CSIR Report Number:
CSIR/NRE/ECO/ER/2007/0118/C

AN ANALYSIS OF THE FIRE HISTORY RECORDS FROM PROTECTED AREAS IN THE WESTERN CAPE

Prepared for:

CapeNature
as a component of the
C.A.P.E. Fire Data Management Project

Prepared by:

GG Forsyth and BW van Wilgen
CSIR Natural Resources and
the Environment
PO Box 320
Stellenbosch 7599
South Africa

September 2007

CapeNature

CAPE ACTION FOR PEOPLE AND THE ENVIRONMENT

CSIR
our future through science

CSIR Report Number: CSIR/NRE/ECO/ER/2007/0118/C

An analysis of the fire history records from protected areas in the Western Cape

FIRST EDITION

Prepared for:	*Funded by Global Environment Facility (GEF) of the World Bank through*
CapeNature	CAPE ACTION FOR PEOPLE AND THE ENVIRONMENT

Prepared by:

G.G Forsyth and B.W. van Wilgen
CSIR: Natural Resources and the Environment
Stellenbosch

CSIR our future through science

September 2007

Cover photographs by Guy Palmer (CapeNature)

Acknowledgements

- We would like to thank the members of the C.A.P.E. Fire Management Data Project Task Team: Zane Erasmus, Helen de Klerk, Guy Palmer, Arne Purves, Peter Viljoen and Shaun Cosset, for their inputs and guidance.
- Guy Palmer provided the photographs that were used on the cover page of this report.
- Our colleagues David Le Maitre and Patrick O' Farrell are thanked for making useful suggestions on data analysis.
- Philip Prins of South African National Parks kindly allowed us to use fire data for the Table Mountain National Park.
- This work arises from the Cape Action for People and the Environment Programme's Fire Management Data Project and was supported financially by the Global Environment Fund (GEF) of the World Bank.

SUMMARY

This report presents an analysis of the past fire regimes based on a total of 1811 fire records from ten protected areas in five eco-zones in the Western Cape Province. Eco-zones were based on the fire potential as defined by climate. A spatial database of all known fires was supplied by CapeNature (except in the case of the Table Mountain National Park) and this formed the basis for this analysis. The areas burnt ranged from < 1.0 ha to 58 897 ha. The total area burnt during the period 1938 to the present was 1 490 736 ha. However, the majority of the fire records are from the period 1970 – 2006.

Mean fire return interval were determined by decade, to establish whether any trends in fire frequency were evident. We also determined the occurrence of short (≤ 6 years) fire return intervals for the following periods: 1970 – 1989; 1990 – 2007; and earlier periods if the record was long enough. Fire season, fire size, and the cause of fires were also examined.

The main findings are:

- *Short-interval (≤ 6 years) fires are becoming more common.*
- *Fire return intervals, measured on a decade-by-decade basis, decreased most markedly in the Table Mountain, Nuweberg and Limietberg areas. In other areas, no marked decreases were noted.*
- *Fynbos fire regimes are dominated by unplanned wildfires, which account for almost 90% of the area burnt.*
- *Fires took place predominantly in summer, or summer and autumn (except in the southeastern coastal zone, where winter fires are reasonably prevalent). Prescribed burning accounted for a little over a third of the area burnt in winter and about a quarter of the area burnt in spring.*
- *The increase in short-interval burning was associated with increased human populations, and therefore ignitions, in some areas. The more remote areas tend to have less short-interval fires.*
- *Lightning is an important source of fire ignition, and it accounted for between 1.2 and 54.1% of the area burnt in different reserves; its influence was greatest in remote areas.*
- *There is some evidence that fires are becoming larger but this needs further investigation.*

Contents

Figures

Tables

1. Introduction

This work was undertaken as part of Phase 2 of the C.A.P.E Programme's Fire Management Data Project funded by the Global Environment Facility (GEF) of the World Bank. This report provides an analysis of the fire regimes within protected areas of the Western Cape. Protected areas for the purposes of this report include Mountain Catchment Areas, Provincial Nature Reserves and Wilderness Areas.

Our terms of reference required us to divide the Fynbos Biome in the Western Cape into distinguishable eco-zones, and then to carry out a comprehensive analysis of the fire regime over a fifty year time span (or for as many years as the CapeNature fire database covers). The analysis should cover the frequency, season, intensity, size and type of fire, and sources of ignition. We were also required to give an indication of how the fire regime has changed over time, in relation to weather patterns, and with different fire management phases.

