013).

These interpretations are partially consistent with those of Mike Meadows and Jean Sugden (1991), where they write, 'The Clanwilliam cedar has at no stage during the past 14 500 years dominated the Cederberg landscapes...'. We think that they dominated the sand plain of the Driehoeksrivier, perhaps even the sand plain below Sneeuberg, but they were clearly sparse on the rocky mountain slopes at De Rif. Frustratingly, it does not tell us anything about the sand plains in the northern Cederberg on the eastern flanks of the Krakadouw, or the sand plains on the Middelberg. But, in the absence of contrary information, the simplest answer is that these were also covered by an open cedar woodland in the early Holocene.

In summary, we do not know whether the distribution range of the cedars was larger in the LGM towards the south – it is possible. We do know that they reached down to somewhat lower elevations and formed open woodlands on the large sandy plain of the Driehoeksrivier. They probably also occurred on sand plains at higher elevations. These woodlands gradually became less dense during the last 10 000 years, a process that was dramatically accelerated some 3 500 years ago. However, most likely they did not form a closed woodland or forest on the rocky slopes, but always occurred as smaller stands.

## References to the Clanwilliam cedar in the 19th century

There are remarkably few comments on the cedars from botanists and travellers prior to 1870. This is surprising, because forests are somewhat unusual in the Cape and timbers suitable for building and furniture were already becoming scarce by 1700, as noted by Willem Adriaan van der Stel (Grut 1977). This is even all the more so in the case of the northwestern parts, compared to the southwestern parts of the Western Cape. There were (and still are), small forest patches and low trees along some streams, but in the open well-drained landscape the tallest trees are generally waboom (*Protea nitida* Mill.) and rockwood (in Afrikaans known as

*kliphout*; *Heeria argentea* Meisn.) among rocks. There is also the highly local Gifberg endemic hyena-poison (in Afrikaans known as *wolwegifboom*; *Hyaenanche globosa* [Gaertn.] Lamb. & Vahl). None of these trees yield timber suitable for building or furniture. Cedars do.

Part of the reason for the absence of early observations of cedars may be that the Cederberg was particularly inaccessible. Carl Peter Thunberg, the Swedish botanist and student of Linnaeus, for example, travelled with Masson from Piketberg to Verlorenvlei near the coast, then inland to Heerenlogement (near Graafwater), before continuing further northwards, in 1774. He consequently stayed on the coastal side of the Olifants River Mountains. He then returned to Cape Town via the Tankwa Karoo and the Hex River Valley, so circumnavigating the Cederberg (Thunberg 1986). He did not mention cedars in his travel account, nor did he collect any specimens. Henry Lichtenstein, who travelled with De Mist to the Hantam and the Roggeveld in 1803, went from St Helena Bay over the Olifants River Mountains and crossed the Nardouws Pass north of Clanwilliam, before continuing to what is today Nieuwoudtville via Doornbosch on the Doorn River and Moedverloor (a rather sandy valley, no wonder that the journey was quite an epic). From there they continued to what is today Sutherland (Lichtenstein 1912), thus again bypassing the Cederberg. A simple explanation for the absence of observations in the Cederberg may be the difficulty of getting wagons across mountain ranges in the absence of roads or passes.

## Cedarwood was available from Cape Town to Calvinia

The former widespread availability of cedarwood is confirmed by three sources. The first was by John Barrow, who accompanied Lord Macartney to set up the administration of the Cape during the first British occupation (1796–1803) and who compiled detailed notes on the region, plus assembling a rather erroneous map. In an account of his travels (Barrow 1801), he published a table listing the 'useful woods, growing in the Colony of the Cape of Good Hope' on pages 339 and 340, curiously, in a description of the Knysna forests. Here he lists, as number 33: 'Cyperus, or Cedar-hour / Height with a branch 12 – 20 feet / diameter 1 foot / Quality of fir / Uses chests, drawers, furniture / Linnean names *Thuia*, new species? / Remarks: The strong smell of turpentine it emits prevents insects from entering it.' It seems likely that this was the Clanwilliam cedar and not the Willowmore cedar (*Widdringtonia schwartzii* [Marloth] Mast.). Presumably, this list was compiled while he was in Cape Town around 1800, implying that the wood was known in Cape Town. There is no indication where the wood came from. Curiously, the first mention of cedars in the literature is not of the trees or forests (if there really were any), but of the wood.

The presence of cedarwood in Cape Town was confirmed by the following advertisement which appeared in the *Kaapsche Courant*, Deel 1 No 15, on 26 April 1806: 'the undersigned presents for sale … cedar wood planks 1 to 2 inches thick, very suitable platten voor huizen [= boards for houses] … at the pakhuis of J.J. v d Berg in Longmarket Street.' This is a mere six years after Barrow probably obtained his information about cedarwood, corroborating the presence of this wood in Cape Town at the beginning of the 19th century. Evidently at this stage cedarwood was sold from Calvinia to Cape Town. It would be interesting to know what the logging rates were (see Chapter 6).

The use of cedarwood in the Nieuwoudtville area was noted by Henry Lichtenstein (who later became the Director of the Zoological Museum at the University of Berlin) in 1803. He travelled with Commissary-General De Mist throughout the Cape Colony. The expedition bypassed the Cederberg to the north and Lichtenstein (who wrote a detailed account of the De Mist expedition; Lichtenstein 1812) noted that at Lokenburg (near what is today known as Nieuwoudtville), 'Wood for building is brought, though not without great difficulty in the transport, from the cedar hills, and the houses in this district are therefore much more roomy, more convenient, and built in a much better taste than in the Roggeveld.' This is presumably cedarwood and corroborates the report the Veeteelt Commissie wrote two years later.

## The Veeteelt Commissie of 1805

There is a remarkable report of the 'Commissie voor Veeteelt en Landbouw in de beide Bokkevelden, de Hantam, etc.' written by Van Rijneveld in 1805, but only published by Theal in 1911 (Van Rijneveld et al. 1911). This is sufficiently important that we quote the relevant sections in full, in the original Dutch, and then explore what to interpret from it:

> In het district van de Bidouw vindt men onder anderen aanmerkelijk het *Ceder hout*, dat op de bergen van die naam wast. Langs de Cederberg woonen eenige Bastaards, welke zig met het kappen van Cederhout erneeren; deeze brengen en verdebiteeren het hout aan het Roggeveld, den Hantam, de Oliphants-rivier, en 24 Rivieren, enz. Dit hout verzagen zij in balken van 6 duim in het vierkant, en van 18 a 20 voeten lang, en in planken ter breedte van 12 tot 18 duim, mitsgaders van 1¼ tot 1½ duim dik. Het Cederhout is zeer geschikt voor timmerhout, is wel eenigermate brosch, doch durabel tegens water en lucht; vooral dient het tot het maken van molens. In dit opzichte suppleert het volkomen aan het cajaten hout. Frans Lubbe heeft er op zijn plaats een water

> rad voor zijn molen van gehad, welk rad 20 jaaren lang geloopen heeft zonder te rotten. Het bosch wordt gereekend 4 uuren lang en eer half uur breed te zijn, op zommige plaatsen is het ten uitersten ongemakkelijk de boomen er uit te haalen. De manier waarop tegenwoordig met dit bosch wordt te werk gegaan kan niet ander strekken dan om hetzelve binnekort te vernielen. Een ieder kapt naar eigen goeddunken, vernielt jonge boomjes, en handeld in deezen zonder eenig opzicht noch bemoeijenis van den veldcornet of iemand anders.

And two paragraphs later:

> Bij de Commissie geroepen, en nopens het bosch ondervraagd zijnde, verhaalden zij dat er nog veel zwaar hout in het bosch is, doch op veele plaatsen moeijelijk om het er uit te krijgen, en dat het zaad rijp word in de maand September, belovende teven om alle jaaren in den maand April de overige klooven van den berg vol to zaaijen 't geen zij zeiden met gemak to kunnen geschieden.

An English summary is that the cedarwood from Cederberg is worked by Basters (a southern African ethnic group), who sell it to the Roggeveld, the Hantam (modern Calvinia to Nieuwoudtville, some 30 farms), the Olifants River (modern Nardouw to Cardouw/Dasklip, south of Citrusdal, some 30 farms) and the Porterville districts. They cut square beams of 160 mm and about 6 m long, and planks 300–450 mm wide and 32–38 mm thick. The wood is useful for carpentry, resistant to water and air, and good for mill wheels. The forest is 4 hours long and half an hour wide, in some places it is extremely difficult to get the wood out. The way the forest is dealt with will soon destroy it. Each person does what they want, there is no control from the authorities. The Basters said that there is still heavy wood in the forest, but that it is often difficult to extract. They said that the seed ripens in September and promised to sow it out in April.

What can we interpret from this?

- The report is a remarkable document. It is a day-by-day report of the commission's trip. They left Cape Town on 25 September 1805 and travelled on horseback via Roodezand (Tulbagh Valley), the Hex River Valley, Verkeerde Vlei, through Karoo Poort into the Tankwa Karoo (Middel Bokkeveld), up onto the Roggeveld Mountains and along these to the Onder Roggeveld and the Hantam. Then via Oorlogskloof to the Bidouw, north past Elizabethsfontein to Nardouw, up the Olifants River Valley to Cardouw. Then along the

Olifants River Mountains to 24 Rivieren (Porterville), then to Piketberg, down the Berg River to the modern Hopefield, and back to Cape Town via Groene Kloof (Darling). They arrived back in Cape Town on 9 November 1805. The report contains lists of sheep, cattle, what the farmers produce, the names of the farmers and their farms, and their condition. There are also notes on the vegetation. Reading it is like watching a travel film, as many of the farm names are still there, making it possible to track their journey and to visualise the vegetation. The beauty of this document is that it is factual, detailed and not adorned.

- The commission obtained this information in the Bidouw and while at the farm Bettjesfontein (presumably the currently known Elizabethsfontein on the Brandewynrivier, just below the Pakhuis Pass). The implication is that the forest was in the northern Cederberg, between Pakhuis and Sneeukop. It seems unlikely that people living near Bidouw would collect wood from the Middelberg, Welbedacht, or the southern Cederberg. It is impossible that the commission themselves could have seen the 'forest', as they always noted when they made excursions (and here they did not mention an excursion), and they were in the area for less than two days. They arrived at Bidouw at noon of 24 September, then continued to Bettjesfontein. On 25 September they continued to the Nardouw Pass and spent the night on the inland side of the pass. Although they visited Jan Dissels (Clanwilliam) on 27 September and Hex River (just north of Citrusdal) on 28 September, there is no mention of cedarwood, so it seems that at that time all the wood was leaving the Cederberg towards the east.

- The extent of the forest is given in horse hours. Author C.A. Smith (1955), who did a wonderful job tracing all the old references, translates these as 24 × 2 miles, or 39 × 3.2 km. Amazingly, 39 km is the distance from Pakhuis to Gabriël's Pass, thus the north–south axis of the current range. Three kilometres is the width of the eastern flanks of these mountains. The *bosch*, which the informants of the commission were aware of, likely covered the eastern flanks of the Cederberg.

- The commission questioned the Basters who worked the forest. There is no obvious reason why the commission should have been misled, as they were not collecting information to tax or control. However, people who grew up in the Cederberg would not know what a dense forest was and probably could not tell the difference between an open woodland and a dense forest. So, the term *bosch* means anything taller or denser than fynbos and, as such, becomes a very vague term. Consequently, it is possible that there was a dense forest from Pakhuis to Gabriël's Pass, or an open woodland, or clumps of trees in an otherwise treeless landscape. We simply do not know how to interpret the word *bosch*. This vagueness continues in modern Afrikaans, where *bos* can mean anything from a thicket to a proper forest (as

at Knysna). What is striking, though, is that they did not use the word *woud*, which would have been more unambiguously a forest.

- The report that the wood was sold to the Hantam district was corroborated independently by Lichtenstein (1812).

- It is unclear how much wood was being extracted, but it seems that not many people were involved (*eenige bastaards* = probably 'some'). However, there could have been many more people working the forest before 1803, as the commission noted that some *bastaards* had left the district. This matches the comment from Nigel Penn (2005: 256) that hundreds of Khoikhoin arrived at the Sak River mission (north of the Roggeveld Mountains) from the Cederberg in 1803.

- The cedars were already being unsustainably logged by 1805. But, there is no mention of fire and none of grazing, only a comment that the young trees were being damaged. That suggests that the seedling regeneration was good, but that the saplings were suffering. It also suggests that the forest had been logged for some time.

- Some of the wood was difficult to extract, meaning that some was easy to extract. The implication is that at some earlier time there was more that was easy to extract.

- The first attempts to manage this resource date back to 1805, by sowing the seed into suitable habitats. This is not all that different from current attempts to conserve the cedars.

- They knew the biology: the seed is indeed ripe beginning summer (September to October), but only released in April. They also knew that the optimal time for sowing the seed was before the winter rains started.

## Wupperthal

The establishment of the mission station at Wupperthal (see Chapter 5) resulted in the missionaries writing about the area, including the cedars, and most likely also led to German plant collectors (Drège, Ecklon and Zeyher) from crossing the northern Cederberg to Wupperthal.

Johann Gottlieb Leipoldt, the first missionary at Wupperthal, wrote in the Barmer Missionsblatt in 1831 that the cedars grew further north from Wupperthal and commented that they stand there in a relatively large number. He also noted that they reach a great height and thickness, and that the cedarwood is the only building wood available there and many

*Bastaards* earn their living by sawing the wood. He recorded that it was easy to work when fresh, but when the wood is old, it became too hard, and that it was indestructible in water (Leipoldt 1831). Also from the same year is an extract from the diary of Von Wurmb (one of the missionaries), in which he noted that the top of the gorge down to Boskloof (possibly what is today known as Krakadouw Pass) was full of big rocks and cedar trees (Von Wurmb 1831). Later the same year (September 1831) Leipoldt noted in his diary that he and some people had spent two days in the mountains to fetch cedar seedlings to plant near Wupperthal, and noted that, as these trees usually grow between rocks, it was difficult to get the seedlings out (Leipoldt 1832). These two comments indicate that cedars were common and large on the eastern slopes of the Cederberg, between Wupperthal and Krakadouw. It also indicates that they are restricted to habitats among rocks and absent from the sand plains. Alternatively, any stands on the sand plains had already been logged out by that time. The Veeteelt Commissie, where it was noted that access was becoming more difficult, was from almost 30 years earlier. Leipoldt's 1832 report indicates that recruitment was good. It was possible to dig out 150 seedlings and, as importantly, it shows that Leipoldt wanted indigenous trees at his mission station, not only European oaks and poplars.

The first botanist to have seen the cedars is likely to have been the remarkable botanical collector, Johann Franz Drège, in 1828 and 1831 (see Chapter 3). It seems likely that he crossed from Clanwilliam (Jan Dissels) and Boschkloof over Krakadouw Pass to Heuningvlei, and travelled further to Wupperthal and Ezelsbank. He did not describe the vegetation: his approach was completely floristic, listing the plant species he found at particular sites.[6] As he listed cedars only above 4 000 feet (1 200 m), that was probably the lower limit of the trees as the time.

## Comments in travel books

From 1836 to 1841 the cedars were mentioned in three travel books and these probably played a big role in shaping the public perception of the Clanwilliam cedar. They were also steeped in mid-19th century romanticism.

[6]The species at this site were listed in *Zwei Pflanzengeographische Dokumente* (Drège 1843–1844): Blaauwberg, in rocky highest localities of the mountain, 4 000 to 5 000 foot, December, January; *Roridula dentata*, *Muraltia heisteri*, *Agathosma craspedota*, 7098. *Brunia capitellata*, *villosa. Psoralea pinnata. Acrosanthes decandra. Lidbeckia lobata. Berkheya fragilis*, *grandiflora. Laurentia micrantha. Erica flava. Eremia recurvata. Selago corymbosa. Leucadendron plumosum*, *spathulatum. Protea macrophylla*, *Leucospermum medium.* ***Calitris arborea*** **[=Clanwilliam cedar]**. *Restio 24998. Disa multifida. Penthea melaleuca. Ficinia striata. Gleichenia polypodioides*.

In 1838 Sir James Alexander[7] wrote about the cedars. His floral writing style was in stark contrast to the factual report of the Veeteelt Commissie (Alexander 1838). Alexander visited Clanwilliam in September 1836 and made two trips on horseback into the Cederberg, but it is not clear where he went – it could have been to Algeria, up the Rondegatrivier, or towards Pakhuis. He wrote, rather lyrically, about the cedars:

> I was particularly interested about the cedars, "the glories of Lebanon," which formerly used to clothe, and do still in part adorn, the higher glens and ravines of these mountains. These noble and imperishable trees are always attractive to the readers of scripture; for with them was the magnificent Temple of the wise Solomon built; but alas! For the cedars of these mountains, they are fast disappearing under the destroying hand of man. Annually the Dutch farmers, the Hottentots, and Bastaards, living about the mountains, burn the grass to improve the pasture. Many fine old trees are thus sacrificed, and hundreds of young ones. No one takes charge of the trees, nor is a word spoken to save them. Their existence is almost unknown at the Cape, where the wood would fetch a high price; and even in the district where they grow, two skillings[8] or sixpence are paid for a foot of planking, and ten dollars or fifteen shillings for a beam. To give an idea of the size of some of these trees, a wide-spreading father of the forest was cut down in 1836 which was 36 feet in girth; and out of the giant arms 1'000 feet of planking were sawed.
>
> I took care to represent to the government at the Cape the expediency of superintending the cedar trees; of preventing their being mercilessly destroyed as at present; and I advised that seed should be continually collected, and sown in proper situations on the mountains.

Presumable Alexander actually saw the trees. He describes them as growing in ravines and glens – thus not from sand plains. He too, like the Veeteelt Commissie, mentioned that the

[7]Sir James Alexander (16 October 1803–2 April 1885) was a Scottish traveller, author and general in the British Army.

[8]'Skilling' is an old Danish coin, a subdivision of the Riksdaaler, more or less equivalent to a shilling. It is unclear why Alexander uses this currency, and how this compares to the sixpence (one skilling was presumably equal to two sixpence).

saplings were being destroyed. This implies that regeneration was still good, but the young trees were being killed by regular fires. He does not mention overharvesting as a problem. However, the fact that he mentioned that a very large tree was felled and the wood sold, clearly means that there was some harvesting from the Clanwilliam side.

Four years later (24 March 1840) James Backhouse travelled from Clanwilliam via Kliphuis, Pakhuis, Groenberg, Heuningvlei and the Koudeberg to Wupperthal (Backhouse 1844). He noted the following:

> The cedar of this part of the country does not grow in woods but scattered among the rugged mountains; it attains to a considerable size, and affords planks resembling coarse deal. In growth it resembles the Red Cedar; probably it is a species of *Pachylepis*, a genus which differs from *Callitris* in having only four divisions in its fruit; the Australian species of *Callitris* have universally six. *Callitris quadrifida*, of the north of Africa, is probably a *Pachylepis*.

This is a wonderfully factual description and the fact that his comments on the taxonomy of the species were correct gives one more confidence in his other comments. Unfortunately, Backhouse probably did not see the sand plains between Krakadouw and Heuningvlei, so there is no evidence whether or not the cedars there spread from the rock outcrops onto the sand plains.

Three years later Von Meyer (1843) travelled the day before Christmas from Clanwilliam to Kliphuis, and over the Pakhuis Pass to Bettjesfontein (presumably what is currently known as Elizabethsfontein). Between Clanwilliam and Kliphuis he saw the tips of the occasional cedar sticking out of deep gorges. He left Kliphuis in the afternoon and spent the night in Bettjesfontein, so presumably rode directly over the Pakhuis Pass, and wrote (p. 131):

> Es ist eine bemerkenswerte Tatsache, dass die Baumart, welche diesen Bergen den Namen gegeben hat, an keinen anderen Orte in der Kapkolonie angetroffen wird. Es ist eine Art Wachholder die eine ziemliche Höhe und Dicke erreicht. Früher war die ganze Bergkette bedeckt, aber die Art und zufällige Feuersbrünste tun ihr Möglichstes, diese kostbaren Wälder auszurotten.

This statement has to be interpreted carefully. Pakhuis is at the northern margin of the distribution range and was probably relatively (at least compared to the Middelberg) accessible. Here logging damage should have been most extensive, yet Von Meyer does not mention

logging at all, only fire. He notes that previously the whole mountain range was covered in cedars. He does not source or support this statement. Nor is it clear what *die ganze Bergkette* refers to; was it just the area around Pakhuis, or the northern Cederberg, or the whole Cederberg? He refers to *Wälder*, which translates unambiguously to 'forest', not like *bos*. He never saw a forest, nor does he advance evidence that there was a forest in the past. Finally, he claims that fire kills the cedars. We suspect from the information in his statement that there were occasional cedars in gorges and amongst rocks in the Pakhuis area, and that there was evidence that the trees were killed by fire. This is also consistent with the reliable bits in the observations of Backhouse and Alexander.

## Maclear, Mann and Wallich

In March 1843, Thomas Maclear, the astronomer at the Cape probably best known for his beacon on the highest point of Table Mountain, travelled to Heerenlogementsberg, Lambertshoek Mountain and Sneeukop in the Cederberg to make a geodesic survey to measure the curvature of the Earth. He was accompanied by the Danish botanist, Dr Nathaniel Wallich, who was in the Cape from Kolkata, where he was Director of the East India Company's botanical garden, on two-years' sick leave to recuperate from the tropical climate (see also Chapter 3). Wallich wrote several letters to Dr Hooker, then Director of the Royal Botanic Gardens at Kew, sending him a packet of seed, as well as a herbarium specimen (now at the Natural History Museum in London). Fortunately, William Mann[9], who also accompanied them, kept a detailed diary and wrote several letters, which were published by Brian Warner (1989).

They travelled from Rondegat, up the Rondegatrivier to Uitkyk, across the Uitkyk Pass to Driehoek, and along the shale band to the top of Engelsmanskloof (named after Thomas Maclear or William Mann), from where they went up Sneeukop. Mann also climbed the Middelberg. He commented several times on the cedars, here cited in full (from Warner 1989) for their eloquence:

> Page 73: I found myself on top[10] and for the first time got amongst the cedar trees; these latter gentlemen have very queer notions, they seem to enjoy the highest and coldest parts of the Mountains,

[9]William Mann was an English astronomer who was sent to Cape Town to assist Thomas Maclear with the measurement of the baseline of the arc of meridian. Mann stayed on in Cape Town and worked at the Observatory until his death in 1873.

[10]Probably Middelberg.

> and apparently thrive best in those spots where one could image nothing could possibly exist. This tree is a kind of Cypress, it grows to a very large size, the wood is much prized for building, and answers well for cabinet work; it smells something like the pencil cedar. A few Bastard Hottentots who live at the foot of the mountain gain their livelihood by cutting down the trees and conveying them to Clanwilliam on sledges. The tops of parts of this range are the only spots in the Colony where the cedar tree is found. They add much, as you may well fancy, to the beauty of the scenery.
>
> Page 74: The cedar trees which are very scanty on the Middel Berg grow only on the top, out of the crevices of the rocks – and from whence they derive their support is not very apparent.
>
> Page 76: When we arrived at our halting place [*Diary*: Most romantic outspan – a large clump of rocks with cedar trees on a plateau of grass at the foot of Sneuw Kop – beautiful scenery][11] ...
>
> Page 77: ... bivouacked in a rocky kloof under shelter of some splendid cedar trees[12] ...
>
> Page 77: ... nothing would satisfy us now but burning whole trees, one of which would keep alight about two or three days; the cedar wood burns well and the perfume is very pleasant.

These comments tell us a lot and are the first detailed comments on the cedars on the western flanks of the Cederberg, from the Middelberg and Welbedacht areas. In 1843 there were no cedars on the sand plains. Mann had been up Middelberg, must have seen the plateau, and notes explicitly that they are only among the rocks. Nor are there any cedars on the sandy plain of the Driehoeksrivier. There is no indication of a forest or even an open woodland of cedars, rather of stands among rocks. Surprisingly, there were few people felling the trees, so we suspect that harvesting intensity was low by 1845. Mann never mentions damage due to logging and the wood is taken out to Clanwilliam by sledge. Here it is curious that Alexander did not mention this. One possibility is that logging on the western flanks only started after 1836 (unlikely) or that Alexander was simply not an astute observer (likely). The cedar trees were big – big enough for them to camp under them and also big enough to elicit comments on their size from Mann.

[11]Possibly the top of Asias se Kloof.
[12]Possibly the top of Engelsmanskloof.

One gets the impression that the cedars were numerous. Sufficiently numerous that they had no compunction burning whole trees to keep warm, or felling them to build sledges. Nowhere does Mann give the impression that the stands were being logged unsustainably.

# The modern period: 1870 to 2020

## Gradual reduction of remaining forests (1870 to 1960)

Between 1870 and 1930 there are several recorded observations, all indicating that the cedars occurred in stands among rocks and that they were suffering, particularly from fire. In 1891 the District Forest Officer C.B. McNaughton inspected the Cederberg, probably visiting both the Middelberg area (a two day trip from Clanwilliam) and the Pakhuis area. He reported (McNaughton 1891) the following:

> The cedars ... do not form a continuous forest, but are found singly and in twos and threes – on crags, in kloofs, and in rocky places at high altitudes, seldom appearing in clumps or patches. There is one patch of some 60 trees on the east slope of the Cedar Mountains over and above Wuperthal, on ground, I was informed, owned by the Rhenish Mission Society. ... The Cedar tree is not found below the snow line. ... It is not the danger so much of overworking which threatens annihilation to these valuable forests, it is a danger more difficult to cope with, namely fire. Many matured and valuable trees and number of young ones are almost annually destroyed by the serious veldt fires which occur on these mountains.

This is a description that could have been written in 2020!

At the end of the century Leipoldt (1899a) reported that the cedars grew in groves in the kloofs and gullies and. In 1896 Amphlett and his companions from the Mountain Club, who ascended the Tafelberg and Sneeukop from Eselbank, reported a single grove in the valley of the Eselsbank River below Sneeukop (Amphlett 1896). Their photograph revealed a dense stand or grove, with touching crowns. However, they noted (Amphlett 1896: 75) the following:

> The cedar trees were particularly interesting, though it was disappointing to find so many either charred by fire or ruthlessly

> hacked about, many having been felled and left, apparently owing to the difficulty of carrying the timber down. The wood has a fragrant scent, is extremely durable, easily worked, and until recently seems to have been used in the Clanwilliam district for every conceivable purpose, being evidently the cheapest wood farmers could obtain.

The occurrence of stands or groves, associated with rock outcrops, is mentioned in diverse Cederberg trip reports of the Mountain Club of South Africa. One of the earliest was by K. Cameron, R. Hallack, R. Primos and G. Travers-Jackson in September 1921 (Cameron 1922) – it must have been a wonderful trip, going from Algeria over Middelberg to Sneeukop, Tafelberg and Sneeuberg, plus some additional peaks. They spent a night in Welbedacht Cave and noted (Cameron 1922: 102) that, 'In the kloof, the upper portion of which was well wooded with cedars ...' A similar situation seems to have been between Crystal Pool Hut and Van Zyls Poort, where Van der Horst (1930) reported, 'With our backs to the Sneeuwkop, we followed the path which threaded its way through a series of small vlaktes fringed by luxuriant cedars, untouched by fire ...' It is still lovely down that valley, but with cedars untouched by fire it must have been magical.

## The photograph survey

These rather disturbing reports on fire damage were confirmed by Joe White[13]. Joe White et al. (2016) used a very interesting method. They assembled old photographs with dates, which could be localised, then revisited the same sites and retook the photographs. This was no easy task, as the length of the lens and distance from the subject all influence the distortion of the image. The new and old images were then overlain and matched, and the fate of each cedar tree established (see, for example, Figure 13A and B), whereby the demography of each site could be determined. They found that of the 1 313 living trees seen on the historical photographs, 967 (74%) had died. This is, in itself, not worrying, as most of the young trees die. However, what is worrying is that there were only 44 new trees of which three had already died. This means that the standing population had been dramatically reduced. This trend is also very clear when the number of living trees visible at each site are compared (see Table 2). The average number declined insignificantly from 8.65 in photographs taken between 1931 and 1951, to 6.86 in photos taken between 1960 and 1987, but then declined dramatically in the last 20 years to 2.71. Furthermore, the percentage of saplings also goes down dramatically.

[13]This was an M.Sc. project in the Botany Department of the University of Cape Town, supervised by Tim Hofman and Ed February.




**Figure 13.** A, Grootlandsvlakte, picture taken by Lamb in September 1979 (reproduced with kind favour of Tim Hoffman); B, repeat photograph taken by Puttick and Jack in October 2012, showing how even trees in putative rocky refugia are lost.

**Table 2.** Average number of cedar trees per site for three time periods, where the original photographs were taken 1923–2013; values with asterisk are significantly different

| Period | Number of photographs | Live trees per site | % saplings |
|---|---|---|---|
| 1931–1951 | 51 | 8.65 ± 0.95 | 27* |
| 1960–1987 | 28 | 6.86 ± 0.83 | 5 |
| 2007–2013 | 79 | 2.71 ± 0.34* | 8 |

This reduction is across the whole distribution range, not only in one region. There seems to be no safe place for the cedars. We are watching, not only a population crash, but an entire species crash. These data also suggest that there is no difference between natural stands and plantations – none can successfully regenerate.

## After 1960: the quantification of loss

By 1960 the situation had deteriorated with every subsequent study showing that the number of trees in the stands was becoming smaller and that some stands had died out completely. Particularly useful in this period was the establishment of permanently marked plots.

The first quantitative survey was in 1966 at Heuningvlei, Welbedacht, Middelberg, Machine Gun Ridge and Hoogvertoon (Lückhoff 1971), which showed that 75% of trees were dead. This varied from 51% at Hoogvertoon to 87% at Middelberg; of 769 living trees counted, only 6 were healthy; there was on average only about 0.88 saplings per mother tree, ranging from 1.69 at Heuningvlei to 0.03 at Middelberg. The good news was that there was no evidence of diseases, but that fire and drought were apparently the main causes of loss. This was grimly summarised for a natural population at Kruger se Land (Table 3). An interesting finding was that the majority of trees were young, with diameters of 300–600 mm. There were very few old trees (diameter more than 1 m) and relatively few saplings (diameter less than 300 mm).

However, snap-shot images like this could be misleading. We do not know how long the dead trees have been dead: we could be looking at many decades of accumulated dead trees. The repeat photograph survey suggests that dead trees can remain standing for three decades and that the wood might need a century to rot. The lack of juveniles could also indicate episodic recruitment, so that most of the time there are very few young trees, but when a cohort is successful, the numbers of adults is increased again. To obtain a clear picture it is necessary to do repeat surveys of fixed plots.

**Table 3.** Analysis of health of natural population at Kruger se Land on 25 June 1966 (Lückhoff 1971)

| Tree health | Stem diameter at breast height (DBH) in mm | | | | | |
|---|---|---|---|---|---|---|
| | <150 | 150–300 | 300–610 | 610–920 | >920 | Totals |
| Healthy, growing well | 0 | 1 | 0 | 0 | 0 | 1 |
| Growing, sunburnt, poor crown | 2 | 3 | 1 | 0 | 0 | 6 |
| Growing poorly won't live long | 7 | 19 | 27 | 7 | 2 | 62 |
| Dead, standing, no fire marks | 8 | 16 | 11 | 3 | 0 | 38 |
| Dead, lying, no fire marks | 3 | 2 | 1 | 0 | 0 | 6 |
| Dead, standing, fire marks | 12 | 59 | 43 | 6 | 2 | 122 |
| Dead, lying, fire marks | 22 | 121 | 114 | 15 | 3 | 275 |
| **Totals** | **54** | **221** | **197** | **31** | **7** | **510** |

Such a survey was set up by Fred Kruger[14] from the South African Forestry Research Institute (SAFRI) from 1971 onwards (see Text Box 2.1). These 1 ha plots were clustered in the Sneeuberg Hut area, Middelberg and at Koupoort. The initial plots were enumerated between 1971 and 1977, and subsequently re-enumerated several times. They formed the basis of much ecological research on the cedars (see Chapter 4). From 1983 to 1985 Pat Manders[15] again re-enumerated the plots, and finally from 2003 to 2005 Ed February and his student Sarah-Jane Fox[16] repeated the process. These latter data are still unpublished and were kindly made available by Ed February. This gives a detailed impression of how the numbers of individuals in different size classes changes through time. What is of interest here is how the number of mature individuals changes – seedlings and small pole trees often germinate in large numbers after fire, only to be killed by the next fire. Also of interest are the larger trees that have persisted

[14]Fred Kruger set up a highly successful ecology research group within SAFRI as his first project. From 1970 to 1990 he was one of the most prominent fynbos ecologists and published several highly influential research papers.

[15]Pat Manders completed an M.Sc. degree with Eugene Moll at the University of Cape Town on cedar biology and, based on this work, built the first demographic model for the species. He also explored variables that might limit seedling establishment. For years afterwards he was one of the specialists on cedar ecology and he worked for SAFRI.

[16]Sarah-Jane Fox completed an M.Sc. degree with Ed February in 2003 on cedar demographic models. In the process she resampled several of the original SAFRI plots on Grootland.

## Text box 2.1: The SAFRI plots

From 1970 the ecology research group of SAFRI started setting up 1 ha permanent plots, marked with creosote poles or stone cairns. Each cedar tree was numbered with a steel tag, and its height, DBH and general condition noted. These plots constitute an invaluable resource, as they allow a comparison of changes and growth rates in the cedars, and have provided the basic data for much of the subsequent research on cedars. Over the next decade the trees were enumerated and measured by SAFRI researchers, and these plots were also re-enumerated by Pat Manders, Sarah-Jane Fox and Ed February (Table 4, Figure 14). These data were used to quantify the survival and growth rates of the cedars, and as such turned out to be much more useful than the plots of Rudolf Andrag (1977; see Text box 4.1). The purpose of these plots was to determine the best management policy to improve the regeneration of the cedar stands.

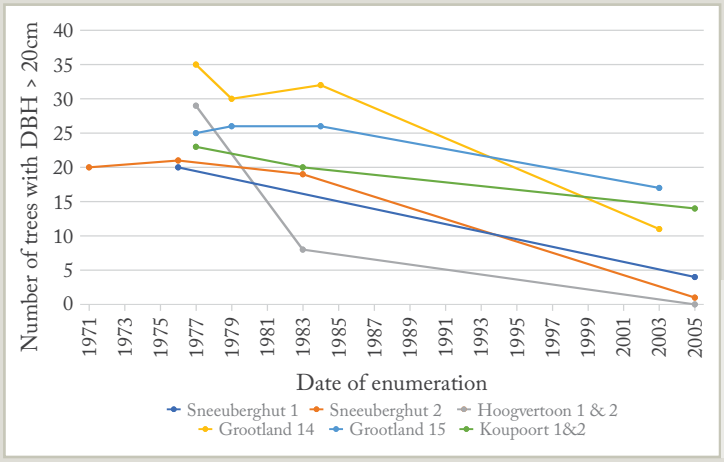



**Figure 14.** Changes in the numbers of trees with a DBH of least 200 mm in the SAFRI plots from 1971 to 2005.

**Table 4.** Plots set up by SAFRI and their resurvey dates. The coordinates of the plots were determined by Ed February

| Plot name | Coordinates | Elevation (m a.s.l.) | Survey dates** | Enumeration by |
|---|---|---|---|---|
| Sneeuberg 1 | -32.4814, 19.1519 | 1 320 | 1970, 1974, 1975, 1976 | Kruger, Haynes, Howe, Van der Riet, Hampson, Durand, Van Wilgen |
| | | | 2005 | February |
| Sneeuberg 2 | -32.4814, 19.1519 | 1 320 | 1970, 1974, 1975, 1976, 2005 | Kruger, Haynes, Howe, Van der Riet, Hampson, Durand, Van Wilgen |

**Table 4.** Plots set up by SAFRI and their resurvey dates. The coordinates of the plots were determined by Ed February (continued)

| Plot name | Coordinates | Elevation (m a.s.l.) | Survey dates** | Enumeration by |
|---|---|---|---|---|
| | | | 1983 | Manders, Viviers, Simmons |
| | | | 2005 | February |
| Sneeuberg 3 | -32.4814, 19.1519 | 1 320 | 1970, 1974, 1975 | Haynes, Howe, Van der Riet, Hampson, Durand, Van Wilgen |
| Hoogvertoon 1 | -32.4766, 19.1531 | 1 340 | 1970, 1974, 1976, 1977, 1979 | Kruger, Haynes, Howe, Van der Riet, Lamb, Forsyth, Andrag |
| | | | 1983 | Manders, Viviers, Simmons |
| | | | 2005 | February |
| Groot Koupoort 10 | -32.2567, 19.0993 | 1 125 | 1977, 1978, 1979, 1981 | Haynes, Lamb, Forsyth, Slabbert |
| | | | 1983 | Manders, Viviers, Simmons |
| | | | 2005 | February |
| Groot Koupoort 11* | -32.2642, 19.0917 | 1 400 | 1977 | Kruger, Haynes, Lamb |
| Sneeukop | -32.3315, 19.1728 | 1 145 | 1977, 1979 | Haynes, Growar, Lamb, Forsyth |
| Grootland 14 | -32.3743, 19.1189 | 1 300 | 1977, 1979 | Lamb, Forsyth |
| | | | 1984 | Manders, Simmers |
| | | | 2003 | Fox |
| Grootland 15 | -32,3818, 19.1166 | 1 400 | 1977 | Lamb, Forsyth |
| | | | 1984 | Manders, Simmers |
| | | | 2003 | Fox |

*In Groot Koupoort 11 only seedling density was determined, there is no evidence that the plot was re-enumerated.

**Not all re-enumerations measured the height of the trees, some only reported the classes.

through several fires. We took as an arbitrary cut-off any trees with a diameter at breast height (DBH) of at least 200 mm and this reveals a very bleak picture. With the exception of the plot at Hoogvertoon, the numbers of mature trees remained more or less constant from 1971 to 1985 and there is evidence of some recruitment replacing trees which had died. However, over the next 20 years the situation became dramatically worse. One plot (Hoogvertoon) lost the last of its mature trees and the two plots nearby Sneeuberg Hut were reduced to one and four trees, respectively. The two Grootland plots lost more than half of their mature trees and Koupoort lost a third. It is now twenty years since the last survey, and so would be worthwhile to re-enumerate these plots, in the hope that the fortunes have been reversed.

## Cedars are in danger of extinction

There is overwhelming evidence that the total number of live cedar trees has become much reduced over the last 3 500 years, and particularly during the last 200 years. It is estimated that, at the moment, the number of living mature trees halves every 30–50 years. At the same time, all really tall trees have disappeared.

Nobody has seen and/or reported an extensive closed forest of cedars. It is possible that such forests did occur prior to the first records from 1831, but we simply lack any observational evidence. All observations from 1831 onwards are of stands of trees among rocks, albeit sometimes forming small closed stands, such as still exists below Skerpioen Crack (Figure 15) or had once existed at De Bos. The fossil evidence suggests that there was an open forest on the sand plains until some 3 000 years ago. There is also no evidence that the overall geographical range of the species has shrunk during the historical period, from 1831 onwards.

There has, however, been a dramatic reduction in the number of trees in the stands, and also a reduction in the number of stands in the last decades, especially of the stands at lower elevations. The last natural, closed-canopy stand was at De Bos (an appropriate name) in the Langkloof but this was destroyed in a wildfire during an extremely dry spell in November 1984. This process of loss accelerated dramatically after about 1975 when it starts to look like the final collapse of the species. In many areas there are now only dead trees or, at best, a few isolated living trees. Very few stands show a normal regeneration pattern of seedlings, pole trees and mature trees (see Chapter 4). Many stands look like collections of 'living dead' in which there is no recruitment replacing dying trees and no trees less than 100 years old. Something is going dramatically wrong. To understand the drivers of this process, we need to explore the biology of the species, the impact of logging, the changing fire regimes and, finally, climate change. But first we investigate the evolutionary history of the species which shaped its biology.

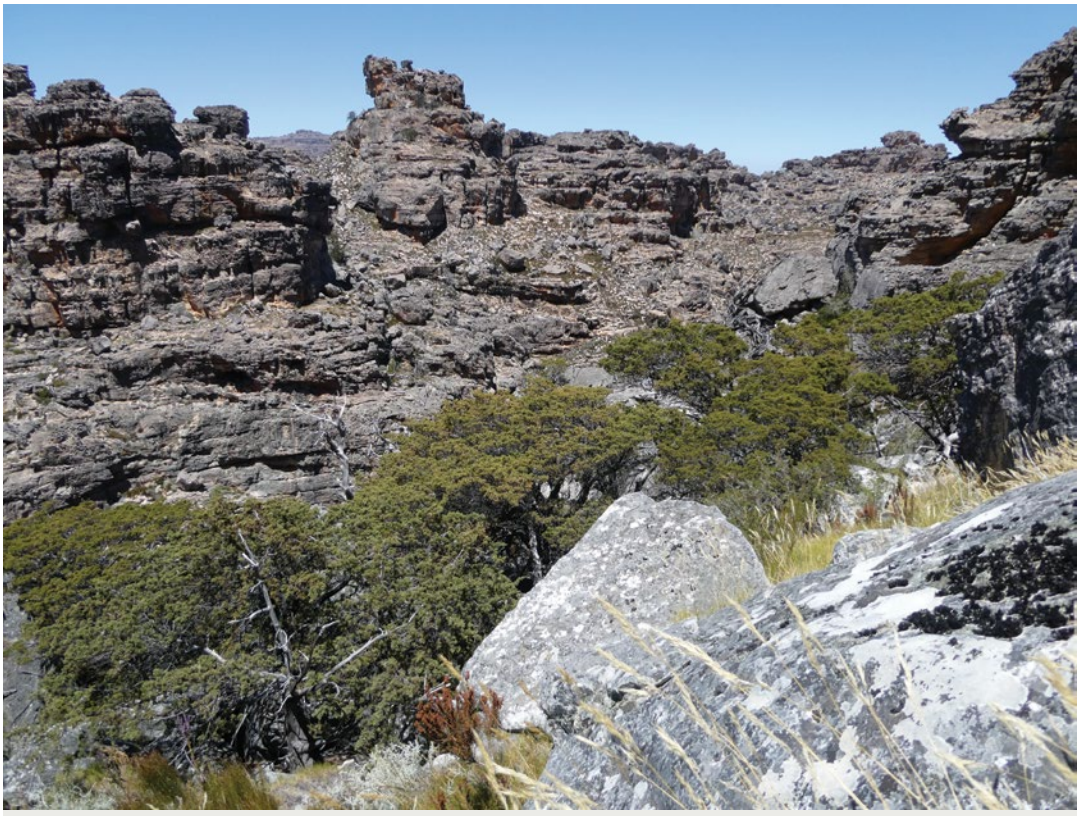


**Figure 15.** Closed canopy stand at entrance to Skerpioen Crack.



3

# Where does the Clanwilliam cedar come from?

## Evolutionary history

The origins of the Clanwilliam cedar (its evolutionary history) tell us in what environments its ancestors had evolved and survived. Consequently, it gives some insight into how well adapted the Clanwilliam cedar may be to the Cederberg and its climate.

There are two contradictory hypotheses on the origins of the southern African cedars (the genus *Widdringtonia*) (Figure 16). The boreal hypothesis, based on evidence from fossilised cones, postulates that *Widdringtonia* was widespread in Europe and North America in the Late Cretaceous (100–70 Ma), dispersed across the African equator into southern Africa where it persisted, and then went extinct in the Northern Hemisphere (McIver 2001). The alternative austral hypothesis is that the closest relatives are found on the southern continents: the South American *Fitzroya*, Tasmanian *Diselma* and Australian *Callitris*. This hypothesis is based on evidence from DNA sequence data[17] obtained from extant species (Gadek

[17]DNA = Deoxyribonucleic acid, the polymer that carries the genetic information of a species. Variation in this genetic information can be used to reconstruct the relationships among species.

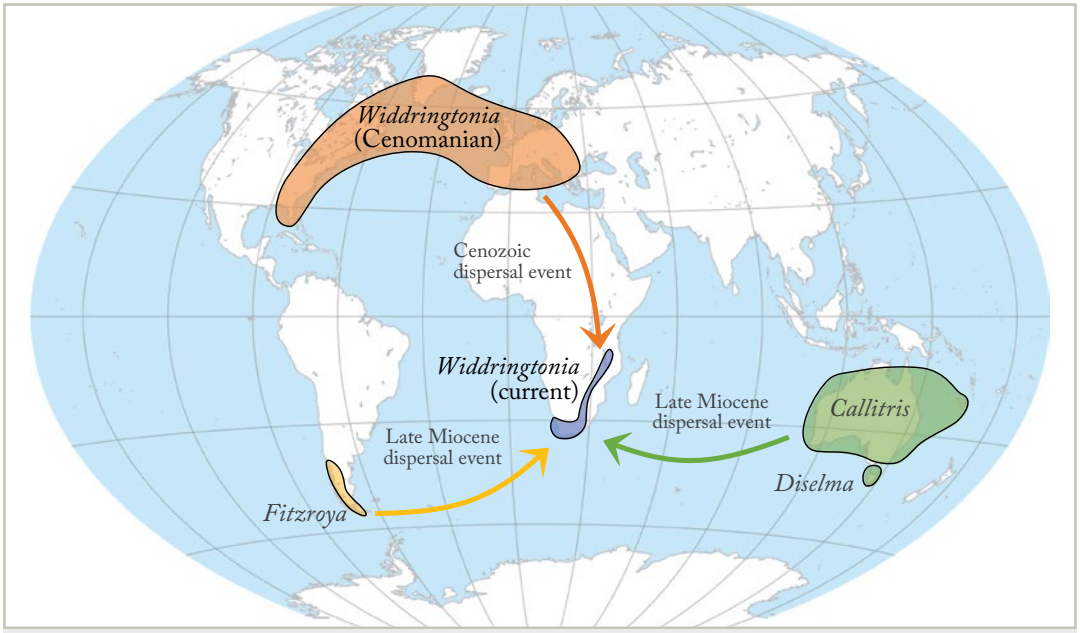



**Figure 16.** The two suggested origins of *Widdringtonia*. The boreal hypothesis is indicated in orange, the austral hypothesis in yellow and green.

et al. 2000; Forest et al. 2018). According to this hypothesis *Widdringtonia* is a member of the Southern Hemisphere subfamily Callitroideae[18], with the implication that the genus *Widdringtonia* evolved in southern Africa after it became isolated from its relatives in Australia and South America. Felix Forest and his collaborators (Forest et al. 2018) inferred the phylogenetic history of all gymnosperms based largely on the amount of divergence in the DNA of the chloroplasts. They also used this to obtain age estimates of the groups, which suggested the surprisingly recent divergence of 7–6 Ma between *Fitzroya*, *Diselma* and *Widdringtonia*. To place this into context, Africa was isolated from the rest of Gondwana about 120 Ma. These two hypotheses are based on totally different types of evidence and cannot be reconciled. Both hypotheses make somewhat unlikely predictions: the austral hypothesis that the ancestor of *Widdringtonia* crossed the Indian or the South Atlantic Ocean about 7 Ma, and the boreal hypothesis that

[18]The conifer family Cupressaceae includes seven subfamilies: Cunninghamioideae (1 genus, East Asia), Taiwanioideae (1 species, East Asia), Athrotaxidoideae (1 genus, Tasmania), Sequoioideae (3 genera, eastern North America), Taxodioideae (3 genera, widespread in the Northern Hemisphere), Callitroideae (7 genera, widespread in the Southern Hemisphere) and Cupressoideae (13 genera, widespread in the Northern Hemisphere).

*Widdringtonia* was once widespread in the Northern Hemisphere. The austral hypothesis is more likely to be correct, as the independent evolution of similar cones in northern and southern conifer lineages is more plausible than the independent evolution of similar DNA sequences.

The Callitroideae (excluding *Widdringtonia*) are distributed around the southern Pacific Ocean: the southern South American west coast, New Zealand, Australia, New Caledonia and New Guinea. According to the austral hypothesis (Figure 17), the lineage leading to *Widdringtonia* dispersed from the southern Pacific to Africa in the late Miocene[19]. This could have been either across the southern Indian Ocean, or the southern Atlantic Ocean.