This report provides a summary of the historical fire regimes based on a total of 1811 fire records from ten protected areas within climatically based eco-zones of the fynbos biome. The areas burnt ranged from < 1.0 ha to 58 897 ha. The total area burnt during the period 1938 to the present was 1 490 736 ha. However, the majority of the fire records are from the period 1970 – 2006 (*Table 1*). The likely impacts of the recorded fire regimes on the biophysical processes within these eco-zones will be dealt with in a further report.

2. Eco-zones in the fynbos biome

Our approach to eco-zones was based on the fire potential as defined by climate. Earlier work, using daily weather records from a range of recording stations across the fynbos biome, recognised five distinct fire climate zones (*Figure 1, van Wilgen 1984*).

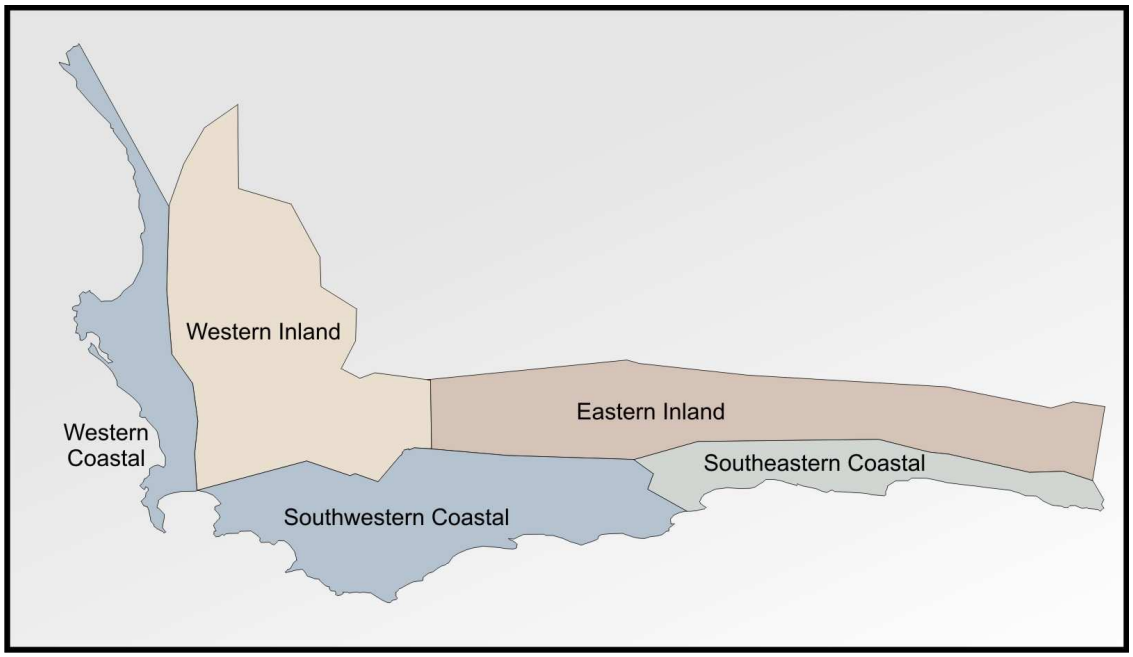


Figure 1. Eco-zones in the fynbos biome (after van Wilgen 1984).

The *western coastal zone* extends from the Cape Peninsula northwards in a fairly narrow (10 km) band along the west coast of the province. Within this zone, mean fire potential is lowest in the winter but seasonal fluctuations about the mean are not marked. Fires are most likely under occasional, extreme conditions of high temperature, low relative humidity and high wind in summer. Much of this zone is occupied by cultivated land or Strandveld of the West Coast, which is less likely to carry fire than fynbos because of lower fuel loads and the discontinuous nature of its canopy and under storey.

The *western inland zone* extends from the western coastal zone as far as an arbitrary line connecting the towns of Sutherland and Barrydale, and north of the Langeberg mountain range, including the north facing slopes of their range. The zone is characterized by strong seasonal trends in fire potential and a high mean fire potential in the summer months. Although winter fires are possible under exceptional, rare circumstances, they hardly ever occur. Fires are common in summer on the other hand, when they also burn the largest areas.

The *southwestern coastal zone* extends from Somerset West in the west to Mossel Bay in the east, including the Groenland, Riviersonderend and Langeberg mountains. Fire potential is highest in the summer months but annual fluctuations about the mean are not marked. Fires are most likely under extreme conditions in summer. Large fires also occur occasionally in winter under bergwind conditions.