Ecologically, some species of the Australian genus *Callitris* grow in arid and fire-disturbed environments, similar to those in which the Clanwilliam cedar does: seasonally arid, often with many years of drought, on nutrient poor soils (Farjon 2008). However, most species of Callitroideae are found in wetter environments, probably more similar

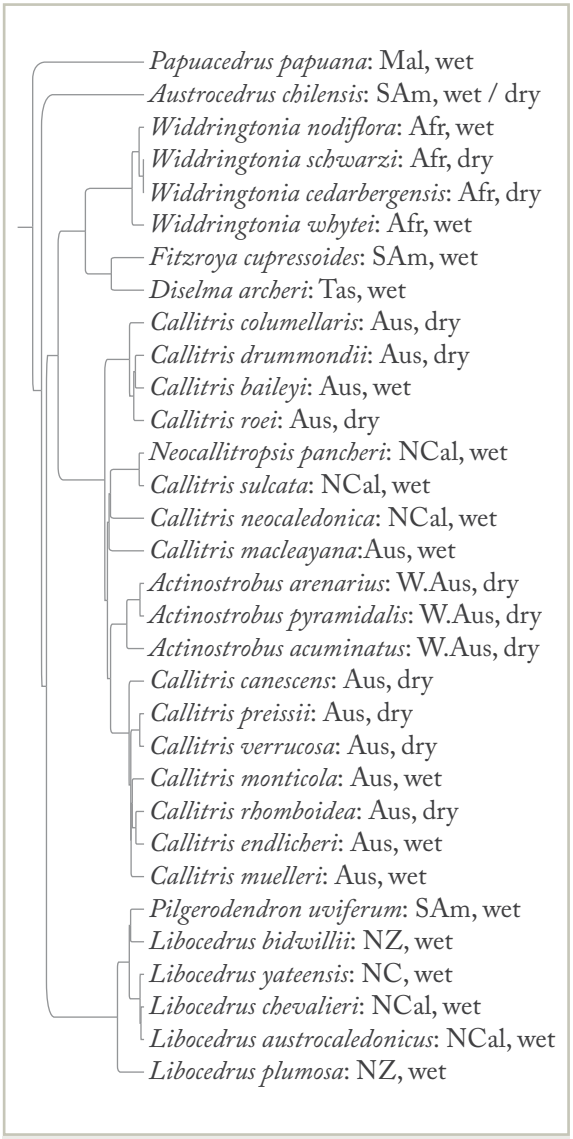



**Figure 17.** Phylogeny of the Callitroideae, according to Forest et al. (2018). Following the species names is a code for the geographical region: Afr = Africa, NCal = New Caledonia, Mal = Malesia, Aus = Australia, WAus = West Australia, NZ = New Zealand and SAm = South America. This is followed by a coarse climate indication (wet or dry).

[19]This is argued by mapping the distributions on the phylogeny (Figure 17), and it is evident that the African distribution is nested within the circum southern Pacific distribution. Consequently, we can argue that the ancestral distribution was circum southern Pacific.

to those where *W. nodiflora* and *W. whytei* grow. The adaptation to arid environments may have happened independently within *Widdringtonia* and *Callitris*. It seems that, although the Callitroideae ancestrally may have been found in more mesic, or at least summer-wet, environments, they have the capacity to adapt to summer drought and so to respond to the Miocene evolution of summer-dry environments in southern Australia and southern Africa.

## The genus *Widdringtonia*

There are four species of *Widdringtonia* (Farjon 2005): the Clanwilliam cedar, *W. cedarbergensis*, restricted to the Cederberg; the Willowmore cedar, *W. schwarzii* (Marloth) Mast., in the Kouga and the Witteberg near Steytlerville; the Mulanje cedar, *W. whytei* Rendle, restricted to Mt Mulanje in Malawi, where it once formed massive trees and very impressive forests as an overstory over a *Podocarpus* forest; and the very widespread, resprouting, multi-stemmed mountain cypress, *W. nodiflora* (L.) Powrie. The first three species are killed by fire and have to re-establish from seed, although all three of them have some means of limiting fire mortality. DNA sequence data were used to evaluate the relationships among these four species by a B.Sc. honours-degree student at the University of Cape Town (De Roo 2002). He showed that *W. cedarbergensis* and *W. schwarzii* are very closely related. This is consistent with the morphology, as these two species are very difficult to separate: both are trees with small, scale-like leaves and similar female cones. Although superficially similar, the former is restricted to the Cederberg and the latter to the Kouga. This relationship was also confirmed by a study by Felix Forest et al. (2018), which furthermore suggests that *W. schwarzii* and *W. cedarbergensis* separated about 1 Ma. The data which Felix Forest et al. (2018) used for these analyses can only give a rough indication of the age and, particularly for very recent divergences, could be quite imprecise. A more likely possible age range is from the LGM (20 000 years ago) to the beginning of the Pleistocene at 2.2 Ma, thus sometime during the Pleistocene. It is tempting to think that at some stage in the past there was a continuous cedar forest from the Cederberg in the west to the Kouga in the east, all along the semi-arid inland margins of the fynbos, perhaps along the Witteberg quartzites of the Swartruggens, Voetpadsberg, Laingsburg Witteberg and the sandstones of the Swartberge. At some stage climate change caused the removal of the central part of the range, leaving the two extremes to diverge.

Together, these two arid-adapted species are the closest relatives of *Widdringtonia nodiflora*. This coppicing species is typical of the wetter mountains in fynbos, in the grasslands of the Drakensberg, the mountains of the Eastern Escarpment of Zimbabwe and Mulanje in Malawi. Its coppicing habit allows it to survive the frequent and intense fires of these

wetter vegetation types. This trio of species is, in turn, the closest relatives of the tall, endemic *W. whytei* of Mt Mulanje. For a long time this latter species was confused with the coppicing *W. nodiflora*, but fieldwork by Anton Pauw showed that it is quite distinct (Pauw & Linder 1997). Both *W. nodiflora* and *W. whytei* grow in mesic conditions, with moist to wet summers. This is climatically different from the *W. cedarbergensis–W. schwarzii* species pair from semi-arid, summer-dry habitats. Because most of the rest of the Callitroideae are also found in wet environments, it seems likely that, at least, a summer-wet environment may have been ancestral for *Widdringtonia* when it established and started differentiation in Africa in the Late Miocene and Pliocene[20]. The lineage which led to *W. cedarbergensis* and *W. schwartzii* is likely to have evolved the necessary adaptation to survive hot, dry summers.

## Names of the cedars

The southern African cedars are best known by their common names. Confusingly, most species have several common names, which are listed by Palmer and Pitman (1972) in their seminal reference book, *The Trees of Southern Africa*, and according to the *Dictionary of names for southern African trees* (Van Wyk et al. 2011). The names we use here are given in bold and are also the most frequently used names:

- *Widdringtonia cedarbergensis*: **Clanwilliam cedar**, cedar, cedar tree, Cape cedar, Clanwilliam Cape-cedar, Clanwilliam cypress; *clanwilliamseder*, *sederboom*, *sederhout* (Afrikaans); *Clanwilliam-Zeder* (German). Drège already labelled his collections as 'Cederboom' in 1828 (Figure 18).

- *W. nodiflora*: **mountain cypress**, mountain cypress, Cape cypress, mountain Cape cedar, widdringtonia, wild cedar; *sapreehout*, *bergsapree*, *bobbejaankers*, *sipresboom*, *bergsipres*, *Dupresknop* (Afrikaans); *Berg-Zeder* (German); *mupanda*, *mupande*, *musheza* (Manyika); *musheza*, *mushize*, *shize* (Ndau); *lerokwana* (Sepedi); *ṭhaululo* (Venda); *unwele-lwe-entaba* (Zulu).

- *W. schwarzii*: **Willowmore cedar**, Willowmore Cape cedar; *baviaanskloofseder*, *sapreehout* (Afrikaans).

[20]The following geological timescale is often used: Holocene (to 10 000 years ago), Pleistocene (10 000 years ago to 2.58 Ma), Pliocene (2.58–3.30 Ma), Miocene (3.3–23.3 Ma), Oligocene (23.3–33.9 Ma).

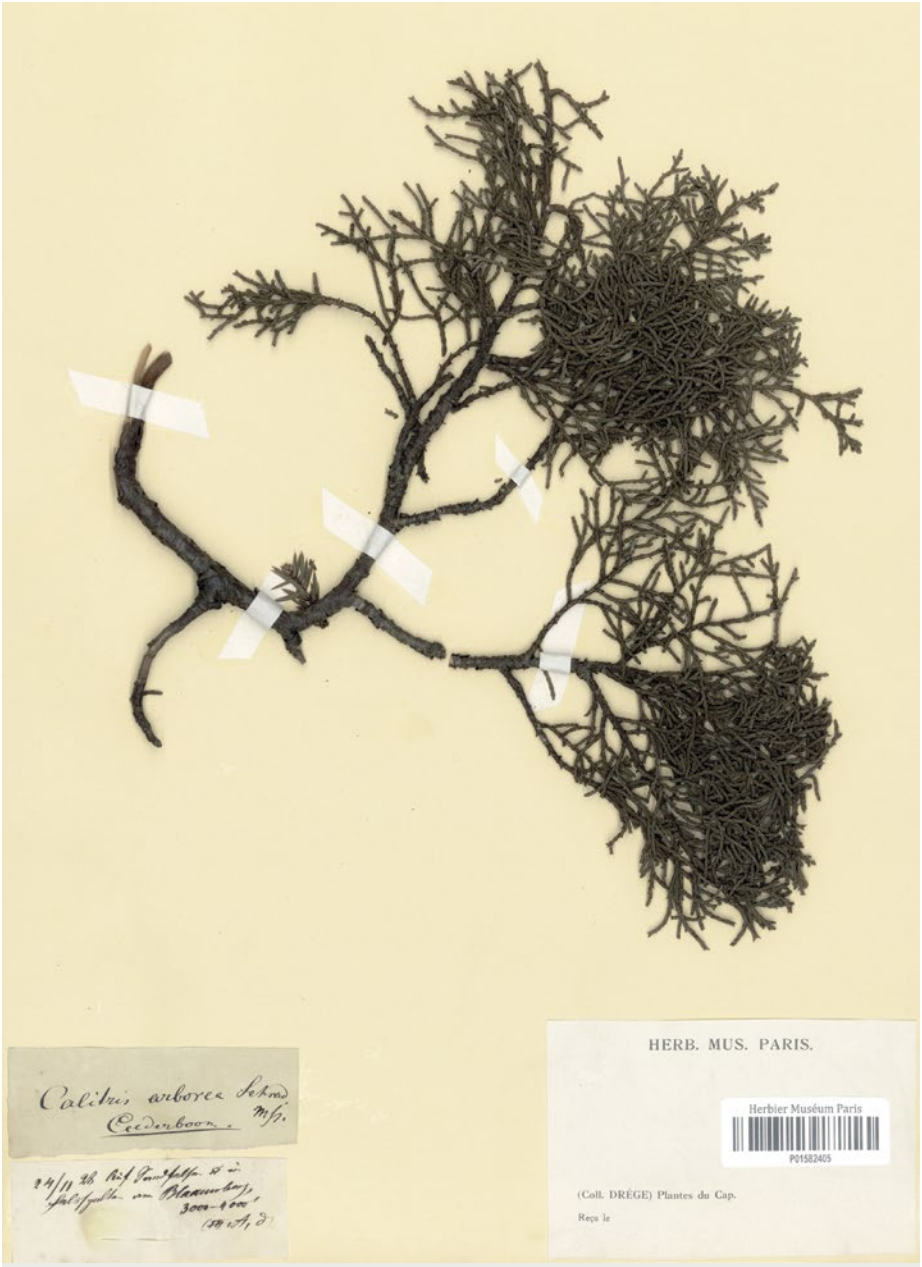



**Figure 18.** The first herbarium specimen of the Clanwilliam cedar with two labels in Drège's handwriting. The upper label gives the name: 'Calitris arborea Lehman mihi, Cederboom'. The lower label, partially legible, gives the locality data: '12/11 28 ... in Felsspalten von Blaauberg, 3000-4000', III,A,d'.]

The Latin (scientific) names represent a complex story. The genus was named for Captain Samuel Edward Cook (1787–1856), an early expert and author on the coniferous forests of Spain. In 1840 Cook took the name of Widdrington, his mother being the heiress of some of the estates of that family.

The Clanwilliam cedar has been known under four scientific names: from 1847 to 1966 as *Widdringtonia juniperoides sensu* Stapf; from 1966 to 2011 as *W. cedarbergensis* J.A.Marsh, from 2011 to 2023 as *W. wallichii* Carrière, from 2024 onwards again as *W. cedarbergensis* J.A.Marsh; and occasionally during the 19th century as *Callitris arborea*. To understand why this confusion of names exists, we need to explore the history of the taxonomic research into the Clanwilliam cedar.

The first botanist to collect specimens of the Clanwilliam cedar was the German Johann Franz Drège, a professional plant collector. The specimens with original labels are kept in the Paris Herbarium (P) and show that Drège actually collected the species twice: on 24 November 1828 (P 01582405) and again on 4 January 1831 (P 01582404). The collections were made near the summit of the 'Blaauwberg', the habitat is described as in rocky places at the highest elevations, given as 1 200–1 500 m (Drège 1843–1844). The location of 'Blaauwberg' is enigmatic. There is a 'Blouberg' at the southern end of the Cederberg, next to Bokkeveld Sneeuberg, but this is outside the modern range of the species. Drège reported his Blaauberg as being between Boskloof and Heuningvallei. Maybe the Blaauwberg is in fact Krakadouwpoort. In any case, it seems most likely that it was in the northern Cederberg. Drège suggested the very appropriate name *Callitris arborea*. This name was taken up by Schrader and is mentioned in *Zwei Pflanzengeographische Documente* (Drège 1843–1844: 73). However, nobody published a formal description for the species, so the name remained without formal content, which is known as a *nomen nudum*. It was used again at the end of the century by D.E. Hutchins, one of the chief foresters in the Cape Colony and a passionate lover of cedarwood (Hutchings 1897, 1902, 1905). In addition, Ecklon and Zeyher also appear to have collected the species and these collections were also distributed by Drège under the same name. As Zeyher collected several times in the Cederberg, it is unlikely that he did not collect any specimens of the most striking species in these mountains.

When Stephan Endlicher described the genus *Widdringtonia* in 1847 and wrote a description of the Clanwilliam cedar (using the Drège collections and information), he named it *Widdringtonia juniperoides* (Endlicher 1847). He took the species epithet from Linnaeus, who first proposed the name *Cupressus juniperoides*, which was based on a specimen of the mountain cypress and so is a synonym of *Widdringtonia nodiflora*. This was realised when Otto Stapf compiled *Widdringtonia* for the Flora Capensis and noted that all synonyms listed

by Endlicher need to be excluded to obtain the concept of the species (Stapf 1933). This is not a valid procedure, which means that *Widdringtonia juniperoides* refers to the mountain cypress and not the Clanwilliam cedar. If Endlicher had used the Drège name and provided it with a description (i.e., *Widdringtonia arborea* Schrad. ex Endlicher) it would have been valid. Recognising that the Clanwilliam cedar did not have a valid scientific name, Marsh[21] (1966a, b), in her account of the 'Cupressaceae' for the *Flora of Southern Africa*, proposed the very appropriate name *Widdringtonia cedarbergensis* J.A.Marsh for the species.

Meanwhile, a second collection was made by the Dane, Nataniel Wallich, the Superintendent of the Botanical Garden in Calcutta (now Kolkata). He spent a few years in the Cape on sick leave, during which time he went on several trips. At the beginning of 1843 he accompanied the astronomer Thomas Maclear to the Cederberg. They travelled along the shale band from Sandrivier to Sneeuberg and during this trip Wallich collected specimens and seed of the cedars. The specimen is now in the herbarium of the Natural History Museum in London (BM). Towards the end of 1843 he accompanied a judge of the Circuit Court to Uitenhage (now Kariega) and collected the mountain cypress at Swellendam. This specimen is kept at Kew (K). In a review of the Southern Hemisphere conifers W.J. Hooker, from Kew, placed the African species similar to *Callitris* in *Pachylepis* (= 'thick scale'). He mentioned that, 'Dr Wallich sent another *Pachylepis* from South Africa certainly distinct from *P. cupressoides*, which may however be the *C. stricta* (Hooker 1845).' It is unclear whether he was referring to the specimen at Kew (= *Widdringtonia nodiflora*) or, more likely, the specimen from the Natural History Museum (= *W. cedarbergensis*) (Hooker 1845).

In his description of the genus *Widdringtonia* in *Synopsis coniferarum*, Endlicher included the Drège collection under *Widdringtonia juniperoides* and proposed the name *W. wallichii* for the odd Wallich collection Hooker had mentioned (Endlicher 1847: 31–34). As he did not provide a description, he probably did not see the specimen and based his opinion on Hooker's comment. In the second edition of *Traité Général des Conifères*, Carrière provided a description for the name *W. wallichii* and continued to recognise *W. juniperoides* (Carrière 1867: 57–63). Sixty years later, Stapf (1933) included *W. wallichii* Carrière as a synonym under *W. juniperoides*. If he had accepted that *W. juniperoides* referred to the mountain cypress (as had Linnaeus, but not Endlicher), then *W. wallichii* Carrière, as interpreted by Stapf,

[21]Judith Anne Marsh (later Mrs Hutchings). Born in 1941, she completed a taxonomic monograph of *Widdringtonia* for an M.Sc. degree at the University of Pretoria in 1965 under supervision of G.K. Theron. This unpublished thesis contains much more information on the morphology and ecology of the genus than the account in the Flora of Southern Africa, or the formal nomenclatural note in *Bothalia*.

would have been the oldest – and so, correct – name for the Clanwilliam cedar. This was missed by Marsh (1966a, b) in the *Flora of Southern Africa*. Stapf argued that the specimen of the Wallich collection in Kew was mislabelled, that it was really from the Cederberg, and thus the same as the specimens from BM. Alex Farjon, specialist on the conifers who compiled a checklist and synonymy of the conifers (Farjon 2001) and authored the most recent monograph on the Cupressaceae (Farjon 2005) was not of the same opinion as Stapf. He regarded the Kew specimen (and so the mountain cypress) as reflecting the opinion of Hooker, therefore the identity of *W. walllichii* sensu Endlicher, which he consequently placed under *W. nodiflora.*

Rafael Govaertz, in the 2011 version of the authoritative Plants of the World Online, seems to have based his opinion on the authority of Stapf rather than Farjon, and so accepted *Widdringtonia wallichii* Endl. ex Carrière as the earliest name for the Clanwilliam cedar. However, the true application of the name *W. wallichii* Carrière depends entirely on what material Carrière cited at the time. The first impression is that it is the same as *W. wallichii* sensu Endl., thus based on the Wallich specimen that Hooker referred to, although there is no clear indication of which Wallich specimen Hooker was referring to. Consequently, *W. wallichii* Carrière needs to be typified separately, preferably in the sense that Carrière used it. Technically, *W. wallichii* Carrière is a new name, as it had not been formally published before. So, the application of the name is not regulated by what material Hooker saw – whether that was the BM specimen of *W. cedarbergensis* or the K specimen of *W. nodiflora.* Of relevance is only which specimen Carrière saw. Carrière cited no specimens, so we cannot use his type specimen to determine what the name applies to, we need to reconstruct what he had in mind. Here we have three clues: his description, the geographical area and the synonyms cited.

Carrière's description of his *Widdringtonia wallichii* is very general and as he does not mention any cones, it is difficult to be sure that it even refers to *Widdringtonia*. He described the tree to be 12 m tall (Clanwilliam cedars become reproductive at about 2 m) and it is likely that he described a tree in cultivation. Therefore, the description does not really help us beyond the family Cupressaceae.

The locality information seems to pin it down to *Widdringtonia.* Carrière noted, 'Habite l'Afrique austral. - Introduit vers 1844. - Gèle a Paris'. As *Widdringtonia* is the only southern African genus of Cupressaceae, the genus is at least clear, although it is uncertain where this information comes from. Carrière might have been repeating what Hooker had written. The last part of the comment suggests that the tree was not hardy in Paris and this information must have come directly from Carrière. There is a specimen of *W. nodiflora* in the Paris

Herbarium, collected in 1868, from a tree cultivated in 'Jardin Ch. Huber et Cie @ Hijores', but we cannot trace this garden. It does, however, indicate that *W. nodiflora* was in cultivation in France at the time.

Carrière cited three synonyms. The first was *Frenela hugelii*, which he had described from Port Moresby in Australia and has six scales in the cones. This clearly places it in *Callitris*. Carrière did note that this synonym was 'pro parte', which suggests that the plant on which he based his description of *Widdringtonia wallichii* had previously, and now in his opinion erroneously, been included in *Frenela hugelii*. Again, this does not provide definite information on his species. The other two synonyms are *W. wallichii* sensu Endlicher and *W. wallichiana* sensu Gordon. The confusion of what is meant to be *W. wallichii* sensu Endlicher is discussed above. *Widdringtonia wallichiana* is similarly a nude name without a description and may well be an error for *W. wallichii*.

In summary, we cannot tell which species of *Widdringtonia* Carrière described. It could be either the mountain cypress or, less likely, the Clanwilliam cedar. The result is a name that can cause much confusion. Consequently, Manning et al. (2024) fixed this problem by assigning a specimen of *W. nodiflora* as neotype for the name *W. wallichii* Carrière. This designates this potentially confusing name as a synonym for *W. nodiflora* and leaves *W. cedarbergensis* as the valid name for the Clanwilliam cedar. This nomenclatural instability caused enough confusion that some insightful scientific publications on the biology of the Clanwilliam cedar (Forest et al. 2018; Slingsby & Slingsby 2019a, b; White et al. 2020) have been published under a scientific name which may not turn up in a list of synonyms for *W. cedarbergensis*.





# 4 Ecology of the cedars

## Introduction

Understanding the ecology of the Clanwilliam cedars, i.e., under what conditions the stands expand or go extinct, is central towards an explanation of the massive erosion of the cedar populations as explained in Chapter 2. To obtain a more comprehensive picture, the survival of the mature trees (coping with fire, drought, frost and disease) should be considered along with their replacement potential (formation of seed, seed dispersal, germination and establishment of seedlings; and seedling growth to saplings, pole trees and finally to mature trees). This implies that long-term genetic health (outbreeding, population sizes, etc.) should also be taken into account. To understand this, both their environment and how the plants cope with this environment must be considered.

Many environmental factors are likely to be important. These include climatic factors like rainfall and temperature, habitat factors such as groundwater availability and fire protection, biotic factors such as seed dispersal and predation, and genetic factors such as outbreeding. Similarly, many aspects of the biology of the plants are important: timing of reproduction, germination triggers, growth rates and timing, and photosynthesis and water use efficiency.

Finally, we also need to have a critical appreciation of what we think we know and what the knowledge

gaps are. There has been extensive research into cedar ecology since 1960, but much of the information is in the grey literature – information disseminated outside reviewed scientific publications. Rather than summarise this research into simplified statements, the available information was critically evaluated to develop a nuanced account. Through this process, we hope to show how cedars function and highlight what we do not know.

# Cedar geographical distribution

Cedars are restricted to the upper slopes of the Cederberg and are absent from the wide, hot valleys flanking the mountains, from the dry plateau and east-trending valleys around Wupperthal and Heuningvlei, and also from the rain shadow side of the mountains that drops down to the Doorn River with its margin of thorn trees and the arid Tanqua Karoo. These dry slopes receive very little of the overall recorded 1 000 mm of rain that comes in from the Atlantic Ocean. Therefore, their distribution range is remarkably restricted, some 50 km north to south and 18 km east to west, an area of only some 518 km$^2$. Whereas it is easy to explain the northern, eastern and western boundaries of the distribution range (the mountains are lower, hotter and drier), the southern boundary is hard to explain. Why are there no cedars in the mountains of the Koue Bokkeveld, on Apollo Peak, the Bokkeveld Sneeukop or Hexberg? The explanation for this restricted geographical range may be found in their habitats.

# Cedar habitat

Cedars are almost exclusively restricted to the cliffs and escarpments that lead up to the shale band, where they occur in the Peninsula and Pakhuis geological formations. These formations weather to form the nutrient-poor soils on which the Cederberg Sandstone Fynbos vegetation type grows (Rebelo et al. 2006). Most cedars are found between 1 050 and 1 650 m a.s.l., with the lowest recorded trees in Duiwelsgat at 750 m a.s.l. and at about 800 m a.s.l. above Algeria. Almost all naturally occurring trees are among rocks and between cliffs of the very hard and erosion-resistant Peninsula Formation sandstone (Figure 19). The Peninsula Formation consist of coarse-grained quartzitic sandstones. Taylor (1996) classified the vegetation of the Cederberg according to the floristic composition and almost all cedars are in 'Community 11 *Stoebe aethiopica–Widdringtonia cedarbergensis* community'. He referred to this as *sederveld* (Afrikaans) or cedar woodland (English), and described it as an 'open woodland with mid-dense restioid understory, or low to mid-high, mid-dense restioid shrubland'. The most common restios were recorded (Taylor 1996) as the tall *Ischyrolepis*



**Figure 19.** A stand of cedars near Van Zylsklip in the broken, rocky cliffs of the Peninsula Formation. In the background Sneeukop and the shale band, both Nardouw Formation, eroding to a smoother surface or into cliffs, but not a broken landscape.

*ocreata*, *I. venustula* and *I. gaudichaudiana*. Cedars are absent from the broad marshy high-elevation Driehoek valley, from Uitkyk southwards. Although this valley is at 950 m a.s.l., it receives only 500 to 600 mm rain per year[22].

The flat sand plains (in Afrikaans known as *suurvlaktes*) that lends charm to Cederberg landscape currently lack cedars, or have a few relictual trees from plantations established a century ago (Figure 20) (see Chapter 8).

The sand plain vegetation consists mostly of short wiry restios (such as *Elegia filacea* Mast., *Ischyrolepis unispicata* H.P.Linder and *Staberoha aemula* Pillans). These sand plains are common around Middelberg, Sneeuberg Hut and in the northern Cederberg from Heuningvlei to Boontjieskloof. The sandy soils are leached out and, in some cases, the sand may be deep.

[22]This is the average recorded rainfall at Driehoek. There is a steep rainfall gradient from Uitkyk to Dwarsrivier, with Dwarsrivier receiving only about half the amount of rainfall of Driehoek.

Hubbard (1937) recorded that: 'Local opinion is emphatic in regarding the cedar as a natural dweller among the rocky outcrops and repudiate any suggestion that, even within its present region of distribution, its occurrence might have extended any closer to the plateau portions of the area.' The question is whether this was always the case, or if it was different before logging in the late 18th century, or during the colder and wetter glacials.

The shale band (Cederberg Formation), with its finer soils, also lacks cedars. The Cederberg Formation consists of shale and siltstone with some fine-grained sandstone. The shale band soils are somewhat richer than the Peninsula, Pakhuis and Nardouw Formation soils, and at De Rif, below Gabriël's Pass, were even farmed. There is a grove of planted cedars at De Rif, but this is on a sandstone shelf above the shale band and it is protected by firebreaks (Figure 21).



**Figure 20.** Solitary trees on a sand plain, relicts of the Grootland Plantation.



**Figure 21.** De Rif plantation below Gabriël's Pass on a sandstone shelf above the smooth shale band. The sequence of rock formation, from top to bottom, is Nardouw Formation (smooth cliffs), Cederberg (shale band), Pakhuis (narrow strip of broken rock) and finally the wild tumble of the Peninsula Formation.

Above the shale band is the Nardouw Formation, also consisting of coarse-grained orthoquartzites[23] (Figures 19, 21).

The Nardouw Formation sandstones are somewhat softer and more reddish than the Pakhuis and Peninsula formations below the shale band. They are, therefore, more easily eroded and this has resulted in some of the spectacular rock formations in the Cederberg, including the Stadsaal, Wolfberg Cracks and Wolfberg Arch. They also form massive cliffs, for example the eastern wall of Sneeuberg and the cliffs protecting the Tafelberg summit plateau. It does not

[23]Defined as a sandstone with more than 90–95% quartz.

form the wild rock wildernesses typical of the Peninsula Formation below the shale band. There are several populations of cedars in the Nardouw Formation east of Langberg.

What restricts the species to this range and these habitats? The likely explanations are to be found in the climate and fire regimes. These rocks and cliffs, no doubt, provide protection against fire, but may also result in more water available as run-off from the rocks.

## Climate and water

How does the climate limit the distribution and habitat range of the Clanwilliam cedar? This is very difficult to answer, as climate variation in the Cederberg is complex, influenced both by the geography and elevation. This complexity is compounded by the limited climate data available for the Cederberg. Furthermore, there are no ecophysiological investigations on how the cedars cope with temperature and moisture extremes.

The climate which the cedars experience is strongly seasonal, with short, cold, wet winters and long, hot, dry summers. This alternation is well illustrated by a simplified Walter-Lieth Climate Diagram[24] for Engelsmanskloof (Figure 22), using only the rainfall data from 2016 to 2021, rather than average rainfall values, and for the temperature using the average maximum, rather than minimum values.

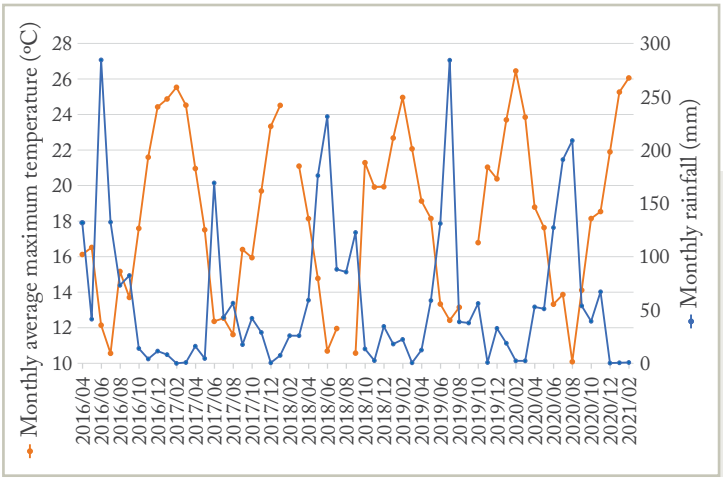



**Figure 22.** Monthly progression of rainfall (blue, solid line) and average maximum temperature (red, broken line) for Engelsmanskloof, right in the middle of the cedar habitat. These data are only available from 2016. Data provided by SAEON.

[24]A graphic representation of climatic conditions, which shows seasonal variations and extremes, as well as mean values, providing a succinct and easily accessible summary of a local climate.

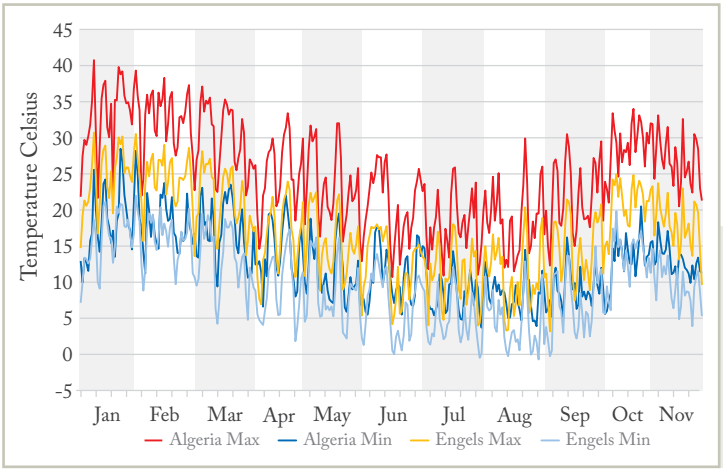



**Figure 23.** Comparison of the daily maximum and minimum temperatures from Engelsmanskloof and Algeria for 2022 (missing December). Data from SAEON.

This is a typical Mediterranean-type climate. Rain falls almost exclusively in winter, usually from March to October, with very little rain from November to February. The rainfall range is 600 to 1 000 mm per year at Engelsmanskloof. For the plants this means that in winter, when there is water available, the low temperatures limit growth, and in summer, when temperatures are good for photosynthesis and growth, there is very little water available.

## Temperature limitation

Temperature has two limiting factors: frost in winter and heat in summer. Fortunately, SAEON established automatic climate stations in the Cederberg within the cedar belt in 2016, so temperature data are available, albeit only for a few years. The results are surprising: despite the high elevation, the summers get hot. At Sneeuberg Hut (at 1 311 m a.s.l.) the maximum temperatures from December to March are between 25 and 35 °C (Figure 23). It cools down at night, with the minimum summer temperatures between 15 and 20 °C, thus some 15 °C cooler than the maxima. A similar summer temperature regime was recorded for Sneeukop Hut, although this is almost 300 m higher (at 1 576 m a.s.l.), but the summer temperatures in Engelsmanskloof (1 537 m a.s.l.) are some 5 °C lower. These latter two stations are near the upper limit of the cedars' elevation range. It is evident that summer days can become very hot. Hot air with strong insolation can result in heat stress or even death for leaves.

At Algeria (at an elevation of 500 m a.s.l.), just below the lower elevation limit of the cedars, it gets much hotter. For 2022 the maximum daily temperatures were on average 8 °C (maximally 11.69 °C) warmer than at Engelsmanskloof and maximum temperatures can exceed 40 °C. The minimum temperatures were on average 3.43 °C higher (albeit occasionally even

lower) at Algeria than at Engelmanskloof. Consequently, it is quite possible that heat stress (in combination with rainfall, see 'Water limitation' section) sets the lower elevation limit for the cedars. It would be satisfying to have ecophysiological data to show whether cedars can tolerate such high temperatures in nature.

It has been suggested that the upper limit of the cedars is determined by the minimum winter temperatures. These are the same for all three stations. Although frost can occur anytime from June to November, minimum temperatures stay above -5 °C, which is not a severe frost. Unfortunately, there is no climate station above 1 600 m a.s.l., the upper limit of the cedars, so we do not know if minimum temperatures drop much lower above this elevation and, consequently, that the hypothesis that minimum temperatures limit the upper elevation of the cedars is realistic. We also have no data on microhabitat variation in the occurrence of frost, i.e., whether habitats among rocks are more protected from frost than open habitats. Anybody who has spent nights out in the Cederberg knows that microhabitat can make a huge difference to how cold the nights feel. On the Wegwaai plateau of the Smalberg, at 1 600 m a.s.l., the cedars occur amongst huge boulders and, where their crowns emerge above the rock, they are sheared off (Figure 24), suggesting that the trees only survive because of the microhabitat protection. This suggests that the limitation of cedars to the Peninsula Formation may, in part, be because this is at a lower elevation than the Nardouw Formation, and that at higher elevations frost may damage seedlings or new shoots.

We do not know when, during their life cycle, the cedars are most sensitive to frost. A possibility is that new growth is frost-sensitive – thus during their growing season from September to April. Another possibility is that the seedlings are more frost-sensitive than adults: Budler[25] reported in 1900 that a plantation of 50 mm-tall seedlings was destroyed by frost followed by a 500 mm deep snowpack that persisted for six days (Hutchins 1901). Cultivation of the Clanwilliam cedar in Scotland showed that saplings survive being completely buried in snow, and also survived winter temperatures to -10 °C, but were killed by -14 °C. It appears that a dry cold may be more dangerous to the plants than a wet cold (Tim Rideout, pers. comm., 4 July 2023).

If frost sensitivity of the seedlings is critical, then the current distribution range of the cedars was determined by temperatures a few decades ago. We have no temperature data from before 2016, so we do not know whether the temperatures a century ago were the same, somewhat lower, or much lower than what they are today.

[25]Johan Friedrich Budler was the first ranger in the Cederberg. He was a 'local boy', born in 1847 (Wupperthal) and died on 2 August 1925 (Clanwilliam). His father was a missionary in Wupperthal.



**Figure 24.** Cedar on the summit of Smalberg, sheared off at the height of surrounded boulders, indicating that at this elevation they need the protection of rocks.

# Water limitation

## Rainfall seasonality and quantity

In winter there is no shortage of rainwater. This wet, cold winter period is short: 2–5 months long from May to August. The summers, in contrast, are hot, dry and some eight months long, with December to March extremely dry. Although there are occasional showers there is no reliable rainfall during the summer months. The autumn transition is short, only the month of April, whereas in spring there is a more gradual reduction in rainfall, from September to November.

This strong rainfall seasonality is evident throughout the Cederberg and its foothills. A comparison of the rainfall at Engelsmanskloof (near the upper limit of the cedar elevation range)

with that for Algeria (below the lower limit of the cedar elevation range) shows that Algeria receives about two-thirds of the rainfall that falls at Engelsmanskloof, but the wet and dry months are very closely correlated (Figure 25). The summer months are almost equally dry, oftentimes Algeria even gets more rain in summer than Engelsmanskloof. However, the big difference comes in winter, when there is very heavy orographic rain at Engelsmanskloof.

The mean annual rainfall in the Cederberg area varies from 216 mm in Clanwilliam to 939 mm on Middelberg (Figure 26). There are three major factors that impact on the mean annual rainfall: interannual variation, elevation and rain shadow effects.

The interannual variation in rainfall (the difference between dry and wet years) is massive. In Algeria the mean annual rainfall varied more than five-fold, from 257 mm in 2017 (the drought year that almost resulted in Cape Town running out of water) to 1 412 mm in 1977. In addition, data from Algeria also shows long-term patterns (see 'Anthropocene', p. 166). Presumably a similar interannual variation in rainfall is also found at other stations in the Cederberg. Consequently, to compare mean annual rainfall among stations, rainfall needs to be measured for long enough to factor out the interannual variation, and for the same period of time to get rid of the long-term variation. As such data are not available, the rainfall data were normalised to that of Algeria (see the inset box); the data are presented in Figure 27.

The major driver of variation in mean annual rainfall is elevation, this explains almost 60% of the spatial patterns in rainfall variation. A comparison of the available high elevation rainfall

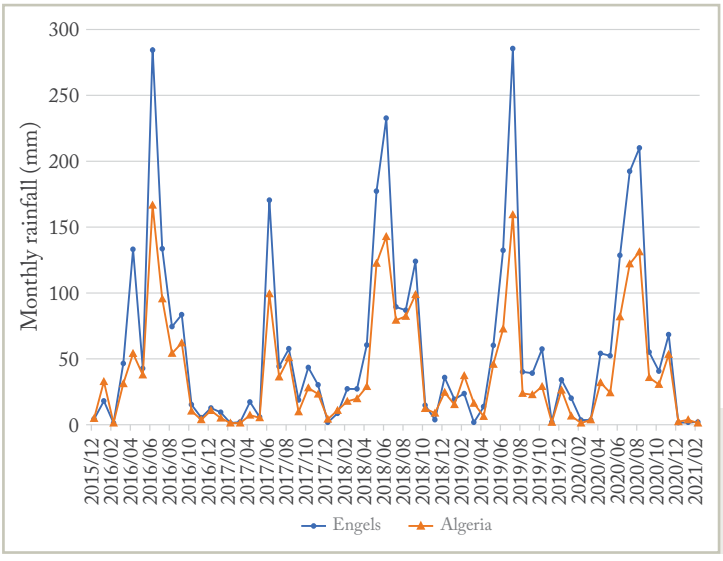



**Figure 25.** A comparison of the monthly rainfall from Algeria with that from Engelsmanskloof.

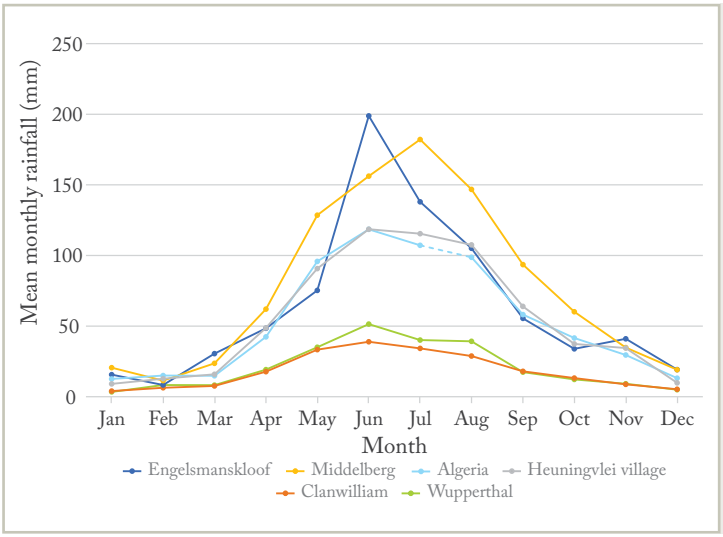



**Figure 26.** Monthly rainfall averages across the Cederberg, from Andrag's M.Sc. thesis (Andrag 1977). Middelberg, with mean annual precipitation (MAP) 939 mm, and Engelsmanskloof, with MAP 721 mm, fall within the cedar habitat; Algeria and Heuningvlei border on the cedar habitat; and Clanwilliam and Wupperthal are quite distant. The Engelsmanskloof data are from SAEON, from 2016–2020, an extremely dry period.

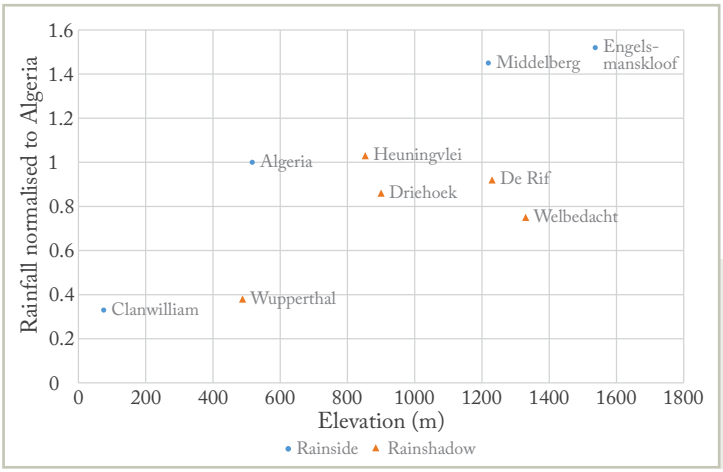



**Figure 27.** Mean annual rainfall and elevation. Round blue markers are locations on the windward side of the mountains, brown triangles on the rain shadow side.

values from Middelberg, Sneeukop Hut, Engelsmanskloof and Sneeuberg Hut suggests that they all receive about the same amount of rain, 800–1 000 mm per year. With decreasing elevation, rainfall rapidly decreases.

The last major driver is a rain shadow effect. Most rain falls in winter and this comes in on northwesterly winds, which means that the north- to west-facing valleys (Rondegat, Jan Dissels and Hex rivers) and the highest ridges (Sneeuberg, Middelberg, Krakadouw, Sneeukop) receive much orographic rain. Conversely, the valleys facing south (Driehoek, Heuningvlei) are in the rain shadow and receive less rain. This accounts for Heuningvlei, Driehoek and

## How to estimate spatial variation in rainfall

Using the Algeria record as baseline, each other station's was calculated by how much it differs from the Algeria record for the years for which there are data. This gives a proportion of the rainfall received, with Algeria given the value of 1. Consequently, the data are 'normalised' to Algeria. The more years the data overlap, the better the prediction becomes, but it should be remembered that it is only a prediction and cannot replace actual measurements. For several stations (Heuningvlei, Wupperthal, Clanwilliam, Middelberg) only monthly averages are available from 1950, with no indication for which years the data were available. These were used as is, since no better data are available.

De Rif receiving more or less the same rain as Algeria, although they are situated at higher elevations. The very low rainfall at Welbedacht Cave is puzzling, the above model predicts that it should be more than De Rif or Driehoek. The rain shadow model predicts that the highest rainfall is on the Smalberg and Sneeuberg – it would have been informative to have had rain gauges there.

It would be fascinating to know if there is a north to south rainfall gradient, i.e. how the rainfall at Pakhuis, at the northern end of the range, compares to that of Bakleikraal at the southern end. Rudolf Andrag[26] (1977) made the interesting observation that the trees in the northern-most populations, north of Pakhuis Pass, all looked very poor. They were also associated with a more drought-loving flora, with *harpuis* (*Euryops speciosissimus* DC.) and *waboom* (*Protea nitida* Mill.). The southern-most population at Bakleikraal, above Kromrivier, by contrast looked very vigorous.

Plants access water from the ground through their roots through a fascinating process. Simple rainfall is only half the story: groundwater is a complex phenomenon. Here it is simplified into four types differing primarily in how long the water stays in the ground before it is taken

[26]Rudolf Hendrik Andrag completed his M.Sc. degree thesis in the Department of Forestry of the University of Stellenbosch in 1977 on the Clanwilliam cedars and the Cederberg. This unpublished work is remarkably wide-ranging, incudes many original observations, and was based on 40 plots placed over the whole ecological and geographical range of the species. This is the most extensive factual work on the ecology of the Clanwilliam cedars. He worked in the planning section of the Department of Forestry and was not associated with the South African Forestry Research Institute (SAFRI), which was later transformed to Forestek. He died in 2019.

up by the roots, and consequently over what length of time water availability is averaged. These four categories are:

1. Transient groundwater, which is rainwater seeping through the soil after rain. This is what shallow-rooted plants, such as grasses or ericas, intercept. Within a few days after rain the transient groundwater is drained from the coarse-grained sandy Cederberg soils and the sand is dry.

2. Local water 'sumps' where rainwater is 'stored' for weeks or months after a rainfall event. Most soils store water; the finer the soil and the more organic matter present, the better it is at storing water. In this respect, the soils in the Cederberg, and particularly where most cedars grow, are very poor performers. However, boulders and bedrock can make a huge difference. Boulders run off their water, thus providing local concentrations of water, which can so penetrate deeper into the soil. Consequently, even small rainfall events can result in the deeper soil reserves being replenished. Furthermore, the soil under the boulders and in cracks in the bedrock is protected from the sun and dry air, slowing evaporation, thereby staying wetter for much longer. Sandstone bedrock is often fractured, leading to local water 'sumps' where water can be stored in cracks in the rock. Bedrock can also form impervious layers, preventing water from draining out.

3. Seepages and drainage lines concentrate the rain that falls further upstream in the catchment and the water then permeates downhill into seepages. These can be visible, especially in the Cape mountains, where water draining in the ground through a sand plain or down a streamline is forced to the surface by a rock band (for example, the green vegetation in Figure 28). Less visible is water that drains through a sand plain or down a streamline and stays underground. Here deep-rooted plants can access this water, even though it is not visible at the surface.

4. Aquifers are the most enigmatic type of groundwater in the Cape mountains. Aquifers store water over years (maybe even centuries or millennia). The persistent 'base flow' in many mountain streams, even after many months of no rain at all, indicates the presence of an aquifer.

## What water do cedars access?

Which groundwater sources do cedars use? Most cedars grow on rocky slopes and outcrops in well-drained habitats. There are a few stands along streams (for example in Engelsmanskloof and in the Vogelsang), but we have not seen any in seepages, so not Type 3. There are several lines of evidence suggesting that cedars access groundwater sumps (Type 2).



**Figure 28.** The darker green vegetation is in a seepage in the Peninsula Formation near Crystal Pool.

Cedars grow in summer, both in diameter (thus, the cambium) and in length. This means that they must be able to access water in summer, which excludes groundwater Type 1. This leaves groundwater sumps (Type 2) and aquifers (Type 4). The difference is that the sumps are responsive to interannual changes in rainfall and aquifers not. There are several indications that the cedars are responsive to interannual changes in rainfall and so water availability. The first is that there is a big variation in the growth rate of the trees – this is evident at the end of summer in the length of the new shoots produced. In some trees and years these can exceed 30 cm, and in others there is no growth at all. We suspect that this might be related to water availability. However, there is good evidence from the variation in wood growth. Cedars have annual rings in the wood, suggesting that there is seasonal variation in the growth rate and possibly some degree of seasonal dormancy. Tree diameter growth occurs in summer, but it is not clear when in summer, from October to March (Dunwiddie & Lamarche 1980) or February to June (February et al. 2007). This is the season when the temperatures are good for growth, but there is a water problem for plants reliant on rainfall, implying that the plants access local groundwater sumps. If water limitation during the long, hot, dry summers limits

cedar growth, then interannual variation in the width of the growth rings should be correlated with variation in rainfall (February & Stock 1998) and, indeed, this is the case (De Mil et al. 2021). The relationship is weak, but significant, and is correlated with spring and summer rain, as could be expected if groundwater Types 1 and 2 are used. Ed February, Adam West and Rosemary Newton (February et al. 2007) explored which of these four groundwater sources the cedars tapped into. They investigated six trees around Welbedacht Cave. They extracted stem sap, measured the carbon isotope ratio of this water, and compared it to rainwater and to the isotope ratio in the sap of shallow-rooted restios. They showed that the trees were probably accessing water trapped in sumps between the layers of sandstone (thus Type 2). They did not have the same isotope profile as co-occurring restios, which were most likely utilising Type 1 groundwater. Nor did they display the isotope profile expected from aquifer water. Such sumps can presumably store the heavy winter rainfall, make it available during the long, hot, dry summer, and are topped up by spring and summer rain.