The *eastern inland zone* extends from the western inland zone eastwards. Although the zone has an even rainfall throughout the year, high evapotranspiration in summer is responsible for what is effectively a winter rainfall regime. There is thus a significant seasonal cycle of mean fire potential with a peak in summer, when most fires occur.

The *southeastern coastal zone* extends from Mossel Bay eastwards and south of the Outeniqua and Kouga mountains. It is characterized by very little fluctuation in mean the energy release component throughout the year. The energy release component is related to the potential fire intensity expressed as the available energy per unit area at the head of a fire and is calculated by simulating fluctuations in fuel moisture content based on fluctuations in weather (*van Wilgen 1984*). The annual fire-potential cycle is essentially bimodal, with fires experienced under occasional suitable conditions in both winter and summer. The weather conditions that favour large fires occur rather irregularly. Winter bergwinds lead to conditions of high fire potential and this explains the June-August maximum at the Outeniqua station.

3. Protected areas within eco-zones

Fire records from a total of ten protected areas were analysed with at least one area representing each eco-zone (*Table 1*). In the case of the western coastal zone, no CapeNature protected area was available, and we used the Table Mountain National Park for this purpose.

Table 1. Protected areas used as a basis for the analysis of fire regimes.

Eco-zone	Nature Reserve (Protected Area)	Size (ha)	Years of fire record
Western Coastal	Table Mountain National Park	26 554	1970 – 2007
Southwestern Coastal	Kogelberg Nature Reserve	37 851	1953 – 2007
	Nuweberg Nature Reserve [1]	59 936	1972 - 2007
	Riviersonderend Nature Reserve	69 046	1970 – 2007
Western Inland	Cedarberg Nature Reserve	122 735	1945 – 2006
	Limietberg Nature Reserve	90 044	1966 – 2006
	Waterval Nature Reserve	108 055	1974 - 2007
Southeastern Coastal	Outeniqua Nature Reserve	41 962	1938 – 2006
Eastern Inland	Kammanassie Nature Reserve	49 591	1970 – 2006
	Swartberg Nature Reserve	120 416	1944 – 2006

Note [1] Nuweberg Nature Reserve includes the Hottentots-Holland, Jonkershoek, Groot Drakenstein, Franschhoek and Groenland mountains.

4. Methods

4.1 Compilation of a fire database

Data for all areas except the Table Mountain National Park were supplied by CapeNature's Scientific Services. Records for the Table Mountain National Park were obtained directly from that park. Typical fire records included a mapped boundary of each fire, along with the dates on which the fire occurred, and the recorded cause of the fire. The boundaries of all fires were captured on a geographic information system for further analysis.

4.2 Fire return intervals

The mean fire return interval was calculated as $RP = y/(b/a)$, where RP is the return interval in years, b is the extent of all fires recorded over y years, and a is the area over which fires were recorded (van Wilgen *et al.* 2000). We calculated this statistic for the area as a whole, as well as by decade, to establish whether any trends in fire frequency were evident.

The above method delivers a single estimate of the fire return interval, and does not provide insight into individual fire return intervals (the time between individual fires on the same area). Very short fire intervals could eliminate obligate re-seeding shrubs if their juvenile periods are longer than the fire interval (Noble & Slatyer 1980; van Wilgen & Forsyth 1992). In order to assess fire return intervals, we delimited areas of unique fire history by overlaying fire records for the protected areas using the method described in De Klerk *et al.* 2007. Each polygon of unique fire history was characterised by a number of fire return intervals (except for polygons where no fires were recorded, or where only one fire was recorded). We then determined the occurrence of short (≤ 6 years) fire return intervals for the following time periods: 1990 – 2006; 1970 – 1989; and earlier periods if the record was long enough.

4.3 Fire season

We calculated the total area burnt in different seasons for each year on the data record. The seasons were summer (November – February inclusive); autumn (March - April inclusive); winter (May – August inclusive); and spring (September and October).

4.4 Fire size distribution

Fire size may be important for a number of ecological reasons (for example in terms of the relative proportion of "edge effects", or the distances that must be covered by species reliant on dispersal for re-colonizing burnt sites). We also wished to examine the relationship between fire size and the occurrence of conditions of extreme fire weather. The size of individual fires was examined with a view to determining the proportion of area burnt in fires of different sizes, as well as to establish whether or not these proportions were changing over time.

5. Results

Results are presented here for each of the individual protected areas.

5.1 Western Coastal Zone: Table Mountain National Park

Large numbers of small fires occur in the Table Mountain National Park, but they burn a relatively small area; on the other hand, a relatively small number of large fires burn most of the area (*Figure 2*). The two biggest fires on record burnt 3439 and 3210 ha respectively within the Park and both started on the same day (16 January 2000). Of the 373 fires on record, only 3 were over 2000 ha, and the 81 fires > 100 ha burnt 88.6% of the area. On the other hand, 292 fires were < 100 ha, but burnt only 11.4 % of the area. No fires in the very large size class (> 5000 ha) have ever been recorded in the Park. The distribution of fire sizes did not differ markedly for the two periods compared, suggesting that fire size distribution is stable (*Figure 3*).

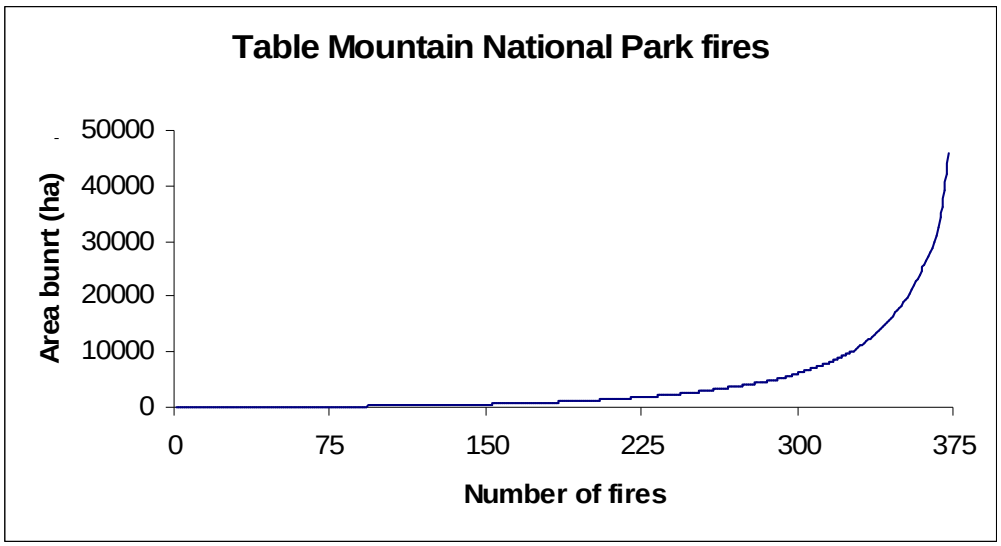


Figure 2. The relationship between the number of fires (373) and area burnt (45 757.3 ha) in the Table Mountain National Park between 1970 and 2007.