However, the situation is not convincingly resolved and it is not clear to what extent water availability is limiting. Ed February at al. (2007) showed that the monthly increases in stem diameter of six cedar trees above Welbedacht was not related to rainfall, so something else should be limiting. Furthermore, variation in stable carbon isotope ratios ($\delta^{13}$ C) of the tree ring cellulose from 1900 to 1980 from De Bos should become more positive if drought stress causes stomatal closure, but there is no correlation between the $\delta^{13}$ C value of rainfall variation from Wupperthal (February & Stock 1999).

It is potentially significant that cedars reach their lowest elevations in Duiwelsgat and at Algeria, these north- to west-facing lower slopes probably receive the highest rainfall per elevation in the Cederberg, suggesting that the lower elevation limit may be moisture rather than temperature regulated, or that moisture can ameliorate the effect of temperature.

The short and sweet of this long tale is that the cedars use groundwater sumps (based on carbon isotope signatures), which are replenished by spring and summer rain (hence the tree-ring response), but (at least at Welbedacht and De Bos, in the middle of the cedar ranges) are not water limited.

Curiously, there have been no investigations into the development and architecture of the cedar root system. The February–Stock hypothesis suggests that the young plants will invest maximally in developing a deep root system to access summer moisture in the deeper soil layers and in fractures in the bedrock. The rootstocks of toppled trees at De Rif revealed that the tap root and three to five shallow lateral roots are equally thick, and that there are no coarse roots between these two. These shallow lateral roots spread a considerable



**Figure 29.** Lateral roots of a dead cedar, presumably they tapped underground water supplies from cracks in the bedrock.

distance (probably more than 10 m), and are often seen crossing foot paths (Figure 29). They can snake anaconda-like over rocky surfaces. Presumably these massive roots tap into local groundwater sumps. These root systems seem to be as massive as the aboveground stems and branches, and it would be fascinating to follow such a root and see where it goes.

## Coping with heat and seasonal drought

What can we interpret from the previous section? The upper elevation limit, more or less at the shale band, could be due to a temperature effect: at higher elevations there are occasionally severe frost events, which kill the trees or seedlings, or that frost during the growing season in early summer damages plants. This implies something like a tree line. Rudolf Marloth (1902) noted that, above 1 800 m a.s.l., fynbos had many structural attributes associated with

alpine vegetation and that taller plants are absent. It is still unclear what the mechanism of this apparent tree line could be, consequently, we do not know what the impact of climate change will be and whether cedars do have expansion space 'upwards'. There is another possibility. Above the shale band the bedrock is different: it is the softer and more easily eroded Nardouw Formation, rather than the hard Peninsula Formation which is found below the shale band. The smoother surfaces of the Nardouw Formation may provide fewer microhabitats with frost and fire protection. However, the Nardouw Formation slopes down towards the east and cedars do occur on it at lower elevation, suggesting that the critical factor may be climate. This is further supported by the obviously struggling cedars on the Wegwaai plateau of the Smalberg at 1 600 m a.s.l. Rudolf Andrag (1977) noted that there were a few populations on the Nardouw Formation, but that they all looked rather poor. The shale band is similarly confusing: there are only two populations on the shale band (Andrag 1977) with both growing quite vigorously.

The lower elevation limit may be summer drought, possibly in interaction with more heat in summer. With less rain in winter, the groundwater sumps are likely to have less water and at the same time summers are hotter at these lower elevations, resulting in more evaporation and transpiration. The result is that the trees may not be able to grow. However, these hypotheses should be tested with experimental plantings: at the upper limit the plants should show frost damage and at the lower limit they should show very slow growth rates.

The plants probably use several mechanisms to cope with the hot, dry summers and the added constraint that it is dry at the time when temperatures are high enough for growth. One mechanism is that trees access short-term water sumps that probably smooth water availability over several months, thus preserving winter and spring rainfall into summer. Being massive dicots (for fynbos species), their roots can forage for water sumps over a much larger area than restios or proteas can. Another mechanism is through morphological adaptations in the leaves and short shoots. These can be interpreted as three remarkable drought adaptions. The first is that the leaves are reduced to scales with the inner, adaxial, leaf surface adpressed to the stems, so that only the outer, abaxial, epidermis is exposed to the air. In both the Clanwilliam and the Willowmore cedars the free parts of the scale leaves are much shorter than the parts fused to the stem, whereas in the other species of *Widdringtonia* the free and fused parts of the scale leaves are more or less equally long (Marsh 1965). This greatly reduces the exposed epidermis and halves the surface area of leaves. The extent of this reduction is readily appreciated if the leaves are compared to the co-occurring *waboom*, *Protea nitida*, with its large, bifacial leaves. Secondly, the scale leaves are tightly adpressed to the stem and, consequently, the whole branchlet forms a smooth cylindrical structure without any protruding leaf blades or margins. This allows free airflow over the leaf surfaces (Figures 30, 31).



**Figure 30.** Open cedar canopy allowing for unhindered air flow, so maximising wind cooling effect.

This, with the branching short shoots, forms an airy structure through which air can move unimpeded and without any large surfaces that could warm the air moving over a large, sun-warmed leaf surface. This results in maximal cooling effect (similar to a car radiator), thus minimising the need for transpiration to cool the leaves.

Thirdly, it could be argued that the summer plant growth is a 'maladaptation' – it is possible that the plants can limit or even halt this growth during a dry year. The correlation between interannual variation in rainfall and the development of the annual rings suggest that this is indeed the case. This set of wonderful drought and heat adaptations is not unique to *Widdringtonia cedarbergensis* and is also found in the sister genus *Callitris* in Australia. Significantly, some species of *Callitris* are found in similarly dry habitats.

## Soils and nutrition

Clanwilliam cedars grow on very impoverished soils. These are derived from sandstones, which are intrinsically poor in major plant nutrients. In addition, the soils are coarse-grained sands and, with a rainfall of almost 1 000 mm falling mostly during a few months, the available nutrients are largely leached out of the soil (Taylor 1996). Many of the common fynbos plant groups have special adaptations to deal with these remarkably poor soils. The Restionaceae and Proteaceae have cluster roots – brush-like concentrations of very fine, ephemeral roots that can explore the soil intensively. Other groups, like the Ericaceae, have special forms of fungal associations.



**Figure 31.** Terminal leafy branches, detailing the feather-like structure, which may maximise the air cooling effect.

Almost all conifers have mycorrhizae (Farjon 2008). These are fungi that exist in a mutualistic relationship with the trees. The very fine hyphae of the fungus can explore a much larger volume of soil than tree roots can, and these nutrients are 'traded' against carbon (photosynthetic products) from the host. This becomes very relevant in the Cape's seasonal climate. Species without mycorrhizae are dependent on the transpiration stream to take up nutrients from the soil. When the soil is wet (i.e., in winter) fast transpiration from the leaves draws water (in which the soil nutrients are dissolved) through the soil to the roots and so into the plants – this process is referred to as mass flow (Cramer et al. 2009). This is possible only if the soils are wet and the plant is capable of rapid transpiration. In species with mycorrhizae these processes are disconnected – the fungal hyphae grow to the nutrients and take them up, so there is no need for mass flow. Consequently, nutrient uptake and transpiration can be disconnected, allowing the plants to have less transpiration in winter. This fits with the leaf adaptations described in the previous section, which limit transpiration in both summer and winter. However, there has been no study of Clanwilliam cedar roots for possible associated mycorrhizae. Therefore, we do not know whether this particular species of conifer has mycorrhizae, or whether it relies on mass flow.

# Growth form and growth rates

## Growth form

The Clanwilliam cedars change dramatically in shape as they grow taller. Young cedar trees are slender, conical, with strong apical dominance and ascending branches, much like cypress trees. The lower side branches persist until the trees are some 40–50 years old. These trees are referred to as pole trees. At this stage the new lateral branches start spreading horizontally, while the ascending lower branches die and drop off. The tree appears to lose its apical dominance and the side branches become massive, forming a large spreading crown (Hubbard 1937). Cedars can grow into tall trees with a single trunk to 7 m tall with the first branches forming a spreading crown, but many extant trees branch from ground level. The trees form a sparse canopy, usually with less than 50% closure. The canopy consists of almost bare branches with a brush of foliage towards the apices. If you lie on your back under a cedar, some 50% of the sky is visible through the canopy. This is in stark contrast to, for example, an oak tree where there is usually no sky visible. Furthermore, of the 50% canopy, much is due to the branches and not foliage. Several classification schemes have been used to categorise cedar growth forms but the biologically most meaningful is that used by the government department formerly known as the Department of Forestry, illustrated in Figure 32. This is based on the leaf-types, the size of the plant, and whether it is a conical pole with dominant central shoot, or whether it has an unbranched trunk and spreading canopy branches.

When the seeds first germinate, the plants have juvenile leaves. These are strap-shaped, pointed, soft, to 10 mm long and resemble 'normal' conifer needles. These leaves are spirally arranged, with a much larger surface area than mature leaves and with both surfaces exposed (Figures 33A and B). Juvenile leaves are formed until the plant is 6–10 years old. Class 1 are seedlings (if cotyledons are still present) or saplings (that have lost their cotyledons) with only juvenile leaves (Figures 33A and C). Classes 2, 3 and 4 are pole trees with mature foliage (Figure 33D). The mature leaves are opposite and scale-like, with their adaxial surfaces adpressed to the branches and almost completely fused with the stem, so that only their tips are free. This means that only the abaxial surface of a leaf is exposed. These three classes of pole trees are separated based on size of the plants. Classes 5 and 6 are mature trees with a distinct bole and crown. Here the lateral branches in the crown grow more rapidly than the main stem, implying that the apical dominance in the tree is lost. Class 5 trees form a single bole, with the side branches only starting several metres above the ground (Figure 34), whereas Class 6 trees are more like shrubs, with the bole short or absent and the main branches from near the ground.

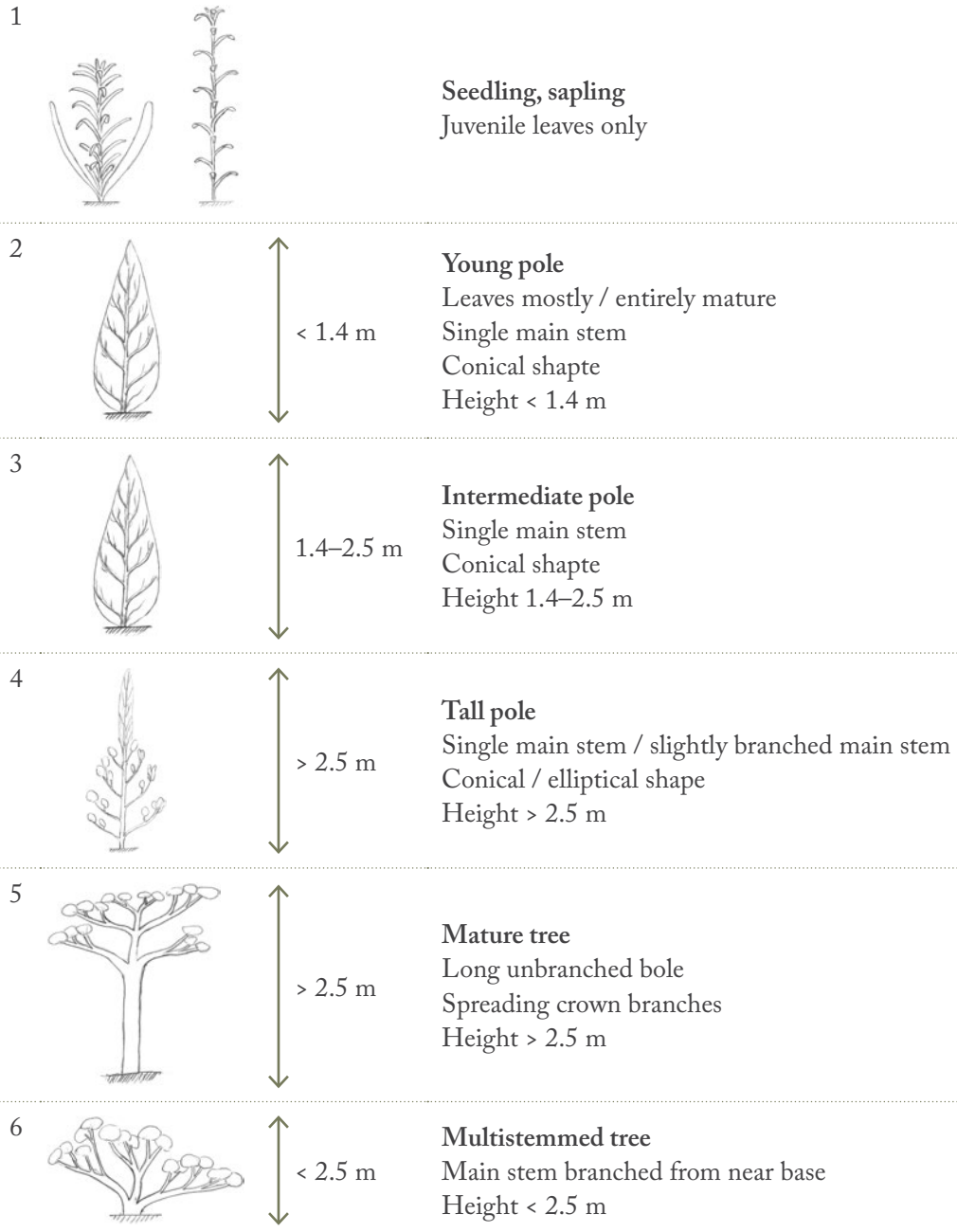



**Figure 32.** Cedar growth progression, a scheme developed by the Department of Forestry.




**Figure 33.** A, struggling Class 1 sapling, with small side branch and juvenile leaves; B, juvenile leaves; C, sapling with juvenile growth transitioning to adult growth with scale leaves and long and short shoots; D, class 4 tree, mature pole stage, approximately 50 years old, with Class 5 adults in the background, on Mied se Berg, with Tafelberg in the background.



**Figure 34.** Class 5 tree with bole and spreading branches (probably much older than 200 years).

Several other classification systems have been used, some arbitrarily classing the plants by their height, irrespective of the tree shape, whereas others use the stem diameter at breast height, usually 1.4 m (DBH, a commonly used measure in the forestry industry), or total height for smaller trees and DBH for older ones. These categories are easier to use and useful for measuring growth rates, but probably not as biologically significant. Unless specified otherwise, the system developed by the Department of Forestry, as illustrated in Figure 32, is used in this book.

## Is cedar growth rate slow or fast?

Central to many questions on the cedars is their growth rate. How long does it take for the plants to switch from saplings (with juvenile leaves) to pole trees (with their characteristic growth form and scale leaves)? At what age are the lower side branches dropped and the adult growth form with a clear bole developed? These questions can be addressed by measuring the increase in height in the tree (similar to the way we record the growth of children on a wall) as being the easiest variable to measure in seedlings, saplings and pole trees. Alternatively, we can measure the increase in DBH. This is most suitable for mature trees where the crown is difficult to reach but the trunk is not. Finally, it can be documented as the transition between life stages. This is a superficially simple method but the problem is that there is a tendency for researchers to develop their own systems, making their data non-comparable. Commercially, growth rates are important because they give some indication of how long it would be before trees can be harvested. Ecologically, growth rates are important because they give a prediction as to how long it would take before trees start producing significant amounts of seed and until they develop some fire resistance.

Simple as it sounds, growth rates are remarkably difficult to measure. We cannot, as we do with children, start with a seedling and follow it through to maturity, recording height and DBH every few years. There are three reasons for this difficulty. The first is that very few seedlings make it to maturity, maybe 1% or less. Obviously, it is unknown which of the hundreds of seedlings before us will make it, so we cannot predict which ones we should measure. Secondly, there is a wide range of growth rates, presumably depending on the habitat conditions of the individual plants, or the genetics of the individual plants, or even an interaction between habitat and genetics. This could be even further complicated by the specific climatic conditions during the decade for which we measure the growth rates. It is possible that only the fastest growing plants will reach maturity, so it is really the maximum growth rates that are interesting and significant. But even if slower growing trees also succeed, the average growth rate is likely to be uninteresting, as the failures will distort the values and these are most likely the slowest growing plants. In addition, how many trees and over what time range

do we need to measure to obtain a reasonable estimate of the potential maximum growth rates? Finally, we need rates over at least the first 100 years of the trees. That implies a project running over a century. It is, therefore, not surprising that our growth rate estimates are precisely that: estimates.

So how fast do Clanwilliam cedars grow? Budler noted, in his first report from 1876 (Anonymous 1877), that cedars grow very slowly. Two decades later, Hutchins[27] noted: 'Lastly, as to rapidity in growth, it is equal or superior to the other valuable SA timbers ... this supported by annual tree rings ... Certain Cedar trees such as those at Wuppertal, are really slow-growing but this is because they have been raised artificially away from the snow-clad mountain, whereon Cedar along flourishes naturally' (Hutchins 1897). So, who is right, Mr Johan Budler, the boy from Wupperthal, or Sir Ernest Hutchins, the British Imperial Forestry specialist?

## Quantifying growth rates

The first quantification of growth rates was by C.S. Hubbard in 1936, as an attempt to compare growth rates of plantation and wild-growing cedars (Hubbard 1937). He used a clever, if very destructive, method: he cut down 35 naturally grown trees (the oldest was 250 years) and 17 trees in plantations. He cut the stems into 0.3 –1.0 m long sections and dated each section using tree rings. This gave the height and DBH of trees at each age. He found a massive range in growth rates. To deal with this he divided the trees into fast-, medium- and slow-growing groups, with the fastest growing reaching 10 m (and basal stem diameter of 80 mm) after 40 years (Figure 35). These data are consistent with the transition from pole to mature growth form at about 50 years and showed that a healthy growing tree adds some 250 mm to its height per year. This method has the advantage that it measures the growth rates of successful trees and not the whole set of trees. This growth rate is the same as the related *Callitris columellaris* F.Muell. (=*C. glaucophylla* Joy Thomps. & L.A.S.Johnson) in Australia, which grows at roughly 250 mm a year (Ross et al. 2008). Interestingly, *C. columellaris* is regarded as a slow-growing tree, so corroborating Budler (Anonymous 1877).

Hubbard's method does not give an estimate of sapling growth rates. Sapling growth rates (i.e., before the decimation of the populations by fire) are easiest measured directly as the size the saplings achieve at a given number of years after fire or planting. Shona Young (1998) measured saplings planted in the Cedar Reserve (see Chapter 8) from 1987 onwards

[27]Sir David Ernest Hutchins (1850–1920) was a British Imperial Forestry expert who worked in India, South Africa and East Africa, and who spent 23 years at the Cape.

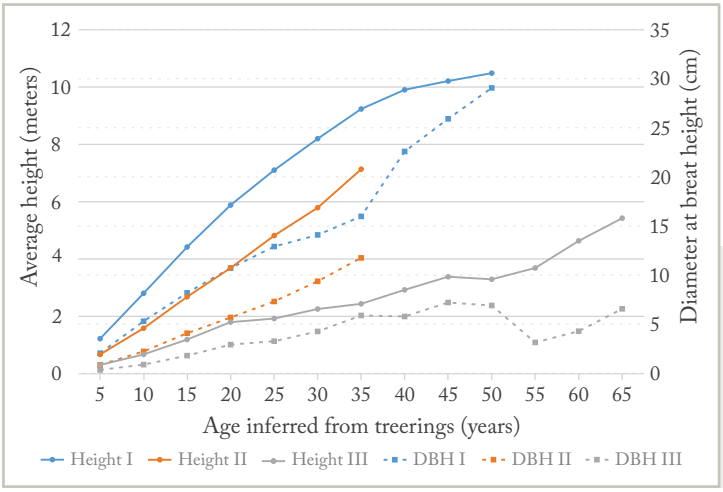



**Figure 35.** Cedar growth rates determined by Hubbard (1937) based on tree rings. The data are divided into fast-growing (I), intermediate (II) and slow-growing (III).

(Figure 36). The best-fit curve suggests an exponential increase in growth rate. However, she reported only the average heights, which is of limited use and cannot be used to assess the faster growth rates. Furthermore, these measurements are from plants planted as seedlings, consequently the exponential increase in growth rates may simply reflect the adjustment of the plants to their new environments.

A more differentiated picture of heights of labelled plants is available for a SAFRI plot at Groot Koupoort. These germinated in 1975 (perhaps after a fire?), and after five years the tallest 25% of the seedlings were more than 350 mm tall, with the tallest reaching a metre.

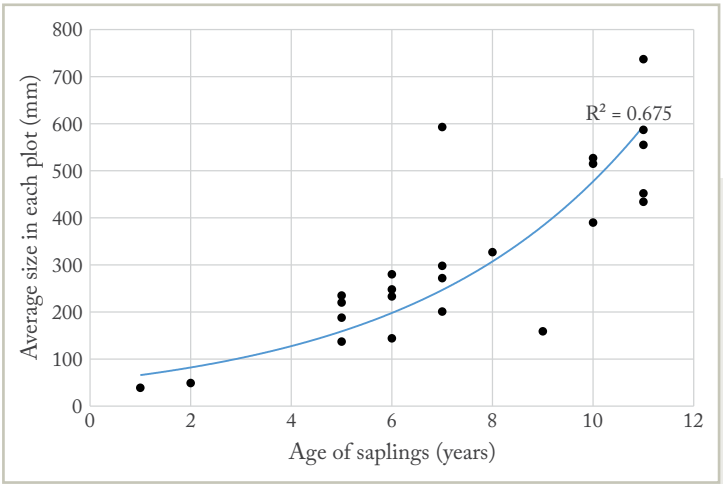



**Figure 36.** Sapling sizes in the Cedar Reserve of plants planted from 1987 onwards, measured by Shona Young (1998). The best-fit curve is exponential, with an average height of 350 mm at 8 years and 600 mm at 11 years.

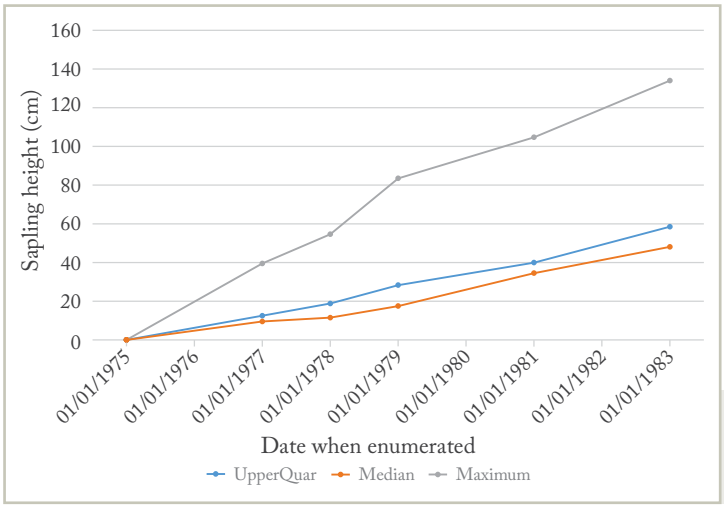



**Figure 37.** Seedling growth rates at Groot Koupoort, based on Plot 10.

The last enumeration was eight years after the germination, by which time the tallest plant had reached 1.4 m, and the average of the tallest 25% was 600 mm (Figure 37). This is substantially more than the average values for the entire sample – these being similar to those reported from the Cedar Reserve. If only the tallest plants will eventually survive, these data suggest that they need about 10 years to reach 1 m in height. Interestingly, there is no evidence of an increase in growth rates, as found for the planted trees in the Cedar Reserve.

A very different impression is gained from the sizes of saplings seven years after fire at De Rif, from data measured by Helen Moss and helpers (Helen Moss, pers. comm., 5 February 2024). From the fourth year after fire the saplings had been 'tended', so survival and growth rates are probably near the upper margin of what is normal. Of the 535 saplings measured, 383 (72%) were less than 500 mm tall, of which 100 were less than 100 mm tall. The remaining 152 saplings (28%) were more than 500 mm tall, of which 72 (13%) were more than 1 m tall, three saplings were at least 2 m tall, and the tallest was 2.62 m (Figure 38). This shows that the vast majority of the seedlings really struggle to get going and only a few take off. The struggling saplings are on the sand plain in the middle (Figure 39), whereas the trees that grow fast are among rocks along the margins of the plantation (Figure 40). This suggests that the habitat (among rocks) is very important for accelerating growth rates. However, this analysis is somewhat simplistic, as new seedlings continue to germinate, so a proportion of the smaller seedlings are not yet seven years old. The very high density of seedlings shows that excellent regeneration can be possible after a mid-summer fire (this happened end December). Noticeable is the absence of saplings under the unburnt forest (Figure 39).

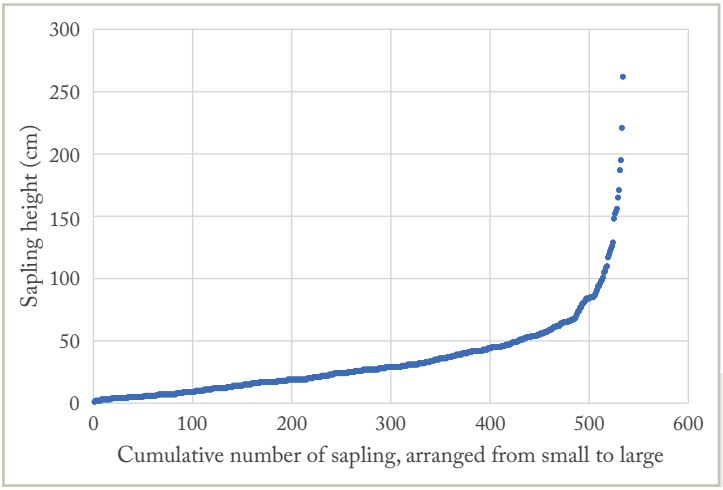



**Figure 38.** Size distributions of saplings at De Rif, seven years after fire.



**Figure 39.** De Rif plantation drone image. Each red dot is a sapling. Photo made and assembled by Tom Smyth.



**Figure 40.** Tallest pole trees among rocks at De Rif, seven years after the fire.

The regeneration in the northern part of the plantation is very poor, consisting almost entirely of stunted, etiolated saplings.

Overall, under optimal conditions, cedars can grow 250 mm per year. In rare cases some plants can exceed this rate, but the vast majority of saplings and plants grow slower. This is the same as the growth rate of the Australian *Callitris glaucophylla* (Ross et al. 2008). Fast growth rates are accepted to be more than 600 mm per year, a moderate growth rate is 300–600 mm per year and a slow growth rate is less than 300 mm per year. Therefore, cedars are, by comparison, slow-growing trees, as stated by Mr Johan Budler (Anonymous 1877).

## Growth rates of 'living dead' stands

We have growth rate data for three stands that appear to be dying at Sneeuberg, Grootland Peak and Welbedacht. The first two are tree-height data and the Welbedacht site DBH

measurements. Sneeuberg is a comparison of 1971 with 1976 (SAFRI data), Grootland is 1977 compared to 2003 by Sarah-Jane Fox (2003), and Welbedacht dendrometer measures of stem diameter of six trees over three years by Ed February and Adam West (February et al. 2007). The results are sobering: all growth-rates (with two exceptions) were slower by an order of magnitude of our ideal 250 mm a year. The exceptions were one tree each at Grootland and Welbedacht, both of which grew exceptionally rapidly.

This implies that populations that are failing have lower growth rates. Why should this be? Is it linked to frequent fires sweeping through the populations, killing regeneration and slowing the growth rates of the survivors? Could it be that the populations no longer have access to an adequate ground water sump supply during summer? Or is there some other, as yet unknown, factor at work? It would be interesting to have growth rate data for the few populations that are still vigorous, to see whether Hubbard's growth rates from a century ago (Hubbard 1937) still apply to these healthy stands.

## Transitions

The transition from a sapling with juvenile leaves to a pole tree with mature, scale-like leaves and the initiation of cone formation happens 6–10 years after germination but is poorly constrained and slow-growing trees may take longer to make this transition. The plants are then some 2 m tall. The transition is unidirectional, thus not reversible.

The transition from pole to mature tree (Class 4 to 5) happens after about 50 years. At that stage the trees are some 10 m tall.

It is not clear how old the trees can get, probably some 400 years, possibly 600 years. Possibly all oldest trees have been logged out, so an iconic individual cannot be located to turn it into a pilgrimage site. However, there has also been no search for the oldest tree in the Cederberg. Consequently, we also do not know what the maximum age is that the trees can reach.

## How long do dead trees stay in the landscape?

The Cederberg is full of dead cedars. In some areas, such as between Engelsmanskloof and Van Zylspoort, the clutter of fallen, dead trees makes getting through the rocky ridges difficult (Figure 41). We do not know how rapidly the old wood decays. When a tree falls in a tropical forest, or even a temperate forest, it is attacked by fungi: mushrooms and bracket fungi soon sprout spectacularly out of the trunks and a few years later only some mould



**Figure 41.** Dead forest near the bottom of Engelsmanskloof.

remains. The cellulose and lignin that makes up the tree is digested by the fungi. This does not happen in the Cederberg. One possibility is that fungal growth is inhibited by the long dry, hot summers. The other possibility is that the resins in the tree preserve the wood. Or both mechanisms operate. To get an impression of how long dead trees stay around, we looked at paired photographs, as assembled by Joe White et al. (2016). Although a systematic search through repeat pictures to quantify the decay rate was not done, it can be estimated that dead trees fall apart after about 30 years and that by 70 years there are only a few relicts on the ground (Figures 42, 43).

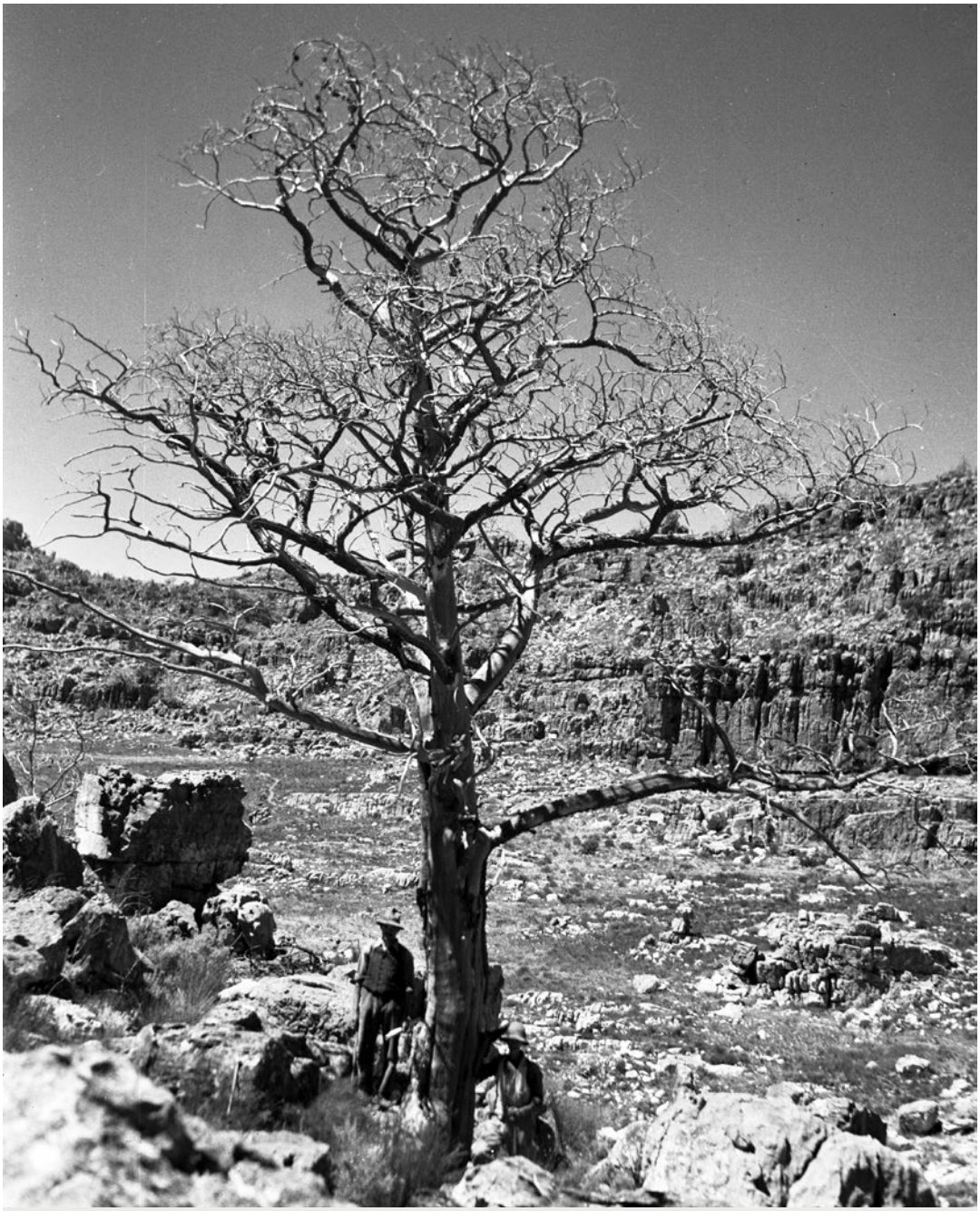


**Figure 42.** Recently dead cedar, with fine twigs still on tree, photographed by C.S. Hubbard in February 1936 near the Middelberg Huts.



**Figure 43.** Repeat photograph of same cedar in Figure 42, now reduced to fragments on the ground, taken by Puttick and Jack in October 2012, thus 76 years later.

# Surviving fire

## Are the trees killed by fire?

For the last 150 years fire has been seen as the major threat to the survival of the cedars. Clanwilliam cedars are generally reported to be killed by fire (Palmer & Pitman 1972), with no resprouting (Higgins et al. 1989). This is similar to the Mulanje and Willowmore cedars, but different from the widespread and hyper-variable mountain cedar. The latter has a large, underground, woody rootstock, as well as buds near the base of the stem from which the plant resprouts after fire. Consequently, the mountain cedar in the Cape is generally multistemmed from the base, compared to the single trunk of the other species of *Widdringtonia*.

Clanwilliam cedars have a thin bark, which is not fire-resistant, unlike cork oaks. Hubbard (1937) measured a bark thickness of 12–15 mm in a tree with a diameter of 1.3 m. The bark is grey, forming very distinctive, persistent, square, flaky scales, like roof shingles, measuring ± 50 × 50 mm (Figure 44). The cedars are very resinous and also high in volatile oils. This has



**Figure 44.** Cedar bark.

led to the widespread assumption that the trees are highly flammable and never survive fire (Lückhoff 1971). This was first articulated by McNaughton as 'the bark acts as a tinder, and only requires a spark to set it alight, and should only a small ring of bark be consumed around the tree, it would cause its certain death' (McNaughton 1891). This unambiguous statement influenced many subsequent botanists, but it is wrong.

Cedars can be killed by fire, but the mechanism is not clear. One possibility is that the cambium is destroyed by heat, a theory consistent with the thin bark. The cambium is the tissue that produces new wood and is situated just below the bark – cutting it is what results in the death of ringbarked trees. For the cambium to be killed, the heat needs to penetrate the bark. Another possibility is that the leaves are killed, thus stopping the transpiration stream and photosynthesis. This requires sufficient fire heat to reach the crown of the trees. Andrag (1977) showed that older trees very often had partially killed crowns, consistent with this type of fire killing. This was explored in a B.Sc. (Honours) thesis by Sean Privett (1994), supervised by William Bond, which showed that cedars are remarkably sensitive to heat: heating leaves to only 80 °C for two minutes resulted in extensive damage and blushing, presumably meaning that the leaves had been scorched to death. He also showed that the juvenile leaves, although these contained more moisture, were more heat-sensitive than adult leaves, and that leaves from the tops of adult trees were less heat-sensitive than lower leaves. It is also possible that both cambium death and leaf scorching mechanisms operate (Bond 1993), but it seems likely that the latter mechanism is the most common one.

The frequent observations of living trees with fire scars (Figure 45), or partially killed trees (Figure 46), show that some trees do survive fire and they also survive some scorching. There seems to be a limited capacity for crown fires, where the fire spreads through the whole stand from one crown to the next. This accounts for the survival of a small part of the De Rif plantation and the persistence of small cores of the original plantations at Heuningvlei and on Middelberg.

## How to survive fire

The big question remains: how does the Clanwilliam cedar manage to live with fire? Fynbos in the Cederberg burns regularly. Because we have no data on the fire frequency before 1944, this has led to futile discussions about 'natural fire frequency', or the fire return time at any particular place: some have argued for a 10 year fire return time, whereas others have suggested a fire return time of several decades. The real situation is, however, much more complex. Between 1944 and 2005 the average number of fires in the Cederberg has been four (thus a mean return time of 15 years). However, almost 9% of the area has burnt only



**Figure 45.** Live tree with a substantial fire scar and many dead branches. Such trees are common. It seems that the fire scar is deepened by subsequent fires.

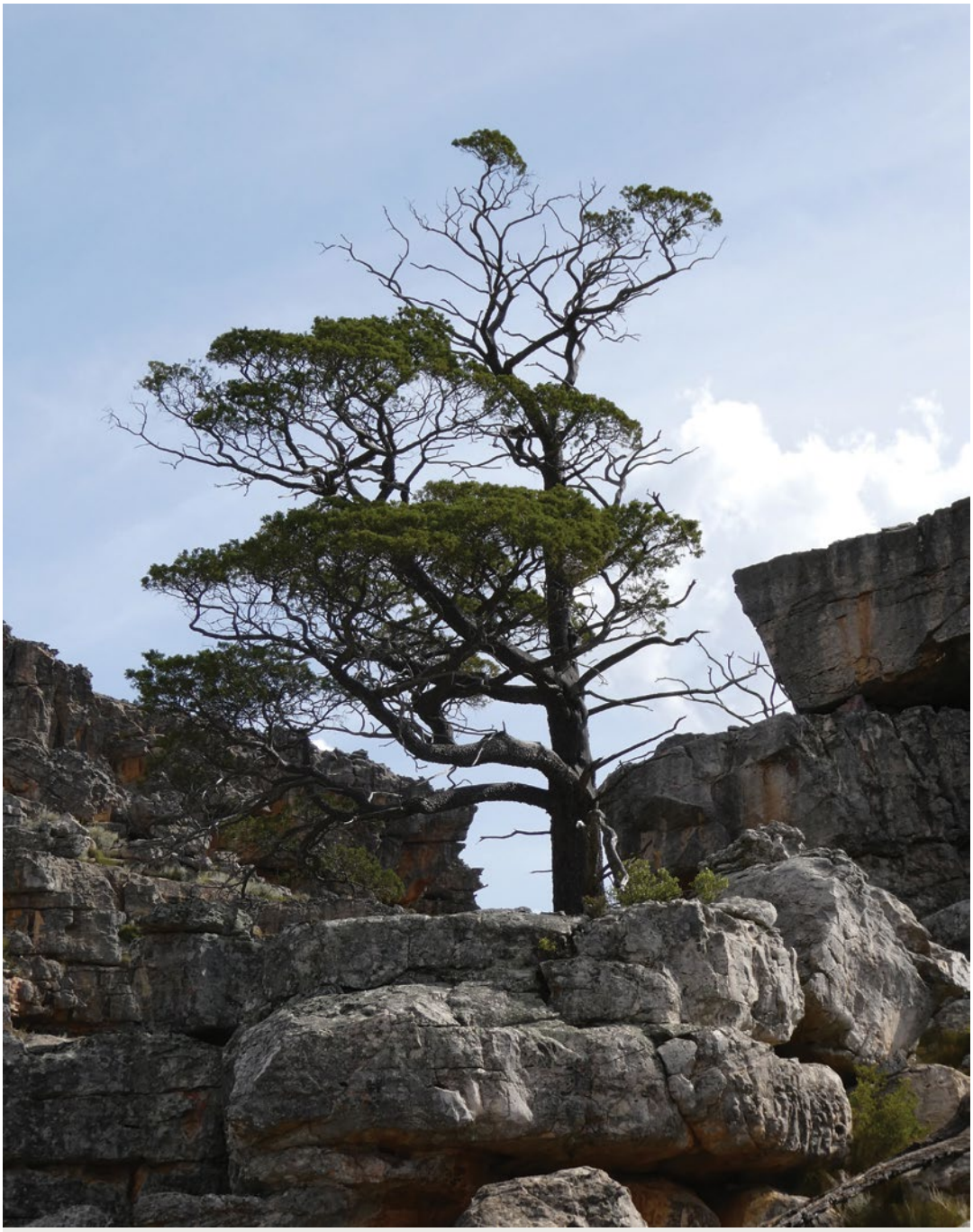


**Figure 46.** Partially fire-killed tree.

twice since 1944: these are the highest and coldest regions, possibly also the driest areas. On the other hand, 23% of the area has burnt more than six times, thus on average once every 10 years. These areas tend to be on the coastal side of the mountains and the summit ridges, presumably the wetter and more mesic areas. Clearly there is substantial variation in fire frequency within the Cederberg and, consequently, it makes no sense to talk about a singular fire regime in the Cederberg. It also suggests that as climate changes the return time of fires could vary. The current older cedars were fire-vulnerable saplings and pole trees 150–350 years ago, during the Little Ice Age[28] (1350 to 1850) when the climate was likely colder and wetter. Consequently, we do not know what fire regimes they were exposed to in exactly the same place where they grow now.

During the last century there were repeated fire summers, during which most of the Cederberg was burnt. These occurred every few decades. Sometimes this was as one massive fire, but oftentimes there were several large fires during a summer. Some speculate that these 'fire summers' were the result of the accumulation of a large amount of flammable biomass after many years of no fires. The alternative hypothesis is that they are climatically driven and occur during unusually hot and dry summers.

The conclusion often reached is that only species adapted to fire can survive in the Cederberg. This is, however, simplistic, as there are habitats which do not burn: riverine forests as found at the base of Krakadouwpoort or Koupoort, fynbos among large rock outcrops and on the summit plateaux of mountains such as Tafelberg or Skerpioensberg, and sand plains where the vegetation is too sparse to carry fire.

Cedars have persisted in the Cederberg, despite the fires. There are still many trees that are more than 100 years old and there must have been many thousands such old trees before the massive logging between 200 and 100 years ago. How could they survive? This question has been much researched, in some cases with large datasets (such as Rudolf Andrag's plots [1977], see also Text Box 4.1), in other cases with very sophisticated statistical analyses (such as Steve Higgins' demographic model [Higgins et al. 2001]). We suggest that there are two interrelated factors: avoiding large accumulations of flammable fynbos and overtopping the fires.

Cedars only start significant seed production at about 40 years old. Consequently, for stands to persist, at least some trees must survive at least 40 years.

[28]A period of colder temperatures, known largely from Europe where expanding glaciers and very cold, freezing winters characterised it. The Western Cape most likely was colder and wetter than the current climate (see Chapter 7).

## Text Box 4.1: Andrag's plots

For his M.Sc. thesis, Rudolf Andrag, who worked for the Department of Forestry, compiled an impressive dataset of 40 plots placed throughout the distribution range of the Clanwilliam cedars and over the whole habitat range. These plots were surveyed from June 1972 to November 1973. Each plot was one hectare (100 × 100 m) and for each plot all cedar trees were listed and assigned to size classes. In addition, he noted for each tree whether it was next to a rock and how dense the vegetation was around the plants (i.e., the fuel load). For each plot he also collected some environmental data. He did not permanently mark the trees and the plots, so it is not possible to re-survey the plots to document the fate of each tree. Those plots which could be relocated are listed in Appendix 2. The Andrag plots are much more numerous than the SAFRI plots (see Text Box 2.1, p. 38), but the latter are permanent plots, which could be re-surveyed. Consequently, the SAFRI plots were used in subsequent research.

## Avoiding large accumulations of flammable fynbos

Fuel load under trees evidently has a major impact on the survival of cedars to maturity. Andrag (1977) showed that saplings and pole trees generally have much more fuel under them than adult trees (Figure 47). His interpretation is that only trees with little fuel under them survive to become adult trees, as those with fuel under them are likely killed by the next fire that sweeps through the stand. There are two situations in which the fuel load is reduced. The first is if the trees themselves shade out the flammable fynbos. The second is that they grow among rocks, where the rocks replace the fynbos.

Large trees, and especially dense stands of trees, are effective at shading out fynbos vegetation, and so flammable fuel (Manders 1987b). If dense stands are not flammable and shade out flammable fynbos, then fire (at least in theory) cannot penetrate them. The cedars may construct their very own fire refuges, a form of niche construction. This is seen in riverine thickets and forest patches in fynbos, which do not burn, and as such constitute a biotically constructed fire refuge. A further mechanism for limiting pyrophytic fynbos under cedars was suggested by Pat Manders (1987a): the litter of cedars may be allelopathic. This means that it contains chemicals which inhibit plant growth. This elegant hypothesis was tested with cedar seedlings, but not with fynbos seedlings, so we do not know whether it works for fynbos. Shading and allelopathy could account for the reduction in fynbos fuel under older rather than younger cedars, as documented by Andrag (1977) and is seen under remnant plantation stands (Figure 48) and where there are still clumps of trees among rocks.

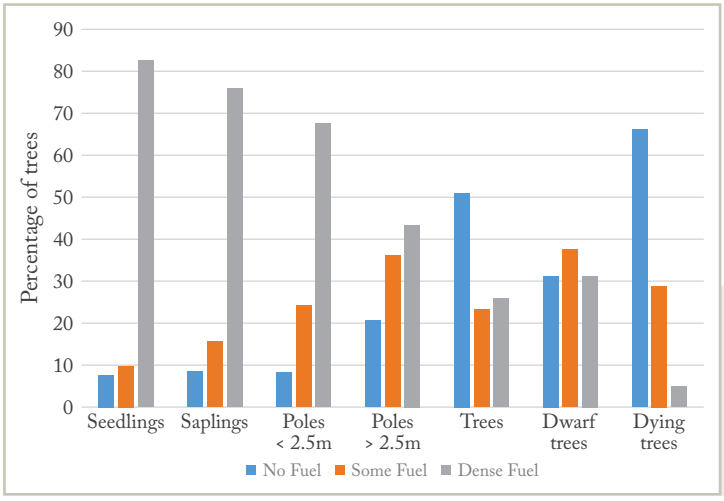



**Figure 47.** Fuel load variation under trees of different size classes, showing that large, old trees have less fuel under them (data from Andrag 1977).



**Figure 48.** Cedar plantation at Heuningvlei with almost bare ground under the trees. This stand has survived numerous fires. Photograph from Ed February.

Rocks also limit plant growth and so reduce fuel load. These are natural fire refuges, rather than constructed niches. Andrag (1977) showed that trees growing among large rocks also have a much higher survival rate. Whereas almost 40% of the immature trees are found away from rocks, this percentage rapidly declines to below 20% for mature trees (Figure 49). Steve Higgins at al. (2001) followed this up 30 years later with statistical niche models, which showed that over 50% of the variation in where cedars occurred was driven by rockiness. Clearly, rocks are important for the occurrence of the species (Figures 50, 51). But is this because they survive fire better in rocks? This was addressed by Sean Privett (1994), albeit for a much smaller dataset using only five sites. Contrasting the habitats and growth forms of trees killed by fire with those that survived fire, showed that trees among rocks had a much higher survival rate. Trees among rocks have less fuel around them, so in this case the fuel and rock reflect the same thing. Rocks also positively influence the water availability (see 'What water do cedars access?', p. 67), and seedlings grow better in shade (see 'Outgrowing fire' below), but this all occurs before the fire limitation takes place. Whatever the most important mechanism is, it is clear that cedars love rocks.