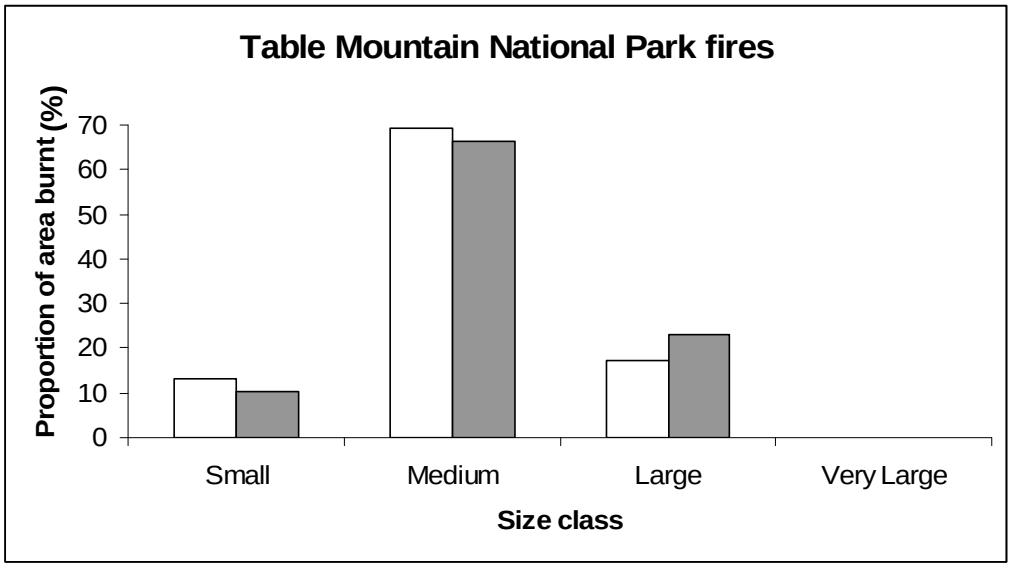


Figure 3. The proportion of the area burnt in fires of different size classes over time in the Table Mountain National Park. Size classes are small (0 – 100 ha); moderate (>100 – 2000 ha); large (>2000 – 5000 ha) and very large (> 5000 ha). Un-shaded and shaded bars are for the periods 1970 – 1989 and 1990 – 2007 respectively.

The total area burnt during the first half of the data record was less than in the second half, and the proportion of fires burnt in summer and autumn increased from 88 to 92 % during that time (*Figure 4*). In the first half of the fire record, 37% of the area burnt had unreliable dates and these areas were not included in Figure 4. Unreliable dates decreased to 6% of the area burnt in the second period.

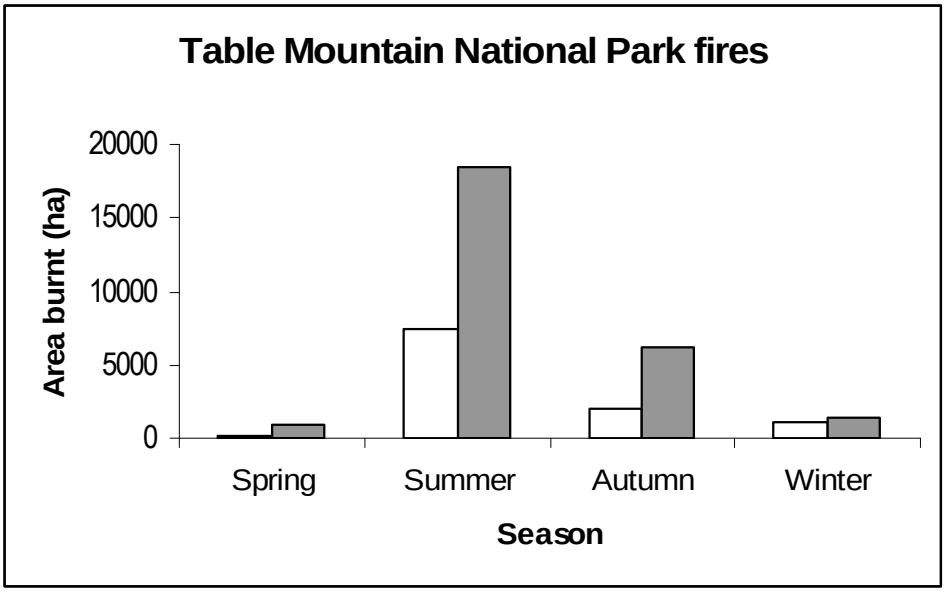


Figure 4. Total area burnt in different seasons in all vegetation types in the Table Mountain National Park during two periods (unshaded bars = 1970 – 1989; shaded bars = 1990 – 2007).

A total of 373 fires > 1 ha, covering 45 757 ha, were recorded between 1970 and 2007; this yielded a mean fire return interval for the whole area of 22 years. Mean fire return intervals declined in each decade of the fire record (*Figure 5*). In fynbos vegetation, mean fire return intervals declined from 37.9 years in the 1970s to 12.6 years between 2000 and 2007. Equivalent estimates for renosterveld and forest are 37.4 to 17.7 years, and 144.6 to 45.6 years respectively (*Figure 5*).

The incidence of short-interval (≤ 6 years) fires also increased significantly from the first half of the data record to the second half (*Table 2*). The extent of these frequently-burnt areas was 2.7 times greater between 1990 and 2007 than it was between 1970 and 1990 in fynbos vegetation. Similarly, frequently-burnt areas were 5 times more extensive in renosterveld. The incidence of short-interval fires was mainly in the north and centre of the park, where developed areas abut on the park boundary (*Figure 6*). The southern portion of the park is bordered mainly by the sea.

Table 2. Areas of different vegetation types subjected to at least one short (≤ 6 year) interval fire during two periods in the Table Mountain National Park.

Vegetation type	Area covered by vegetation type (ha)	Proportion (%) subjected to short-interval fire	
		1970 – 1989	1990 – 2007
Fynbos	22906	4.2	11.4
Renosterveld	828	5.4	27
Forest	1009	0.7	0.3

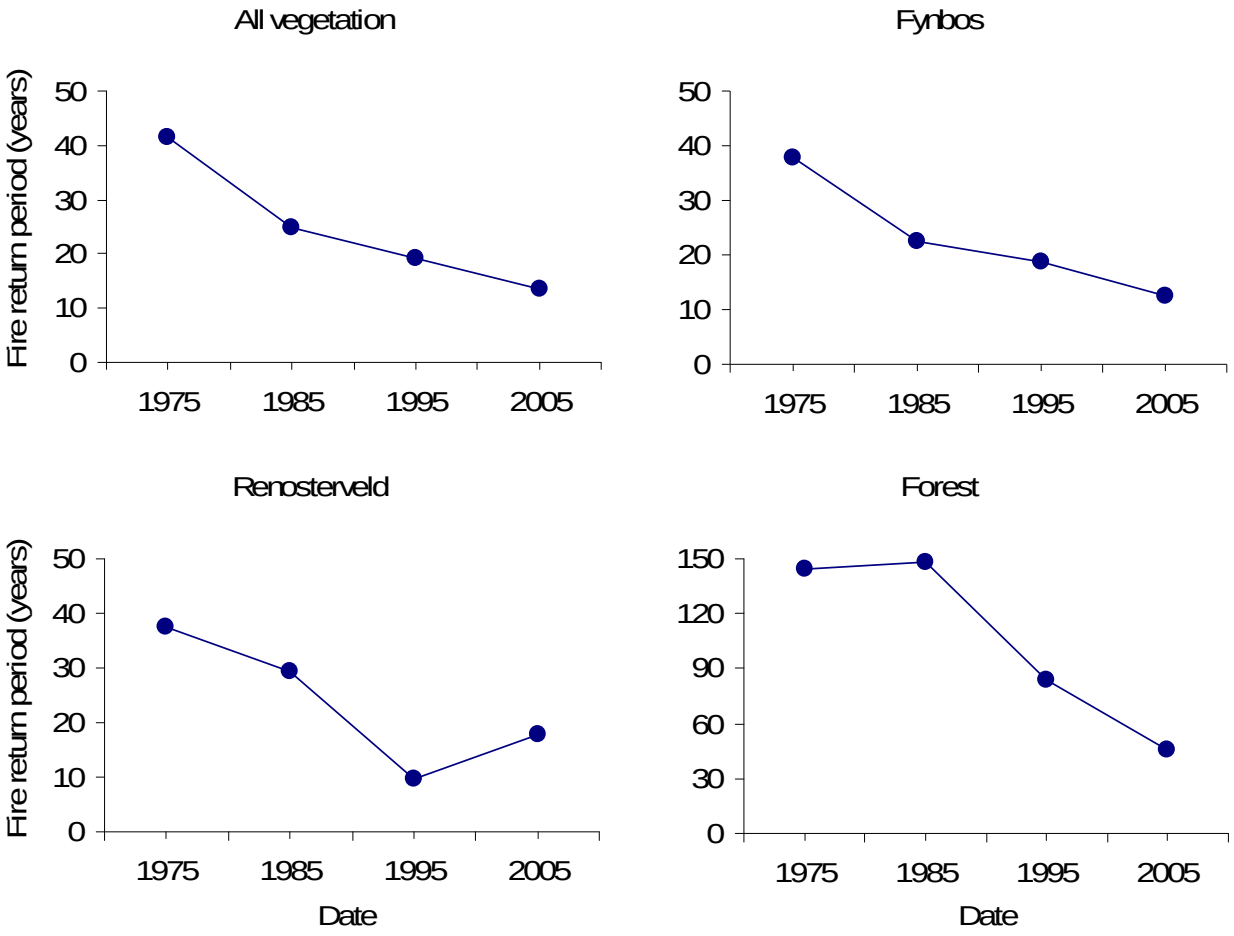


Figure 5. Mean fire return intervals per decade in the Table Mountain National Park, and in three component vegetation types. Note the difference in scale for forest vegetation.