## Outgrowing fire

Tree shape and size has a major impact on fire survival. All studies have shown that older trees have a much higher fire survival rate than younger trees. This, of course, also translates into shape, as younger trees are conical with growth driven by the central stem and many small side branches reaching down to the ground. These trees subsequently develop into pole trees, with still the same shape (see 'Growth form', p. 74 and Figure 32). Older trees usually

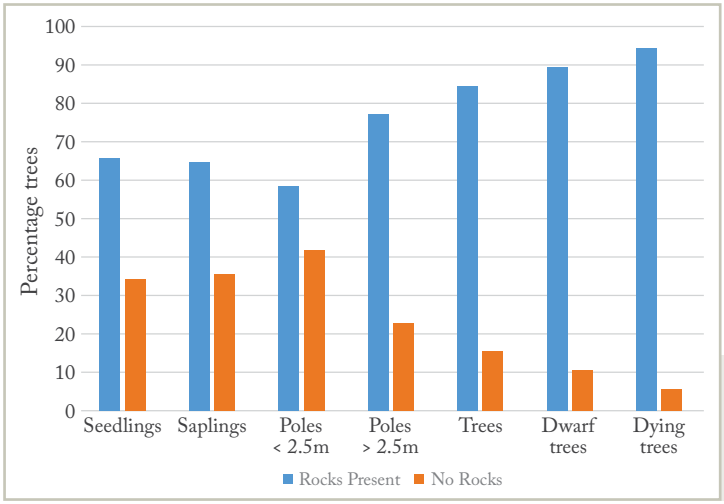



**Figure 49.** Andrag data showing that association with rock is essential for cedars to survive to maturity.



**Figure 50.** Young cedar (approximately four years old) growing between rocks on Mied se Berg.



**Figure 51.** Tall pole cedar growing among rocks.

have a clear trunk with strong side branches starting several metres above the ground. Such old trees with long boles lifting the first branches high above the fynbos must have been much more common before logging started in the middle of the eighteenth century. The argument that older trees, with a clear trunk, are more likely to survive fire than young pole trees may be circular – once all trees in fire-sensitive habitats (away from rock, with much fuel around the base) have burnt out, obviously the ones that survived to that stage will also be more likely to survive later fires. This does not apply to the survivors of plantations where trees are not in a rock-protected habitat, but rather grow in open vegetation, like the solitary trees on Geelvlei (Figure 52) and are at least initially protected by a firebreak. Theoretically, it can be expected that tall trees, carrying their crown high over the fynbos, should be more likely to escape crown scorching, especially, as Andrag (1977) noted, if there is sufficient wind to disperse the flame-heat. Sean Privett (1994) obtained a strong indication that crown height and tree shape are linked to fire survival, but the interactions with rocks confused the results (Figure 53).



**Figure 52.** Relict of the Geelvlei plantation, these trees could grow into mature trees inside a plantation, protected by firebreaks. Now it appears that the crowns are above the fire heat, as there is no evidence of damage on the branches. How many fires have these trees survived?



**Figure 53.** Tree with some branches killed and only the central crown surviving.

## Not all fires are the same

Whether a tree is killed by fire depends on three factors: the fuel load around the base of the tree, the length of the trunk lifting the foliage above the fire and the intensity of the fire.

The extensive use of controlled winter fires after 1972 led to the demonstration that most saplings were killed by all fires, but that the survival of large adult trees was better with low intensity, cool, winter fires than with high intensity, hot, summer fires. The numbers reported varied. For example, Brian van Wilgen (1980) reported in his very first paper, based on an aerial survey of an area burnt in September 1978 (thus a cool, end-of-winter burn), a 2.8–8.6% mortality of large adult trees, whereas a wildfire in January 1979 resulted in 31.4–32.6% mortality. This contrasts with the results of Pat Manders et al. (1990), who recorded a 5–30% mortality in cool, winter fires, compared to 80–95% of the trees in hot, summer fires. Although winter fires consistently kill fewer adults than summer fires, the actual mortality varies enormously between fires and this might have to do with local climatic conditions at the time of the fire. Andrag (1977) suggested that there is no simple categorisation of the effects of winter or summer fires and the age of the fuel bed. Theoretically, fire intensity is determined by fuel load, air temperatures and dryness of the vegetation. Furthermore, wind speed also plays an important role and this can change from locality to locality even for the same fire.

## Summary

Thus, we have some answers to the question of how a species with no obvious adaptations to surviving fire can persist in the pyrophytic fynbos of the Cederberg. Firstly, seedling and pole trees survive in rocky habitats, which provide some protection from fire, thus in fire refuges. Seedlings that germinate away from rocks could well grow into tall, mature trees, but only if there is no fire for a sufficiently long time (perhaps at least 100 years). If there are frequent fires, the only cedar survivors are among rocks. Secondly, mature trees may outgrow fire. This can only happen if the fire interval is long enough for the trees to grow tall enough to raise the crown above the flame heat, such as the solitary survivors of the Geelvlei plantation (Figure 52). Finally, and maybe improbably, dense enough stands may also result in a reduction in flammable fynbos and so mitigate the lethal effects of fire, allowing stands of trees to survive even if the crown has not been raised above the flame height.

It seems to us that the question is not how cedars survive fire, but rather why large mature plants, in optimal habitats among rocks, are sometimes killed by fires. These individuals must have survived numerous fires, so what is it about these particular fires that killed them?

# Predators and pathogens

What actually kills an adult plant? Sometimes (rarely) it is drought. In the Cape fynbos, fire is probably the most frequent cause of mortality. A hard to see cause of mortality is disease and this can be particularly important for plants already stressed by a climate that is marginal for their survival. Such weakened plants are then more susceptible to death by disease and otherwise harmless pathogens can become lethal.

A survey led by Mike Wingfield in the 1980s found no diseases associated with mature cedar trees (Wingfield et al. 1988). They also found that naturally growing trees were healthier and looked more robust than plantation trees. However, the seeds and seedlings were not investigated. Furthermore, it is quite possible that, half a century later, diseases may have reached the Clanwilliam cedars, and a reinvestigation might be sensible.

The cypress aphid, *Cinara cupressi* sensu lato, is a worry. This aphid is from eastern Greece, where it feeds on *Cupressus sempervirens* L. It was first recorded from South Africa in 1993. The insects feed by pushing their mouthparts through the bark and suck out the sap. This can lead to the death of terminal parts of twigs. The excess sap is secreted as a honeydew on which a sooty fungus can become established. It is not yet established if this aphid has reached the Clanwilliam cedar.

A potential portal for disease is by bark borer beetles, currently being studied by Handré Basson at the University of Stellenbosch. There are three indigenous bark borers on the Clanwilliam cedar, each on a different part of the plant. All three are undescribed species in the genus *Lanurus*. One is found only on the cones, one on the young twigs and one on older wood. They generally do not attack healthy, live branches – possibly the resin canals in the trees offer a sufficient protection, as chewing into a resin canal may be the death of a beetle. The beetles carry a rich diversity of fungi with them. The beetles cannot digest cellulose and lignin and, consequently, are reliant on the fungi for their digestion. The fungi cannot penetrate the bark and are reliant on the beetles to gain entrance into the tissues. This is a typical symbiosis in which both parties benefit from the relationship. Although the beetles are harmless, a potential problem is that they might introduce fungi that could damage the trees. Fortunately, there is no evidence of this at this stage.

# Reproductive biology

Cedars can live up to 600 years (Ed February, pers. comm., April 2024) and each adult tree that dies should, to keep the population stable, be replaced by a new, genetically fit, adult

successor capable of producing as many and at least as genetically fit seeds as its predecessor. This sounds simple, but the path there is complex and filled with hazards. Because the process extends over decades and possibly even centuries, it is difficult for us to estimate how effective reproduction actually is, complicating the science and leaving many unanswered questions. The reproductive process starts with pollination and the mechanisms that maintain genetic diversity, progresses to the number of seeds produced, to the hazardous transformation of the seed on the parent plant to a seedling, to the almost as hazardous development of the seedling into a pole tree, and, finally, to the next adult plant. Research by many competent students and botanists over the last half a century has led to remarkable insights into the reproductive biology of cedars – and also exposed unexpected lacunae in our knowledge.

## Seed formation

Possibly as important as the number of seeds produced is the genetic diversity of the seeds. The long-term health of any natural population is dependent on genetic diversity and inbred populations soon run into trouble. In plants (as in humans), genetic diversity is generated by combining two sets of genes: one from the mother plant (contained in the ovule), the other brought in by pollen, hopefully from a different, genetically distant plant.

Like all conifers, cedars are wind pollinated, meaning that the pollen is transported by wind from male (pollen-producing) to female (seed-producing) cones. Although the cones are unisexual, each plant bears both male and female cones – the plants are monoecious, that is, both sexes are borne on the same plant, but in separate cones. The two types of cones are produced on the same long shoot, so in close proximity to each other.

Where and when are the cones formed? The new long shoots that will bear the cones start growing at the end of the wet season, although we do not know precisely when, and grow though summer. These shoots can grow 100–250 mm in one season (Figure 54). In their first year the long shoots are green, have a few widely scattered scale leaves and clusters of side branches. By the second year the shoots have turned into brown twigs, which thicken over the years by a process known as secondary thickening, eventually forming thick, woody branches. The trunk and branches of the tree all started as long shoots.

The first-formed side branches of the young long shoots form leafy, branching twiglets, and by the end of summer the tips of these twiglets start forming male cones. These twiglets have a determinate growth and primarily bear male cones and leaves. Although no longer capable of further tip growth after the formation of the male cones, they persist for 5–8 years and constitute the photosynthetic structures of the plants. Growth of the main shoot, with sparse



**Figure 54.** A long shoot (in the middle), with internodes longer than scale leaves; branching short shoots towards the base (the left) densely covered in scale leaves. These will bear the male cones. Photograph from a tree at De Rif in 2022.



**Figure 55.** Male cones with ripe pollen in the sporangia. These are about to release the pollen.

scale leaves, is not terminated by a cone, and so is indeterminate.

The male cones are minute, ephemeral and hard to see. They are only slightly wider than the leafy branch, 2–4 mm long and with 5–7 pairs of scales, or microsporophylls[29], each bearing four pollen sacs (Figure 55). Male cones can be very numerous, so that the whole branch can look yellow when the pollen is ripe (Figure 56).

The pollen has been observed to be released between mid-March and end of June. Andrag (1977) thought that the cones were pollinated in winter, between May and September, but Marsh (1965) observed the

[29]The term 'microsporophylls' literally mean the small leaves that bear sporangia.



**Figure 56.** Part of canopy, yellow in colour due to numerous male cones.

greatest profusion of male cones on herbarium specimens collected in April. At least in the De Rif plantation, pollen release is not synchronised, but we do not know what triggers pollen release events. Pollen release is quite spectacular, as yellow clouds of pollen drift off in the wind (Figure 57).

The pollen is more or less ellipsoid (shaped like a rugby ball) and small, some 0.025 mm long. It differs from the pollen of angiosperms by the absence of a germination opening, and from those of pines by the absence of airbladders (Figure 58).

After they have dropped their pollen load, the male cones dry out and eventually drop off.



**Figure 57.** Pollen cloud on 14 March 2023 at Van Zylspoort.

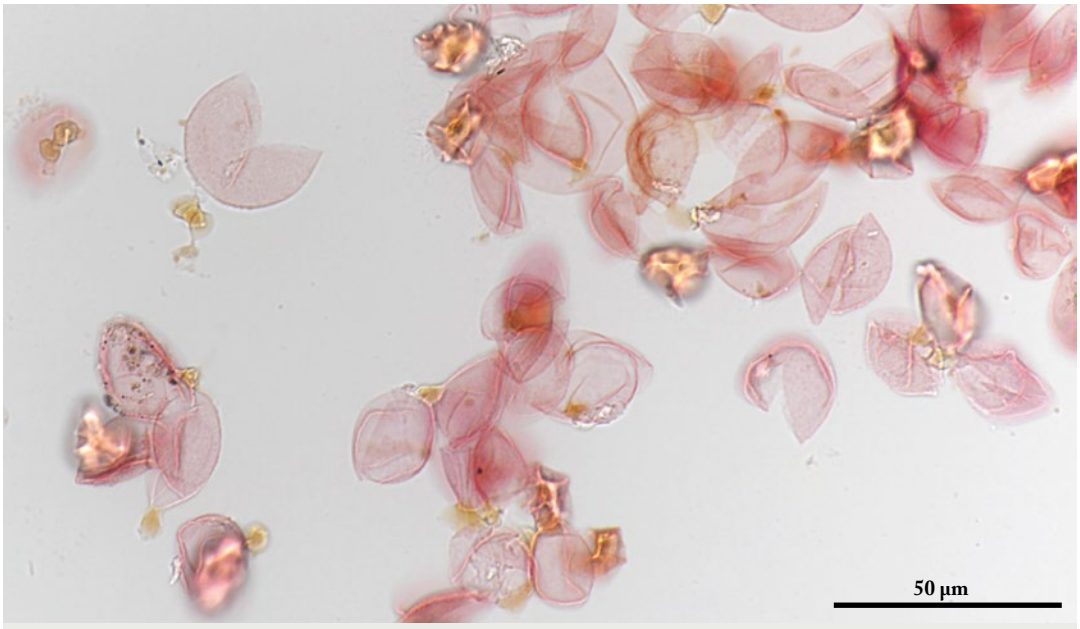



**Figure 58.** Light microscope image of acetolysed pollen showing the small, rather simple, pollen grains. Image taken by Lynne Quicke, slide prepared by Jean Sugden.

The female cones are formed on short, sub-terminal side branches of the long shoots, so that they appear almost sessile on the long shoots. These side branches bear up to 10 densely clustered female cones (Figure 59A). Female cones are minute, only a few millimetres in diameter, and ready for pollination in late autumn. Each cone consists of four thick scales, each scale with five ovules (Figure 59B). Each ovule, if fertilised, develops into a seed. Consequently, the mature cone can have up to 20 seeds. After fertilisation (from May onwards into winter), the four scales shut and are glued closed with resin. The ovules start developing into seed, taking ± 30 months (2.5 years) to mature (Botha 1990). In the first year the scales increase massively in size so that, after a year, the cones have almost reached their full size of some 30 mm in diameter with the outlines of the four scales still visible. Each scale starts developing a central knob, and the whole cone is green (Figure 59C). During this time, the long shoot bearing the short side shoots with the cones thicken into a branch, strong enough to bear the weight of these cones. The next year's long shoot has also added some 100–300 mm to the length of the branch, so the cluster of one-year-old cones is now this distance behind the tip of the branch. At this stage the cones are greenish purple. Over the next year the cones change colour to grey-brown and start drying. Finally, in midsummer (more or less in December), almost 30 months after fertilisation, the seeds are ripe. At this stage the cones turn grey (Figure 59D and E).

The seeds are only released when the four cone scales open (Figure 60), which they do when the cones die. According to Fanie Botha[30] the cones usually open when killed by fire. This could explain the massive recruitment after fire observed by many researchers (Manders 1986a). Fanie Botha further reported that cones open when the scales have been hollowed out by the bark-borer or cone beetle, *Lanurgus* sp. The beetles attack mature cone scales, after seeds have ripened, but do not damage the seeds. Most likely the beetles cannot attack the younger cones, as the network of resin canals is too dense. If the beetle breaks a resin canal, it gets stuck and dies. The scales open in late summer and autumn (mostly in March), after being attacked by the bark-borer beetle, releasing the seeds (White et al. 2020). The bark-borer beetle infestation spreads gradually through the cones, resulting in a sequential opening of the cones, with some persisting to five years with mature seed before opening (Botha 1990) (Figure 61). The implication is that, in the absence of fire, baboons or this species of bark-borer beetle, the cones would retain the seed until killed by fire or the tree dies of old age. This is corroborated by a lovely tree cultivated at Knolfontein, on the Katbakkies

[30]S.A. [Fanie] Botha completed an M.Sc. degree in the Forestry Department of the University of Stellenbosch on the impact of small mammals on the population biology of the cedars in 1988. He worked in SAFRI with Pat Manders and Brian van Wilgen until this group was disbanded. His M.Sc. thesis work is not available online, but was published as two research papers.

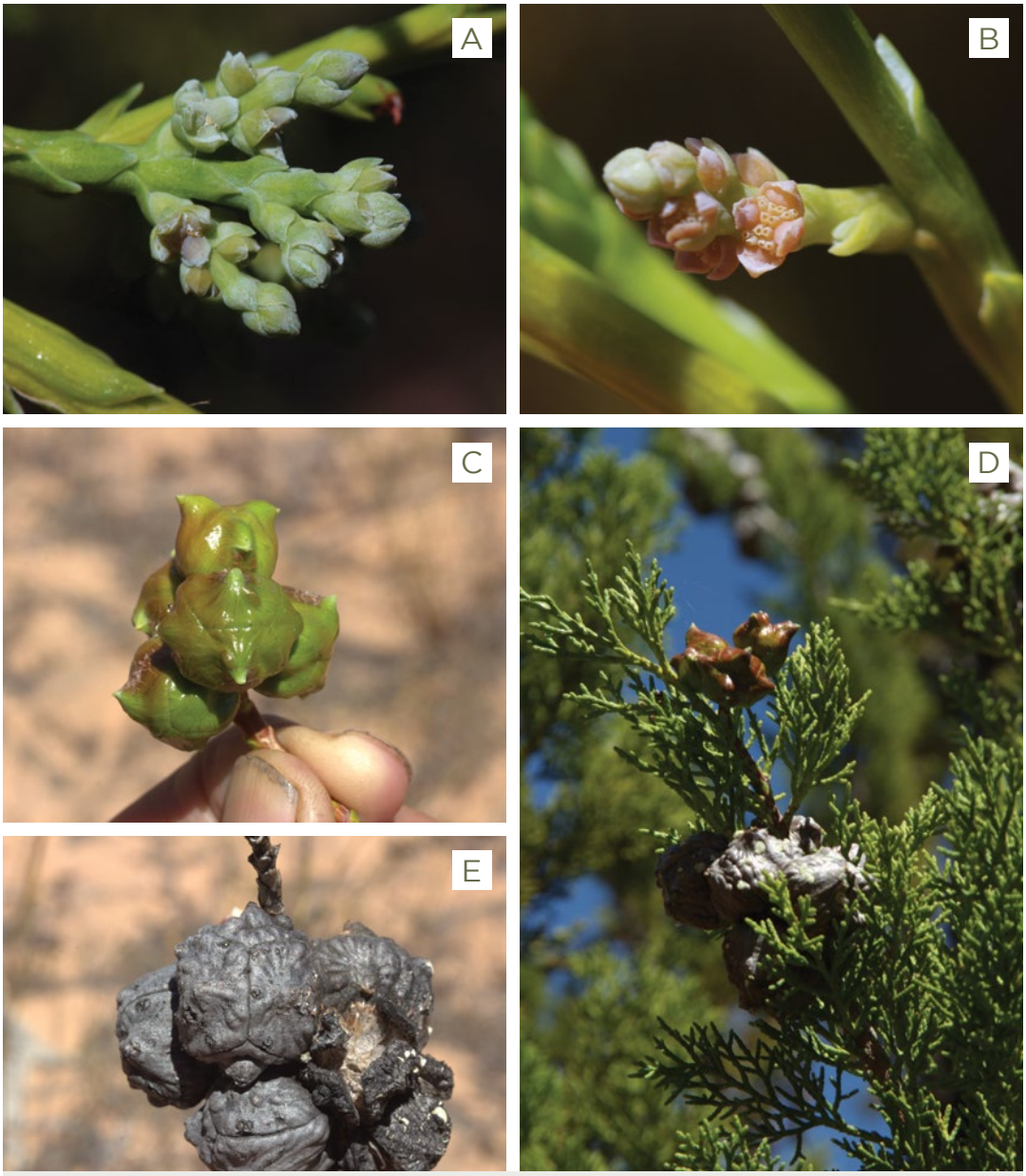



**Figure 59.** A, young female cones, only lowermost open, on a side branch of a long shoot; B, female cone with four scales and 20 ovules; C, green cones, one year after fertilisation, with the four scales and their tooth-like outgrowths are clearly visible; D, shoot with green one-year-old cones near the top and grey two-year-old cones below, the latter are surrounded by short shoots; E, grey cones, 2.5 years after fertilisation, containing ripe seed.



**Figure 60.** Old female cone after seed release, showing the four scales.



**Figure 61.** Branch with two years of ripe cones.

Pass in the Koue Bokkeveld. This isolated tree has a magnificent cone production and, amazingly, the cones are all closed, with the oldest cones more than seven years old. Maybe this tree has no bark-borer beetles, and consequently the cones do not open. This means that the Clanwilliam cedar is, contrary to the assertion by White et al. (2020), serotinous.

The seed is trigonous to conical in shape, with very narrow (or maybe no) wings[31], grey-black in colour with a white swelling on the wide side (Figure 62), and heavy at 0.09 g per seed (Ladd et al. 2013). This is all unusual: the seed is three times heavier than any other seed in *Widdringtonia* or *Callitris*, and in all other species the seed is winged. The heavy, nut-like seed and absence of wings is the best way to tell the Clanwilliam and Willowmore cedars apart.

## How much seed does a plant produce?

This is a critical question, as it is possible that, with the cedar stands becoming smaller, seed production may no longer be adequate to ensure regeneration. This becomes particularly problematic as the number of suitable habitats for seedling establishment may be limited (see 'Germination triggers', p. 114).

[31]The other species of *Widdringtonia* have lighter, obviously winged seeds, leading to a tendency to see wings on the seed of the Clanwilliam cedar.



**Figure 62.** Two seeds on a palm.

The plants need at least 12 years to the first cone production according to Andrag (1977), but six-year-old plants already producing cones have been observed. Substantial seed production starts only after 40 years of age and a vigorous, old tree may produce 3 000 seeds or more per year (Manders et al. 1990). A long-lived tree may thus produce over a million seeds. However, estimates of seed production per tree have not been convincingly quantified. There are two variables: the number of seeds per cone and the number of cones per tree. Pat Manders (1987b) estimated an average of 10.97 seeds per cone but without giving the standard error or sample size. Unpublished data from the Department of Forestry indicated that older trees produced between 7 and 22 seeds per cone (with a mean of 12.5 and a standard error of 2.5) and younger trees 7–17 seeds per cone (with a mean of 12 and a standard error of 2.1). So roughly 11 or 12 seeds per cone, but with substantial variation among the cones. Estimating the number of cones per tree is much more complicated. Sarah-Jane Fox (2003) counted the number of cones produced per tree to be about a third of the number obtained by Pat Manders (1987b). There are several possible explanations for this discrepancy. One, unlikely, explanation is that there were errors in the counts of the number of cones per tree. The other, more likely, explanation is that cone production varies from year to year and from region to region, depending on the climate and the health of the trees. Theoretically, there should be an increase in cone production per tree as the tree becomes older and bigger. The number of seeds produced per tree is a critical variable in maintaining the populations: not enough seeds means not enough regeneration to replace the old trees as they die. So, unfortunately, we do not know how many seeds a tree produces, whether and by how much this varies among years and among regions, nor what the correlates of this variation are.

Seed production in the wind-pollinated, highly self-fertile, monoecious Canadian *Taxus canadensis* Marshall is pollen limited, meaning that some plants do not receive enough pollen to fertilise all the ovules that are produced. Pollen limitation is influenced by both the number of male cones produced per tree and the spatial isolation of the trees (Allison 1990). A similar situation may exist in the Clanwilliam cedar, especially as stands are becoming smaller, comprising fewer trees and sometimes only one individual. Often, stands are also quite isolated. This is an important issue that needs to be investigated, as it could influence

decisions of whether to maintain a few large stands or many very sparse stands. This is separate from the genetic health of these seeds.

## Pollination, fertilisation and genetic diversity

A high genetic diversity, resulting from outcrossing, is generally considered to be important for the long-term conservation of species. The situation in the Clanwilliam cedars is unclear. Theoretically, as the plants are monoecious, and the stands relatively small, self-fertilisation (selfing) may be common.

There have been two population-genetic analyses of the Clanwilliam cedar. Janet Thomas, for her M.Sc. thesis at the University of Cape Town, used electrophoresis to study the patterns of allele variation, based on material collected in 1990 (Thomas & Bond 1997). This approach counts the number of variants of particular proteins in a plant. This showed rather high levels of selfing (pollen fertilising ovules on the same tree) in the Clanwilliam cedar, possibly a consequence of the reduction in stand sizes. With fewer plants in a stand, the possibilities for outcrossing are reduced. The male cones release their pollen in clouds and, as all plants usually respond to the same trigger for pollen release, these pollen clouds are made up of the pollen of all trees in a stand. The female cones trap pollen out of this pollen cloud. The more trees in a stand, the greater the genetic diversity in the cloud and, the higher the number of other trees near the tree with the female cone, the greater the probability that the ovules in the cone will be fertilised by pollen from other trees.

It is also critical to know how far pollen can travel – this determines whether a single plant is 'isolated' or still part of a larger genetic community. Two factors control this: the actual distance that pollen can stay airborne and how long pollen remains viable. The first is determined by turbulence – the more turbulent the airflow, the longer at least some pollen stays airborne. In the rocky mountainous landscape in which cedars are usually found, airflow is very turbulent, indicating that long distances (perhaps up to several tens of metres) are possible. The second is determined by how fast the pollen desiccates. Pollen has a massive surface to volume ratio, so can lose moisture very rapidly. Eventually, desiccation kills the pollen and collapses the cell walls. We have no idea how long cedar pollen stays viable. So, in short, we do not know how far viable pollen travels, but suspect it is tens rather than hundreds of metres.

But does it matter? Is seed set in outcrossed cones better or more viable than seed set in cones fertilised by pollen from the same tree, i.e., self-pollinated? In the closely related genus *Callitris* selfing is possible (at least in *C. macleayana* (F.Muell.) F.Muell. and *C. sulcata* (Parl.) Schltr.), but apparently with reduced viability (Ladd et al. 2013). Leila Mitrani (2017)

investigated this for an M.Sc. degree under the supervision of Ed February. She compared seed viability of trees that were near others (thus more likely outcrossed), with seed viability in spatially isolated trees (thus more likely to be self-pollinated). Half of all seeds were empty (reasons for this is unclear: perhaps they were not pollinated, or stressed plants aborted seeds, or perhaps selfed ovules abort), and of the remaining seeds just under half (44%) were viable, thus able to germinate. This is a surprisingly low figure, as previous reports suggesting closer to 70% germination. There was no correlation between the number of empty seeds, the viability of the seeds and the distance to the nearest neighbour, indicating that selfing does not negatively impact reproductive capacity. This is good news, as it suggests that even single trees can continue to produce viable seed. This was also corroborated by ad hoc observations that isolated trees set viable seed (Jeremy Midgley and Dawie Burger, pers. comm., February 2024). However, genetic analysis using ISSR markers, which estimates differences in the genetic code, the DNA, directly, by Leila Mitrani (2017) of two populations (Sneeuberg and Welbedacht), showed that only 0–12% of the seedlings obtained by germinating seed from known individual trees germinated from self-pollinated seed. This very low proportion suggests that something is blocking seedling establishment from self-fertilised embryos. Consequently, although self-pollination occurs and results in viable seed, effectively the predominant mating system is outcrossing. These results are confusing. As the stands are becoming increasingly depleted, and often reduced to single trees, it is important to understand what the consequences of selfing could be.

Levels of genetic heterozygosity were found to be high (albeit lower than in the Willowmore and the mountain cedars) and the cedars were still genetically healthy (Thomas & Bond 1997). However, Leila Mitrani (2017) found indications of a low genetic diversity. There is a need to understand what the situation actually is.

The trees become reproductively active at 10–14 years and seed and pollen production increases as the trees become older and larger. A common assumption is that large, old trees, rather than younger pole trees, contribute most to reproduction. This is not only an academic point – numerous 40-year-old trees generating the next batch of seedlings are genetically very different from a single very large 400-year-old tree generating the next cohort of seedlings. If large, old trees contribute substantially to the next generation, then the effective population size becomes much smaller, the evolutionary potential decreases and with it the ability to adapt to changing climates. In addition, the old tree passed through its vulnerable seedling stage under the climate that existed 400 years ago (during the Little Ice Age), not the climate that existed 40 years ago. It may have traits that are suboptimal under the current climate. This could become increasingly relevant as we are forcing rapid climate change with our excessive $CO_2$ emissions.

## Seed dispersal and loss

The route from cone to seedling is immensely hazardous and few of the million or so seeds an old cedar tree produced in its lifetime make it. This is not surprising: seeds are packed with nutrients for the germinating seedling and there are many animals (including humans) that love eating seeds. Seeds are also vulnerable to dangers such as fire and drought. Furthermore, seeds that land in the wrong places will not germinate, or the seedlings will promptly die. This is indeed a tricky transition.

Cedar seed dispersal is spatially limited, most seeds falling under the parent plants (unpublished data of Fanie Botha, cited by Pat Manders [1987a]) and most seedlings found within 30 m of the parent plants. However, some seeds are able to move somewhat further, as is clear from open cedar stands where the seedlings appeared well scattered among the trees, with some young plants at least 30 m from the nearest adult. Clearly, something moves at least some seeds. Rudolf Andrag (1977) suggested that seed dispersal is by wind and water, but this seemed unlikely, as the seeds have no adaptations for wind dispersal, such as wings, and are relatively heavy. Furthermore, there is very little surface flow of water in the Cederberg. Thomas and Bond (1997) found evidence that populations are genetically differentiated, suggesting poor long-distance seed dispersal. The implication is that if a cedar stand is obliterated, it may take a long time for seeds to reach the locality to re-establish it.

The seeds have many predators – not surprising for large seeds in the nutrient-deficient fynbos flora. Baboons harvest cones in the year before they ripen and also after they have ripened but not yet released the seeds (Figure 63). According to Dawie Burger (pers. comm., March 2024) and Botha (1990) baboons sometimes carry the cones to nearby rock outcrops where they open them and eat the seeds. In the process they also drop some, resulting in dispersal distances of some 50 m. In two stands near Sneeuberg Hut investigated by Botha (1990) baboons had a major impact, harvesting about 50% of the cones.

There is a rich rodent fauna associated with cedar stands and Botha (1989) trapped eight species: the insectivorous Cape rock sengi (*Elephantulus edwardii*) and *Myosorex varius*; and the granivorous Namaqua rock rat (*Micaelamys namaquensis*), Cape spiny mouse (*Acomys subspinosus*), four-striped grass mouse (*Rhabdomys pumilio*), African pygmy mouse (*Mus minutoides*), spectacled dormouse (*Graphiurus ocularis*) and Southern African vlei rat (*Otomys irroratus*). Of these, the last four species are very rare in cedar stands (Botha 1989). Rodents eat seeds on the ground after release (De Hoogh 1968). Rodent exclosures increased seed germination of seeds sown in autumn, from 12% without exclosures to 46% within exclosures, demonstrating the massive effect of rodent predation (Botha 1989). Indeed, for many



**Figure 63.** Branch with cones torn off the parent tree, probably harvested by baboons.

years it was believed that heavy rodent predation was the reason for the poor recruitment in the species after winter and spring fires (Manders & Botha 1987).

Joe White[32] and collaborators (Midgley 2002; White et al. 2020) showed that mice are also involved in seed dispersal. They made small depots of seeds in several cedar stands and glued 300 mm of fluorescent thread to each seed to facilitate following the movement of the seeds. In addition, trap-triggered video cameras were set to record any mammal visits to the seed depots. This allowed them, not only to determine who was visiting the depot, but also the fate of the seeds. In 40% of the depots no seeds were removed, showing that in almost half of the stands investigated rodent predation was not evident. The remaining 60% of the depots were completely removed. Three small mammals were observed to visit the depots. The predominantly

[32]This was part of a Ph.D. study with Jeremy Midgley on dispersal biology of cedars.

insectivorous Cape rock sengi removed seeds at three middens and this seems to be almost accidental. The Namaqua rock rat removed most seeds from most depots, with two-thirds of the seeds consumed at the depot while the residual third could not be relocated. The Namaqua rock rat seems to function primarily as seed predator, consistent with a role it has throughout its distribution range in the Cape (White et al. 2017). The last species, the Cape spiny mouse, was quite rare and was the seed removal agent at just three depots in Cederhoutkloof and at Welbedacht, with 29% of the seeds at these depots buried and the remainder not relocated. So, it seemed that the knight in shiny armour for cedar seed dispersal is the rare Cape spiny mouse. If this is the case, seedlings should come from seed buried in the ground and not lying on the surface. Digging out seedlings revealed that they mostly germinated from seed buried 20 mm in the ground, which fits the prediction. That seedlings germinate from buried seeds also fits observations by Pat Manders (pers. comm., March 2023). The buried seeds are protected against fire and more difficult to find for the other mice. Most seeds were carried off singly, indicating that the caches in most cases will contain a single seed (Jeremy Midgley, pers. comm., February 2024), but it is not known how far the mice carry the seeds.

## Germination triggers

Seed germination is unproblematic and all viable seeds germinate after being wetted. This has been known since the late 19th century. The seeds do not need to be exposed to smoke in order to germinate (White et al. 2020). This is quite different from many other Cape fynbos species, which have almost no germination with only wetting and where, in most cases, smoke is also needed to trigger germination. The implication is that all seeds germinate in the first winter after being dropped and that there is no soil seed bank (Higgins et al. 1989). This absence of a soil seed bank is consistent with presence of heavy predation and consistent with a canopy seed bank (i.e., serotiny).

There are conflicting reports on how long seeds take to germinate. Marsh (1965) reported that the seeds of *Widdringtonia cedarbergensis*, *W. nodiflora* and *W. schwarzii* germinate within two weeks on moist vermiculate. This is consistent with experience in the Cederberg and of studies by Leila Mitrani (Ed February, pers. comm., March 2024). Germination is slower under colder conditions. However, White et al. (2020) found that germination only starts after 48 days (almost seven weeks, compared to the normal two weeks) and all seeds germinated only after 72 days (more than ten weeks). If the seeds experience a short heat shock, similar to what would happen if a fire passed over the sites where they are buried, or if cone-bearing branches were burnt in the summer months when the ripe seeds are still protected in the cones, then seeds will start germinating after 24 days and all the seeds will have germinated within a week after germination starts. It is unclear why White et al. (2020) obtained such different results.

Recruitment under dense stands of cedars is very poor. Observations at De Rif indicate that seeds germinate under dense cedar stands, but that the seedlings are chlorotic, do not grow and soon die. This was also observed by Fred Kruger (1970 and cited by Pat Manders [1987a]). Manders (1987a) suggested that this was due to allelopathy (see 'Surviving fire', p. 88), which inhibits the growth of the seedlings. He showed experimentally that seedling establishment in soil with cedar litter, or soils from under cedars where the litter has been scraped off, is poor, averaging 7.7% and 4.3% respectively. However, in fynbos soils, or cedar stand soils with the litter burnt off, germination averaged 45.3% and 49% respectively. This is exactly what would be expected if there were an allelopathic effect: cedar litter produces chemicals which inhibit seed germination or seedling growth. Consequently, it means that cedar stands can only regenerate after the litter layer has been burnt off. This pattern also largely holds for natural stands: seedlings are rarely found in the litter under adult plants (although it has been observed), even though the seed density there should be largest (Figure 64). This is a further explanation for the massive recruitment after fire observed by many researchers (Manders 1986a) and seen at De Rif (Figure 65).



**Figure 64.** Cedar litter under a tree in a natural stand.



**Figure 65.** Regeneration six years after fire at De Rif plantation.

## From seedling to adult

Clanwilliam cedar seedlings are probably unique in fynbos in that they grow better in shade than in full sun. This was tested by Manders (1986b) in a cultivation experiment, comparing several parameters of growth (height, biomass, leaf number, proportion of total biomass invested in roots) among seedlings grown under full sun and increasing proportion of shade (40%, 60% and 75% shading). There was a strong, but non-significant, tendency for more heavily shaded seedlings to gain more biomass, with significant gains in height and number of leaves with increasing shade. Pat Manders (1986b) interpreted this as an adaptation to growing in the shade of rocks, but it is, of course, also an adaptation to growing in the shade of other plants. This also fits the observation by Pat Manders and Fanie Botha (1987) that seed germination is significantly better in older than younger fynbos, but this is countered by better seedling survival in young than in old vegetation. At De Rif seedlings and saplings were observed to survive summers better in shade than in direct sun (Helen Moss, pers. comm., April 2024).

Seedlings have a different leaf morphology than adults: seedlings have needle-like to slender, almost tongue-shaped, leaves (in other words, 'normal' leaves), which are arranged in a spiral (Figure 66). In adults, leaves are reduced to scales, which are opposite and with the pairs alternating (opposite decussate). It seems possible that the seedling leaves perform better in shade and the scale-like adult leaves in full sun, but this hypothesis has not been tested. When they first germinate the seedlings produce two (very rarely three) large, strap-shaped cotyledons, some 25–35 mm long and 4–5 mm wide, which persist for several months (Figure 66).

Few seedlings survive their first summer. The two major causes of mortality at this stage are drought and browsing. Pat Manders and Fanie Botha (1989) showed that in exclosures, where the seedlings were protected against rodents and dassies (rock hyraxes), seedling survival in the first year was 60%, compared to 22% in the unprotected controls. However, exclosures also impact the microclimate by reducing wind and, therefore, desiccation. The microclimate (specifically, the effect of drought) was directly tested with experiments in Jonkershoek (thus



**Figure 66.** Newly germinated seedling, with its two large strap-shaped cotyledons and the juvenile leaves. One cotyledon is already turning yellow.



**Figure 67.** Seedling, 30 mm tall and with a 200 mm long root, from De Rif plantation.

in much cooler summer conditions than in the Cederberg), where microclimate shelters resulted a massive increase in the survival of the first summer (Higgins et al. 1989).

The microclimatic effect on seedlings in the first summer may account for why the Clanwilliam cedar has the heaviest seeds of all its relatives (*Callitris* and the other species of *Widdringtonia*) – it is three times heavier than the next heaviest seed (Ladd et al. 2013). The reason (thus the adaptation, or the selection force that selected for the heavy seeds originally) could be that the large seed gives the seedling a head start to develop a deep taproot with which to survive the dry summer. The test for this would be to compare seed weight and seedling root growth rates between Clanwilliam and the Willowmore cedars (Figure 67). This is obviously also linked to the length and severity of the summer drought, which is extreme in the Cederberg. This is consistent with the high levels of mortality observed in the seedlings in their first summer, when the roots may not yet reach into the groundwater sumps. Pat Manders and Fanie Botha (1987) showed experimentally that seedlings in wet habitats on sandy plains survived the summer better than in dry habitats, but that the best seedling survival was on rocky slopes. Once the plants tap into groundwater, they are more resistant to drought.

Observing seedling growth at De Rif after the fire of December 2016, where Helen Moss and her helpers had been looking after the seedlings, showed that microhabitat is of

enormous importance. After six years, seedlings growing between boulders were over 2 m tall and growing fast with long, new shoots, whereas their siblings away from rocks were scarcely 0.5 m tall, and barely surviving. This implies that only those seeds that fall into a suitable habitat (among rocks, where possible in a damp place) have a realistic chance of establishment.

It is a long and dangerous road from the production of a seed to the next sapling, with baboons harvesting the seeds from the trees, rodents the seeds on the ground, drought killing young seedlings in their first summer and finally the attentions of rodents and dassies nibbling off the growing shoots.

It appears as if there has been a veritable collapse in recruitment in the last decades. Reports from the 19th century frequently refer to hundreds of young trees, suggesting that there was much recruitment (McNaughton 1891). This massive recruitment is also evident from photographs taken before 1980. The Department of Forestry plots from the 1970s likewise also document numerous saplings and Pat Manders (1986a) reported between 21 and 662 (average 365) seedlings per hectare after summer fires. Over the last four decades this seems to have changed dramatically. Where we would expect numerous saplings 5–10 years after a fire through a cedar stand, there are now often none: only in rare stands are numbers as reported by Manders (1986a) observed. The recruitment collapse is enigmatic. Has the climate become too dry? Is seed production inadequate to reach the very few microsites suitable for the trees? Are fires penetrating more frequently among the rocks and killing the saplings? Is the dispersal mutualism with the Cape spiny mouse critical? Could it be the result of the exceptionally severe drought from 2015 to 2020? Is there an undiscovered disease?

Once the saplings are established, after two or three years, mortality rates appear to drop. The next major killer is fire. This is occasional, so it is much harder to obtain data, but an estimate is that between 80% and 100% of saplings are killed by fire, if it occurs. In the absence of fire a forest of pole trees grows up. Interestingly, precisely those microhabitats between rocks where the young seedlings grow best are also the habitats best protected from fire. If this is the case and fire eliminates fewer plants in these rocky habitats, these may grow into reproductive trees and this might provide the selection regime for cedar seedlings to grow better in shade than in full sun.

## Stand regeneration

What is the age distribution in a healthy stand? This is comparable to human demographics: what proportion of a self-sustaining population should be babies, children, teenagers and adolescents to ensure that the population does not shrink?

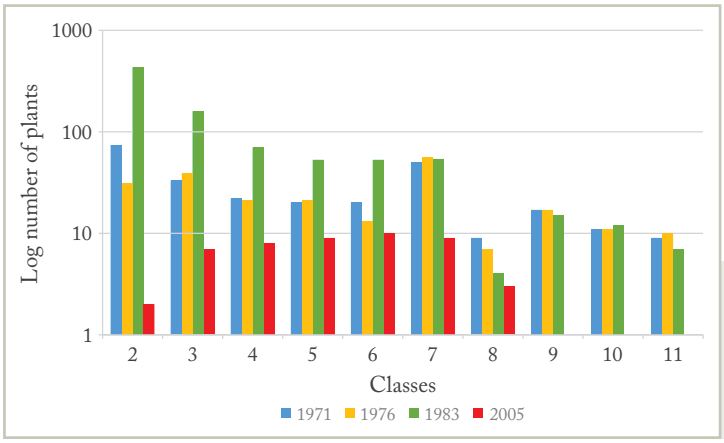



**Figure 68.** Age class distribution of cedars in the Sneeuberghut 2 plot. Note that the number of plants has been log-transformed.

The SAFRI plots (see Text box 2.1, p. 38) give an excellent measure of this, especially when combined with the resurvey data that Ed February compiled (pers. comm., March 2023). Note that here I use a different tree class classification, based on tree height and DBH, rather than transitions from sapling to pole to adult. This presumably gives a more continuous measure of the age of the trees.

Sneeuberghut 2 plot data (Figure 68) show an excellent regeneration pattern, with gradually decreasing numbers as the trees become larger. Recruitment seems to have been episodic, with one just before 1971 and another just before 1983. Fires occurred in 1948, 1959, 1975, 1988 and 2004. The latter fire seems to have removed all the older trees, but otherwise there is no obvious correlation between fire and tree size distribution.

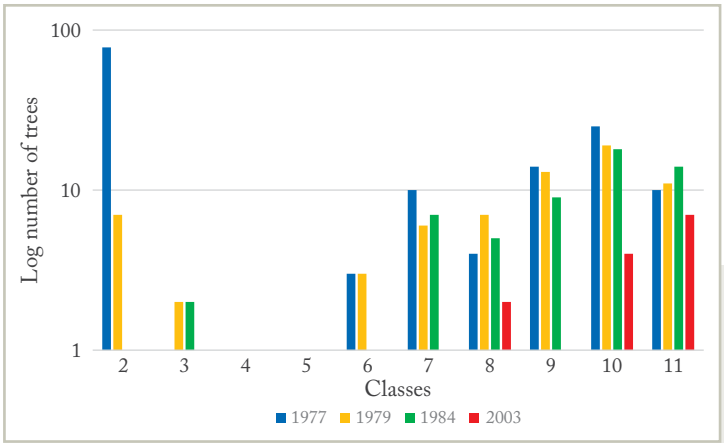



**Figure 69.** Age class distribution of cedars in the Grootland 14 plot. Note that the number of plants has been log-transformed.

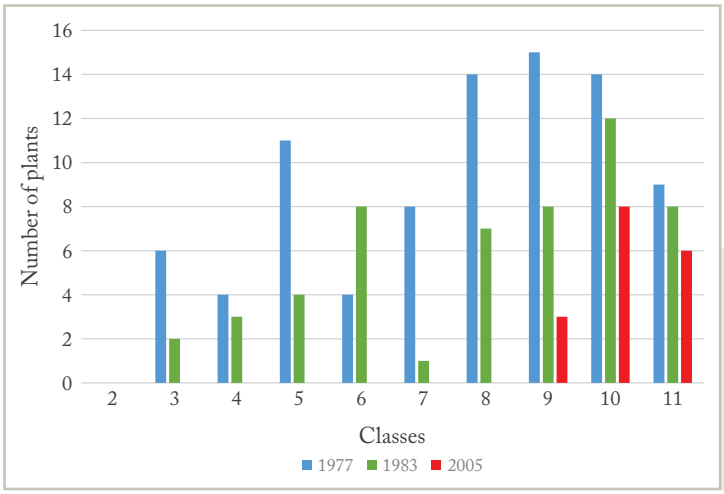



**Figure 70.** Age class distribution of cedars in the Groot Koupoort plot surveyed in 1977, 1983 and 2005. Note that the number of plants has not been log-transformed.

The two Grootland plots show very similar age distributions, so only Grootland 14 is illustrated here (Figure 69). Both show a complete regeneration failure. Apart from the smallest class, the largest classes are the most common and this failure becomes more apparent in the more recent surveys. There was an excellent recruitment event just before 1977, but almost no saplings survived the two years from 1977 to 1979. Presumably they were destroyed in a fire. The older age classes suggest that such erosion of the stand had been ongoing.

The same pattern, but without the 1977 recruitment event, is shown by the Groot Koupoort plot (Figure 70). Here the same age distribution is seen as for the Grootland plots, but the erosion of the numbers is more extreme. This shows a complete lack of regeneration, a pattern which is widespread in the Cederberg.

Helen Moss and I searched the central Cederberg, Middelberg and southern Cederberg for populations that appeared to regenerate, trying to find some evidence that the species was not on the brink of extinction. Over most of the Cederberg we found numerous dead trees, a few scattered adults (sometimes even lovely stands of them), rarely a few seedlings (a few centimetres tall), and occasionally a pole tree in a fire refuge, high up on cliffs. Overall, many more adults than saplings and very few poles. This is what we expect from the Grootland and Koupoort plots. However, we found four small populations (about 1 hectare each) that were regenerating well and one plantation with excellent regeneration. In each of these we counted the number of plants in each class (sapling, small pole, large pole, adult and standing dead). The regeneration patterns in the healthy stands were very interesting. The data (excluding the standing dead plants) are summarised in Figure 71.

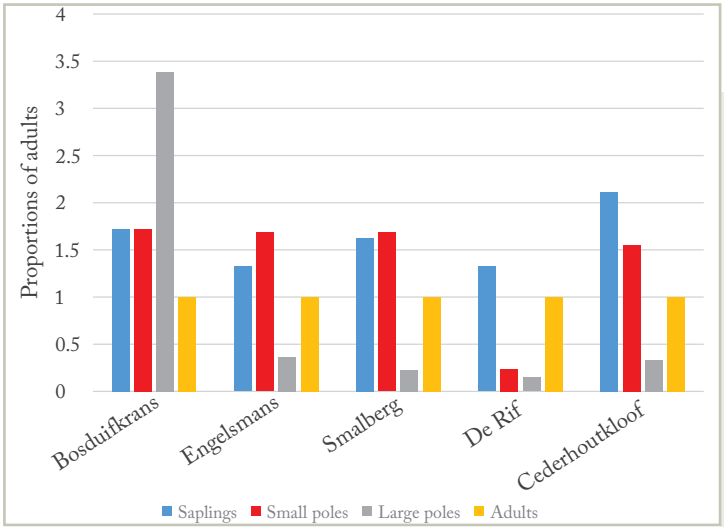



**Figure 71.** Regeneration patterns in five typical stands, giving the proportion of saplings, small and large poles relative to the adults. A value of 1 shows that there are as many as adults, a fraction that there are fewer, and more than 1 that there are more. Reporting proportions avoids problems of more or few plants in the stands.

Bosduifkrans is a small valley between Middelberg and Algeria, with a footpath leading right through the middle of it. What is striking about it is the large stand of large poles above the path – our count of the poles is certainly an underestimate, suggesting that there are at least four times more poles than adult trees. This may well represent the ideal regeneration pattern, as is also evident from the photograph from 1941 (Figure 72) from Van Zylspoort.