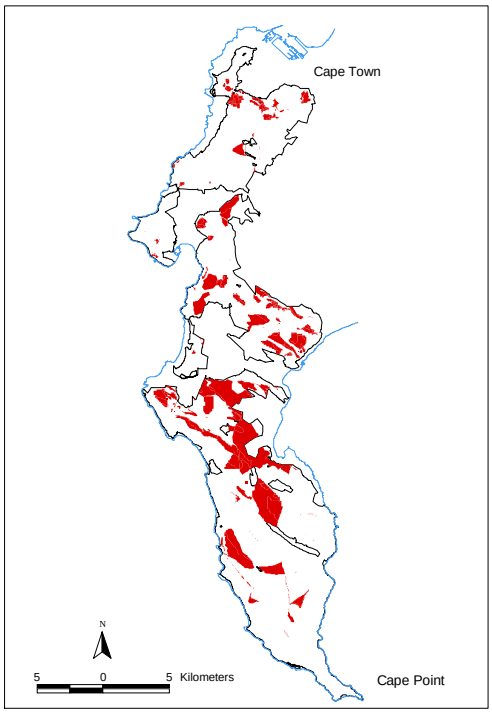


Figure 6 a

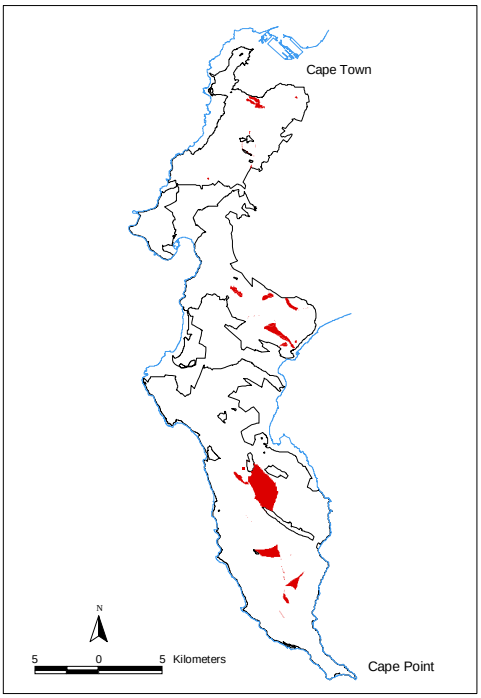


Figure 6 b

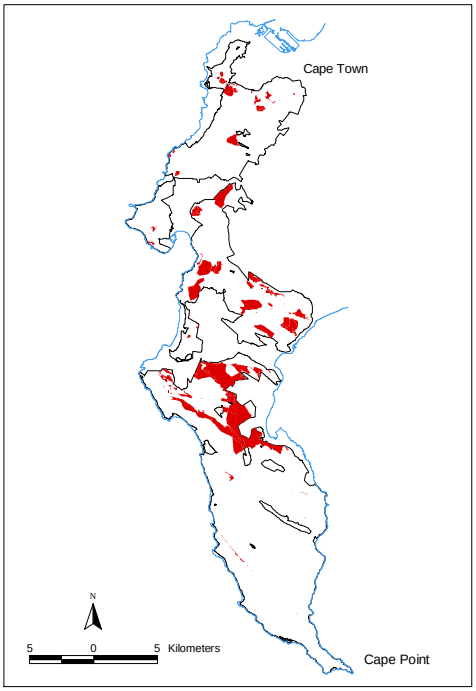


Figure 6 c

Figure 6. The spatial occurrence of short (≤ 6 years) fire return intervals in the Table Mountain National Park for the periods (a) = 1970 to 2007; (b) = 1970 to 1989; and (c) = 1990 – 2007. Note that some areas depicted in (a) do not appear in either (b) or (c) as the datasets were split, eliminating short fire return intervals that straddled the two datasets.

Fires of unknown origin accounted for the largest category in terms of area burnt. Lightning accounted for only 1.2% in terms of the area burnt while prescribed burning, including escaped prescribed burns, accounted for 21.5 % (*Table 3*).

Table 3. The total area burnt in the Table Mountain National Park by different causes during the period 1970 – 2007.

Cause	Number	Area burnt	% of area burnt
Accidental	30	3 416.7	7.5
Arson	23	2 615.3	5.7
Escaped prescribed burn	16	3 164.9	6.9
Falling rocks	1	5.4	0
Flare	7	132.0	0.3
Lightning	5	534.9	1.2
Powerline	2	107.9	0.2
Prescribed burn	45	6 661.8	14.6
Unknown	244	29 118.4	63.6
Total	**373**	**45 757.3**	**100**

5.2 Southwestern Coastal Zone: Kogelberg Nature Reserve /…

5.2 Southwestern Coastal Zone: Kogelberg Nature Reserve

The relationship between the number of fires and the area burnt is shown in Figure 7. A small number of fires were responsible for burning most of the area. There has been a tendency for the area burnt in very large fires to increase over time, at the expense of medium and large sized fires (*Figure 8*).