**Figure 72.** Van Zylspoort: note the dense stand of tall poles directly in front of the man. Photograph taken by Howes-Howell in October 1941. By kind favour of Tim Hoffman.



**Figure 73.** Tall poles (Class 5) in a fire refuge at the bottom of Engelsmanskloof.

Such stands must have been common in 1870 to allow Budler (see 'The telegraph pole saga', p. 154) to harvest 8 000 pole trees. The last three fires have bypassed the Bosduifkrans Valley (Jacques van Rooi [CapeNature, Algeria], pers. comm., March 2024), leaving it as one of the few areas of hopeful regeneration.

The situation at the bottom of Engelsmanskloof is quite different. This is an area of many small sandstone ridges between sandy plains, and with scattered cedar stands and trees surviving on these ridges where they are protected from fire. Here are some large poles in fire-refuge habitats, with none away from these habitats (Figure 73), and often a good scatter of saplings and small poles. The impression is that the cedars in this area may be surviving in more protected habitats and have been burnt out of the less protected ones, as illustrated in Figure 72.

Smalberg, a rarely visited ridge along the western border of the cedar distribution range, north of Sneeuberg, has a very similar age profile to Engelsmanskloof, but here the stands are scattered over the whole mountain slope, which is a complex maze of cliffs and boulders (Figure 74). This differs from Engelsmanskloof where the dead trees vastly outnumber the



**Figure 74.** Regeneration on the steep east-facing slopes of Smalberg with fewer large trees than dead trees and more poles than adult trees.

live trees. The good regeneration on the Smalberg is possibly because the slope had not burnt for many decades, as attested by the enormous *Protea magnifica* plants (at least 2 m high and several metres across). It is also possible that the Smalberg receives a higher rainfall than the other regions. A major difference between Smalberg and Engelsmanskloof is that, on the southern part of Smalberg, the living trees outnumber the dead trees.

The Cederhoutkloof stand is small, about 1 hectare in size, with a similar age distribution profile. This stand is on a rocky promontory, which has probably not burnt in several fires. Similar small stands were also seen on Mied se Berg and above Hoogvertoon, and these may be islands that, for some fortunate reason, were not burnt. Typical of all these stands (also Smalberg and Engelsmanskloof) is the wide age range of the regeneration, from seedlings with cotyledons, to tall pole trees transitioning to adult trees, so presumably almost a century old. Regeneration is clearly not episodic, not dependent on fire, and seedlings, saplings and poles can be found growing through the fynbos (Figure 75).



**Figure 75.** Cedar sapling growing through old fynbos: this did not need fire to germinate.

De Rif presents a completely different picture, representing regeneration of a plantation on a sand plain after fire[33]. Here regeneration is episodic, with most seed germination happening in the first winter after the fire, and consequently almost all young plants are still saplings – currently, eight years since the fire, a few have made the transition to adult growth and so to being young poles. But, they are mostly all the same age. This regeneration may be similar to the large stand of tall poles at Bosduifkrans. There have been reports in the past of such massive regeneration events after fire in plantations and what is interesting is that this can also happen on sand plains (so the saplings are not restricted to rocky habitats). The shade, which the saplings prefer, comes from the dead tree trunks plus largely from the vegetation in which they are growing, including *Cliffortia* and *Rafnia* species. These regenerations are particularly vulnerable, as the absence of rock means that there is no structural protection against fire and, because the adults have been burnt, highly flammable *slangbos* (*Seriphium plumosum* L.) can grow up with the saplings and immolate them in the next fire. At least at De Rif, and maybe also in the other large dense stands, each fire eats further into the stand, unless there is enough time for the poles along the margins to become fireproof (Figure 76).

[33]De Rif is a very unusual site, situated on a small Nardouw sandstone shelf above the shale band, with a spring near the lower margin, indicating that most likely there is strong groundwater. In addition, the cliffs to the east and the old farm fields to the west provide some fire protection.



**Figure 76.** Post-fire regeneration at De Rif, photographed in 2011. These hopeful saplings and the stand behind them were destroyed in a fire in 2016

# Regeneration and fire

The vexed question of the relationship between the Clanwilliam cedars and fire really has two components: can cedars survive fire and can cedars survive without fire? The same pair of questions also dominates fire research for fynbos in general. This issue is well explored in Pooley's (2014) book on the history of fire management in the Cape. The first question was initially answered with a 'no' for both fynbos and for cedars. After fire, there is a black ash desert. However, in the middle of the last century research started showing the different ways in which fynbos species can survive fire. At the same time it also became clear that the frequency of fires (number of years between fires), the intensity of the fire and also the season of the fires strongly influenced the regrowth rates. By 1980 it was thought that it was best to have late summer burns, of moderate intensity, some 15–20 years apart. By 2015 it was thought that, to maintain the highest diversity of species in fynbos, there should be a variable regime of relatively high-intensity fires of moderate frequency (Van Wilgen et al. 2016). It seems that the best fire regimes change with the fashions. As explained (see 'Stand regeneration', p. 119), mature cedars can also survive fires: if they are tall enough, if they grow in places with little fynbos understory, if the fire frequency is sufficiently low and if the fires are not too hot. But what about regeneration? Can regeneration occur after a fire has killed the adults and does it occur without fire? The observations above suggest that the cedars, almost uniquely in fynbos, regenerate both with and without fire.

## Serotiny and fire-driven regeneration

Cedar seed biology is well adapted to summer fires. The seed ripens sometime between August and December and is not released before March or April, sometimes only after several years. Consequently, during the main natural fire season of December to March (Figure 77) the seeds are protected in the woody cones, which release the seeds after heating in a fire. The seeds are dropped into the fertile ash bed, from which (presumably) the rodents have been obliterated. This fits reports of excellent germination after summer fires and is confirmed by observations at De Rif. It seems as if cedar re-establishment after an annihilating fire might critically depend on summer fires releasing serotinous seeds into a post-fire ash bed, but only once the trees have developed a large enough seed store (at least after 40 years, possibly even later, after germination). Cones not attacked by bark beetles stay closed, so the tree can have up to five generations (years) of cones on it (Botha 1990). Two populations at Sneeuberg Hut were investigated by Botha (1990): these showed that the cones with mature seeds were increasingly attacked by bark beetles, so that almost none persisted as long as five years unopened on the tree. It seems as if the cedars have evolved an excellent mechanism to cope

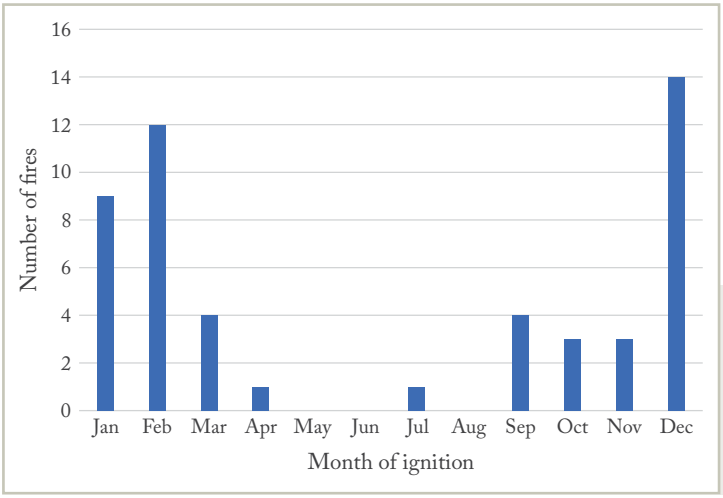



**Figure 77.** Monthly fires with natural ignition occurrence for the Cederberg 1944–2020, showing that December, January and February are the main fire months.

with fire: full serotiny, accumulating the full seed production in the canopy and releasing this after fire. Sadly, the bark beetles reduced the efficiency of this mechanism by killing the cones, resulting in the scales opening and releasing the seed.

This mechanism might operate optimally in habitats where large, dense cedar populations can be established, such as at De Rif. Fires burning into the margins of the stands can then lead to excellent regeneration of a new, dense stand of pole trees. Observations over the last century indicate, though, that it will only be effective if the interval between fires is at least 50 years, so that a new cohort of young adults with a large seed crop can grow up. Shorter intervals can remove the pole trees before they have a large enough seed crop and obliterate the stand (probably seen at Grootland, Figure 69). Possibly, under a cooler, wetter climate regime as during the Little Ice Age, with lower fire frequency, this biology could have been effective, and may have resulted in a much larger than current cedar population being maintained in the Cederberg.

## Regeneration without fire

The second question, can fynbos and cedars survive without fire, waited much longer for the surprising answer – there are indeed some fynbos species, such as the marsh rose *Orothamnus zeyheri* Pappe ex Hook., which will only germinate after fire. By 1990, research at Kirstenbosch National Botanical Garden showed that a surprisingly large proportion of fynbos species have very low rates of germination if they are not exposed to smoke. Many, if not most of these, would not effectively regenerate their populations in the absence of fire. Many



**Figure 78.** A group of young cedars in a habitat that appeared to escape fire, as indicated by the very old *Protea grandiceps* Tratt. in the foreground. Maybe these young cedars have not yet been challenged by fire.

of these species have soil seed banks and it is not known how long the seed can persist in the soil and, consequently, how long the population can survive without fire.

This is not the case for the cedars. The seed does germinate well in the absence of fire (Figure 78). This has been demonstrated experimentally (White et al. 2020), is consistent with 150 years of growing cedars and matches our field observations. We have seen many young plants established in natural stands without fire. This is evident when more than a decade after fire there are juveniles of all ages, from newly germinated seedlings with cotyledons, to tall plants up to 2 m high in the transition between sapling and pole stages (Figure 71). Cedars can evidently spread into mature fynbos, if the latter is not too dense (Manders 1986a). The ability of seedlings and saplings to grow in shade allows them to grow under fynbos and, more importantly, among rocks where the saplings and pole trees have some protection from fire.

**Table 5.** Advantages and disadvantages of post-fire and interfire regeneration modes in the Clanwilliam cedars

| Trait | Interfire regeneration | Post-fire regeneration |
|---|---|---|
| Seed predation | High (mice, baboons). | Low (seed predators presumably decimated by fire). |
| Seed dispersal | Good (mice, baboons), seedlings establishing away from parent trees. | Poor: seed released from cones into ash bed, seedlings establishing under burnt parents, dispersal agents killed. |
| Seed density | Low, so seedling densities low. | High, so seedling/sapling densities high. |
| Sapling shade tolerance | Optimal, allows establishment under fynbos or rocks. | Problematic: seedlings in high light intensity ash bed. |
| Large seeds | Optimal, allows establishment in shade. | Optimal, to allow rapid access to groundwater. |
| Advantages | Stand persistence among rocks with a hemicentennial (every 50 years) fire frequency. | Stand persistence away from rocks with a low (centennial) fire frequency. |
| Examples | Vogelsang, Smalberg. | De Rif. |

It is possible that the Cape spiny mouse plays an important role in protecting the seed against predation (Manders 1986c) and moving them from under the parent tree. Natural seed drop in the absence of fire presumably drizzles seeds down into an intact mouse community, where most of the seeds will be consumed. However, in a good 40% of the stands studied by Joe White et al. (2020), there is no seed predation (Manders 1986c), consistent with earlier observations that even in the absence of mouse exclusion, some seeds still germinate. Observations in open, natural stands show that seedlings establish in the fynbos some distance from the parent trees. As there is no wind dispersal of the relatively heavy seeds, this could be from caches established by the Cape spiny mouse (probably shorter distances), carried by baboons (probably larger distances), or due to random chance (which, as is intrinsic to random events, baffles rationality).

## Two regeneration modes?

Cedars, probably uniquely in the fynbos, have two regeneration modes: one post-fire and one interfire. The (dis-)advantages of each is listed in Table 5. The two quite different regeneration

modes allow them to persist under different fire regimes and with adaptations to both. Most likely, at any given time, both are used, but their success rate varies. Possibly the plantations, if planted during the Little Ice Age, may have succeeded.

## Quantifying growth and decline of cedar stands: population viability analyses

The observations above can be used to develop a model that predicts the fate of stands (or the cedars) based on the germination and growth rates. Such models have the advantage of producing predictions that apply to the whole species, instead of descriptions of what happens in particular stands, such as what Helen Moss and I collected (see 'Stand regeneration', p. 119).

The first such model was developed by Pat Manders in 1987 (Manders 1987b). This was a 'transition stage model' which determines, for each stage of the life of the plant, the probabilities of extinction, transition to the next stage, or staying in that stage. The data on which this model was developed were obtained from five plots, initially set up as part of the SAFRI research programme in the mid-1970s, in which all trees had been marked (see Text box 2.1, p. 38) and that were re-surveyed in 1983 and 1984 for the transition model. In each survey each tree was assigned to one of eleven classes, based on the size of the tree and the diameter of the trunk (thus not the seven life-stage model of the Department of Forestry).

Setting up the transition stage model was complicated by several problems. First, the estimation of annual seed production is confounded by our ignorance of how much inter-annual variation there is in seed production and what the impact may be of reduced stand sizes. A correct estimate is important, as this gives the first transition in the model. Secondly, Pat Manders (1987b) also assumed that germination rate stayed constant from year to year and was not enhanced by fire. Observation suggests that, although there is continuous germination, this can be a massively increased after fire. Third, mortality is fire-driven, thus also highly episodic, and so needs data over many decades to give a reliable value. Because the plots were not resurveyed every year, a standardised transition rate was fitted to the data and the best-fit transition rates estimated. These indicated that the population sizes are growing. In retrospect this is clearly unlikely. Sean Privett (1994) replaced Pat Manders' (1987b) estimates of fire-driven mortality with observations based on the December 1988–January 1989 fire and re-ran the models. This re-analysis showed that fire frequencies would have to be dramatically reduced, ideally to only once every 80 years, for the cedar populations to expand – this is a much more likely situation. Privett (1994) also conducted an 'elasticity analysis', which puts numbers on how important each stage is for obtaining the overall population

growth rate. Not surprisingly, the mature, seed-producing stages emerged as the most important, contributing 75.3% to the total 'elasticity' in cedars. Losing mature, seed-producing trees is catastrophic, whereas loss of saplings and pole stages is much less critical. Although regeneration overall is critically important, any particular cohort is of less importance. This suggests that the century of logging, when hundreds (perhaps thousands?) of the largest, mature and probably fire-resistant trees were removed, may really have had a catastrophic impact.

A much more sophisticated cedar viability analysis was developed by Steve Higgins, Ed February and Andrew Skowno (2001). In this analysis, rather than having transition rates between classes, each individual tree was allowed to grow in the model. This took into account the variation in transition rates among individual trees, which could result from differences in habitat or genetics among them. The analysis was based on 1 323 stratified random 50 × 50 m plots sampled in 2000, 555 without cedars and 768 centred on a cedar tree. Estimates of seed production, seedling establishment and growth rates were taken from the data which Pat Manders had collected from 1970 to 1990. This showed that plant survival was very strongly linked to being next to rocks. Surprisingly, it also showed that there was no problem with the persistence of the populations and that recruitment was sufficient to replace mortality. This is quite different from the stage transition models of Pat Manders (1987b) and Sean Privett (1994), which suggested persistence only under almost impossible fire regimes. Two decades later it is clear that this prediction was wrong. Investigating some of the underlying parameters showed that, for several parameters (such as fire cycle time, seed production, extinction rates, germination rates), a very small shift might result in a catastrophic population collapse. This also suggests that any errors in the estimates of these variables could result in dramatically wrong results. Thus, although a very nice and analytically impressive analysis, it probably needs to be based on much more demographic data.

Sarah-Jane Fox (2003) compared the Manders (1987b), Privett (1994) and Higgins (2001) models and found a substantial improvement from the first to the last. In 2003 she assessed the state of the two Grootland plots of Pat Manders and then reran the models to see how close they came to predicting the situation shown by her observations. The Higgins model, which is by far the most sophisticated, came remarkably close to predicting the results. These demographic models, which come to a rather optimistic conclusion, were all based heavily on the demographic data assembled and collected by Pat Manders – tree enumerations and measurements from 1971 to 1984. This decade had the highest rainfall in the century of recorded data for the Cederberg (see Chapter 7, p. 161), and as such may well be based on an exceptionally high recruitment and establishment rate. Furthermore, this was near the end of the Department of Forestry's intensive effort to limit the extent and frequency of wildfires.

From 1990 rainfall decreased and fire frequency increased, changes which were not taken into account in these models and which could lead to dramatically different results.

There is further uncertainty about how well a model can deal with the evident complexity of the cedar biology in the Cederberg. A long-term persisting species with individuals able to survive at least 400 years, with two regeneration modes, can generate age distributions and transition/growth rates that are riddled with complexity. The (maybe fallacious) escape from this complexity can be to suggest that it is a long-lived, sporadic recruiter, as discussed in the following section.

## A long-lived sporadic recruiter?

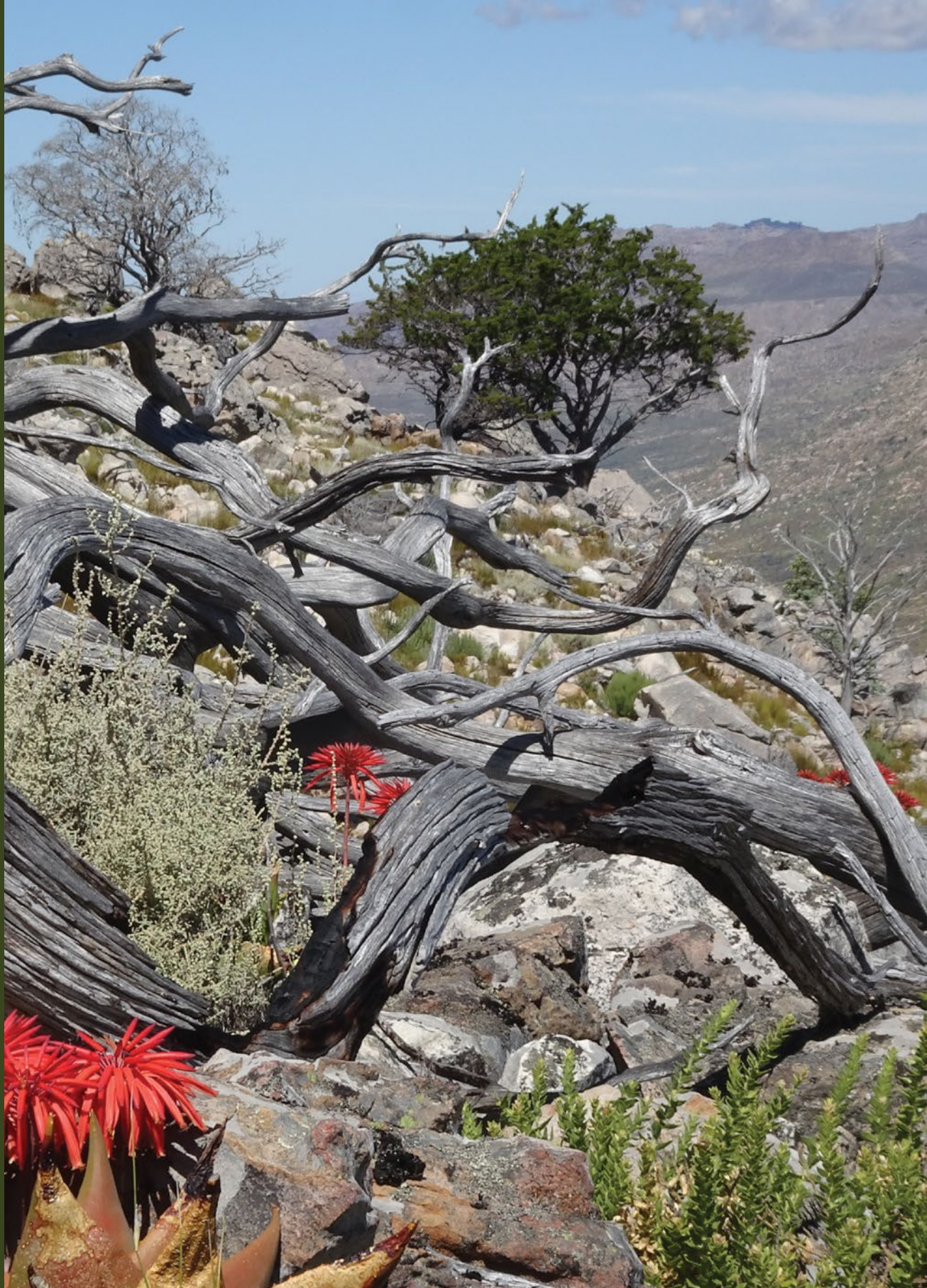
Schweiger and collaborators (2020) suggest that the Clanwilliam cedar is a 'long-term sporadic recruiter', suggesting that recruitment – forming a new cohort of reproductive plants – is a rare and irregular event, dependent on an unusual combination of conditions. Such episodic recruiting species have several attributes. Firstly, they need to be long-lived. This applies to the Clanwilliam cedar, especially compared to the other species with it in the system: cedars can live to 10 times longer than other woody species. Recruitment then happens every 15–150 years and, minimally, needs one recruitment event within the life-expectancy of the trees. This could apply to the cedars. If recruitment only happens when there is a long enough fire-free period to allow the establishment of dense stands, which could keep fire out, or at the very least to boost the numbers of large trees in partially fire-protected sites, then recruitment could be episodic. However, we have no convincing evidence that such a situation has existed in the past 150 years, or at any time before this. If this were the case, then the mature trees would be in even-aged classes and this has not been observed. It seems to be a high-risk strategy to assume that this can happen, because if we rely on episodic recruitment and it does not happen, the species will go extinct.

## Conclusion

Since 1970 we have learnt much about the ecology of Clanwilliam cedars: they use sump groundwater, they grow in summer and have year rings, the maximum growth rate is 0.25 m per year, they are serotinous with remarkably heavy seeds and their seeds are mammal dispersed (mouse and baboons). This knowledge, of course, highlights what we do not know, i.e., what are the climatic extremes that the species can tolerate, how important is groundwater in summer, how far does the pollen travel, what is the spatial genetic structure, does seed

production fluctuate from year to year, under what circumstances do saplings grow very fast, why is germination often so poor after fires, how does long-distance dispersal occur? And likely many more questions. The cedars are unusual in the fynbos in that they can survive fire and that their seeds do not need a fire trigger in order to germinate. The cedars clearly present a rich array of questions and ample work for researchers.





5

# Human occupation of Cederberg

Humans have had, for at least the last 60 000 years, an enormous impact on the global environment. We have transformed huge ecosystems and driven numerous species into extinction, including the extensive megaherbivore extinctions on all continents except Africa. It is likely that the rugged and isolated Cederberg and its characteristic cedars were also impacted by humans. To this end we explore human occupations and activities through time in the Cederberg in this and the next chapter.

## Khoisan[34]

The San hunter-gatherers have likely been present in southern Africa and the Cape for several tens of thousands of years, while the pastoralist Khoikhoin, with their sheep, likely for several millennia, and with cattle at least since 1 300 years ago (Bilbe 1999). John Parkington (2003), from the University of Cape Town, estimates that there are 1 000 or more rock painting sites in the Cederberg and that these are between 1 000 to 1 500 years old. Jean Sugden and Mike Meadows (1990) suggested that Khoikhoin and San impacted the Cederberg from about

[34]The term 'Khoisan' is here used to refer to both San and Khoikhoin.

4 000 years ago, both through increased fire and through grazing, and interpret the sudden drop in cedar pollen in the Driehoek Vlei (see Chapter 2, p. 15) as being a result of this. This argument was also developed by Hubbard (1937), who suggested that 'the earlier Hottentot inhabitants [presumably meaning both San and Khoikhoin], with whom the practice of veld burning was a recognised art ...' may have resulted in increased fire occurrence, removing cedars from the sand plains and plateaux.

The San may have deliberately fired fynbos, a practice known as 'fire-stick farming'. This lures animals to the lush post-fire regrowth and stimulates flowering of watsonias and gladioli, of which the San ate the corms. It is also possible that the San were in substantial numbers in the Cederberg in summer, as the streams there are perennial, whereas in the lowlands there may have been water shortages.

The Grigriqua group of Khoikhoin resided in the Cederberg, Koue Bokkeveld, Sandveld and Piketberg regions in the early 1700s. Their resistance to Dutch expansion was finally broken by the war of 1739 (Penn 2005) and their populations decimated by the epidemics of 1713, 1755 and 1767. It is unclear whether the Grigriqua had any kraals in the Cederberg, as this area is quite marginal as grazing land[35], the vegetation being 'sour' with a very low nutrient status. However, it seems very likely that they moved their livestock through the Cederberg from summer grazing in the Olifants River Valley to the winter grazing in the Tankwa Karoo. But, if there were Khoikhoin, their sheep and cattle, and fires to improve the palatability of the vegetation, would have impacted the cedars, especially if there were cedar groves in the Driehoek Valley.

Both San and Khoikhoin as societies had disappeared from the Cederberg by 1800.

## 'Bastaards'

'Bastaards' and Khoisan whose tribal structures had collapsed settled along the northern border of the Cape Colony and were gradually displaced by Dutch agro-pastoralists. In the Cederberg, by 1800, the 'Bastaards' occupied the steeper and more isolated valleys higher in the mountains (such as the upper Rondegatrivier, Heuningvlei and Driehoek), whereas the Dutch farms were in the wider and more accessible valleys (such as Bidouw,

[35]Nigel Penn (2005) argued that the Grigriqua had small herds and were a weak grouping, possibly due to the poor grazing in their territory between the northern loop of the Berg River and the Knersvlakte, which included much poor mountain land (e.g. the Cederberg and Koue Bokkeveld).

Elizabethsfontein and the Olifants River Valley). The first reference to the 'Bastaards' living in the Cederberg is in the report of the Veeteelt Commissie. The 'Bastaards' were reported to be the most important people logging the forests, at least from the end of the 18th century and during the first third of the 19thcCentury. Nigel Penn (2005) discussed the complex terminology used: 'Bastaard-Hottentots' referred to the children of Black slaves with Khoikhoin, whereas simple 'Bastaard' to the descendants of Dutch fathers and Khoikhoin or Black slave mothers, for example the Ockhuizen brothers at Heuningvlei, who were the sons of a Dutch fugitive and his Khoikhoin wife, Vytje Swart. There is no record of the number of families who worked the cedar trees, nor is it clear whether this was an additional 'cash crop' for subsistence farmers, or whether this was the sole income of these families. The lack of detailed information is frustrating: the only glimpse which we have into this world is from the Veeteelt Commissie report (Van Rijneveld et al. 1911). There may have been a substantial number of people involved, and possibly from early on (perhaps the 1750s), as at the end of the century a large group moved north to the Sakrivier Mission (between the Roggeveld and the Orange River) (Penn 2005, p. 256). The 'Bastaards' knew when the seed ripened on the trees and promised to collect these and sow them out. This reveals that they knew the biological rhythm of the cedar trees, indicating that they had had years to observe the trees. The comment in the Veeteelt Commissie that the forests were being damaged by the logging could also only have come from the 'Bastaards', which indicates an awareness of how the stands had changed. This is good evidence that they had been logging for several decades before the interview with the Veeteelt Commissie, and knew the 'before' situation. All these lines of evidence suggest that there was a 'Bastaard'–Khoikhoin community in the valleys of the eastern slopes of the Cederberg that were in contact with, and probably logging, the cedars, at least from the middle of the 18th century. The major impact that this community had on the cedars through logging is discussed in the next chapter. From this time on the mountain range was also named after the cedars, showing that this charismatic tree had become iconic of the mountains.

## European agro-pastoralists

When the Veeteelt Commissie circumnavigated the Cederberg in 1805, there were farms at Bidouw, Betjesfontein (Elizabethsfontein) and along the Olifants River: these farms date back to c. 1740 (Penn 2005). The Veeteelt Commissie did not mention any farms closer to the Cederberg (thus bordering on the cedars). In the Cederberg the first European agro-pastoralist farm was Driehoek, established by Kock in the mid-18th century. His descendants (now as Kok) were still there in 1820, but by 1840 a Botma was farming at Driehoek (Warner 1989). He had married a Kok. By 1820 there were also farms at Dwarsrivier, Kromrivier and Ezelbank

(Table 6). Shortly afterwards, in 1822, another batch of farms were demarcated along the eastern margins of the Cederberg: Pakhuis, Heuningvlei, Grasvlei and Kleinvlei. Later more farms were delimited in the Cederberg: Uitkyk and, as segregates from Driehoek: Welbedacht, Eikeboom and Perdevlei (Figure 79). These farms were all agro-pastoralist. Land transformed for agriculture was all outside the current range of the cedars, so this had no direct impact on the trees. Transport out to markets was difficult and, consequently, cultivation may have been largely for subsistence. The story is different for the pastoralist part. Most of these farmers relied heavily on grazing in the mountains. This led to a conflict of interests, with the farmers wanting to burn regularly to improve grazing and the Department of Forestry trying to prevent all fires. This led to a repeated ban on grazing on state land and then allowing grazing again, but under the condition of no fires. In the mid-19th century there were also reports that goats and sheep nibbled off the tops of cedar seedlings (Lister 1883).

The impact of grazing is difficult to understand and has not been investigated for the fynbos in the Western Cape. Theoretically, grazing should reduce the standing biomass and



**Figure 79.** Cederberg farms from Mied se Kop: Driehoek on the left and Dwarsriver in the background on the right.

**Table 6.** Farms bordering on the Cederberg, when they were surveyed and who the original owners were. Partially from Nieuwoudt (2015). The establishment of small holdings, such as at De Rif and Hoogvertoon, has not been traceable

| Current farm | Number | Original name | Initial survey | Initial owner |
|---|---|---|---|---|
| Kromrivier | | Kromme Rivier | Schütte 1819 | Daniel Johannes Theron |
| Dwarsrivier | | | Schütte 1819 | H. Bouwe |
| Vogelfontein | | | Schütte 1819 | Jan Matthys (Johan Matthias) Kok |
| Perdekloof | | Driehoek | | Nikolaas Kok |
| Driehoek | 331 | Driehoek | Schütte 1819 | Nikolaas Kok |
| Welbedacht | | Driehoek | | Nikolaas Kok |
| Matjiesrivier | | | Schütte 1819 | Barend Frederik Lubbe |
| Eikeboom | | Driehoek | | Nikolaas Kok |
| Algeria | 284 | Steem Rug | 1877 | J. Nieuwoudt |
| Keurbosfontein | | | Schütte 1819 | Jurie Mulder |
| Nuwerus | 322 | Nieuwe-Rust | 1908 | A.M.M. Esterhuyzen & J.H. Nieuwoudt |
| Fontein Mariba | | Nuwerus | 1930 | |
| Grootrivier | | Rietrivier | | Carl Christian Philip Wagner |
| Uitkyk | | | | |
| Ezelbank | 299 | Ezelsbank | 1819 | Barend Frederik Lubbe |
| Wupperthal | | Rietmond | | |
| Heuningvlei | 178 | | 1822 | Fytje Swart |
| Pakhuis | 130 | | 1822 | Johannes Jacobus Bota |
| Grasvallei (Wupperthal) | | Gras Valy | 1822 | Johan Christiaan Baerewinkel |
| Kleinvlei (Wupperthal) | 290 | Kleine Valy | 1822 | C. Baerewinkel |
| Langekloof | 303 | | 1831 | David Willemse |

so reduce fire intensity. However, grazing could also change the composition of the flora, possibly shifting it from woody to more grassy species, leading to an increased fire frequency.

There is no record at all of any European farmers working cedarwood. Working the forests was the domain of the 'Bastaards' and later of their descendants, the 'coloured' people. Dutch agropastoralists provided a market for the wood.

By the 1930s the introduction of mechanised farming helped open up larger areas of land for cultivation. The production of chewing tobacco was phased out, as demand for smoking tobacco grew, and farmers in the Cederberg shifted to citrus, vegetables and wine. Farmers were also encouraged to plant rooibos, a tea crop that is endemic to the area (Nieuwoudt 2015, p. 35). In 1961, the new Uitkyk Pass and low-water bridge over the Olifants River shortened the travel time from the Cederberg to Cape Town from seven to five hours (Nieuwoudt 2015, p. 109). The importance of grazing in the farm economy was reduced and cultivation increased, reducing the pressure on the cedars from domestic animal browsing and burning for better grazing.

## Establishment of the towns

Clanwilliam was founded on the farm Jan Disselsrivier, which was listed by Veeteelt Commissie in 1805. The stimulus to found a village came with the settlement of Irish settlers (who mostly did not stay) in 1820. There is no documented link between the cedarwood trade and Clanwilliam. The woodcutters probably sold the timber directly, not via traders in Clanwilliam. The only, belated, connection was over Strassbergers furniture factory, which moved from Wupperthal to Clanwilliam after the Second World War. Clanwilliam, however, is a good place to see elegant cedarwood furniture, e.g., in the old courthouse, the Anglican church and in the Clanwilliam Museum (Figures 80, 81).

The Rhenish Mission Station Wupperthal was founded in 1830 on the farm Rietmond in the upper basin of the Tra-Tra River. The first missionary was Johann Gottlieb Leipoldt. In 1835 the church was inaugurated, and in 1836 a tannery and shoe factory started[36]. By 1838 there were 163 residents, most of them likely Khoikhoin (Bilbi 1999). This number swelled to a couple of thousand at the high point of the village. Towards the end of the 19th century the mission bought up the neighbouring farms of Heuningvlei, Grasvlei, Kleinvlei,

[36]Leipoldt was a trained cobbler, which may explain why he started a tannery and shoe-factory, rather than using the cedarwood.



**Figure 80.** Cedarwood pews in the Clanwilliam Anglican church.

Langkloof and Ezelbank. With this, Wupperthal formed most of the eastern boundary of the Cederberg and the distribution range of the cedars.

The people from Wupperthal were important actors in the cedarwood industry. From the report of the Veeteelt Commissie it would seem that 'Bastaards', probably living on the eastern slopes of the Cederberg, were working the forests well before the establishment of the mission station. Indeed, of the first three converts, two were 'Bastaards' who worked the cedar forests (Anonymous 1855). It was some years before Wagenar, the first carpenter-missionary, arrived and established a carpentry workshop in Wupperthal in 1841. However, he soon left to



**Figure 81.** Cedarwood door in the Clanwilliam Anglican church.

build up the farm Matjiesrivier on the southern border of the cedar tree range. This lack of a wood-based industry in Wupperthal only changed with the establishment of Strassbergers sawmill, where the main product was coffins, but this factory moved to Clanwilliam. There is still a weak connection to the cedar forests in the community of Wupperthal.

## The growth of tourism

The problems of wildfires and grazing in the Cederberg were addressed with the consolidation of the Cederberg reserve area and the state acquisition of farms such as Uitkyk, Welbedacht, Eikeboom and De Rif. This was done to decrease the grazing pressure (and associated fire risk) in the reserve areas and the areas adjoining the reserve areas, and so to reduce the impact of agro-pastoralism on the cedars. This was followed by a shift in farming interests to wine and tourists. On 27 July 1972, the Cederberg was proclaimed a wilderness area under the auspices of the Department of Forestry. From the 1990s the Cederberg became a popular hiking, climbing and holiday destination and a number of farms, such as Kromrivier, Dwarsrivier and Driehoek, added campsites and bungalows to service the growing demand for accommodation from visitors. Amateur astronomers built a small observatory on Dwarsrivier farm (Nieuwoudt 2015, p.144–146).

The underlying shift was from a region that produces agricultural product, to one that sells a 'wilderness experience'. This was associated with a massive decrease in the number of farmers and an even more massive increase in tourists. At the same time, the houses at Welbedacht, Heuningvlei, Hoogvertoon, De Rif and Eikeboom were demolished. The higher tourist profile had the positive effect of the development of 'citizen science' involving school groups and adults planting out cedars and caring for the trees. This has also expanded to the farm Driehoek with the planting out of cedars (albeit outside the currently natural ecological range of the species).

## Conclusion

Within the lifetime of one cedar tree, the human impact shifted from hunter-gatherers and occasional fire under the Khoisan, to intensive logging under the 'Bastaards', to grazing and probably frequent fires under agro-pastoralists, to management under conservation-tourism. In the following chapters we explore in more detail what impact, first the exploitation of the wood and, secondly, the increasing wealth and ecological dominance of humans, have had on the cedars.





# 6 Exploitation of the wood

What impact did the exploitation of the cedarwood have on the cedar stands? Can the current sad state of the cedar population be ultimately blamed on exploitation 200 years ago? This is surprisingly contentious. In the 19th century it was claimed that the forests had been exploited to the limit and that all commercially useful trees had been removed. On the other hand, Steve Higgins et al. (2001) suggest that the exploitation was rather limited, implying that its impact was exaggerated. In this chapter we explore what we know about the exploitation of the wood and what we can infer.

## Uses and desirability of the wood

This is a very beautiful wood. Palmer & Pitman (1972), in their seminal work on South African trees, noted that cedarwood 'is ... both beautiful and exceedingly durable, "half-hard", sweet scented, white or yellow in colour. It takes a good polish, is easily worked, and almost insect-proof.' Eighty years earlier, Hutchins (1897), a Conservator of Forests in the Cape Province, wrote that 'Cedar wood, of the three best SA woods Stinkwood, Sneezewood and Clanwilliam Cedar, is everything considered, probably the most valuable. It is not imperishable like Sneezewood, but there are few woods in the world more durable, whether in the ground or out of it.

In weight, density and facility of working it is more useful than Sneezewood. Compared to Stinkwood it is not beautiful, but more durable and more easily worked and it seasons better ... It has two virtues possessed by no other valuable South African timber – (1) it is hardy in exposed open forests; and (2) it is propagated with facility from seed ... Lastly, as to rapidity is growth, it is equal or superior to the other valuable South African timbers ... this supported by annual tree rings ... Certain Cedar trees such as those at Wuppertal, are really slow-growing but this is because they have been raised artificially away from the snow-clad mountain, whereon Cedar along flourishes naturally.'

A description of the wood from Scott (1927) reads as follows:

> General description. A useful and very durable light softwood, used for general construction and furniture but should not be used for drawers to contain documents, negatives, metal work, etc., since certain oils evaporate from the wood, which are detrimental to these and other substances; white deposits are left on the surfaces of the wood when the oils evaporate. Works easily and well, and inclined to be sticky to the touch, and has a very characteristic sweet, fragrant cedarlike smell. Weight: 30 (28 - 31,5) lbs. per cu. ft. oven dry. Colour: Light brownish grey. Solution in water: Pale yellowish green after some time. Burning: Burns very well, leaving white billowy ash.
>
> Structure - macroscopic. Growth rings: Seen as darker areas not clearly defined, 10 – 14 to the inch. Pores: Not seen. Tracheids: Just visible with hand lens on well cleaned up transverse section. Parenchyma: Not seen. Rays: Fine, show up as brown lustrous lines, or as flakes on radial surfaces. Resin canals: Absent. Structure - microscopic. Growth rings: Not very well defined, and with comparatively little contrast between spring and summer wood. Tracheids: Fairly regularly arranged, and with very numerous fairly large bordered pits. Parenchyma: Very frequent resin cells in summer wood; also occasional resin cells in spring wood. Rays: Usually uniseriate, but occasionally biseriate from 1 to 20 cells deep, with average sized pitting.

Cedars have a lovely and distinctive aroma: some of the older readers may remember with pleasure the smell of cedar-wood fire. This – now long since banned – pleasure gave the Cederberg an olfactory uniqueness that is difficult to beat. Most likely the common name

'cedar' was because of the aromatic wood, which may have been associated by the Bible-reading early European farmers with cedars of Lebanon, used by Solomon to build the temple in Jerusalem. The Dutch settlers generally named the trees for the similarity of their woods to European trees, rather than their relationships or the appearance of leaves and flowers. Consequently, we have *boekenhout* (*Myrsine melanophloeos* (L.) R.Br. ex Sweet), a member of the Primulaceae with no similarity to European beeches, or the *rooiels* (*Cunonia capensis* L.), totally different from elm trees. Cedar is likely a different story, not named because of the wood but because of the aroma. The scent is produced by more than 20 different types of essential oils, these even differ between the leaves and the wood (Kamatou et al. 2010). This strong scent made the wood popular for chests and cupboards, as the scent was said to keep out moths and also perfumed the clothes.

The wood is clearly quite versatile, and in the middle of the 19th century, when it was readily available, Pappe (1867) listed a spectacular range of uses: timber for ship- and house-building, wood for furniture such as chests, drawers, chairs, table, wardrobes, etc. He claimed that the resinous smells repelled insects.

From the Dutch agropastoralist expansion into the Olifants River valley and beyond from 1740, cedarwood was the only available building and carpentry timber, until the resource was depleted in 1870 and the state prohibited further logging of live trees.

There are beautiful examples of houses fitted out in cedarwood, from Calvinia in the north to Clanwilliam in the south. The oldest house that we have seen is the farmhouse at Bidouw farm, built in 1775, and the most recent the Hantam Huis in Calvinia, built in 1854. South of the Olifants River Mountains it may have been cheaper to obtain timber from Cape Town, but to the north of the Cederberg there was no other source of building timber.

These houses have ceilings and floors of cedar planks, about 300 mm wide and 1.5–3.0 m long (Figures 82, 83). These dimensions are consistent with the Veeteelt Commissie report (see 'The Veeteelt Commissie of 1805', p. 24). In most cases the floors have been replaced, but the ceilings are still intact. The ceilings were originally painted. The planks vary somewhat in breadth, probably reflecting the size of the block that was cut (see Figure 83).

The roof beams are rarely cedar and are most commonly poplar. Where we found cedar beams, they were 140–180 mm wide and 4.8–5.8 m long, so also fitting the dimensions reported by the Veeteelt Commissie. It is not clear why cedar beams were not more commonly used – one possibility is that such long beams were scarce, another is that poplar is more flexible. Doors and door and window frames (Figure 84) were almost all of cedarwood and often beautifully finished. Cedar was also much used for cupboards, kists and tables.



**Figure 82.** Cedar ceiling and beam dating to 1775 at Bidouw Farm.



**Figure 83.** Cedar kist (newly made out of old planks) and floor dating to 1830 at Mertenhof.



**Figure 84.** Cedar door frame and door in the Hantam Huis, Calvinia.



**Figure 85.** Carving made of cedarwood by Frieda Ollemans.

The best publicly accessible house built out in cedarwood is the Hantam Huis in Calvinia, which was carefully restored by Erwin and Alma Coetzee. Sadly, the cedar floors had decayed and had to be replaced. Other outstanding examples are the beautifully worked doors, pews and carved altar in the Clanwilliam Anglican church (Figures 80, 81) and furnishings in the Clanwilliam courthouse.

Cedarwood was extensively used for all sorts of purposes in the region (Figures 85, 86), including the doors of chicken coops, coffins and fence posts. One of the spectacular uses was for water wheels to drive flour mills (see: https://www.theheritageportal.co.za/article/mills-cederberg). The wheel, axel, platform on which the mill stones were, and hopper that fed the grain between the mill stones were all of cedarwood.

We know of only one case where cedarwood was used for a carving, the result is spectacular, as the smooth yellow wood makes a beautiful surface (Figure 85).



**Figure 86.** Cedarwood bread trough in the Clanwilliam Museum.

The resin of cedars was also used medicinally in the past, as fumigations for gout, rheumatism and oedemata (Pappe 1857, 1867).

## How many trees were felled?

It is difficult to estimate how many living trees were felled, yet this information is an important part of the history of the cedars and an important puzzle piece in explaining the current collapse of the species. We will here try to develop such an estimate, but it must be kept in mind that it could be far off the mark. There are two approaches: the one using the number of permits issued, the other attempting to assess how much wood was used in each house.

From 1879 only dead trees could be legally harvested and then only with a permit. With the appointment of the first ranger, J.F. Budler, a system of permits was introduced. It is not mentioned whether all applicants were granted permits, nor how often trees were logged without permits, but it does give us some indication of the logging rates. Each permit was for 60 cubic feet (1.7 $m^3$) and from 1877 to 1902, on average, 14.5 permits were issued per

year. At the time, planks of 12 × 1 inch (300 × 25 mm) were cut, so 60 cubic feet = 720 feet (220 m) of plank (McNaughton 1891). On average, trees were said to yield about 40 feet of planks, so on this calculation a permit is for some 18 trees. This means that, per year, some 230 dead trees were felled. However, this calculation was made in the mid-20th century, when tall-boled trees had all been removed.

Logging may have started after the first quarter of the 18th century (Grut 1977). Nigel Penn (2005) analysed the history of colonial expansion towards the north in the 18th century and the devastating impact that it had on the Khoisan communities. He recorded that the first loan farm in the Olifants River was granted in 1725 and that by 1732 the colonial settlement had reached the confluence of the Doorn and Olifants rivers. Settlement spread into the Onder Bokkeveld (the modern Nieuwoudtville) by 1740 and in 1750 Akkerendam, the modern Calvinia, was granted as a loan-farm. Most likely the timber for the houses was cedarwood, as recorded in 1803, half a century later, for the Onder Bokkeveld by Lichtenstein (1812), and for the Biedouw by the Veeteelt Commissie (Van Rijneveld et al. 1911). The Veeteelt Commissie reports a waterwheel on the farm Biedouw that had been in use for 20 years without rotting. As they observed this in 1805, the wheel was constructed, at the latest, in 1785, giving the earliest factual record of the use of cedarwood.

We (myself, Ed February, Nicky Allsop and Helen Moss) studied three houses in Calvinia and Bidouw, built in 1775, 1830 and 1854 respectively. In all three houses both floors and ceilings were cedar planks, but only in the oldest house were some of the beams cedar, in the others the roof beams were all poplar wood. Furthermore, all doors, door and window frames, as well as the cupboards were of cedarwood.

The ceiling and floor planks were 250–340 mm wide, consistent with the 12 to 18 inches reported by the Veeteelt Commissie (see 'The Veeteelt Commissie of 1805', p. 24). The planks varied in length from 1.0 to 3.8 m, with shorter planks in the most recent house, and the longest planks in the oldest house. Consequently, we can calculate how many planks are needed for 10 $m^2$ of ceiling or floor. This varies from 5.5 planks in the 1775 house to 9 planks in the 1854 house, presumably as a result of tallest trees having been logged out, leaving only shorter, smaller trees.

We can use these numbers to calculate the number of trees logged for each house. The length of the planks presumably reflects the length of the blocks cut – there seems to be a reason why the planks should be cut shorter than the blocks. From a block 300 × 300 mm in size, seven planks, each 35 mm thick, can be cut and about 50 mm will be lost along the cuts. Therefore, seven planks represent one tree. Using this information, we can calculate that about 60 trees

were used for the ceilings and floorboards of the four rooms of the Hantam Huis. Then we need to add the wood for the doors, cupboards and door and window frames, finally adding up to about 65 trees. In the older houses, with larger planks, the number becomes less. For two rooms in the 1775 house about 20 trees were used. By 1830 approximately 45 trees were used for a three-roomed house (with rooms of about 5 × 6 m in size). Extrapolating up from this becomes hugely speculative. We do not know how many houses of what sizes were built, how many had wooden floors and ceilings, and how many rooms they had. With careful fieldwork and the associated historical research it should be possible to obtain an approximate figure. This is a fascinating bit of cultural history waiting to be unravelled.

What was the ecological impact of this massive tree felling? Firstly, it is likely that the largest, and so the oldest, 200–400-year-old, trees in the stands were felled first. This would shift both age and size distribution of the stands. Tall old trees have a stabilising function, they have survived fires in the past and are likely to continue to do so. Furthermore, if tall trees protect the stands from fire by shading out fynbos, then this could have opened the stands to invasion by fynbos and so, fire. This situation could not correct quickly, due to the slow growth of the trees. Even if all the gaps left by the felled trees were replaced by recruitment, it would take at least 200 years (so to about the year 2000) for the pre-1750 situation to be re-established. These arguments suggest that the damage from the logging could have been considerable and persistent.

Presumably this early logging was largely in the northern Cederberg, with the timber carried out to Heuningvlei, and that there was no logging in the central and southern Cederberg until the 19th century. By 1840 there were several loggers living in the upper Rondevlei River area and transporting the wood out to Clanwilliam by sledge (Warner 1989). The District Forest Officer, C.B. McNaughton, who inspected the Cederberg in 1891, noted that the logging work was confined to about 15 families of 'Bastaards' and necessitates great hardship and privation for these families (McNaughton 1891).

## The telegraph pole saga

The second great catastrophe to hit the cedars was the saga of the telegraph poles, when the regrowth that could have replaced the felled mature trees was logged out. The story runs as follows: in 1882 the telegraph line from Malmesbury to Calvinia was opened. This was part of a project to connect all outlying districts to Cape Town by telegraph. This line, 326 km long (Lister 1880), was entirely on cedar poles (Lister 1883). Rudolf Andrag (1977) calculated that if there was a pole every 40 m, then a total of 7 250 poles would have been

needed (actually, he miscalculated: it is 8 150 poles for the distance from Malmesbury to Calvinia). In 1879, Budler reported that 'The chopping of telegraph poles goes well. About 1 000 are ready. Useless wood, also the branches of the worked trees, remain on the mountain' (Budler 1880). These were presumably pole trees, 4–5 m tall, so probably about 50 years old (thus seeds that germinated from 1800 to 1830). Frustratingly, there is no Forestry Report for 1880, the year during which the logging should have been completed. In 1883 Lister[37] remarked that the whole length of the telegraph line between Piketberg and Calvinia was on cedar poles (Lister 1883), implying that the work had been completed. Interestingly, he did not report that it was from Malmesbury to Calvinia, so it is not clear whether the section from Malmesbury to Piketberg was also on cedar poles. If it was only from Piketberg to Calvinia, then the distance was 290 km and 7 250 poles would have been needed, which is the number that Andrag (1977) reported.

The saga leaves many unanswered questions. Some are technical: how tall were the poles when chopped, what was their basal diameter, from where in the Cederberg did they come, what was the final number that was used, and how were they transported out? Then there are also political questions. What was the justification for this logging? Could the State not have accessed poles from elsewhere, or used iron poles as argued in 1881 by the general manager of telegraphs (Sivewright 1882)? Was this an attempt to prove the importance of the cedar forest, and South African forests in general, or simply the importance of the Department of Forestry to the politicians? Did Lister not realise that he was endangering the survival of the species, for some political agenda? Not surprisingly, in 1882 Lister, as the Superintendent of Woods and Forests, noted that 'The Clanwilliam cedar forests, now almost destroyed, have produced no revenue this year' (Lister 1880).

The damage this logging must have done was surely massive. After more than 130 years of exploitation of the forest, the regeneration was evidently still good, allowing for a massive logging of pole trees. At that stage there clearly were no large forest patches, as Budler had reported in 1877 that 'The forest is composed chiefly of cedar trees which ... spring up at considerable distances from each other ...' (Merriman 1877). This good recruitment is, however, consistent with other remarks on seedlings and saplings. This exploitation history suggests that over 130 years almost all tall old mature trees with straight boles were logged. This may have provided the gap in which the cohort of pole trees that were logged in 1880 was established. Then, these tall poles were also removed. These two sets of actions would

[37]Joseph Storr Lister (1852–1927), born in Uitenhage, Superintendent of Plantations in the Cape Colony from 1875 and Chief Conservator of Forests in the Union from 1910. He started the Forestry School in Tokai in 1906 (later Saasveld College for Foresters).

have left the shrubby trees from which no planks could be cut and the younger poles. The latter are fire-susceptible. When Budler was appointed as ranger in 1876, he reported that the 'natives' had done much and intensive damage to the forest (Merriman 1877). Yet, at that stage the State was doing even more damage? In a modern context, this would need careful justification, but maybe in the 1870s the concept that resources could be depleted was poorly developed. By 1880, 140 years ago, the situation of the species must have been pretty desperate.

## Logging methods

Adolphe Linder interviewed several men in Wupperthal and Kleinvlei in October 2001. These men (Pieter Zimeri, Koos 'Bol' Zimeri, Sakkie Ockhuis and Dirk 'Olly' Ockhuis) had all been woodcutters, so could talk from their own experience. They said that the selected tree was felled by sawing through the stem. If possible, the trunk was carried to Heuningvlei, where there was a permanent scaffolding. Otherwise, it was worked on site. The trunk was cleaned and shaped into a square beam with an adze (*dissel*). This was a painstaking job and it was difficult to get a smooth and straight finish. The beam was then raised onto a scaffolding (*saagsteier*) improvised on site. Cedarwood is relatively light and the men had no difficulty in handling the trunk. The first line to be sawn was marked by spanning a string blackened with cedarwood charcoal. Further lines to give the required thickness of the planks were marked with the help of a compass (*paster* or *passer*). This was done about every 300 mm along the length of the plank. The planks were then sawn by two men with the 'plank saw' (Figure 87). One man stood on top. His job was to pull the saw up and to guide the saw along the marked line. The other man stood underneath. He had to keep the saw going perfectly vertically and to affect the swing (Figure 88). It might take a week to cut up a tree, so they would spend the whole week in the mountain, felling, sawing and sleeping there. A good tree would give about nine planks, generally six or seven feet (2 m) in length. The finished products were carried into Wupperthal. One man could carry six planks (Figure 89).

The community at Kleinvlei generally supplied cedarwood to Wupperthal, but people in Langkloof and Ezelbank also cut a lot of wood. Some wood was transported over Heuningvlei, which was more easily reached from the outside world. A man in Heuningvlei owned an ox-wagon, and there was a wagon road past Groenberg down to Klein Pakhuis. Another possibility was that at Wupperthal the wood was loaded on donkey wagon (*donkiewa*) and transported to the Hantam, where it was sold. This way of working the trees probably dates back to 1750 and it is similar to how Mulanje cedars used to be logged in Malawi.



**Figure 87.** Long saw for cutting planks out of beams in the Clanwilliam Museum.

Heini Strassberger established a sawmill at Wupperthal around 1950 and manufactured coffins from the wood of dead cedar trees. The wood mainly came from Heuningvlei. In about 1952 the sawmill was moved to Clanwilliam, where it continued making coffins from cedarwood.

# Conclusion

The Clanwilliam cedars appear to have been very heavily exploited. From 1750 to 1800 the accessible tall-boled trees (presumably more than 200 years old) had been felled in an unregulated, free-for-all logging, leaving only the gnarled trees. In 1870 the replacement



**Figure 88.** Two men sawing planks on a *saagsteier* (scaffolding). Photograph: Howes-Howell.



**Figure 89.** Tree cutters carrying down a load of planks in 1958. Photograph: E. February.

generation of pole trees were then also felled, under the stewardship of precisely the people and organisation who were supposed to protect the trees. Theoretically, the populations should have been able to re-establish, if conditions were optimal. But the next catastrophe, global climate change, was waiting in the wings.





7

# Global change and its impact

Could global change be responsible for the collapse in the Clanwilliam cedar populations? The natural environment has always been dynamic, with gradual changes in the climate through time (e.g., Greenland was tropical in the Miocene and much of England was glaciated 50 000 years ago), mountains are uplifted and erode away, and new plants and animals evolve or arrive and others go locally or globally extinct. These changes are summarised for the Cederberg in Table 7. However, in the last decades, global change (particularly climate change) has been accelerating and this could well contribute to the problems of the Clanwilliam cedars. Cedars grow at higher elevations in the Cederberg, these being the coolest and wettest areas in the region. An increase in temperature, or a decrease in rainfall, is likely to be problematic for the species (if it is indeed climatically limited, see Chapter 4), as there is limited possibility to migrate to higher habitats with a cooler and wetter climate. The species is also obviously sensitive to fire, therefore, an increase in the fire frequency could also shift the balance of death and regeneration, increasing the extinction risk. Under these circumstances it becomes valuable to know what the species has experienced during its evolutionary history, as this will indicate what hidden competencies it may have (see Chapter 3). In particular, it would be good to know whether it had experienced colder and wetter conditions, or warmer and drier, or both, in the (relatively recent) past.

**Table 7.** Time scale for the environment of the Clanwilliam cedar and the Cederberg

| Date (Ma) | Era | Period | Epoch | Event |
|---|---|---|---|---|
| 500 | Palaeozoic | Cambrian | | Deposition of sand (that will form Table Mountain Sandstone) in shallow sea off coast |
| 330 | | Carboniferous | | Folding of the sandstone mountains from collision with Falklands |
| 120 | Mesozoic | Cretaceous | | Opening of South Atlantic |
| 60 | Cenozoic | Paleogene | Paleocene | Exhumation of Cape Fold Mountains |
| 14 | | Neogene | Middle Miocene | Establishment of modern, winter-rainfall climate |
| 7 | | | Late Miocene | Origin of genus *Widdringtonia* |
| 2.5 | | Quaternary | Pleistocene | Glacial/interglacial cycles start |
| 2 | | | Separation of Willowmore and Clanwilliam cedars | |
| 0.1 | | | Holocene | Start of current interglacial |
| 0.05 | | | Start of Little Ice Age | |

# Landscape change

The Cederberg, and the Cape Fold Mountains in general, have likely been in place since the Paleogene[38], some 60 Ma. This is a remarkably long time, given the propensity of mountains to be uplifted and eroded down within a few tens of millions of years. The Cape Fold Mountains are built of hard, resistant, almost quartzitic sandstone. This was formed from sand deposited 510–400 Ma in a shallow sea at the southern margin of Africa (Table 7). This massive deposit of sandstone, some 8 000 m thick, was intensely folded from 330 Ma onwards, when the

[38]Paleogene Period (53–66 Ma), the first period of the Cenozoic Era, the age of the mammals, following the extinction of the dinosaurs at the end of the Cretaceous Era, 66 Ma.

Falklands[39] drifted against Africa. This collision formed an enormous mountain range, with the folded Cape Peninsula Formation sandstones forming the northern part. This mountain range was eroded northwards and in the process the Cape Fold Mountains were massively reduced in size. The erosional sediments filled the Karoo basin and also buried the northern remains of the folded Cape Peninsula sandstone mountains. When Africa and South America separated c. 120 Ma, a huge rift valley formed, in the bottom of which the South Atlantic Ocean floor started forming. This ocean floor is formed along a long linear volcano, forming a ridge down the middle of the ocean, and this ridge is currently under Tristan da Cunha. The rift formed a massive cliff on the margins of the continent and this cliff started eroding. This erosion front was slowly driven inland and now forms the Great Escarpment (i.e., Roggeveld Mountains) (Figure 7). Because the Karoo shales are relatively soft and the quartzitic sandstones very resistant to erosion, the Cape Fold Mountains did not erode, but were exhumed as the Karoo shales were removed. This left the coastal plain (West Coast, Swartland, etc.) more or less at sea level, from which protruded the exhumed Piketberg, Olifants River Mountains and Cederberg, and behind them the Tankwa, which was eroded down to an older sea level[40]. Currently, the rift wall in the Western Cape is the Roggeveld range, which forms the Great Escarpment opposite the Cederberg and which is clearly visible from the higher Cederberg peaks. So, most likely throughout the evolutionary history of the fynbos, and definitely throughout the history of the cedar trees, the geological environment of the Cederberg has not changed.

## Past climates

What climates has the Cederberg experienced in the past? We have no good palaeoclimate indicators for the Cape mountains, consequently we have to rely on 'postdictions' based on models of how the Cederberg climate functions.

The climate of the Cederberg is driven by several hemispherical variables. Due to the latitude of 32 degrees south, the horse latitudes[41] pass over the Cederberg. In the summer the horse latitudes (subtropical highs) are situated to the south of Cape Town and the most frequent

[39]The Falkland Islands are on the Falkland Plateau, which is part of South America and which, at the time, was curved around the southern tip of Africa.

[40]Some of these sea level changes were due to local uplift events, which, at least locally, have the same effect as lowering the sea level. Southern Africa probably had two uplift episodes, in the Miocene and Pliocene, resulting in the spectacular gorge of the Storms River between Knysna and Humansdorp.

[41]The horse latitude high pressure ridges at the divergence of the trade winds (between the horse latitudes and the equator) and the westerlies (between horse latitudes and the polar fronts).

winds in the Western Cape are the southeasterly trade winds. These bring moisture and rain, which these winds pick up over the warm Indian Ocean. However, the Cederberg (and indeed the mountains from Worcester to the Kamiesberg) lies in the rain shadow of the southern Cape Langeberg, so the trade winds are dry when they reach the Cederberg. This dryness is accentuated by the cold Benguela Upwelling System, which means any winds blowing along the coast stay dry. The cold ocean also establishes a high pressure cell, which helps block moist winds that cross the subcontinent. Consequently, the Cederberg receives very little rain in summer. In winter the Cederberg is south of the horse latitudes (which are then situated near the Orange River) and in the zone of the circum-Antarctic westerly winds. These have a long fetch across the Atlantic Ocean and are, therefore, moisture-laden. Cold fronts circling around low pressure cells embedded in these winds can deposit substantial quantities of rain in the Cederberg, as anybody caught in a winter storm in the mountains will be able to testify. The oscillation between these two systems is driven by the tilt of the Earth. During the austral summer, the interface between the trade winds and the westerlies (the horse latitudes) moves southwards, and the westerly winds with their cold fronts pass south of Cape Town. In winter the whole system moves northwards and a deep cold front can even reach southern Namibia with snowfalls to Grunau. This set of hemispherical variables generates the strongly seasonal climate described in Chapter 3.

This climatic system of cold wet winters and warm dry summers has been in place at least since the Late Miocene, some 8–10 million years ago, when the cold water Benguela Upwelling System reached its modern strength (Dupont et al. 2011). This cold surface water, with the late Mio–Pliocene uplift of the eastern coast (Partridge 1998), resulted in the dry summers of the southern African west coast. The Benguela is a flow of Antarctic water melting off the base of the Antarctic sea ice. Being cold and, consequently, heavy, it drops to the ocean floor, travels northwards and is drawn to the surface on the southern African west coast by the dominant southeasterly trade winds blowing the surface waters northwards.[42] The cedars arrived in the Cape well after the formation of this seasonal climatic system.

[42]Whereas the southeasters leave no fossil record, the Benguela Upwelling does, because it brings nutrients from the ocean floor to the surface, and so increases the biological activity, which is then fossilised. Consequently, the southeaster system (and presumably its attendant summer drought) can be detected from the offshore fossil record. Many fynbos plant groups are much older than this. Some, like restios, date to the Palaeocene at c. 60 Ma. Others, like proteas or phylicas, arrived in the Oligocene or early Miocene. It seems possible that early restio-dominated heathlands may have developed on the nutrient-poor sandstone soils before this climate system was established and that this vegetation expanded with the onset of the summer drought system. Note that much of this is speculation in the absence of a good terrestrial fossil record – the best evidence is at the moment from offshore pollen deposits.

# Pleistocene

The Pleistocene (the last 2.58 million years) has been characterised by enormous climatic fluctuations, during which the Northern Hemisphere continents were repeatedly glaciated (glacial periods) and deglaciated (interglacial periods). Currently, we are in an interglacial period. Eight glacial cycles have been identified. New Zealand, southern South America and southeastern Australia also had much larger ice caps during the glacials than at present. The southwestern Cape appears to have been relatively little impacted by these dramatic global climate fluctuations (Dynesius & Jansson 2000), the southern tip of Africa is buffered between the Atlantic and Indian oceans and there is no evidence of glacier formation in the Cape mountains during the glacials. During the globally colder glacial periods the horse latitudes probably moved towards the equator, with the result that the westerly winds and the cold, wet weather they bring to the Cape lasted longer, thus the West Coast (including the Cederberg) had a longer winter rainy season and a shorter summer dry season. Consequently, the Cederberg should have received more rain and experienced colder conditions in winter, and fewer really hot, dry periods in summer. There is some fossil evidence, for example from the Elandsbaai cave, that suggests colder and wetter glacials along the West Coast (Parkington et al. 2000).

As the global climate warms, the horse latitudes are predicted to shift polewards, so in the case of the Cederberg, southwards towards the South Pole. The result may be shorter winters (i.e., a shorter period during which the westerlies blow in the Cederberg), consequently fewer cold fronts and so less winter rain in the Cederberg, with more of the rain-bearing cold fronts passing south of Cape Town. This fits climate change predictions (Scholes et al. 2015; Perren et al. 2020). At the same time, the summers should become longer and consequently have more opportunity to result in excessively hot, dry phases. A curious side-effect might be more rain in summer, with the southeasterly winds bringing more moisture across the southern end of the subcontinent. This could benefit the cedars, which are not water-limited in winter but are in summer, especially as they grow in summer.

# Holocene

If this model is right (and there is substantial fossil evidence supporting it), it has become drier and warmer since the LGM at about 20 000 years ago, but the rate and timing of this climate change is poorly understood. There is no evidence of any dramatic climatic changes in the Cape during the last 10 000 years (the Holocene). This is quite different from tropical Africa where there were some dramatic changes in rainfall, resulting, for example, in the repeated desiccation of Lake Malawi (Ivory et al. 2016). However, it seems likely that the

cedars may have experienced colder and wetter conditions, but not that they survived hotter and drier conditions.

The last 1 000 years have been climatically turbulent, at least in the Northern Hemisphere. Some 700 years ago (± 1350), the Little Ice Age started. In the Northern Hemisphere this was characterised by significantly lower temperatures and resulted in a substantial increase in glaciers. The Little Ice Age persistent until ± 1850. The Little Ice Age influenced the position of the horse latitudes (Perren et al. 2020). In the winter-rainfall Western Cape it resulted in lower temperatures and an increase in the winter rainfall (Tyson & Lindesay 1992). As cedar trees live for several centuries, this could provide a time frame for an expansion and contraction of the populations with a time lag of several centuries. Indeed, Lückhoff (1971) postulated that the forests of cedars reported by earlier travellers may have developed under a different climate, which may have been more suitable for the cedars. He may well have been right.

A potential way of reconstructing recent past climate change (the last few centuries) is to use tree-ring variation (dendroclimatology). Tree rings are wider during years with mesic climates (i.e., warmer, wetter) than years with harsher climates (i.e., drier, colder). This has been shown to have potential in a study of 32 cedar trees from De Bos in the Langkloof. This exploratory study reconstructed tree ring variation back to 1564, so to the middle of the Little Ice Age. Not only do the rings reflect fluctuation in rainfall, but also occasional fire scars (Dunwiddie & Lamarche 1980). The initial analysis was problematic and could not be corroborated by Ed February and Willie Stock (1998). A re-analysis of the original De Bos samples, but using a much better rainfall variation reconstruction, and using other variables in the tree rings (for example, the density of summer and winter wood) did corroborate the relationship between rainfall and tree ring data (De Mil et al. 2021), but this has not as yet been used to reconstruct the Little Ice Age rainfall for the Cederberg. We are awaiting results.

This all suggests that, compared to the rest of the planet, the climate of the Cederberg has been remarkably stable, at least during the Pleistocene, and that it is currently probably the driest that it has been since the Pliocene, maybe even further back. That is consistent with the exceptionally large number of endemic species in the Cederberg Sandstone Fynbos (Rebelo et al. 2006), of which *Widdringtonia cedarbergensis* is part.

# Anthropocene

In the last two centuries, the concentration of $CO_2$ in the atmosphere has risen dramatically, from ± 280 parts per million (ppm) in 1800 to ± 420 ppm currently (Figure 90). Over the past 2.58 million years (i.e. through the Pleistocene and during the whole existence




**Figure 90.** Increase in atmospheric $CO_2$ in the last million years. From: https://climate.nasa.gov/climate_resources/24/graphic-the-relentless-rise-of-carbon-dioxide.

of the Clanwilliam cedar) it fluctuated between 180 ppm during the glacials and 300 ppm during the interglacials. This dramatic increase is not surprising: we burn a mind-numbing amount of coal and oil each year. Global coal consumption peaked in 2016 at 9 gigatons[43] (9 045 027 366 tons) – just for that year! In the same year, we burnt 35 gigabarrels[44] (35 442 913 090 barrels) of oil. Burning this coal and oil released 35 gigatons of $CO_2$ into the atmosphere in 2016 and these 35 gigatons of $CO_2$, in turn, contained about 8.75 gigatons of carbon that was previously safely sequestered underground. Note that this is for just one year. Some of the $CO_2$ is tied up in photosynthesis and some dissolves in the oceans but the vast majority stays in the atmosphere where it acts like a blanket, keeping us warm. It goes without saying that this will change the climate. Because of the Industrial Revolution, the global climate has been strongly influenced by humans in the last two centuries and, as a result, this era has been dubbed the Anthropocene. When the new $CO_2$ levels in the atmosphere stabilise, and our climate has equilibrated to the new level, we will be living under a very different climate than that under which we and the cedars evolved.

The two climate parameters, temperature and rainfall, react quite differently to an increase in $CO_2$ in the atmosphere. Temperature is directly impacted by increased atmospheric $CO_2$ partial pressure, as increased $CO_2$ reduces the radiation of heat from the planetary surface out into space, thus slowing the rate at which the planet sheds the heat that it has absorbed from the sun.

Temperature change has been much investigated and shows statistically significant increases for almost every parameter measured for the whole of South Africa (Van der Walt & Fitchett 2021). Increases in the extremes of heat are biologically more interesting than increases in the average temperature. The occurrence of hot weather is associated with an increased

[43]Source: https://www.worldometers.info/coal/. Accessed on: 15 April 2021.
[44]Source: https://www.worldometers.info/oil/. Accessed on: 15 April 2021.

probability of fire (see Chapter 8) and may also lead to water stress if trees are using transpiration to cool themselves.

Van der Walt and Fitchett (2021) explored the trends in extreme temperatures for 20 meteorological stations across South Africa, using data from 1960 to 2016. They found very similar trends across the whole country, showing that the climate change patterns are general. The station closest to the Cederberg that they analysed was at Vredendal – there are no longer-term temperature data for the Cederberg. This analysis showed that daily maximum temperatures increased significantly by 0.03 °C per year, irrespective of whether calculated as the annual mean or the maximum in each month (the hottest day each month).

Measures of how long the heat endures (thus of heatwaves) is biologically very important and here too the increases have been statistically significant: the number of days with temperatures higher than 25 °C increased by more than 0.54 days per year and the number of days with temperatures higher than 35 °C by more than 0.02 days per year. There is also an indication that heatwaves are significantly more frequent and the number of days (starting from at least three consecutive days) with 10% of the hottest temperatures has increased by more than 0.09 days per year. This indicates that the hottest days are more aggregated, resulting in more intense heatwaves. These data show that in Vredendal it has not only become hotter (about 1 °C hotter in the last 33 years) but that there are also longer warm or hot periods (on average 0.67 more days over 35 °C).

Does this apply to the climate the cedars experience at 1 200 m in the Cederberg? We do not yet know, as we have only ten years of temperature data. However, the global trend is for temperature increases to be more rapid at higher elevations. It seems very likely that the climate has become significantly hotter in the elevation zone of the cedars. It seems equally likely that the number of days (and probably also contiguous days) with temperatures over 35 °C has also increased. If this is the case, then most likely the mortality of seedlings in the first summer is higher, the drought stress on mature plants has increased, and the risk of fire has increased. These are all parameters that make it less likely for the cedar populations to be able to persist. It would be so much more 'real' if we could put numbers on this: how many more heat days are there? How many degrees C higher is the daily maximum temperature in January in 2025 than in 1960? However, we cannot yet put numbers on the temperature increases, as we do not know how similar the changes are to Vredendal.

There have been several attempts to predict future temperatures, using models and existing data. Earlier models were quite far out and their results can now be ignored. Current models have become much more realistic and have been shown to model temperature changes in the

last 50 years quite accurately (Kruger et al. 2019). These models all indicate that the temperatures will increase at least until 2050. However, how fast they increase and whether they continue to increase after that, depends on how much $CO_2$ we release in the atmosphere – so, how much coal, gas and oil we burn. Or in simple terms, how much you and I fly aeroplanes, drive cars, or use electricity generated by gas- or coal-burning power stations. The survival of the cedars depends on the behaviour of each individual. The government, usually enthralled by profit and big business, is not likely to do much.

The second climatic parameter, rainfall, is only indirectly affected by the increase in atmospheric $CO_2$. Rainfall responds primarily to wind direction and strength, and the sea surface temperature in the fetch of the wind. Ocean temperature responds slowly to changes in atmospheric temperature, so several years of increased temperature is needed for the water in the Atlantic Ocean to warm up. In addition, there is massive inter-annual variation in rainfall, much more so than for temperature. So not only is there a lag in rainfall response to climate change, but we need a longer series of data to compensate for the larger inter-annual variation in rainfall. Consequently, most analyses of rainfall change in southern Africa fail to find a consistent signal. This is ironic, as, contrary to temperature data, we have good rainfall data from very close to the range of the cedars. Although rainfall data from the actual habitat range of the cedars are only available from 2016, we do have rainfall data from Algeria, just below the natural range of cedars, since 1908. This shows an interesting pattern (Figure 91).

Fitting a power curve to the rainfall data from Algeria (to smooth the annual rainfall over many years) indicates an increase in the mean annual rainfall, from an average in 1908 of

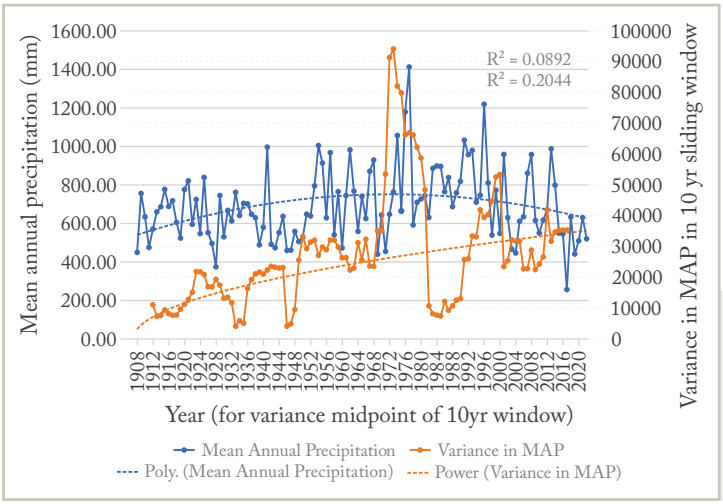



**Figure 91.** Mean annual rainfall (blue, solid line) and its variance calculated in a sliding 10-year window (red, broken line) at Algeria.

some 550 mm p.a. to over 750 mm p.a. by the year 1977 (the wettest year in the last 110 years, with 1 410 mm of rain), followed by a gradual decrease to the present, just over 600 mm p.a. The seasonal distribution in the rainfall, between winter and summer, shows a slight increase in the proportion of summer rain, from just under 20% to just over 20%. This is not yet a convincing change. Nor do we see an increase in the number of 'dry' months in the year (i.e., months with either no rain, or less than 10 mm of rain). Consequently, we do not (yet) see the predicted decrease in rainfall and increase in summer drought.

However, the inter-annual variance in the rainfall shows a strong increase (Figure 91). We calculated this for a sliding 10-year window (for 10 years the mean annual rainfall is calculated and the deviation for each year from this mean determined). If the rainfall is the same each year, then the variance will be zero. The larger the differences in rainfall from year to year (one year very wet, the next very dry), the larger the variance becomes. Climatologists tell us that an increase in the variance is what we expect under global climate change – and that is precisely what we see here. We can speculate on the biological consequences of this. In wet years the vegetation grows very well and a large biomass is built up quickly. In the dry years this becomes highly flammable. Theoretically, then, we can predict that an increase in the variance might lead to an increase in fire frequency and intensity. This is indeed what we observe (see Chapter 8).

## Consequences for cedars

During the history of the Clanwilliam cedar there have likely been repeated climatic fluctuations but the geological environment has remained constant. However, the climate changes during the Anthropocene may already have resulted in more extreme heat and more very hot days than the species has experienced before now. Most likely, the temperatures will become hotter and the differences between wet and dry years become more extreme in the near future. This will, most likely, result in an increase in fire frequency. In addition, climatologists predict that the total rainfall should become less. Furthermore, it likely exposes cedars to climatic conditions which they may never have encountered during their evolutionary history and which they may not have the tools to deal with. Our burning of fossil fuels may have created an inhospitable world for the beautiful Clanwilliam cedar.

How have conservation managers tried to protect cedars against this human and climatic onslaught? This is explored in the next chapter.





# 8 Conservation and management

The Clanwilliam cedar is formally classified as Critically Endangered by the International Union for the Conservation of Plants, the IUCN (Farjon et al. 2013). This category is for species that are thought to be heading towards extinction. The reason for the classification is the continued and apparently irreversible decline in number and quality of stands in the last century, discussed in Chapter 2. Over the last 150 years there has been a major effort to protect the cedars in their natural habitat and to increase their population size (Table 8). In this chapter we explore the different approaches to managing and protecting the cedars over the last two centuries and evaluate their success.

Prior to 1876 there was no control over the use of the natural resources in the Cederberg – this included harvesting of cedar timber, hunting of animals, collecting herbs, collecting the bark of *Heeria argentea* Meisn. (*kliphout*; used for tanning) and harvesting *Aspalathus linearis* (Burm.f.) R.Dahlgren (rooibos tea). The mountains were also used for grazing. In essence, it was public land where anybody could fetch whatever they wanted. Thus 70 years passed from the time that the Veeteelt Commissie commented on value of the timber and the excessive impact of harvesting until the date that the State started its attempt to protect the resource. Although there were repeated warnings that a valuable timber resource was being depleted, the State took its time to respond.

**Table 8.** Timeline of formal protection status of cedars and the Cederberg

| Year | Action |
|---|---|
| 1876 | Appointment of ranger to look after the Cederberg. |
| 1897 | Declaration as State Forest. This was the only formal status available at the time. |
| 1945 | Wicht Report suggests that Cederberg be recognised as a 'National Nature Reserve', together with Hottentots Holland, Swartberg, Langeberg and Outeniqua mountains. The drive towards this may well have come from Prof. Harold Compton, who had been arguing for some years that the mountains should be better protected. |
| 1964 | Clanwilliam cedar declared a protected tree. |
| 1973 | Cederberg declared as Wilderness Area (highest conservation status possible in South Africa). |
| 1986 | Cederberg management transferred from the Department of Forestry to CapeNature. |
| 2004 | Cederberg declared World Heritage Site. |

The first forest ranger was appointed in 1876 and over the decades this office has been greatly expanded. In 1973, almost a century later, the Cederberg Wilderness Area (CWA) was declared. This was the second Wilderness Area declared in South Africa after the Drakensberg. Wilderness Areas have the highest level of protection possible in South Africa. By 1967 the Department of Forestry realised that, unless the Clanwilliam cedar could be successfully re-established, this tree species would be doomed to vanish from its natural habitat (Anonymous 1968). This led to the major research programme into the ecology of the species, which started in the 1970s (see Chapter 4). From 1986 the CWA was managed by Cape Nature Conservation. During the 250 years, from 1750 to 2000, the status of cedars changed from a resource, to a rare species that needed protection, to an iconic species that reflects the impact of humans on the natural environment.

## Regulation (last half of 19th century)

When the State did start taking notice of the cedars and the Cederberg, its response was through regulation. The regulation of the exploitation of the Cederberg started with the appointment of Ranger J.F. Budler in 1876. Budler was based in Clanwilliam, which was the most central place from which to reach all corners of the Cederberg. From 1876 a permit was needed for the exploitation of any natural resources on state land. From 1879 only dead trees were allowed to

be harvested, ironically only after the State had felled about 8 000 live trees at pole stage for the Malmesbury to Calvinia telegraph line (see Chapter 6). Nobody can accuse the State of setting a good example! From 1967 the harvesting of dead trees was also prohibited.

Grazing was prohibited from 1891 but, as it could not be enforced, the prohibition was lifted in 1910 in response to strong pressure from the surrounding farmers, and then reinstated in 1937. The prohibition was preceded by numerous observations of the damage caused by grazing. The earliest comments were that the tips of cedar saplings were eaten off, presumably largely by goats. In 1891 McNaughton also commented, after inspecting the Cederberg, that fires lit to improve the grazing for cattle pastured on the top and slopes of the mountains were causing severe damage to the cedar forests. However, the impact of grazing is not properly understood. Apart from direct browsing damage to saplings and deliberate fires to improve grazing quality, grazing surely impacts the fire regimes by changing both the amount and type of biomass. It is possible that the removal of grazing led to an increase in biomass and so to more intense fires.

Enforcement of the regulations was very problematic in the 19th century. The problem until 1904 was that the only ranger was based in Clanwilliam, so there really was no effective control on what happened in the mountains. Count M. de Vasselot de Regné, originally a French forester, appointed in the Cape Colony as Superintendent of Woods and Forests, visited Garskraal on the Rondegat River, just below Uitkyk, in 1882, and considered this a good place to have the forestry station. He proposed the name Algeria possibly because he thought that the Cederberg look like the Algerian Atlas Mountains, where he had worked on the *Cedrus atlantica* (Endl.) Manetti ex Carrière forests (Smith 2002). In 1903 Budler moved to Garskraal/Algeria. This was a much better base than Clanwilliam from which to control the Cederberg.

Regulation apparently led to a dramatic decrease in the frequency of fires: according to Leipoldt (1899a) summer fires in the Cederberg used to be a daily event but became much scarcer with more control towards the end of the 19th century. There are no quantitative data to support Leipoldt's impression. We have no reports on how the cedar stands responded to the enforcement of controls after 1880.

# Plantations – developing a sustainable resource (first half of 20th century)

## Rationale for the plantations

From 1897 to 1907 there was a massive programme to 'reforest' the Cederberg. This started almost two decades after a whole cohort of pole trees had been logged out of the mountains,

resulting in the conclusion that the commercially useful timber had all been removed and temporarily shutting the mountain to logging. This was an extension of the plantation policy, vigorously advocated by J.S. Lister from 1880 onwards, and justified by Hutchins (1902). The economic rationale for this afforestation programme was to save the cost of importing timber for railway sleepers in the mines and for construction purposes (Lister 1883). The solution was sought through several large plantations of several species (e.g., on Table Mountain) for the supra-regional users like railways, as well as small plantations in each town to satisfy local needs of fuel, poles and building timber. Several large nurseries were established, for example at Tokai and at Worcester. These nurseries were used both for experimentation to find the most suitable species, as well as producing large numbers of 'transplants' (seedlings) for both the public and the department. An additional argument for the plantations was the belief that plantations increased rainfall, as argued by Lister (1882). This was called 'climatic forestry' and is described in detail in the book on Table Mountain fires by Pooley (2014).

The call for more forests goes back to an appeal by John X. Merriman (1876) but for 20 years nothing was done in the Cederberg. The first argumentation for the cedar plantations was primarily economic and Hutchins argued in 1895 that 'The value of Cedarwood has been repeatedly referred to in forest and other reports (*vide* more recently G.51-'95 p.41). It is easily worked, sweetly scented and almost imperishable. A plantation would within a reasonable time, return its entire cost, and should the railways be extended northwards, return a handsome profit' (Hutchins 1896). The conservation argument, protecting these unusual forests, was rather incidental. Whatever the ecological arguments were, the vision and scale of the afforestation project in the Cederberg was impressive.

The initial budget was £400[45]. The start was managed in the field by Budler from 1896, in his last years as chief ranger. The project began, sensibly, with experimental plantings in 1896 at Heuningvlei. When these seedlings grew well and Budler was optimistic that plantations would be possible, a massive sowing campaign was started. Where possible, the ground was first ploughed and, in most cases, the seed was sown in the next year by the bucket-load. This seems to have been by broadcasting the seed. Where it was too rocky for ploughing, the seeds were planted in holes. In most plantations there were gaps in the seedling establishment and these gaps were filled in with more seed in the following years. The quantity of seeds sown was prodigious (Table 9): according to Budler more than 10 tons. From about 1904 the method was changed to planting out seedlings, rather than broadcasting the seeds. In the end, more than 300 000 seedlings had been planted.

[45] This translates to about £65 000.00, or R1.5 million in modern terms.

**Table 9.** Summary of the cedar plantation sowings and plantings, as could be extracted from the annual reports

| Year | Mass of seed sown (kg) | Saplings planted | Region | Area (ha) | Resowing | Notes |
|---|---|---|---|---|---|---|
| 1897 | 375 | | Heuningvlei | 12 | | |
| 1898 | 261 | | Heuningvlei | 12 | | |
| | 522 | | Middelberg | 16 | | |
| 1899 | 2 700 | | Heuningvlei | 28.6 | Also | |
| | | | Middelberg | 36.4 | Also | |
| 1900 | 1 134 | | Middelberg | | Yes | |
| | 227 | | Heuningvlei | | Yes | |
| 1901 | 1 200 | | (unknown) | | | |
| 1902 | 1 940 [68] | | Mostly Middelberg area | | | |
| 1903 | | 28 949 | (unknown) | (unknown) | | |
| | 412 | | (unknown) | 12 | | |
| | 1 660 | | | | Yes | |
| 1905 | | 32 866 | (unknown) | | | |
| | | 17 040 | | | Yes | |
| | | 32 866 | | | | |
| 1906 | | 203 000 | Railway Sleeper Plantation | 117 | | Several other species too |
| **Totals** | **10 431** | **314 721** | | **234** | | |

The concept of these plantations was rather odd, with two unusual things about them. Firstly, most plantations were on the sand plains, not on the rocky outcrops. Almost all commentators up to 1895 noted that the cedars were restricted to rocky outcrops and absent from the sand plains. Secondly, there was a concerted effort to plant up dense, closed canopy stands, with numerous comments about filling the gaps in the stands. Yet, all earlier commentators

reported that the cedars occurred as small stands or even solitary trees. They knew that at least in the last half of the 19th century there were no big forest patches on the sand plains.

The clue to this concept of planting dense stands on the sand plains is found in Hutchins' report of 1895: 'It is evident that fire is the controlling agent in the distribution and multiplication of these interesting trees, and that the forest remaining is mainly that situated on ground so stony and bare that little or no other vegetation grows and where consequently there is nothing to burn. Its seems probable that the forest formerly consisted of two classes: 1. the best: dense and uninflammable filling fertile valleys; and 2. the inferior, scattered and open in almost bare rock where there is no inflammable vegetation. Of the first only vestiges remain' (Hutchins 1896).

This statement contains several improbably elements. The first is of forests filling so-called 'fertile valleys', as there are no fertile valleys in the Cederberg. The whole system is remarkably nutrient-poor. Presumably Hutchins meant the sand plains, referred to in Afrikaans as *suurvlaktes*, because they are so leached out. The secondly is of 'dense and uninflammable' forests. There is no record whatsoever in the literature that such forests have been observed and Budler, the local boy from Wupperthal, was quite clear years earlier that there were none. The third is the notion that dense stands could be fire-resistant. This is possibly true (see Chapter 4) but there was no evidence for this. The fourth is Hutchins' claim, almost as if he knew that there was no evidence in support of his statements, that 'vestiges' of these forests remain. Even if he did see some clumps of trees on the sand plains, how did he know that these were vestiges of a once continuous dense stand? It seems that here ideology is over-riding empirical observation[46]. Maybe Hutchins did not understand the difference between the evergreen Afromontane forests (such as existed in Orange Kloof, on the southern slopes of Table Mountain and widespread in the Southern Cape) and a 'fynbos forest' of cedars.

The real importance of this statement is that it provides a logical justification for the plantation policy: plant up dense stands in the sand plains; protect them against fire until they form a closed forest; these closed forests should then keep out fire. If it works, it is a win-win situation, providing a source of the best indigenous timber in the Cape and protecting a threatened species. This vision was sufficiently compelling to lead to half a century of intensive effort: establishing numerous plantations, maintaining firebreaks and building an

[46]Hutchins grew up in Britain, studied forestry in Britain and France, and would have been taught that the climax vegetation was forest. It also accounts for his quoting Milner (who commanded the Imperial armies against the Boer republics) as an epigraph to his chapter on 'Forestry in South Africa': 'I am as certain as I stand here that Nature intended wide tracts of South Africa to be forest country.'



**Figure 92.** Remains of the Castle Rock Plantation in 2024.

infrastructure of bridle paths, huts and finally even roads. A century later very little is left of the plantations (Figure 92).

## Establishing plantations

From 1896 the establishment of the plantations was forced. Reconstructing the progress of establishing the plantations is difficult, as the information in the annual reports is incomplete, reported differently each year, and it is difficult to disentangle what is summary information reporting what had been done to date and what is new. This is confounded by the intermingling of reports of establishing new plantations versus filling in gaps in existing plantations. Detailed reporting stops in 1906. The exact location of all these plantations is also still unclear. We tried to summarise the available information in Table 9 and Figure 93. Several patterns emerge. Firstly, by 1900 most plantations had been established. Secondly, the massive pouring in of seed continued until 1903, filling in the gaps in the plantations. Finally, from 1904 'transplants' were largely used – both for the small areas of new plantations and for the filling of gaps in the older plantations. It is not clear how long this effort continued.

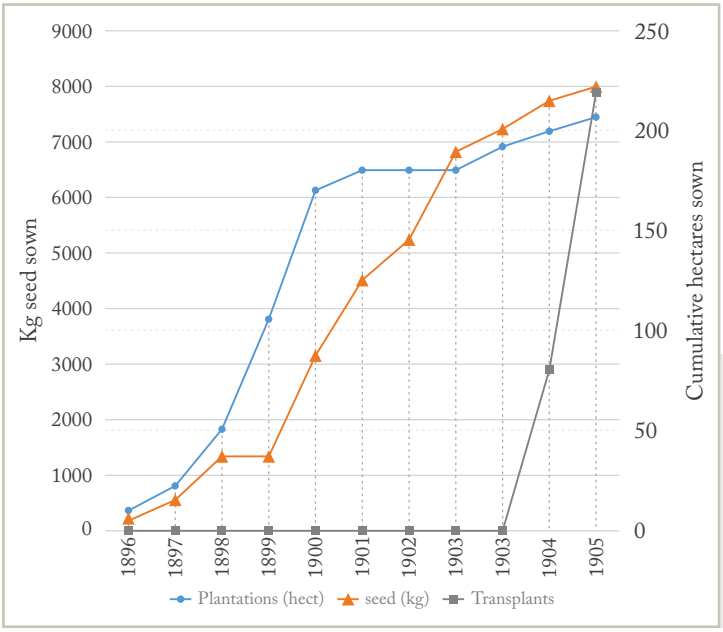



**Figure 93.** Summary of the growth of the plantations, both in terms of the quantity of seed sown and the hectares. The Railway Sleeper Plantation is not included, as the reporting was hard to decipher.

Two large plantation systems were established at Heuningvlei in the northern Cederberg and on the Middelberg above Algeria. Both consisted of numerous smaller plantations. The Middelberg plantations included the Railway Sleeper Plantation (probably on the path from Algeria to Middelberg), Kruger se Land, Geelland, Cathedral (or Castle) Rocks and Grootland (Figure 94). The Heuningvlei plantations also included Moedersielskloof (a wonderful name, roughly translating to 'the valley of the soul of a mother') and Budlers Kloof. In 1905 Hutchins claimed that the plantations contained 81 000 trees and covered at least 232 acres (Hutchins 1905), and by 1906 at least 8 tons of seed had been sown and 80 000 seedlings planted into plantations covering about 220 hectares.

The plantations were followed by 'planting experiments', of which possibly the most extensive were by Hilgar Lückhoff from 1967 to 1973 and documented in his field books. The questions were whether to fertilise, and if so, with how much. Some plantations were sown, others planted with seedlings of various ages. We could not find a summary of the results of these experiments.

## Fate of the plantations

A century later, some plantations had been completely destroyed by fire and the remainder reduced to a few small patches. The project was a huge failure and no timber was harvested.

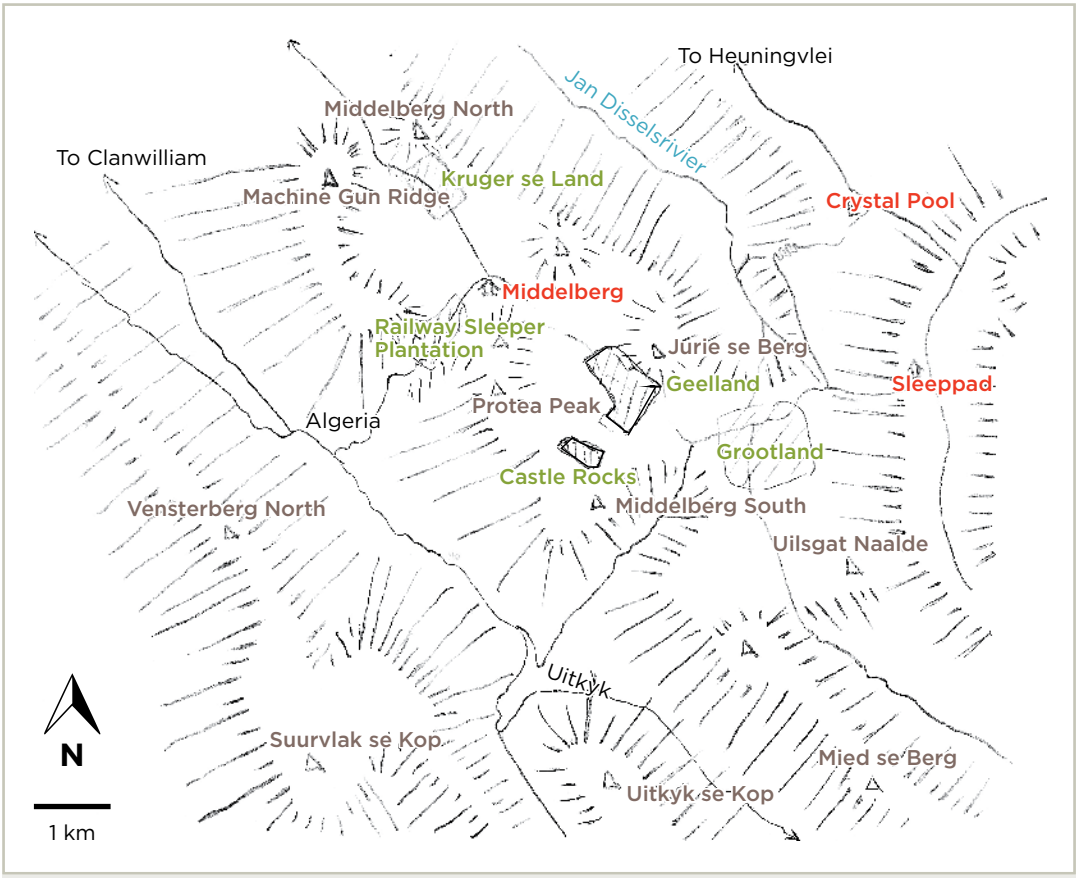



**Figure 94.** The Middelberg plantations. Plantations are labelled in green, peaks in brown, huts in red.

In the end it was not possible to keep fire out, the plantations were not fireproof and natural recruitment could not make up for the losses due, largely, to fire. Yet, it all started so well, so what went wrong? Why don't we have beautiful shady cedar forests along the hot path to Middelberg Huts, and on Kruger se Land, Geelvlei, the lovely Cathedral Rocks, Grootland, Moedersielskloof, Budlerskloof and Heuningvlei? It would have been lovely to walk through a cedar forest from Middelberg to Klein Hartseer!

Early reports on the plantations were mostly enthusiastic. Leipoldt (1899b) reported on the condition of the Heuningvlei plantation four years after it was planted. Germination seems to have been good, and Leipoldt was optimistic about success. Budler's annual reports were also optimistic:

1899: 'The cedars growing promise very well and the older sowings are now fully stocked' (Budler 1900).

1900: 'Honig Vley. First sowings in 1896 are now trees 11 inches high[47]. The broadcast sowings of 1898 show trees 2,5 inches high ... I am proud of the Honigvlei plantations' (Budler 1901).

1903: 'The cedar trees planted 1896 at Honig Vley are now 16 feet tall[48]. The broadcast sowings of 1898 are 7 feet high, and the general appearance of these trees is good. The number of vacancies in the area stocked by sowings is however very large and will be restocked with nursery transplants and it is intended in future to work largely with nursery transplants' (Budler 1904).

Hutchins (1905), who inspected the plantations in 1904, was much less impressed. He got Budler to count and measure the trees, the results are summarised in Table 10. It is evident that these numbers are smaller than those reported annually by Budler, the areas almost by an order of magnitude! Was Budler exaggerating?

In the 1920s the Middelberg plantations were doing well (Cameron 1922, 1924). These plantations were still thriving in 1936 (Hubbard 1937) and Hubbard showed that the trees in the plantations were growing faster than the trees from the natural populations. However, by 1959 many plantations were in a poor to very poor condition, as is evident from Lückhoff's field books (Table 11). It is not clear, however, how these comments are to be interpreted. The first uncertainty is whether all plantations are listed, or only some. In the absence of a comprehensive listing and naming of the plantations, this cannot be checked. Maybe Lückhoff listed only the damaged plantations. The second uncertainty is what he means with 'poor and patchy'? Since then the plantations have been further reduced, as shown by the repeat photographs (Figure 95A and B).

The last large intact plantation was the Railway Sleeper plantation at Middelberg. This was largely destroyed by a wildfire in 1997 which CapeNature did not fight, as it had a natural ignition. They watched from Algeria, inactive, while this century-old plantation of genetically diverse cedars burnt out. This is surely one of the best examples of nature non-conservation. The last largely intact plantation at De Rif was half-destroyed by a wildfire in 2016 and the

[47]Budler may well have exaggerated at times, especially in the weight of seed sown and the hectares planted. A glimpse of it is here: trees are more than 300 mm tall!

[48]The reported 5 m growth in seven years would be exceptionally fast – these do not match Hutchins' comments shortly afterwards, reinforcing the impression that Budler exaggerated.

**Table 10.** Plantations and their details. Unfortunately, the plantation numbers cannot be aligned with names

| Region | Plantation | Area (ha) | Number of trees | Average height (m) |
|---|---|---|---|---|
| Heuningvlei | 1 | 0.4047 | 690 | 1.8288 |
| Heuningvlei | 2 | 2.8329 | 7 720 | 1.2192 |
| Heuningvlei | 3 | 10.9269 | 34 425 | 1.8288 |
| Heuningvlei | 4 | 0.101175 | 173 | 4.572 |
| Heuningvlei | 5 | 1.6188 | 5 402 | 0.4572 |
| **Total Heuningvlei** | | **15.88448** | **48 410** | |
| | | | | |
| Middelberg | 6 | 4.047 | 9 500 | 0.6096 |
| Middelberg | 7 | 0.20235 | 974 | 0.3048 |
| Middelberg | 7 | 0.101175 | 789 | 0.1524 |
| Middelberg | 8 | 0.101175 | 564 | 0.1524 |
| Middelberg | 9 | 0.910575 | 232 | 0.1524 |
| Middelberg | 10 | 1.315275 | 241 | 0.254 |
| Middelberg | 11 | 3.6423 | 4 648 | 0.4572 |
| Middelberg | 12 | 0.910575 | 2 782 | 0.1524 |
| Middelberg | 13 | 11.3316 | 13 150 | 0.3048 |
| Middelberg | 14 | 4.047 | | |
| **Total Middelberg** | | **26.60903** | **32 880** | |

remnants are still not protected (in 2024) by a firebreak. Nor did CapeNature do anything to protect the seedlings that established under the burnt forest in this popular stopping place. That was eventually done by volunteers.

## Why did the plantations fail?

Clearly, the plantation project was a gigantic failure. It did not result in the establishment of a viable population of cedars (as was hoped by Leipoldt [1899a, b]), nor did it produce timber (the fond hope of the Department of Forestry). The Department of Forestry did try very

**Table 11.** Summary of condition of plantations reported by H.A. Lückhoff in February 1959

| Plantation | Region | Condition |
|---|---|---|
| Castle Plantation | Middelberg | Trees poor, not ecologically suitable |
| Juriesberg M5 | Uilspiek | Completely destroyed by fire |
| Geelvlei M4 | Uilspiek | Almost destroyed by fire, few shrubby trees remain |
| Geelvlei M3 | Uilspiek | Largely destroyed by recent fire |
| Grootland M2 | Uilspiek | Completely destroyed by fire, already in 1927 |
| Hartseer M1 | Uilspiek | Completely destroyed by fire |
| Haevelskloof H5 | Heuningvlei | Poor and unhealthy |
| Groothoek H2 | Heuningvlei | Poor and patchy |
| Budlerskloof H3 | Heuningvlei | Some very good trees (possibly underground water) |
| Moedersielshoek H4 | Heuningvlei | Patchy with some excellent trees |

hard. They sowed more than 10 tons of seed. When that did not work well enough, they germinated the seed and planted in more than 300 000 seedlings. They worked hard for almost a century to control fires, to facilitate regeneration. They put in substantial infrastructure to make all this possible. The reasons for the failure are complex.

Obviously, the proximal cause of the failure of the plantations was fire. In the absence of fire, presumably some sort of forest of tall trees would have developed, as is still visible at De Rif (Figures 96–98), Geelland and Cathedral Rocks. The plantations never became 'uninflammable' or fire-proof. Even though they were protected by firebreaks, fires still penetrated into the plantations and killed the majority of trees. Regeneration could not make up for the losses. Where there is an adequate firebreak, the plantations do relatively well. This is illustrated by the 50-year-old northern half of the De Rif plantation (Figure 96), protected by a blown-out firebreak to the north (Figure 97) and the tall, older plantation to the south (Figure 98). The distal reasons must be those that account for this failure.

Regeneration failure could be the result of not enough seedlings establishing after the fire, or because the next fire swept through the population before the young plants had produced enough seed to replace themselves. The latter seems the more likely, as there are several indications of 10–100 saplings establishing per adult after fire. This is currently (2023) the situation at De Rif and was also the case at Heuningvlei in c. 2000 (Figure 99). These saplings need a fire-free environment for at least 50 years before they develop any fire resistance




**Figure 95.** A, plantation on the Middelberg, photographed in 1931 by Howes-Howell (reproduced with permission of Tim Hoffman); B, repeat of Figure 100, by Puttick and Jack in 2012 (reproduced with permission of Tim Hoffman). Of the plantation only a few trunks are left on the ground.



**Figure 96.** Plantation at De Rif, presumably planted c. 1950, so these pole trees are some 70 years old. There is almost no regeneration in this plantation, despite substantial seed production. Presumably the sandy, rock-free habitat and the overstorey of trees are inimical to cedar seedling survival. In the much older neighbouring plantation, regeneration after fire was excellent.



**Figure 97.** The northern De Rif plantation in 2023. Trees are about 70 years old and there is no evidence that a fire has entered the plantation. Large gaps among the trees are evident and on the right (northern) side a blown-out firebreak is visible.



**Figure 98.** Remnant of the old plantation at De Rif, probably 100 years old.

and before they produce a large enough seed crop to re-establish after fire. The faster the trees grow, the more quickly they will be able to produce a sufficient seed crop to re-establish after fire, or become tall enough to survive fire. It is possible that environmental conditions on the sand plains are too harsh, so that the trees grew too slowly to escape from the fire trap, or the dry summers killed most of the seedlings, simply not leaving enough survivors. However, the comments by Leipoldt suggest that this is not the case, as are the high growth rates reported by Budler, as well as the evidence from Hubbard (1937) that trees in plantations seem to grow more rapidly than trees in natural stands.



**Figure 99.** Cedar regeneration at Heuningvlei a few years after fire. Photograph: Ed February.

The third proximal explanation might be that water reserves in the sand plains are not large enough to support a dense stand of mature cedars. The comments by Budler about the extensive 'vacancies' and the obvious difficulties in establishing a dense stand of young trees suggests that water availability may be a problem. This problem might get worse as the plants get older, as saplings (which need less water than mature trees) can form much denser stands, but as the pole trees grow taller, there is no longer sufficient soil moisture available for summer growth. There are several observations that support this (i.e., the younger northern plantation at De Rif, Figure 97). The dense, southern stand at De Rif is directly above a permanent spring and it is quite possible that these trees are accessing this spring water, thus enabling the dense stand, which could shade out the pyrophytic fynbos, to be supported. It is possible that without permanent groundwater, a stand cannot construct a fire-proof habitat. However, there is no critical evidence to support this possible explanation. The fourth proximal explanation is that the hypothesis that cedar forests are not flammable is false and that it is possible for cedar crown fires to sweep through a plantation. The implication is that they cannot construct their own fire-proof niche, as a crown fire could kill them. The bulk of the evidence suggests that they do not carry crown fires, but the matter is not yet absolutely resolved and it might depend on how hot and dry the air is. Possibly all these distal causes contributed to the proximal cause: too much fire.

Hutchins should have paid more attention to the evidence, and he should have taken people with field experience, like Budler, more seriously. This expensive failed exercise (Figure 100A and B), which may well have harmed the natural stands among the rocks by the massive seed collection, warns against being blinded by theory.

## Consequences of the plantations

The impact of this heavy seed harvesting is not known and has not been explored. Presumably, this translated into a reduced rodent population and also in a reduction in the number of natural seedlings of cedars. In addition, Pat Manders (1986a) suggested that seed collection was probably associated with damaging the branches, thereby limiting future seed production.

Genetic research by Janet Thomas and William Bond (1997), using isozymes, showed that many stands were genetically differentiated. If the seed used in the plantations did not come from the immediate area, then any local differentiation may have been lost. The largest and longest-lived plantation was at Middelberg and this was shown to be genetically very heterogenous, as though the seed had been collected from across the range of the species.

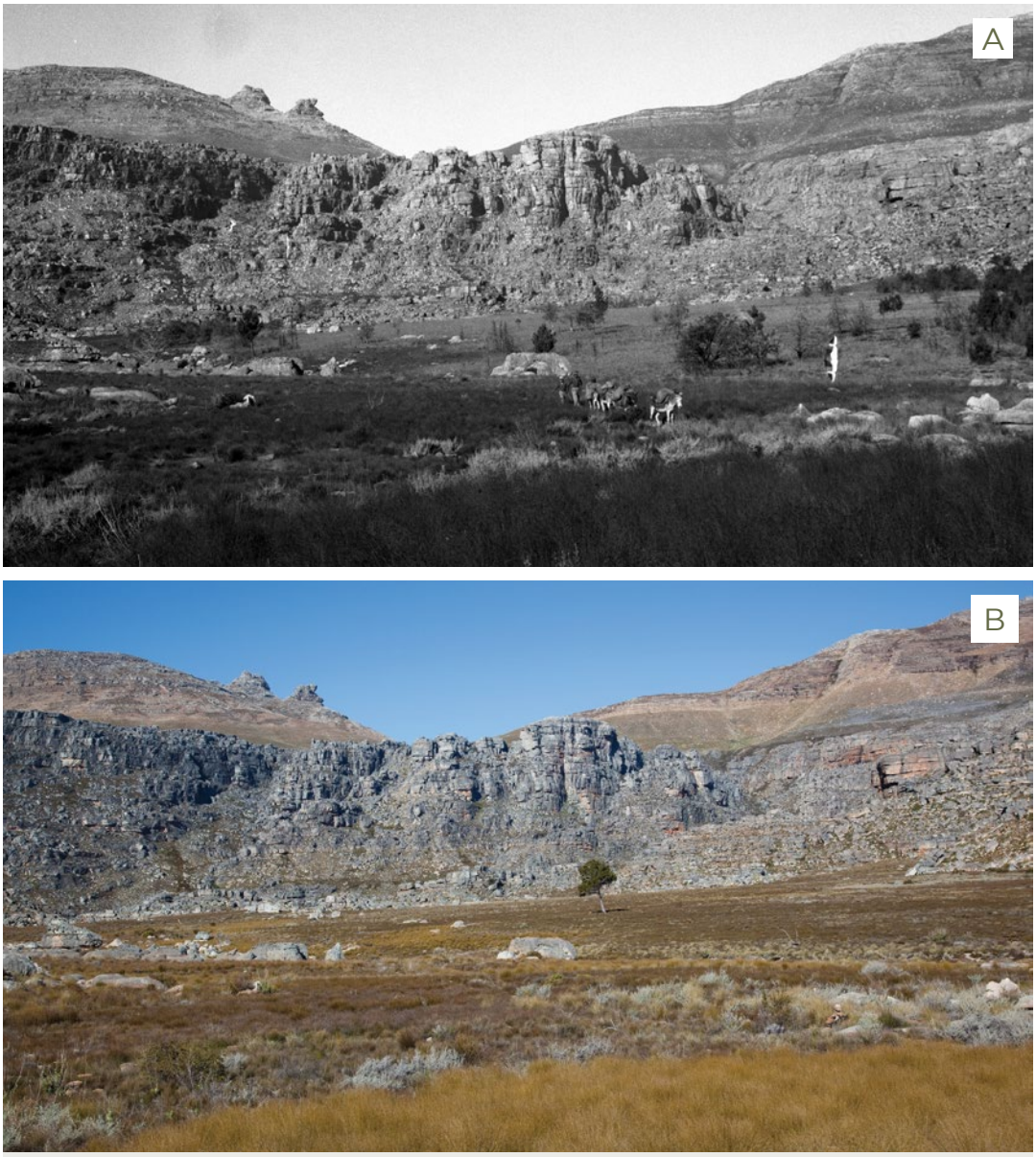



**Figure 100.** A, Grootland plantation in April 1951, with a few scattered trees left (photographed by Howes-Howell, reproduced with permission from Tim Hoffman); B, repeat image of the Grootland plantation photographed by Puttick and Jack in 2012. Only one tree was left and it still persists (though much bigger) in 2024. This is consistent with the hypothesis that sand plains cannot support dense stands of trees, so only widely spaced trees survived. With permission from Tim Hoffman.

# Fire management

## Central importance

From very early on, fire was seen as the major enemy of cedars and McNaughton, in his report on the Cederberg forests from February 1891, wrote: 'The danger is not overworking – but fire. Many matured and numbers of young trees are almost annually destroyed by the serious wildfires which occur in these mountains' (McNaughton 1891). This theme has been harped on consistently over the years and persistently it is noted that there are too many fires. The converse was also commented on several times: when, for many years, there had been no fire, regeneration of the cedars was very good. However, it was not clear whether this was in the plantations or in natural stands. Controlling fire is still one of the most difficult and complex tasks of the managers of the Cederberg.

The fire management policy for the Cederberg in general, and for the cedars in particular, has changed several times in the last 150 years (Table 12), although it can be simplified to four regimes: total fire suppression (1876–1973), controlled pre-emptive fire (1972–1986), suppressing only fires with unnatural origins (1987–2001) and suppressing fires in sensitive vegetation (2002 onwards). These changes in policy in the last century are frustrating, as the time to a mature tree is minimally 50 years, which means that oftentimes the policy was changed again before it was possible to see whether the previous policy had successfully led to establishment of a new cohort of mature, reproducing, somewhat fire-resistant trees. Fire policy probably responds more to public perception (dominant beliefs or paradigms) and finances (what sort of fire management can be afforded) than scientific information.

## Fire suppression

The initial approach to fire in the Cederberg was to limit, or even better, prevent it altogether. Fire suppression in the Cederberg dates back to 1876 with prohibitions on fire; specific fire bans; the construction of firebreaks, bridle paths and lookout houses; and establishing a team of fire fighters. Thus, fire suppression includes both the prevention of ignition (fire bans) and limiting the extent of the fire (firebreaks).

Fire occurs when three critical variables are met:

1. There is sufficient biomass to carry fire.
2. A hot and dry climate that dries out the vegetation and makes it more flammable.
3. Ignition.

**Table 12.** Timeline of fire management policy for the Cederberg

| Dates | Management policy | Simplified |
|---|---|---|
| 1876–1937 | Areas with cedars with complete fire protection; areas for buchu and rooibos collection burnt on 3-year cycles | No fires |
| 1937–1956 | Complete fire protection for the whole area | |
| 1956–1958 | Areas with cedars burnt on 4-year cycle, everywhere else complete protection [This was apparently not implemented] | |
| 1958–1972 | Complete protection for the whole area | |
| 1972–1986 | Block burns with 12-year cycle for whole area | Control fires |
| 1986–2001 | Fires with natural origin allowed to burn | Natural fires allowed |
| 2002– | Dynamic management, fires threatening sensitive plants or vegetation controlled | Dynamic control |

It is a bit simplistic to separate these variables, as they obviously interact: the spark from a rockfall is more likely to touch vegetation when the latter is dense, and more likely to ignite it if it is hot and dry. Nonetheless, it does simplify matters to discuss them separately.

It is usually stated that in the fynbos four years are sufficient to accumulate enough biomass to carry a fire. Indeed, fires in fynbos less than four years are rare and often stop fairly soon when they burn into such 'young' vegetation (Brown et al. 1991). This general rule is simplistic, as the vegetation grows slower at higher and colder elevations, and also on the drier inland slopes of the mountains, suggesting that these areas may need more years before there is sufficient biomass to carry a fire. The zone where cedars grow receives generally good rain and is below the alpine zone, so most likely has a high growth rate. Most likely there is sufficient biomass from four years after fire to carry the next fire. Vegetation growth increases with rainfall, especially summer rainfall, so shifts in the seasonality and amount of rainfall could impact the fire frequency.

There have been many anecdotal comments of large and out-of-control fires being associated with hot and dry conditions. That this is so was demonstrated by a careful analysis of climate and fire occurrence across the whole fynbos region for the two decades, from 1980 to 2000, using fire data assembled for CapeNature by Helen de Klerk (Wilson et al. 2010). This

showed that excessively hot seasons had more fires than usual and that these usually occurred in the hottest week of the season. Another strong influence was the annual rainfall, thus: hot, dry conditions. This confirmed statistically what had always been suspected. What was not known was that the Antarctic Ocean Oscillation (AOO) also impacts fire probability. This describes the equatorial boundary of the circum-Antarctic west wind (same as the southern horse latitude, see Chapter 7) – when this boundary shifts towards the equator, the AOO is in a negative phase, causing more moisture and cool air to reach the Cape, thereby reducing fire probability. When the AOO is in a positive phase, the west wind belt contracts towards Antarctica, the Cape becomes hotter and drier with more southeasterly trade winds and fire probability increases. These very hot conditions are expected to increase with global climate change.

The last limiting factor is ignition. Natural ignition has been observed from lighting strikes and rockfalls. Ignition by humans has increased through time. A proportion of these are deliberate. Until c. 1900 at least some ignition was to improve grazing. The story is that shepherds would ignite fires when the first winter northwesterly winds started blowing, the fire would burn a few hours and would then be rained out when the cold front arrived. Biologically, this timing would be perfect. The Department of Forestry tried to remove this source of ignition by a complete prohibition of grazing in the reserve in 1891. This prohibition met with much resistance and, consequently, was soon lifted with the stipulation that any fires would result in the loss of the grazing permit. It was only reinstated in 1937. However, most human ignitions are likely to be accidental. In the 19th century the blame was usually put on honey-collectors, who were said not to extinguish their fires. Now many accidental ignitions are by tourists. Many of these were the result of ignorance, for example, burning of toilet paper or not adequately extinguishing camp fires. Fire prevention approaches attempt to limit these human ignitions.

The second approach was to limit the extent of the fires with a system of firebreaks. These were developed in association with the plantations (Figure 97), and from 1900 all areas where cedars grew had complete fire protection (Andrag 1977). To access the mountains to work on firebreaks and fight fires, bridle paths, jeep tracks and huts were built. An extensive network of firebreaks was maintained. According to Sakkie Ockhuis from Kleinvlei (interviewed in October 2001 by Adolphe Linder), they (himself, some other workers and the forester Pistorius) burnt the firebreaks 200 m wide, all along the top of the mountains and then at right angles, dividing the whole mountain area into blocks. They would spend a week, sometimes two weeks, at a time on the mountain, Pistorius staying with them all the time, and on occasion Van Rooyen (the chief forester, based at Algeria) would join them. When they stayed longer than a week, a man would be sent down on Saturday to bring bread for

the next week. They cooked dried peas, dried beans or whatever was available, using empty tins (billy cans) instead of cooking pots. The burning of the firebreaks was generally done in April and May.

Eight huts were built in the Cederberg to be used as bases when the forestry staff was working in the mountains. The huts were situated at Middelberg, Crystal Pool, Heuningvlei, Boontjieskloof, Sneeuberg, Sleeppad (Figure 101) and Sneeukop (Table 13). All the huts have two rooms with a fireplace in each room, except the two huts at Middelberg, which were single-roomed with a fireplace (Andrag 1977). The fireplaces are now closed up, as open fires are completely prohibited in the Cederberg.

The annual foresters' reports also commented on the occurrence of fires. It appears as if this system of firebreaks did indeed reduce the fire frequency and, at least for a few decades, succeeded in protecting the cedar plantations. This is corroborated by the extensive fire in 1902, which was the biggest fire in a decade, burning for three days. The extent of the fire was blamed on the inability to maintain the firebreaks in the previous years due to the Anglo-Boer



**Figure 101.** Sleeppad Hut, on the shale band below Sneeukop, with a view down to Clanwilliam.

war when, for a year, the Cederberg was on the frontier between the British Empire and the Boer forces (Hutchins 1903). Until 1937 areas where rooibos and buchu were harvested were burnt on a three-year rotation, but from 1937 this was changed and the whole area was completely protected. This required a large staff and in 1954 there was a forester stationed at Algeria and foremen at Algeria, Uitkyk, Welbedacht and Heuningvlei, in addition to 18

**Table 13.** Construction of infrastructure in the Cederberg

| Infrastructure | Date completed | Builders and notes |
|---|---|---|
| Middelberg Huts | 1905 | Mathys Willemse and an unknown resident from Heuningvlei |
| Crystal Pool Hut | 1905 | ? |
| Boontjieskloof Hut | ? | ? |
| Sneeukop Hut | ? | Johannes Salomo and either Dawid Hendriks or Klaas Salomo |
| Sneeuberg Hut | 1937/1938 | Now demolished. It had a stunning view of Tafelberg. |
| Sleeppad Hut | ? | Johannes Salomo and either Dawid Hendriks or Klaas Salomo |
| Heuningvlei House | ? | The window frames, window sills, lintel and door frame were made of cedar |
| Bridle path Algeria–Middelberg | 1899 | |
| Bridle path Middelberg–Heuningvlei | 1903 | £40 00.00 |
| Bridle path Gabriël's Pass | ? | |
| Bridle path Langkloof (Welbedacht to Langkloof) | ? | |
| Bridle path Duiwelsgat | ? | |
| Jeeptrack Pakhuis to Heuningvlei | 1954 | Gysbert Nicolaas Pistorius, who was the ranger at Heuningvlei for several decades |
| Telephone line Algeria–Middelberg–Sleeppad | 1972 | To serve the fire lookout. The poles were of cedar. The line is now removed and only a few metal stays left in the ground. |

workers. This staffing frequently changed, for example in 1968 there were three foremen (Algeria, Uitkyk and Kliphuis) and 45 workers. For a while there was also a foreman at Eikeboom farm, which was initially part of Driehoek farm, first called Cederhoutskloof. The farm buildings there were later demolished, as were those at Heuningvlei and Welbedacht.

The complete protection programme was not totally effective and extensive areas of the Cederberg were still burnt by wildfires (Brown et al. 1991). Lückhoff (1971) noted that there was no effective counter to the wildfires that swept through the mountains, with particularly widespread fires in 1927 and 1959. These fires extensively damaged the remaining cedar stands (Lückhoff 1971). Rudolf Andrag (1977) consequently came to the conclusion that the reason for the decline in the cedars were the occasional, very hot, extensive fires, which result from a massive accumulation of flammable biomass if fire is kept out of the system for too many years. Consequently, the idea started spreading that precisely the total fire protection programme was the cause of the decline of the cedars, because these resulted in such very hot fires.

## Using fire to control fire

Fire management critically uses fire to control fires, thus controlled burning before an out-of-control wildfire starts. This was first proposed by Wicht[49] (1945), with the basic idea of keeping the flammable biomass low with control burns, thus preventing the vegetation from becoming old and dense. For managers the idea was attractive, but at the time popular sentiment was very opposed to deliberate fire – many botanists saw fire as something that destroyed the vegetation and did not appreciate that fynbos needs fire (Pooley 2012, 2014). The Department of Forestry formulated a policy of managing fynbos by prescribed burning in 1948 but did not implement this due to a vocal anti-fire lobby. Among foresters and ecologists the idea to manage fire in fynbos with controlled burning gained support. Finally, in 1968, the Department of Forestry changed their policy to control burns. The original proposal stimulated much research into fynbos growth rates, phenology and the impact of fire. This led to rapid advances in understanding fynbos biology. It was revealed that many fynbos species reproduce only after fire, that the best fire season is late summer (when the seed is released into an ashbed and immediately germinates with the first winter rains), and that many fynbos species start producing an adequate number of seed some 10 years after fire. This led to the postulate that the vegetation should be burnt on a 15–20-year cycle, with no fires in winter between May and October. To achieve this, the mountains were divided into blocks

[49]Christian L. Wicht was Professor of Forestry at the University of Stellenbosch from 1950 to 1974 and trained a whole new cohort of forestry researchers and managers who followed the concept of fighting fire with fire, and who so developed programmes of pre-emptive block burning.

and burnt in sequence, so that the vegetation was a mosaic of old and young vegetation. This should prevent massive wildfires and keep the fire intensities low (Brown et al. 1991).

The system of controlled fires was implemented in the Cederberg in 1972. The mountains were divided into compartments of about 900 ha and each block was to be burned under control. Consequently, there should be no natural ignition and all fires should be controllable. However, the block-burn system turned out to be impractical. There were simply not enough safe days for burning: biologically safe, i.e., late summer when germination is stimulated almost immediately with the onset of the winter rains; and fire safe, when it was cool and moist enough that the fire would not burn out of control. Although, theoretically, no burns should be set during the winter months, from May to October, as winter fires had been shown to result in very poor post-fire regeneration, almost all prescribed burns were during this period (Brown et al. 1991). Besides, the costs of firebreaks and the skills required were both high. The result was that simply not enough blocks could be burnt to maintain the 12-year rotation that the policy required. When CapeNature took over the management of the Cederberg in 1986 with a reduced budget, and without many of the highly skilled forestry staff, the control burn system was abandoned. This is disappointing: for once a science-based fire management system had been designed and implemented, then abandoned for political reasons. The South African political establishment prioritised defending the apartheid system, rather than looking after their beautiful natural heritage.

There were also several biological problems with the block-burn system. The block-burn system was predicated on the assumption that the extent and intensity of fires were related to the biomass accumulated. Brown et al. (1991) analysed the success and failures of the method in the Cederberg, and concluded that the fire frequency and extent may be more regulated by the climatic conditions (length of preceding drought, air humidity, daily temperature) than the age of the vegetation. The importance of the climate was subsequently corroborated by the fynbos-wide study by Wilson et al. (2010). The issue of the relative importance of these two parameters has still not been experimentally evaluated. Secondly, it was built on the notion that the shortest possible fire cycle should be used (to keep biomass low), rather than the longest possible fire cycle, thereby increasing the risk that species that needed more time to regenerate (like the cedars) would be removed from the system.

The Department of Forestry was in charge of managing the mountain catchments until 1986. At the same time, they also maintained commercial plantations. In the Cederberg these were two small plantations on both sides of Algeria. Because commercial plantations required protection against wildfires, this meant that Department of Forestry could maintain a single fire-management team for both the fynbos and protecting the plantations. In this way, the plantations cross-subsidised the fynbos management.

## CapeNature fire policy

When Cape Nature Conservation (now CapeNature) took over the management of the Cederberg Wilderness Area, they changed the fire policy from that adopted by Department of Forestry. Simplistically, fires with natural causes were left to burn out, unless they threatened people or infrastructure. Fires with human causes were extinguished. There was no block burning and no extensive firebreaks. The largest fire that the Cederberg ever experienced occurred in the first year of this policy.

In the early years of the 21st century the fire policy was changed. Rather than all natural ignition fires being allowed to burn out, fires that threatened vegetation that was still too young, or fire sensitive, were extinguished. This takes into account the age of the vegetation and other factors that might be important in protecting the vegetation and flora. This includes special features such as regenerating stands of cedars or fire-sensitive vegetation. This is a much more nuanced fire policy, which allows a sensitive management of fires to minimise the impact. It requires annual assessment of the fire sensitivity of the vegetation and biota, therefore, its success is dependent on careful management. It is without doubt, at least from the point of view of the cedars, a much better policy than the preceding one.

At the same time the tools available for fighting fires changed. Until 1980, fires were contained with firebreaks and teams of fire fighters who were locally based. From the 1980s water-bombing from helicopters and regionally centralised fire teams were used much more extensively. These replaced firebreaks and local teams of fire fighters. The latter two are still used effectively by the farmers in the Cederberg.

# How well did these four policies work?

Despite all these efforts, fire has remained the major driver of loss of trees in the last decades (White et al. 2016). This is remarkably similar to the conclusion reached by McNaughton in 1892. Despite a massive experimentation with firebreaks and the use of helicopters; despite experimenting with regulation and with block burns; and despite extensive research, fires still constitute the major threat to the survival of the Clanwilliam cedar and there is no clear solution to this problem. Indeed, there are several indications that fires have become more devastating. The most obvious indication is that the damage to cedars and cedar plantations has become worse. Plantations that survived for a hundred years were destroyed in the last thirty years. In addition, trees among rocks that have survived for centuries have been killed. Fires may also have become more extensive: a fire that was started by lightning

on 26 December 1988 in Duiwelsgat raged for days across the Cederberg, destroying farm properties and 50 000 hectares of fynbos, including most of the cedars in the area.

However, the total area burnt each year varies enormously, obscuring trends in fire frequency and readily leading to incorrect ad hoc interpretations. A long-term, data-based analysis is essential for robust interpretation of changes in fire frequencies. Important for any stand of cedars are both fire intensity and the fire return period (i.e., how long between fires). Both are difficult to measure. Fire intensity can vary within a fire, depending on local wind, slope, air temperatures and accumulation of fuel. The fire return period is best measured by observing a particular stand over decades and recording each time a fire passes through it – obviously, an impossible task. It is easier to document the area burnt but very few fires burn everything within their perimeter and often small islands of unburnt vegetation are left (Figure 102).

CapeNature has mapped all fires in the Cederberg since 1944 and these data are publicly available (See: CapeNature Fires - All 2019\20 [Vector] 2020, available from the Biodiversity GIS at https://metadata.sanbi.org/srv/api/records/a75df690-91bd-4032-a732-8e53d691b26c, downloaded on 11 May 2021). These data were used to obtain a measure of how fires have changed since 1944 (Figure 103). The area estimates per fire to the area within



**Figure 102.** Stand of trees, with good regeneration, on a fire refuge near Vogelsang. All regeneration is in such fire refuges, some living trees are in more exposed habitats.

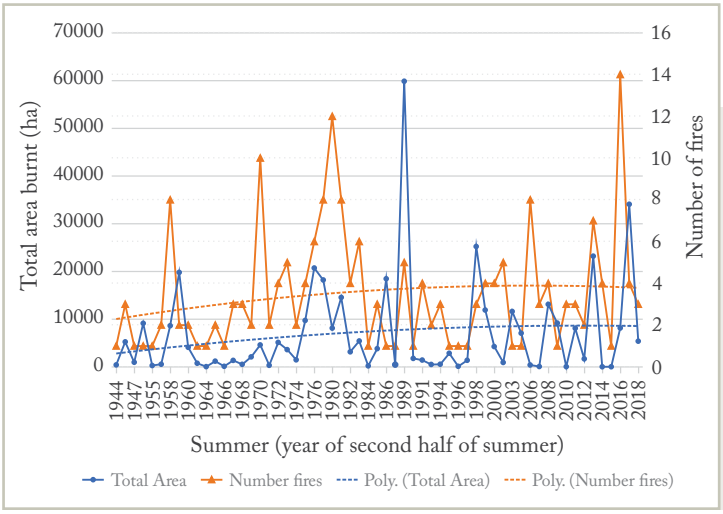



**Figure 103.** The total area burnt, and the number of fires, annually from 1944 to 2020, with the exception fire of 1988. Note massive interannual fluctuation, and that the number and extent of fires do not co-vary. To obtain trends 2-order trend lines were fitted. This is based on data from CapeNature.

the reserve was not limited – so the total area burnt in some fires is bigger than if limited to the reserve. The rationale is that we want to make the data comparable over the whole period: it thus means that the same spatial limitation is used and changes to the reserve area could modify this. Secondly, the years were changed so that they are from August to July, not January to December. This is to keep the whole summer fire season together in one year. The total area burnt each year was used as an estimate of the fire return time. A moving average was obtained by fitting a second-order polynomial line to the data. This shows that during the second half of the 20th century the average area that burnt annually more than quadrupled, from 2 000 ha to 8 000 ha annually. This implies that fire return times at the end of the century were a quarter of what they were in 1945: if they were 40 years in 1945, then they were 10 years in 2000. Interestingly, in the last two decades the average number of fires, and the extent burnt, has stabilised. Possibly the more nuanced fire policy of CapeNature is showing positive results.

Why have fires become more extensive and more frequent? There are several possible reasons: increase in ignitions, changes in fire management, climate change and vegetation change. To explore the possible impacts of these, the two CapeNature policies were grouped and the interaction graphically explored in Figure 104.

Possible impacts of variables illustrated in Figure 104:

1. An increase in ignitions. The massive increase in block burns, deliberately started by the managers in the period from 1974 to 1987, is very evident. Because of this we cannot

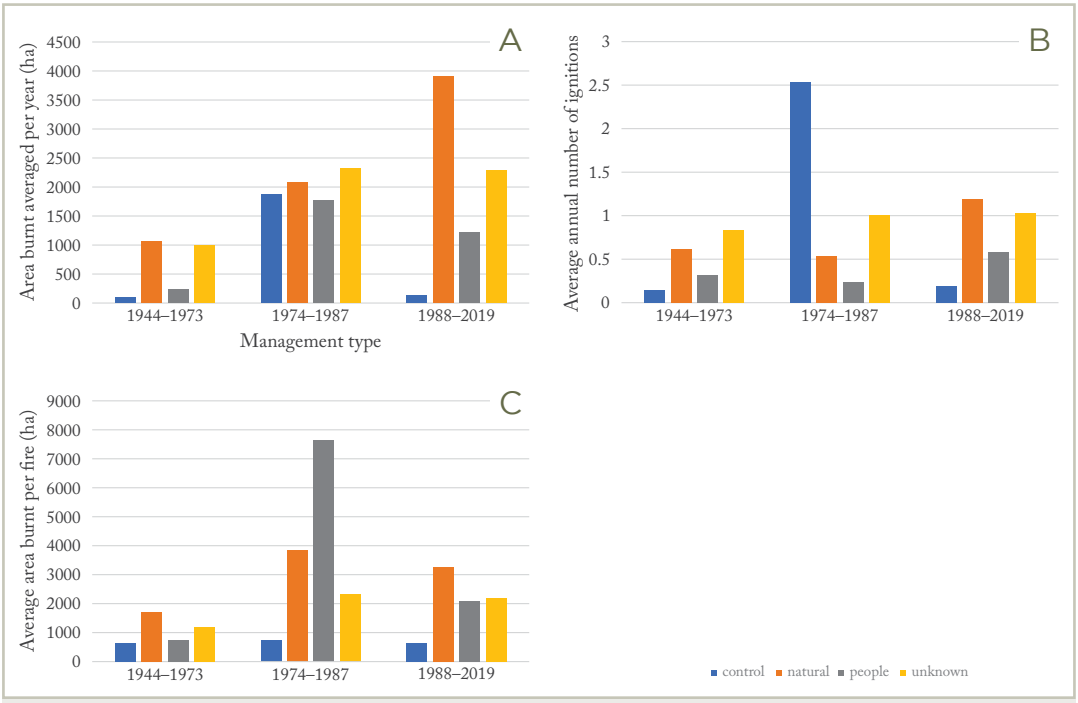



**Figure 104.** Comparison of fires for the three management periods: 1944–1973: no fires; 1974–1986: block burns; 1987–2020: natural fires. The ignition type is colour coded. These graphs are based on data from CapeNature. See: CapeNature Fires - All 2019/20 [Vector] 2020, available from the Biodiversity GIS at https://metadata.sanbi.org/srv/api/records/a75df690-91bd-4032-a732-8e53d691b26c, downloaded on 11 May 2021.

simply compare the total number of fires/ignitions across the whole period, but have to decompose these into the causes of the ignitions. There was a doubling in accidental human ignitions after 1987, in part due to people deliberately or accidentally setting fire. Although people have been in the Cederberg for thousands of years, there have been dramatic shifts in what people do in the Cederberg (see Chapter 5): from primarily foragers until 1750, agro-pastoralism from 1750 to 1960, and tourists from 1960 onwards. This suggests that the increase of accidental ignition is the result of more tourists. The doubling in natural ignitions after 1988 is intriguing as the number of lightning strikes or rockfalls should remain constant – unless climate change is leading to an increase in summer lightning storms. However, we count the number of ignitions, and this requires not only a spark but also flammable vegetation, so maybe the doubling in natural ignitions in the last three decades is due to climate change causing the vegetation to be more flammable. If so, then this is a dramatic indication of the impact of climate change.

2. Fire management may have become less effective, resulting in much more extensive fires. This is abundantly illustrated in Figure 104: the areas burnt per fire more than doubled after the complete control was abandoned in 1974, irrespective of whether by natural, human or unknown ignitions. Through much of the last century the Cederberg was divided by firebreaks, which were regularly maintained, and there was an experienced local staff available to fight fires. Forestry reports from 1890 to 1950 frequently comment on how effectively they have been able to contain fires. However, occasional massive fires managed to sweep across the whole of the Cederberg (e.g., in 1948, 1959, 1975, 1980) despite the firebreaks. Although there were frequent comments about the damage caused to the cedars, all three current sources (White's photosurvey, Slingsby's aerial survey and our own field observations) indicate that fires have become more devastating after the firebreak system was abandoned.

3. Climate change has resulted in more hot, dry weather events. Due to the absence of temperature data from the Cederberg the correlation between heatwaves, natural ignitions and extent of fires cannot be statistically tested, but it seems likely to account for the increased ignitions after 1988 and may also account for the increased extent of the fires. Throughout the last century it appears that out-of-control wildfires are the result of hot, dry climate conditions, rather than solely due to a massive biomass accumulation. Furthermore, if hot, dry summers alternated with years conducive to fast plant growth (high rainfall years), this could result in both a rapid accumulation of flammable biomass and flammable conditions. That this might be the case is shown by the increase in the variance in annual rainfall (see Chapter 7, Anthropocene).

4. There may have been a shift in the vegetation from restios to fine-leaved shrubs such as *slangbos* (*Seriphium plumosum*). These shrubs are more flammable, burn hotter and tend to be more common among rocks. This could result in the greater number of ignitions observed, and also facilitate fire penetrating among the boulders protecting the cedars. Such a shift was suggested by Mike Viviers (pers. comm., 6 July 2021), who thought that this was a result of winter fires. The shift from summer to winter fires was in order to have controlled fires for the block burns. Fires ignited in winter are easier to control. In the 1990s winter burns were also used by CapeNature to protect remaining cedar stands in the cedar reserve. However, there are no published data to support this contention.

These data can be interpreted to indicate that the old firebreak system and no-fire policy was the best. However, we have several interacting variables (fire policy, climate change, human use) and not enough data to statistically disentangle the impact of these variables. Surprisingly, the block-burn system performed rather poorly and if it did result in a shift in the

vegetation to more fine-leaved shrubs, then it was downright disastrous. This is reinforced by the massive fire of 1988–1989, which swept through the Cederberg just when the block-burn system was abandoned and when there should still have been extensive areas of young vegetation (but potentially with more fine-leaved shrubs). Interestingly, that was followed by almost a decade without fire. The current fire policy appears to perform better than the block-burn system, but worse than the original no-fire policy.

## Cedar reserve and volunteers

In 1987 a new policy was implemented by the conservation officer at Algeria, S.W. van der Merwe: the establishment of a 'Cedar Reserve' in the middle of the CWA, which had the primary aim of preventing the cedars from going extinct. The Cedar Reserve was 5 252 ha in size, comprising 21% of the current distribution area of the cedars, and was situated in the wild rocky country between Welbedacht and the shale band, and from the Sleeppad Hut to De Rif (Mustart 1993; Van der Merwe & Wessels 1993).

The reason for the Cedar Reserve was that the CWA, as a whole, was managed primarily to retain the wilderness experience for visitors and not to conserve the cedars. The conservation of single species (in this case the Clanwilliam cedar) was contentious, as it was argued that it diverted resources from other species. In fynbos, this becomes even more contentious when the single species is believed to have an unusual fire biology, as managing for that species may be to the direct detriment of other species. Donaldson (1993) argued that single-species conservation is appropriate when:

1. The species can be used as a flagship for conservation in general.

2. It will reveal patterns of decline common to other species.

3. It will reveal biological patterns common to other species.

4. It is economically and phylogenetically interesting.

The Clanwilliam cedar clearly ticks boxes 1 and 4, and maybe 2 and 3. It is to be hoped that other fynbos species do not follow the same pattern of decline shown by the Clanwilliam cedar (thus Category 2), but it is quite possible, as we have little data on population sizes in other locally restricted species. Some biological patterns of the cedars do seem to be quite different (seedlings growing better in shade, long life expectancy) but others are the same (serotiny, enhanced germination after fire). As for the last category, being economically and phylogenetically interesting, it is very clearly ticked.

The Cedar Reserve had a different fire policy from the rest of the CWA: burning was aimed at protecting trees more than 15 years old by very regular, short-frequency (4–6 years), cool, late-autumn or winter burns under the trees to remove flammable fynbos, to allow the trees to survive wildfires (however, see comments under 'How well did these four policies work?' about the invasion of *slangbos* under this fire regime). These fires should result in patchy burns, thus reducing the risk of widespread fires. At the same time, winter burns do not result in good seed germination, so saplings were planted in to increase the population sizes. These may be important to increase population sizes, and so seed production, to eventually facilitate effective post-fire recruitment. Seeds were germinated in a nursery at Welbedacht and planted out. Some 8 000 saplings were planted out annually. Initially, these plantings were very successful: one-year-old seedlings had a 39% survival rate and three-year-old seedlings had a 61% survival rate (Mustart et al. 1995). Seedlings planted in somewhat shady habitats (mostly next to rocks) had a better survival rate than seedlings in full sun. One could argue that this was implementing the recommendations from the Veeteelt Commissie of 1805!

Penny Mustart organised a meeting at Algeria in 1993 of all people who had been working on the Clanwilliam cedar, under the auspices of the Flora Conservation Committee of the Botanical Society of South Africa. After the meeting, in 1994, the Cederberg Interest Group was established which helped CapeNature with the annual planting of cedars (volunteer work). In 2000 the nursery at Welbedacht needed maintenance and CapeNature did not have funding available[50]. A grant was obtained from the United Kingdom-based Fauna and Flora International and a new nursery was developed at Matjiesrivier. However, the climate there was unsuitable, so the nursery of Bushmans Kloof Conservation Trust agreed to help[51]. This led to the Elizabethfontein school having a cedar planting day at Heuningvlei, sponsored by Bushmans Kloof. Sadly, this young grove was destroyed by a wildfire.

Planting continued annually from 1987, each year in a different site, between De Rif to the south and Uilspiek to the north. Most years one-year-old seedlings were planted out and most years several thousand (but not 8 000) seedlings were planted. The survival rates and growth rates were measured in 1994 and 1998 – theoretically each year fixed plots with numbered trees should have been established to monitor growth, but this was done rather sporadically. The plots were monitored at the beginning of 1998 by Shona Young (1998) and the results were very impressive. Survival rates were very variable, from 20% to 100%. Some of the low survival rates were in plots that had experienced fire, some of the high survival rates were in plots first enumerated several years after planting. The plots with high survival

[50]It is tempting to suggest that CapeNature had other priorities, as they surely had money.
[51]Where the climate is also less than suitable for the cedars.

rates were on the south side of rocks (i.e., shaded), in areas with boulders (i.e., with more water input) and on slopes (i.e., not on well-drained, sunny summits). From the additional notes, as well as the percentage survival, it is clear that by 1998 the project was working very well.

The Cedar Reserve was an excellent idea. Conceptually, the plan is good. It was discussed with all researchers involved and garnered broad support. It was expanded with citizen science involvement, thus accessing a broad support base. This also built on the charismatic species justification. There is no biological reason why it should not have been continued. At least some of the trees are still growing (Figure 105). It is sensible, before any new programmes are started, to evaluate the success of this cedar planting programme and to use this to determine the best way to continue it. At least some saplings planted by CapeNature as part of the Cedar Reserve project are numbered (Figure 106) and georeferenced. It will be possible to check each one and get a quantification of the survival rate more than 25 years later. This means that the survival in different habitats can be critically evaluated and provide a quantified foundation for future planting attempts.



**Figure 105.** Cedar pole on the slopes above Welbedacht Farm planted in the Cedar Reserve through its planting programme. This is part of a cluster of some eight pole trees, see Figure 106 for the associated tag.




**Figure 106.** Tag associated with the planted pole figured in Figure 105.

## Current volunteer work

Currently, volunteer work on cedars does not seem to be coordinated, so it is difficult

to obtain an overview. The AirSeed Project is developing a drone-based seed planting system, which uses seed encased in a ball of very carefully researched mix of clay, ash and nutrients (Figure 107). These balls improve germination and establishment of the seedlings and, with the use of drones, the seed can be placed very precisely into suitable habitats among rocks, which are generally difficult to access by humans. Each planting is also automatically geo-referenced, making it easier to subsequently check on the success of the plantings. A second project involves a group of people with Helen Moss who have been protecting and monitoring the regeneration in the De Rif plantation after the fire of 2016 (Figure 108). In 2023, the Sustainable Ceder NPO was founded to organise



**Figure 107.** Seed ball containing one seed encased in mud and nutrients.




**Figure 108.** Sign at De Rif explaining why parts are closed off. This stand is shown pre-fire in Figure 83.



**Figure 109.** Damien Schuman planting a cedar seedling. Photograph: Dawie Burger.

germination of seedlings and planting programmes (Figure 109). Since 2023, Dawie Burger at Driehoek has organised annual meetings of all volunteer groups in the Cederberg, which should result in more coordination among them.

A critical analysis of the interventions of volunteer groups since the Cederberg Action Group and the Cedar Reserve will be most useful. It would be useful to know what has been successful and what not. This should be used in future to guide volunteer activities.





# 9 The future of the cedar

## Predicting the future

Predicting the future is a tricky business and, all too often, the future proves predictions wrong. Yet, we base many of our decisions and actions in the present on an expectation of what the future will bring. Consequently, it is important to make predictions.

We have two tools for predicting the future. The simplest one is based on past experience. The sun has always risen in the morning, so it will rise again tomorrow morning. Or all swans that I have seen have been white, so the next swan I will see will also be white. We carefully record what we know of the past and assume that the future will continue this pattern. Logicians call this the inductive method. This method is patently flawed: in Antarctica the sun does not appear for several months and in Australia the swans are black. However, we can simply add these exceptions to the rule: the sun rises every morning outside the polar circles and all swans outside Australia are white. Induction tends to over-simplify the world and so can lead to wrong conclusions.

The second approach is mechanistic: we build a model of how something works and, when the conditions of this model are fulfilled, it happens. This mechanistic approach is based on the mechanisms and not on the experience. Consequently, it can also predict things which have never happened before.

Logicians call this the deductive method: given a set of conditions and a knowledge of the mechanisms, we predict what will happen. This approach depends on a thorough understanding of the system within which we work: we need to know a lot about how something works before we can build an adequate mechanistic model.

## Inductive predictions

The number of cedars in the Cederberg has been drastically reduced since the first descriptions from the beginning of the 19th century to now, as has been documented in Chapter 2. Although it seems likely that by 1800 there was no 'cedar forest', but rather numerous stands, there is no doubt that the number of mature trees in the stands, and the number of stands, have both been massively reduced since then. Anecdotal descriptions suggest a first stage of decay until 1880, and then a second dramatic decay since 1980. There seems to be little evidence as to what happened between 1880 and c. 1950. Clearly, if the trend since 1980 continues, the cedars will soon be extinct in the wild. No doubt, a few isolated trees growing in particularly well-protected habitats among rocks may persist for decades if not centuries but they may not constitute viable populations: they may be the living dead.

In 1876 three measures were introduced to halt the loss of the cedars. The one was a ban on felling living trees and was effectively translated (except for 8 000 pole trees). The second was an attempt to stop frequent fires. Although we have no data, it is possible that this was increasingly effective for the next century, until 1974. The third was to remove grazing by domestic stock. This may well have been effective. Unfortunately, we have no data on how the cedar stands changed from 1880 to about 1960. It is possible that during this period the natural stands did regenerate. From 1974 onwards the fire frequency increased almost four-fold, and the cedar populations started crashing. It is not clear why the fire frequency increased that much. One possible explanation is that global climate change is resulting in more long, hot spells, thus increasing flammability of the vegetation and decreasing the likelihood of fires being controlled. A second possible explanation is that the abandonment of firebreaks and the demolition of local fire-fighting teams has reduced the efficacy of fire control. A third possibility is that the abandonment of controlled block burns may have resulted in more fires. All three variables may also be operating and mutually reinforce each other. Extensive sowing of seed and planting of cedars had no impact on this sad regress in the populations.

The inductive logic shows a bleak picture: based on this, the species is on the way to extinction despite all the measures taken in the last half a century to save it. This is a profoundly

depressing scenario. There seems to be little hope for the Clanwilliam cedar and that the Cederberg may need to be renamed in the future ('Nullarbor Mountains' springs to mind).

## Deductive predictions

The deductive approach gives us some more optimism, it allows us to develop a more nuanced picture, which may be used to predict under which circumstances stands may be able to survive. This means that predictions can be stand-specific, rather than apply to the species as a whole.

The demographic models constitute the best way of developing a mechanistic interpretation, and in verbal form this could look as follows:

1. Seed germination and sapling establishment: massive seed germination and sapling establishment seems to only follow fire and, between fires, only occasional seedling germination was observed. Seed germination and sapling establishment was effective until c. 1980, when the SAFRI plots still revealed high densities of saplings. It was also observed at De Rif plantation after the 2016 fire. If a self-fertilised seed is still viable, then regeneration, even under a single tree, should be possible.

2. Sapling survival through to seed-bearing age needs intervals between fires measured in decades, or the saplings have to be in fire refuges, thus in rocky places on ridges where wind or other factors may reduce flame heat. In all sites where good establishment of pole trees has been observed (Smalberg, Mied se Berg, above Cederhoutkloof and at Bosduifkrans above Algeria) it was also evident that fire had not penetrated for several decades (Figure 110). These sites also showed new seedling establishment, indicating ongoing recruitment. Cumulative, over the decades, an excellent age distribution of saplings and poles can accumulate.

3. Persistence – although this does not require complete absence of fires, fires do kill some trees (Figure 111). Research from the 1980s suggested that established trees have a higher survival probability with cool winter fires. Observations in the last two decades imply that frequent summer fires are devastating. There seems to be no doubt that the best fire regime for persistence is no fire at all. This is also the regime that is most likely to allow the mouse and baboon population to thrive, thus maximising the cached seeds in the event of a fire.

4. Climate constitutes a coarse filter – too much frost could kill the plants, too little rain slow growth rates. Climate change may be shifting many of the parameters. Although



**Figure 110.** One of the few natural stands with good regeneration on Mied se Berg.

the management of the Cederberg cannot stop climate change, it can ameliorate the consequences. Climate change most likely has already led to an increase in the maximum extreme temperatures and the duration of hot periods. It has not yet led to change in rainfall, although that is predicted to happen. Increased temperatures may lead to more frequent fires. However, we do not know whether temperature changes directly affect the cedars. There is no information on the minimum temperature tolerance, nor their maximum temperature tolerance.

It seems that a mechanistic model could predict (on current knowledge, as summarised in Chapter 3) the survival probability of each stand, given climate and fire conditions. I do not think that the Clanwilliam cedar is doomed to extinction – it seems likely that some stands will stay viable. It lies in our hand how many stands remain viable and it may take a serious effort to keep enough stands viable to ensure the survival of the species.



**Figure 111.** Persistence of old trees in a rocky refuge – but there is no regeneration.

# Management recommendations

It is not difficult to make management recommendations, especially when we look back over 200 years of human interactions with the Clanwilliam cedar. The following guidelines apply:

1. Fires: this is a simple if difficult recommendation – suppress the fires. A complete fire suppression policy does not stop fires altogether, but results in a reduction in their frequency and extent, allowing the occasional seedling cohorts to grow through to maturity. Data from the last 80 years shows unambiguously that the least fires occur under a no-fire policy. This suggests re-establishing the firebreaks and maintaining these (at least around good cedar stands), and maintaining a fire-fighting team in the Cederberg. This allows a group of people to become competent at fire-fighting in the Cederberg. No fires should be tolerated around stands that are regenerating, nor, ideally, around any stands. It should be

clear that such a policy does not totally stop fires, in the same way that a good health care service does not stop death. But it delays it as long as possible, giving us the possibility to do much with our lives and, for the cedars, the possibility that the stands can expand again.

2. The genetics of the species needs to be better investigated. This includes the spatial genetic pattern in the species (of which there is some indication [Thomas 1997] but this needs to be checked with modern methods), how many individuals are the result of selfing, and how far the pollen travels.

3. Cedar monitoring. It would be great to have, for a few stands, annual data on seedling germination, mortality, fire events, evidence of browsing damage and plant size changes. These simple demographic data could test the diverse theories on the effects of fire and climatic fluctuations. Such data need to be collected annually (because of fires and climate fluctuation) and over decades (this species is a dinosaur – nothing happens quickly). Long-term data with a fine time resolution are essential to understanding its persistence.

4. Climate data. We are in the middle of a dramatic anthropogenic global climate change and we really need to know what happens where. The absence of long-term temperature data for the Cederberg means that we do not know what the impact of the change is. By how many degrees has the extreme summer temperature at Sneeuberg Hut increased? How more likely are hot spells that last longer than three days? SAEON has established some automatic gauges but it needs more: a gauge on the top of Sneeukop and one each at Middelberg, Smalberg, Heuningvlei and Pakhuis.

5. Cedar autecological research. There are many questions on cedars for which we have no answers, or indications that things should be followed up on. These include the temperature tolerances of the species (how much frost does it tolerate and when during its growth phenological cycle is it most sensitive). What is the impact of drought? How fast does the rooting system grow, where do mature plants access their water from (this work was started by Ed February and it should be continued), how does fire kill adults, is seed production the same each year or does it fluctuate in response to climate or the pollen genetic diversity?

The two most important recommendations are possibly the most difficult:

1. Conservation of the cedars must be adequately financed. Maintaining firebreaks and maintaining a full-time team that can do such maintenance work and fight fires is costly. If the South African political establishment is not prepared to vote this money, then it should be accessed internationally. Setting up the structure to save the cedars will cost less

than the cost of a single cabinet minister and will, arguably, improve the life quality of our descendants more.

2. The top priority in the Cederberg should be conserving the cedars. Before 1876 the priority was providing building timber and the cedars were sacrificed for this aim. This culminated in the telegraph pole saga, where the ability of the government in Cape Town to communicate quickly with the authorities in Calvinia was more important than saving the cedars from extinction. Now the top priority in the Cederberg is to provide a 'wilderness experience' and the fate of the cedars is, again, given a second priority. Do we explain to our grandchildren that the Clanwilliam cedar is now extinct, because it was more important for rich Capetonians to have a 'wilderness experience' than it was to ensure that there were adequate firebreaks and other infrastructure to stop fires?

## Why protect the Clanwilliam cedar from extinction?

Conserving the Clanwilliam cedar is clearly neither trivial nor cheap. So why should we do this? By an evolutionary argument there is little importance to conserving the Clanwilliam cedar. Firstly, it is genetically scarcely divergent from, and morphologically very similar to, the Willowmore cedar (*Widdringtonia schwarzii*) and if resources are scarce then conserving either species could retain this remarkable set of evolutionary adaptations. It is an evolutionary young species and, on the principle of 'last in, first out', should not be prioritised for protection. Secondly, these two species are recently diverged (in evolutionary terms) from the widespread and not at all threatened *W. nodiflora*. If resources are really scarce, then protecting that species should keep the genetic potential. Finally, it could be argued ecologically that its survival depends on a complex interaction between climate, fire frequency, dispersal availability and seed production rates. This complex arrangement is highly vulnerable, meaning that even a major conservation effort may fail.

However, this misses the human side of the story. The Clanwilliam cedar is a beautiful tree. Early observers raved about the beauty of the wild Cederberg landscape with the spectacular cedars. A whole mountain range is called after it and it is used to symbolise this mountain range. Thereby it is worthy of protection from a sociolinguistic point of view. It also has cultural heritage value: its wood was an important resource in building the first infrastructure in the region: roofing timbers, water wheels, furniture, telegraph poles and, finally, coffins. Clanwilliam cedars are aesthetically pleasing as well as being an important part of the cultural history of a whole region. This is a typical flagship species, representing the conservation of

the Cederberg and indeed the whole Cape flora. We surely cannot let our greed for, initially timber then the 'wilderness experience', drive such a magnificent and culturally valuable species into extinction?

One may ask, what about the rest of the flora? Donaldson (1993) argued against single-species conservation. Cedars are large trees, forming stands where we can easily see seedlings, saplings, mature trees and dead trees. We can see the changes in demography as they happen. It is, in this sense, by far the most visible species in the Cape flora. How many more Cape flora species are being driven to extinction by climate change and human greed? We do not know and we are scarcely looking. Clanwilliam cedars are a loud wake-up call and an excellent species on which to observe what could happen to more cryptic species.

We should not be daunted by the magnitude of the task, but rise to the challenge and commit ourselves to the protection of this magnificent and interesting tree.

# Acknowledgements

Many people have freely shared their knowledge on, and insights into, the Clanwilliam cedar and been supportive of this project (Figure 112).

Without Ed February's help this account of the Clanwilliam cedars would have been much poorer. Ed has been working on cedars for more than 25 years – only Rudolf Andrag had seen more cedars and cedar populations than Ed has. He relocated the Andrag plots, resurveyed the SAFRI plots and gave me access to all these data. We had numerous stimulating and robust discussions about cedars, often starting with opposite ideas and usually converging on a common conclusion.




**Figure 112.** Cedar specialists at De Rif in March 2022, from left to right: Dawie Burger, Helen Moss, Ed February and Jasper Slingsby.

Dawie Burger, who farms at Driehoek and who has a deep passion for the Cederberg and the Clanwilliam cedar, helped me very much to understand the biology of cedars.

Many others contributed much to this book: Jeremy Midgley was an important sparring partner about cedar ecology and helped me focus my thoughts; Joe White explained aspects of his work on the dispersal biology of cedars that I could not understand; Brian van Wilgen shared his memories of working in SAFRI; Jasper Slingsby (then working for SAEON) organised access to the SAEON climate data and their archives; Jan Vlok, Mike Viviers and Pat Manders discussed aspects of cedar biology and management with me. Barry and Mariette Lubbe, Bertus and Rika van der Merwe, and Erwin and Alta Coetzee allowed me access to their houses to study the use of cedar timber.

Helen Moss, who has an exceptionally sharp eye for finding cedar seedlings, walked all over the Cederberg with me looking at cedars and helped me with numerous cedar plots. Importantly, she kept her good humour even when it was hot, dry and the vegetation scratchy.

CapeNature supported this project: Monique Ruthenberg facilitating access to the Cederberg, Jacques van Rooi shared his knowledge about cedars and the Cederberg and Rika du Plessis gave me the Algeria rainfall data.

This book was started by my father, Adolphe (Dolfie) Linder, in two senses. Firstly, he introduced me to the Cederberg as a child and inculcated a lifelong passion for these mountains and their flora. Secondly, he started the book by researching the historical knowledge about cedars, much of Chapters 2 and 3 was based on his notes. However, he passed away before he could write the book on the Clanwilliam cedars.

# Bibliography

ALEXANDER, J.E. 1838. *An expedition of discovery into the interior of Africa*. Henry Colburn, London.

ALLISON, T.B. 1990. Pollen production and plant density affect pollination and seed production in *Taxus canadensis*. *Ecology* 71: 516–522.

AMPHLETT, G.T. 1896. A trip to the Cedarberg. *The Cape Illustrated Magazine* 7: 64–78.

ANDRAG, R.H. 1977. Studies in die Sederberge oor (i) Die status van die Clanwilliam seder *Widdringtonia cedarbergensis* Marsh; (ii) Buitelugontspanning. M.Sc. thesis, University of Stellenbosch, Stellenbosch.

ANONYMOUS. 1855. *Berichte der Rheinischen Missionsgesellschaft*. 1855: 149.

ANONYMOUS. 1877. Report on the Condition of Crown Forests and Drift Sands for 1876. *Inventory of the Cape Colony Publications 1800–1910*: 1/2/1/33 G.56 1877.

ANONYMOUS. 1968. *Forestry Report for Year Ending 31.3.1967*. Annexure Session 1968 Vol III, R.P. 37-1968, Cape Town, SRP 1/2/277. 77.

BACKHOUSE, J. 1844. *A narrative of a visit to the Mauritius and South Africa*. Hamilton, Adams and Co., London.

BALLANTYNE, F. 2010. Palaeoecology and vegetation dynamics in the Cederberg wilderness area. M.Sc. thesis, University of Cape Town, Cape Town.

BARROW, J. 1801. An account of travels into the interior of southern Africa in the years 1797 and 1798. Cadell & Davies, London.

BILBE, M. 1999. Wupperthal: listening to the past. M.A. thesis, University of Cape Town, Cape Town.

BOND, W.J. 1993. *Widdringtonia* – an ecological paradox. Proceedings of the workshop: the Clanwilliam cedar: what is being done? Cape Town.

BOTHA, S.A. 1989. Effect of sowing season and granivory on the establishment of the Clanwillam cedar. *South African Journal for Wildllife Research* 19: 112–117.

BOTHA, S.A. 1990. Seed-bank dynamics in the Clanwilliam cedar (*Widdringtonia cedarbergensis*) and the implications of beetle-triggered seed release for the survival of the species. *South African Journal of Ecology* 1: 53–59.

BROWN, P.J., MANDERS, P.T., BANDS, D.P., KRUGER, F.J. & ANDRAG, R.H. 1991. Prescribed burning as a conservation management practice: a case study from the Cederberg Mountains, Cape Province, South Africa. *Biological Conservation* 56: 133–150.

BUDLER, J.F. 1880. *Clanwilliam, in Report on Crown Forests and Plantations of the Colony, for the year 1879*. Annexures to the Votes and Procedures of the House of Assembly, Cape Town.

BUDLER, J.F. 1900. *Inventory of the Cape Colony Publications 1800–1910*: 1/2/1/111 G.24-1900.

BUDLER, J.F. 1901. *Inventory of the Cape Colony Publications 1800–1910*: 1/2/1/111 G.24-1900.

BUDLER, J.F. 1904. *Inventory of the Cape Colony Publications 1800–1910*: 1/2/1/125 G.26-1904.

CAMERON, K. 1922. The Cedar Mountains of Clanwilliam. *Journal of the Mountain Club of South Africa* 25: 84–100.

CAMERON, K. 1924. The Cedar Mountains of Clanwilliam. A second visit. *Journal of the Mountain Club of South Africa* 27: 20–33.

CARRIÈRE, E-A. 1867. *Traité Général des Conifères*. Muséum d'Histoire Naturelle, Paris.

CRAMER, M.D., HAWKINS, H.J. & VERBOOM, G.A. 2009. The importance of nutritional regulation of plant water flux. *Oecologia* 161: 15–24.

DE HOOGH, R.J. 1968. An investigation of the influence of rodents on the failure of natural regeneration of the cedar (*Widdringtonia cedarbergensis* Marsh). Unpublished report.

DE MIL, T., MEKO, M., BELMECHERI, S., FEBRUARY, E., THERRELL, M., VAN DEN BULCKE, J. & TROUET, V. 2021. A lonely dot on the map: Exploring the climate signal in tree-ring density and stable isotopes of Clanwilliam cedar, South Africa. *Dendrochronologia* 69: 125879.

DE ROO, R.T. 2002. Molecular systematics of the genus *Widdringtonia* Endl. B.Sc. (Honours) thesis, University of Cape Town, Cape Town.

DONALDSON, J.S. 1993. Single species conservation: what about biodiversity? Proceedings of the workshop: the Clanwilliam cedar: what is being done? Cape Town.

DRÈGE, J.F. 1843–1844. Zwei Pflanzengeographischen Documenten. *Besondere Beigabe zur Flora* 2, Leipzig.

DUNWIDDIE, P.W. & LAMARCHE, V.C. 1980. A climatically-responsive tree-ring record from *Widdringtonia cedarbergensis*, Cape Province, South Africa. *Nature* 286: 796–797.

DUPONT, L.M., LINDER, H.P., ROMMERSKIRCHEN, F. & SCHEFUSS, E. 2011. Climate-driven rampant speciation of the Cape flora. *Journal of Biogeography* 38: 1059–1068.

DYNESIUS, M. & JANSSON, R. 2000. Evolutionary consequences of changes in species' geographical distributions driven by Milankovitch climate oscillations. *Proceedings of the National Academy of Sciences USA* 97: 9115–9120.

ENDLICHER, S. 1847. *Synopsis Coniferarum*. Apud Scheitlin & Zollikofer, Sangalli.

FARJON, A. 2001. *World checklist and bibliography of conifers.* Royal Botanic Garden, Kew.

FARJON, A. 2005. A monograph of Cupressaceae and *Sciadopitys*. Royal Botanic Garden, Kew.

FARJON, A. 2008. A natural history of Conifers. Timber Press, Portland.
FARJON, A., FEBRUARY, E., HIGGINS, S., FOX, S. & RAIMONDO, D. 2013. *Widdringtonia cedarbergensis*. *The IUCN Red List of Threatened Species 2013*: e. T30365A2793077.
FEBRUARY, E.C. & STOCK, W.D. 1998. The relationship between ring width measures and precipitation for *Widdringtonia cedarbergensis*. *South African Journal of Botany* 64: 213–216.
FEBRUARY, E.C. & STOCK, W.D. 1999. Declining trend in the C-13/C-12 ratio of atmospheric carbon dioxide from tree rings of South African *Widdringtonia cedarbergensis*. *Quaternary Research* 52: 229–236.
FEBRUARY, E.C., WEST, A.G. & NEWTON, R.J. 2007. The relationship between rainfall, water source and growth for an endangered tree. *Austral Ecology* 32: 397–402.
FOREST, F., MOAT, J., BALOCH, E., BRUMMITT, N.A., BACHMAN, S.P., ICKERT-BOND, S., HOLLINGSWORTH, P.M., LISTON, A., LITTLE, D.P., MATHEWS, S., RAI, H., RYDIN, C., STEVENSON, D.W., THOMAS, P. & BUERKI, S. 2018. Gymnosperms on the EDGE. *Scientific Reports* 8: 6053.
FOX, S-J.C. 2003. An assessment of the population status and demographic models of *Widdringtonia cedarbergensis*. B.Sc. (Honours), University of Cape Town, Cape Town.
GADEK, P.A., ALPERS, D.L., HESLEWOOD, M.M. & QUINN, C.J. 2000. Relationships within Cupressaceae sensu lato: A combined morphological and molecular approach. *American Journal of Botany* 87: 1044–1057.
GRUT, M. 1977. Notes on the history of forestry in the Western Cape 1652–1872. *South African Forestry Journal* 100: 32–37.
HIGGINS, K.B., MANDERS, P.T. & LAMB, A.J. 1989. The efficacy of microclimate shelters in improving seedling survival in re-establishment of the Clanwilliam cedar. *South African Forestry Journal* 151: 1–5.
HIGGINS, S., FEBRUARY, E. & SKOWNO, A. 2001. Distribution and population viability of the Clanwilliam cedar (*Widdringtonia cedarbergensis*, Cupressaceae). Final Report to WWF-SA Table Mountain Fund.
HOOKER, J.D. 1845. On the Huon Pine, and on *Microcachrys*, a new genus of Coniferae from Tasmania; together with remarks upon the geographical distribution of that order in the Southern Hemisphere. *Hooker London Journal of Botany* 4: 137–157.
HUBBARD, C.S. 1937. Observations on the distribution and the rate of growth of Clanwilliam cedar *Widdringtonia juniperoides* Endl. *South African Journal of Science* 33: 572–586.
HUTCHINS, D.E. 1896. *Reports of the Conservators of Forests for the year 1895*. Annexures to the votes and procedures of the House of Assembly, Cape Town, G.11. 48–49.
HUTCHINS, D.E. 1897. *Report of the Conservator of Forests, Cape Town (1896)*. Annexures to the votes and procedures of the House of Assembly, Cape Town, G.17.

HUTCHINS, D.E. 1901. *Report of the Conservator of Forests, Western Conservancy (1900)*. Annexures to the votes and procedures of the House of Assembly, Cape Town, G.39.
HUTCHINS, D.E. 1902. Cape national forests. *Transactions of the South African Philosophical Society* 11: 53–66.
HUTCHINS, D.E. 1903. *Report of the Conservator of Forests, Western Conservancy (1902)*. Annexures to the votes and procedures of the House of Assembly, Cape Town, G.55.
HUTCHINS, D.E. 1905. Forestry in South Africa. In: W. Flint & J.D.F. Gilchrist (eds), *Science in South Africa. A handbook and review*: 391–413. Maskew Miller, Cape Town.
HUTCHINS, D.E. 1905. *Report of the Conservator of Forests, Western Conservancy (1904)*. Annexures to the votes and procedures of the House of Assembly, Cape Town, G.26.
IVORY, S.J., BLOME, M.W., KING, J.W., MCGLUE, M.M., COLE, J.E. & COHEN, A.S. 2016. Environmental change explains cichlid adaptive radiation at Lake Malawi over the past 1.2 million years. *Proceedings of the National Academy of Sciences* 113: 11895–11900.
KAMATOU, G.P.P., VILJOEN, A.M., ÖZEK, T. & BAŞER, K.H.C. 2010. Chemical composition of the wood and leaf oils from the "Clanwilliam Cedar" (*Widdringtonia cedarbergensis* J.A. Marsh): A critically endangered species. *South African Journal of Botany* 76: 652–654.
KRUGER, A.C., RAUTENBACH, H., MBATHA, S., NGWENYA, S. & MAKGOALE, T.E. 2019. Historical and projected trends in near-surface temperature indices for 22 locations in South Africa. *South African Journal of Science* 115 (5/6), #4846; available at: http://dx.doi.org/10.17159/sajs.2019/4846.
KRUGER, F.J. 1970. Cedar burns. Unpublished report.
LADD, P.G., MIDGLEY, J.J. & NIELD, A.P. 2013. Serotiny in southern hemisphere conifers. *Australian Journal of Botany* 61: 486–496.
LEIPOLDT, C.L. 1899a. The Clanwilliam cedar, part 1. *The Cape Illustrated Magazine* 9: 241–251.
LEIPOLDT, C.L. 1899b. The Clanwilliam cedar, part 2. *The Cape Illustrated Magazine* 9: 318–327.
LEIPOLDT, J.G. 1831. Das afrikanische Wupperthal. *Berichte der Rheinischen Missionsgesellschaft* 2: 26–32.
LEIPOLDT, J.G. 1832. Missionstation Wupperthal. *Berichte der Rheinischen Missionsgesellschaft* 3: 58–68.
LICHTENSTEIN, H. 1812. *Travels in Southern Africa*. Henry Colburn, London.
LISTER, J.S. 1880. *Report on Crown Forests and Plantations of the Colony, for the year 1879*. Annexures to the Votes and Procedures of the House of Assembly, Cape Town, G.59.
LISTER, J.S. 1882. *Report of the Superintendent of Woods and Forests*. Annexures to the votes and procedures of the House of Assembly, Cape Town, G.1.

LISTER, J.S. 1883. *Report of the Superintendent of Woods and Forests for the year 1882*. Annexures to the votes and procedures of the House of Assembly, Cape Town, G.105.

LÜCKHOFF, H.A. 1971. The Clanwilliam cedar. *The Journal of the Mountain Club of South Africa* 33–39.

MANDERS, P.T. 1986a. An assessment of the current status of the Clanwilliam cedar (*Widdringtonia cedarbergensis*) and the reasons for its decline. *South African Forestry Journal* 139: 48–53.

MANDERS, P.T. 1986b. The effects of shading on nursery grown seedlings of the Clanwilliam cedar. *South African Forestry Journal* 138: 15.

MANDERS, P.T. 1986c. Seed dispersal and seedling recruitment in *Protea laurifolia*. *South African Journal of Botany* 52: 421–424.

MANDERS, P.T. 1987a. Is there allelopathic self-inhibition of generative regeneration within *Widdringtonia cedarbergensis* stands? *South African Journal of Botany* 53: 408–410.

MANDERS, P.T. 1987b. A transition matrix model of the population dynamics of the Clanwilliam cedar (*Widdringtonia cedarbergensis*) in natural stands subject to fire. *Forest Ecology and Management* 20: 171–186.

MANDERS, P.T. & BOTHA, S.A. 1987. Experimental re-establishment of the Clanwilliam cedar *Widdringwnia cedarbergensis*: A preliminary study. *South African Journal of Wildlife Research* 17: 86–90.

MANDERS, P.T. & BOTHA, S.A. 1989. A note on establishment of *Widdringtonia cedarbergensis* (Clanwilliam cedar). *Journal of Applied Ecology* 26: 571–574.

MANDERS, P.T., BOTHA, S.A., BOND, W.J. & MEADOWS, M.E. 1990. The enigmatic Clanwilliam cedar. *Veld & Flora* 8–11.

MANNING, J.C. & GOLDBLATT, P. 2012. Plants of the Greater Cape Floristic Region. 1. The Core Cape Flora. *Strelitzia* 29. South African National Biodiversity Institute, Pretoria.

MANNING, J.C., LINDER, H.P., GOVAERTS, R. & MCNEILL, J. 2024. The mysterious *Widdringtonia wallichii* (Cupressaceae) and the correct scientific name for the Clanwilliam cedar. *Bothalia* 54, a2; available at: http://dx.doi.org/10.38201/btha.abc.v54.

MARLOTH, R. 1902. Notes on the occurrence of alpine types in the vegetation of the higher peaks of the south-western region of the Cape. *Transactions of the Philosophical Society of South Africa* 11: 161–168.

MARSH, J.A. 1965. A monographic study of the genus *Widdringtonia* Endl. M.Sc. thesis, University of Pretoria, Pretoria.

MARSH, J.A. 1966a. Cupressaceae. In: L.E. Codd, B. De Winter & H.B. Rycroft (eds), *Flora of Southern Africa*: 43–53. Department of Agricultural Technical Services, Pretoria.

MARSH, J.A. 1966b. Notes on *Widdringtonia*. *Bothalia* 9: 124–126.

MCIVER, E.E. 2001. Cretaceous *Widdringtonia* Endl. (Cupressaceae) from North America. *International Journal of Plant Sciences* 162: 937–961.

McNAUGHTON, C.B. 1891. *Report by the District Forest Officer, CB McNaughton, on the Cedarberg Forests.* Annexures to the Votes and Procedures of the House of Assembly, Cape Town, G.412-91, Annexure D-6. pp. 91–92.

MEADOWS, M.E., CHASE, B.M. & SELIANE, M. 2010. Holocene palaeoenvironments of the Cederberg and Swartruggens mountains, Western Cape, South Africa: Pollen and stable isotope evidence from hyrax dung middens. *Journal of Arid Environments* 74: 786–793.

MEADOWS, M.E. & SUGDEN, J.M. 1991. A vegetation history of the last 14000 years on the Cederberg, south-western Cape Province. *South African Journal of Science* 87: 34–43.

MERRIMAN, J.X. 1876. *Report on the Condition of Crown Forests and Drift Sands for 1875*. Annexures to the Votes and Procedures of the House of Assembly, Cape Town, G.46.

MERRIMAN, J.X. 1877. *Report on the Condition of Crown Forests and Drift Sands*. Annexures to the Votes and Procedures of the House of Assembly, Cape Town, G.56.

MIDGLEY, J.J. 2002. More fynbos mouse stories. Scatter-hoarding of nuts by the Cape spiny mouse. *Veld & Flora*: 55.

MITRANI, L.M. 2017. Reproduction and establishment of two endangered African cedars, *Widdringtonia cedarbergensis* and *Widdringtonia whytei*. Unpublished M.Sc. Thesis, Department of Botany, University of Cape Town.

MUSTART, P.J. 1993. What is the Cederberg with the cedar? *Veld & Flora* 114–117.

MUSTART, P.J., JURITZ, J., MAKUA, C., VAN DER MERWE, S.W. & WESSELS, N. 1995. Restoration of the Clanwilliam cedar *Widdringtonia cedarbergensis* – the importance of monitoring seedlings planted in the Cederberg, South Africa. *Biological Conservation* 72: 73–76.

NIEUWOUDT, O. 2015. My Cederberg story. Published privately.

PALMER, E. & PITMAN, N. 1972. *Trees of Southern Africa*. A.A.Balkema, Cape Town.

PAPPE, L. 1857. *Flora Capensis Medicae*. W. Brittain, Cape Town.

PAPPE, L. 1867. *Silva Capensis*. Ward, London.

PARKINGTON, J. 2003. *Cederberg Rock Paintings (Follow the San)*. Creda, South Africa.

PARKINGTON, J., CARTWRIGHT, C., COWLING, R.M., BAXTER, A. & MEADOWS, M. 2000. Palaeovegetation at the Last Glacial Maximum in the western Cape, South Africa: wood charcoal and pollen evidence from Elands Bay Cave. *South African Journal of Science* 96: 543–546.

PARTRIDGE, T.C. 1998. Of diamonds, dinosaurs and diastrophism: 150 million years of landscape evolution in southern Africa. *South African Journal of Geology* 101: 167–184.

PAUW, C.A. & LINDER, H.P. 1997. Tropical African cedars (*Widdringtonia*, Cupressaceae): systematics, ecology and conservation status. *Botanical Journal of the Linnean Society* 123: 297–319.

PENN, N. 2005. *The forgotten frontier. Colonist and Khoisan on the Cape's northern frontier in the 18th century*. Double Storey Books, Cape Town.

PERREN, B.B., HODGSON, D.A., ROBERTS, S.J., SIME, L., VAN NIEUWENHUYZE, W., VERLEYEN, E. & VYVERMAN, W. 2020. Southward migration of the Southern Hemisphere westerly winds corresponds with warming climate over centennial timescales. *Communications Earth & Environment* 1: 58.

POOLEY, S. 2012. Recovering the lost history of fire in South Africa's fynbos. *Environmental History* 17: 55–83.

POOLEY, S. 2014. *Burning Table Mountain: an environmental history of fire on the Cape Peninsula*. Palgrave Macmillan, Basingstoke.

PRIVETT, S.D.J. 1994. Restoration of the Clanwilliam cedar, *Widdringtonia cedarbergensis*: a study on the potential of fire as a management tool. B.Sc. (Honours) thesis, University of Cape Town, Cape Town.

QUICK, L.J., CHASE, B.M., MEADOWS, M.E., SCOTT, L. & REIMER, P.J. 2011. A 19.5 kyr vegetation history from the central Cederberg Mountains, South Africa: Palynological evidence from rock hyrax middens. *Palaeogeography Palaeoclimatology Palaeoecology* 309: 253–270.

REBELO, A.G., BOUCHER, C., HELME, N.A., MUCINA, L. & RUTHERFORD, M.C. 2006. Fynbos biome. In: L. Mucina & M.C. Rutherford (eds), The Vegetation of South Africa, Lesotho and Swaziland. *Strelitzia* 19: 53–219. South African National Biodiversity Institute, Pretoria.

RICHARDSON, D.M. 1993. A review of work on the Clanwilliam cedar by the South African Forestry Research Institute. Proceedings of the workshop: The Clanwilliam cedar: what is being done? Cape Town.

ROSS, K.A., BEDWARD, M., ELLIS, M.V., DEANE, A., SIMPSON, C.C. & BRADSTOCK, R.A. 2008. Modelling the dynamics of white cypress pine *Callitris glaucophylla* woodlands in inland south-eastern Australia. *Ecological Modelling* 211: 11–24.

SCHOLES, R.J., SCHOLES, M. & LUCAS, M. 2015. *Climate Change. Briefings from Southern Africa.* Wits University Press, Johannesburg.

SCHWEIGER, A.H., IRL, S.D.H., SVENNING, J-C. & HIGGINS, S.I. 2020. Dynamic management needs for long-lived, sporadically recruiting plant species in human-dominated landscapes. *PLANTS, PEOPLE, PLANET* 2: 186–200.

SCOTT, L. & WOODBORNE, S. 2007. Pollen analysis and dating of Late Quaternary faecal deposits (hyraceum) in the Cederberg, Western Cape, South Africa. *Review of Palaeobotany and Palynology* 144: 123–134.

SCOTT, M.H. 1927. Notes on the characteristics and minute structure of thirty woods indigenous to South Africa. *South African Journal of Science* 24: 298–316.

SIVEWRIGHT, J. 1882. *Report of the General Manager of Telegraphs for the year 1881*. Annexures to the votes and procedures of the House of Assembly, Cape Town, G.10.

SLINGSBY, J.A. & SLINGSBY, P.W.O. 2019a. Global distribution of Clanwilliam cedar tree localities in 2013. Dataset accompaning Slingsby & Slingsby 2019b.

SLINGSBY, J.A. & SLINGSBY, P.W.O. 2019b. Monitoring the critically endangered Clanwilliam cedar with freely available Google Earth imagery. *PeerJ* 7: e7005.

SMITH, C.A. 1955. Early 19th Century records of the Clanwilliam cedar. *The Journal of the South African Forestry Association* 25: 58–65.

SMITH, F.A. 2002. Governmental relations in the management of the Cederberg Wilderness Area: some organisational aspects. *Politeia* 21: 58–79.

STAPF, O. 1933. Cupressaceae. In: A.W. Hill (ed.), *Flora Capensis*: 14–24. Reeve, London.

SUGDEN, J.M. & MEADOWS, M.E. 1990. The history of the Clanwilliam cedar (*Widdringtonia cedarbergensis*): evidence from pollen analysis. *South African Forestry Journal* 153: 64–71.

TAYLOR, H.C. 1996. *Cederberg Vegetation and Flora*. National Botanical Institute, Pretoria.

THOMAS, J.C. & BOND, W.J. 1997. Genetic variation in an endangered cedar (*Widdringtonia cedarbergensis*) versus two congeneric species. *South African Journal of Botany* 63: 133–140.

THUNBERG, C.P. 1986. *Travels at the Cape of Good Hope 1772-1775*. Van Riebeeck Society, Cape Town.

TYSON, P.D. & LINDESAY, J.A. 1992. The climate of the last 2000 years in southern Africa. *Holocene* 2: 271–278.

VALSECCHI, V., CHASE, B.M., SLINGSBY, J.A., CARR, A.S., QUICK L.J., MEADOWS, M.E., CHEDDADI, R. & REIMER, P.J. 2013. A high resolution 15,600-year pollen and microcharcoal record from the Cederberg Mountains, South Africa. *Palaeogeography Palaeoclimatology Palaeoecology* 387: 6–16.

VAN DER HORST, S.T. 1930. A through-trek and some new Krakadouw peaks. *Journal of the Mountain Club of South Africa* 33: 57–61.

VAN DER MERWE, S.W. & WESSELS, N. 1993. Current management - what is being done? Proceedings of the workshop: the Clanwilliam cedar: what is being done? Cape Town.

VAN DER WALT, A.J. & FITCHETT, J.M. 2021. Exploring extreme warm temperature trends in South Africa: 1960–2016. *Theoretical and Applied Climatology* 143: 1341–1360.

VAN RIJNEVELD, W.S., TRUTER, P.J. & HUIZER, L. 1911. Notul of dagverhaal der reis en verrichtinen van president en gecommiteerde leden uit de commissie van veeteelt en landbouw in de beide Roggevelden, den Hantam, &c. In: G.M. Theal (ed.), *Belangrijke Historische Dokumenten*: 324–428. Goevernment van de Unie van Zuid Afrika.

VAN WILGEN, B.W. 1980. Assessment of the effects of burning on populations of the Clanwilliam cedar using aerial photography. *South African Forestry Journal* 114: 72–74.

VAN WILGEN, B.W., CARRUTHERS, J., COWLING, R.M., ESLER, K.J., FORSYTH, A.T., GAERTNER, M., HOFFMAN, M.T., KRUGER, F.J., MIDGLEY, G.F., PALMER, G., PENCE, G.Q.K., RAIMONDO, D.C., RICHARDSON, D.M., VAN WILGEN, N.J. & WILSON, J.R.U. 2016. Ecological research and conservation management in the Cape Floristic Region between 1945 and 2015: History, current understanding and future challenges. *Transactions of the Royal Society of South Africa* 71: 207–303.

VAN WYK, B., VAN DEN BERG, E., COATES PALGRAVE, M. & JORDAAN, M. 2011 *Dictionary of names for southern African trees*. Briza, Pretoria.

VON MEYER, W. 1843. *Reisen in Süd-Afrika während der Jahre 1840 und 1841*. J.B. Grie, Hamburg.

VON WURMB, T. 1831. Das afrikanische Wupperthal. *Berichte der Rheinischen Missionsgesellschaft* 2: 32–53.

WARNER, B. 1989. *The Cape diary and letters of William Mann. Astronomer and Mountaineer. 1839-1843*. Friends oif the South African Library, Cape Town.

WHITE, J.D.M., BRONNER, G.N. & MIDGLEY, J.J. 2017. Camera-trapping and seed-labelling reveals widespread granivory and scatter-hoarding of nuts by rodents in the Fynbos Biome. *African Zoology* 52: 31–41.

WHITE, J.D.M., JACK, S.L., HOFFMAN, M.T., PUTTICK, J., BONORA, D., VISSER, V. & FEBRUARY, E.C. 2016. Collapse of an iconic conifer: long-term changes in the demography of *Widdringtonia cedarbergensis* using repeat photography. *BMC Ecology* 16: 53.

WHITE, J.D.M., STEVENS, M., BERNDT, J., COETZEE, B.W.T., MASSAD, T.J., NUPEN, L.J., TYE, D. & MIDGLEY, J.J. 2020. Understanding recruitment limitations in a critically endangered species: The story of the iconic Cape cedar (*Widdringtonia wallichii*). *Global Ecology and Conservation* 23: e01062.

WICHT, C.L. 1945. *Report of the committee on the preservation of the vegetation of the South Western Cape*. Royal Society of South Africa, Cape Town.

WILSON, A.M., LATIMER, A.M., SILANDER, J.A., GELFAND, A.E. & DE KLERK, H. 2010. A hierarchical Bayesian model of wildfire in a Mediterranean biodiversity hotspot: Implications of weather variability and global circulation. *Ecological Modelling* 221: 106–112.

WINGFIELD, M.J., VON BROEMBSEN, S.L. & MANDERS, P.T. 1988. A preliminary assessment of the threat of diseases and pests to *Widdringtonia cedarbergensis*. *South African Forestry Journal* 147: 32–34.

YOUNG, S. 1998. A report on the restoration programme of the Clanwilliam cedar (*Widdringtonia cedarbergensrs*) in the Cederberg from 1987 - 1998. Environmental and Geographical Science Department, University of Cape Town, Cape Town.

# Additional sources

Cultural historic survey in the Cederberg Wilderness Area, by Lynn Naik. This is an unpublished report, which gives very substantial background information.

# Appendices

## 1. Places

A summary of the geographic coordinates of places not on the topographical maps.

| Name | Latitude | Longitude | Elevation (m a.s.l.) | Notes |
|---|---|---|---|---|
| De Rif | -32.4397 | 19.2334 | 1 240 | Along the bridle path from Driehoek to Gabriël's Pass, on the shale band. |
| Sederkop | -32.445 | 19.2208 | 1 200 | This is not Cederhoutkop. |
| Welbedacht mill | -32.4193 | 19.1696 | 940 | The, now demolished, structure was at the base of the Welbedacht kloof, just above the farm house. |
| Die Bos | -32.4 | 19.21667 | 1 240 | |
| Cederhoutkop | -32.3997 | 19.1687 | 1 410 | This was an old campsite along the track on the shale band. |
| Sterrebosbank | -32.48 | 19.14 | | Between Sneeuberg and Noordpoort, the precise location is not known. |
| Budlerskloof | -32.2283 | 19.0904 | 1 100 | Mentioned by Lückhoff, near Heuningvlei, often confused with Moedersielskloof. It is probably at the base of Moedersielskloof. |
| Sederpoort | -32.4045 | 19.17 | 1 350 | Below Cederhoutkop. |
| Kielvlei | -32.367 | 19.105 | 1 390 | Probably Geelvlei. |
| Haevelskloof | | | | Mentioned by Lückhoff, near Heuningvlei. This could be Halveskop, the large plantation at the Heuningvlei manager's house. This suspicion is strengthened by the apparent absence of a name for this plantation. |

# 2. Coordinates of plots

These coordinates were assembled or reconstructed by Ed February and are included here with his permission.

| Plot name, researcher, date | Latitude | Longitude |
|---|---|---|
| Sneeuberg Hut 1, Manders, 1971 | -32.48095S | 19.15488 |
| Sneeuberg Hut 2, Manders, 1971 | -32.48089S | 19.15407 |
| Koupoort 1, Manders, 1971 | -32.25833 | 19.10306 |
| Koupoort 2, Manders, 1971 | -32.26333 | 19.09722 |
| Hoogvertoon 1, Manders, 1971 | -32.4725 | 19.14917 |
| Hoogvertoon 2, Manders, 1971 | -32.47167 | 19.14944 |
| Welbedacht cut stump, February | -32.41568 | 19.17569 |
| Welbedacht dead tree, February | -32.41419 | 19.34182 |
| Welbedacht big tree, February | -32.41253 | 19.17561 |
| Welbedacht trees, February | -32.41149 | 19.17679 |
| Welbedacht more dead trees, February | -32.41051 | 19.17905 |
| Welbedacht UCT study site living trees, February | -32.40946 | 19.17981 |
| Die Bos, Dunwiddie and La Marche, 1980 | -32.4 | 19.21667 |
| Driehoek live cedars, February, 2011 | -32.44639 | 19.22361 |
| Driehoek live Cedars 2, February, 2011 | -32.44139 | 19.22806 |
| Middelberg live trees, February, 2014 | -32.36153 | 19.07637 |
| Middelberg live trees 2, February, 2014 | -32.35859 | 19.07788 |
| Middelberg live trees 3, February, 2014 | -32.35958 | 19.0707 |
| Pakhuis Pass, 1970 | -32.11361 | 19.02972 |
| Plot 1, Andrag, 1977 | -32.45306 | 19.11083 |
| Plot 2, Andrag, 1977 | -32.18917 | 19.07639 |
| Plot 3, Andrag, 1977 | -32.18833 | 19.07611 |
| Plot 4, Andrag, 1977 | -32.18361 | 19.08333 |
| Plot 6, Andrag, 1977 | -32.18833 | 19.07611 |
| Plot 7, Andrag, 1977 | -32.45167 | 19.10667 |

| Plot name, researcher, date | Latitude | Longitude |
|---|---|---|
| Plot 8, Andrag, 1977 | -32.38306 | 19.10389 |
| Plot 11, Andrag, 1977 | -32.245 | 19.11361 |
| Plot 16, Andrag, 1977 | -32.36361 | 19.17528 |
| Plot 17, Andrag, 1977 | -32.35861 | 19.19667 |
| Plot 22, Andrag, 1977 | -32.33 | 19.07361 |
| Plot 23, Andrag, 1977 | -32.34556 | 19.06583 |
| Plot 24, Andrag, 1977 | -32.36861 | 19.13417 |
| Plot 25, Andrag, 1977 | -32.3725 | 19.09222 |
| Plot 26, Andrag, 1977 | -32.48583 | 19.16556 |
| Plot 28, Andrag, 1977 | -32.48667 | 19.14806 |
| Plot 29, Andrag, 1977 | -32.48333 | 19.13806 |
| Plot 30, Andrag, 1977 | -32.48972 | 19.14083 |
| Plot 31, Andrag, 1977 | -32.50917 | 19.17639 |
| Plot 32, Andrag, 1977 | -32.52722 | 19.13028 |
| Plot 33, Andrag, 1977 | -32.-32944 | 19.19667 |
| Plot 34, Andrag, 1977 | -32.40111 | 19.20472 |
| Plot 35, Andrag, 1977 | -32.43778 | 19.23944 |
| Plot 36, Andrag, 1977 | -32.12056 | 19.00139 |
| Plot 37, Andrag, 1977 | -32.15806 | 19.00694 |
| Plot 38, Andrag, 1977 | -32.30472 | 19.18528 |
| Plot 39, Andrag, 1977 | -32.41861 | 19.14222 |
| Plot 40, Andrag, 1977 | -32.39167 | 19.21 |
| Plot 42, Andrag, 1977 | -32.4425 | 19.22778 |

# 3. Glossary of non-English words used in the text

**Buchu (sometimes 'boegoe'):** ..... *Agathosma crenulata*; indigenous herb, collected for its aromatic oils.

**Dassie:** ..... Rock hyrax (*Procavia capensis*).

**Harpuis (sometimes 'harpuisbos'):** .. *Euryops speciosissimus*; indigenous flowering shrub, also known as Clanwilliam daisy.

**Koppie:** ..... a small rocky hill, usually less than 100 m high.

**Rooibos:** ..... *Aspalathus linearis*, used as a herbal tea. It used to be wild-collected; in cultivation from the beginning of the 20th century.

**Slangbos:** ..... *Seriphium plumosum*; indigenous, somewhat invasive, highly flammable shrub.

**Vlei:** ..... a marshy area or shallow lake that usually stays wet in the middle. This is in contrast with a 'pan', which dries out completely in the dry season.

**Waboom:** ..... *Protea nitida*; indigenous tree, previously used for making wagon wheels.

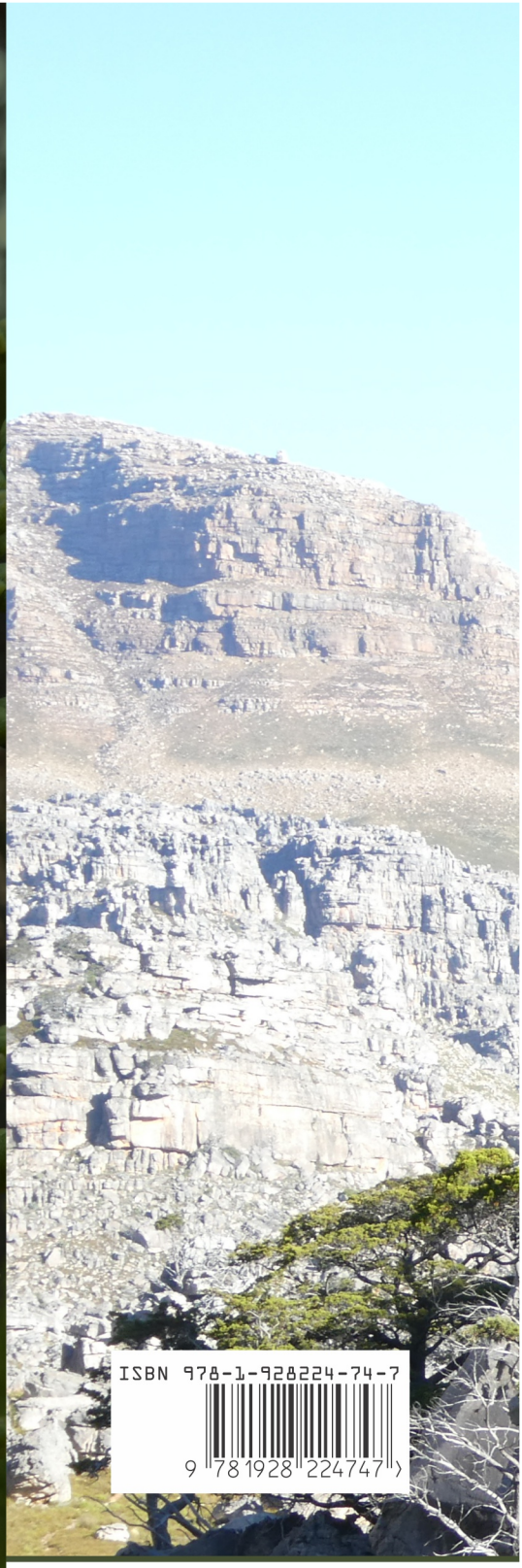
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The Clanwilliam cedar (*Widdringtonia cedarbergensis*) is arguably the most charismatic South African tree species. The impact of humans on the species has been disastrous, starting with heavy logging from 1750 to 1880, followed by increased fire frequency, and finally climate change decimating the stands, so that the species is now probably drifting into extinction. In this book the decline of the cedars is documented and the biology explored, especially attempting to understand why the species is limited to the Cederberg and solving the mystery of its persistence in the fire-prone fynbos. The book tells the story of the Clanwilliam cedar: where it came from, how it functions, what its adaptations to the harsh Cederberg environment are and what our impact on the species has been. It ends with suggestions on how the species can be saved from extinction.



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