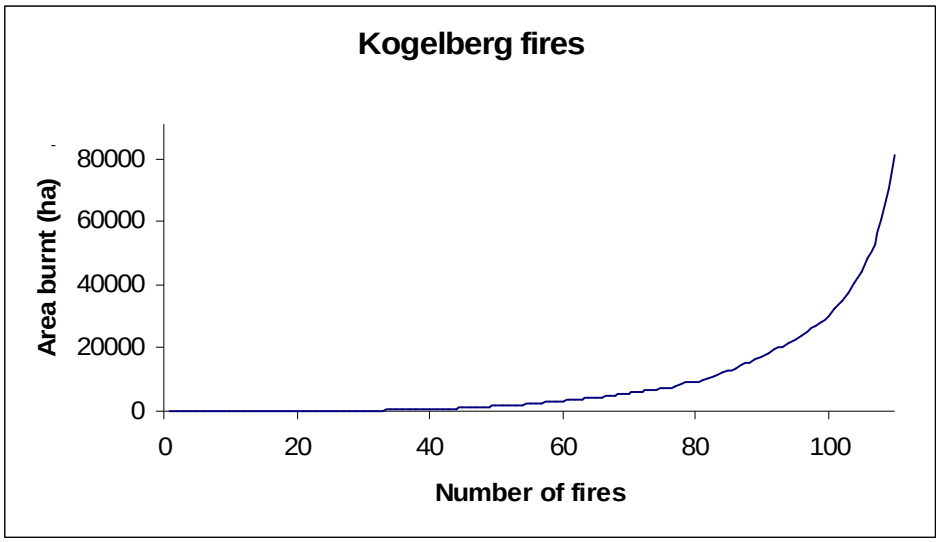


Figure 7. The relationship between the number of fires (110) and area burnt in the Kogelberg Nature Reserve (80 948.4 ha) between 1953 and 2007.

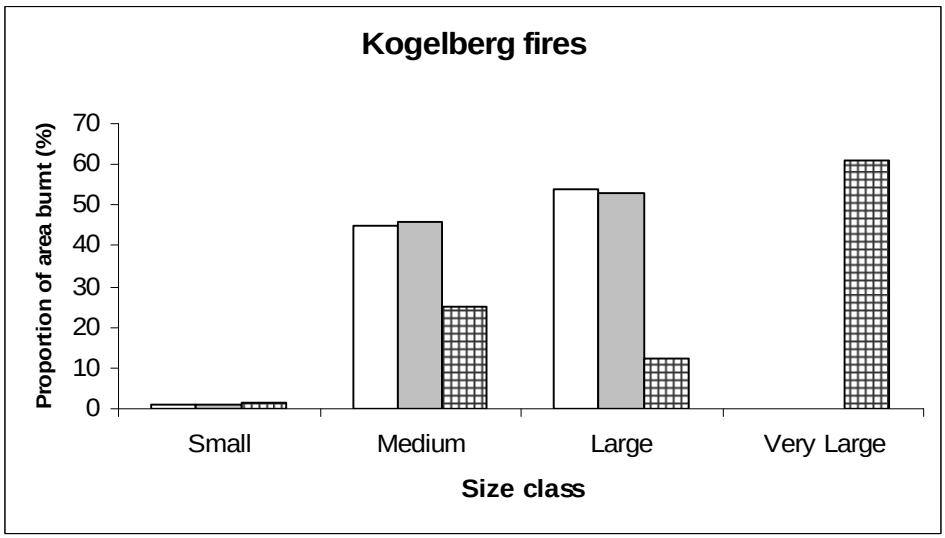


Figure 8. The proportion of the area burnt in fires of different size classes over time in the Kogelberg Nature Reserve. Size classes are small (0 – 100 ha); medium (>100 – 2000 ha); large (>2000 – 5000 ha) and very large (>5000 ha). Un-shaded, shaded and hashed bars are for the periods 1953 – 1969 and 1970 – 1989 and 1990 - 2007 respectively.

Most fires were in summer and autumn (*Figure 9*). The incidence of spring and winter fires between 1970 and 1989 was largely due to prescribed burning activities.

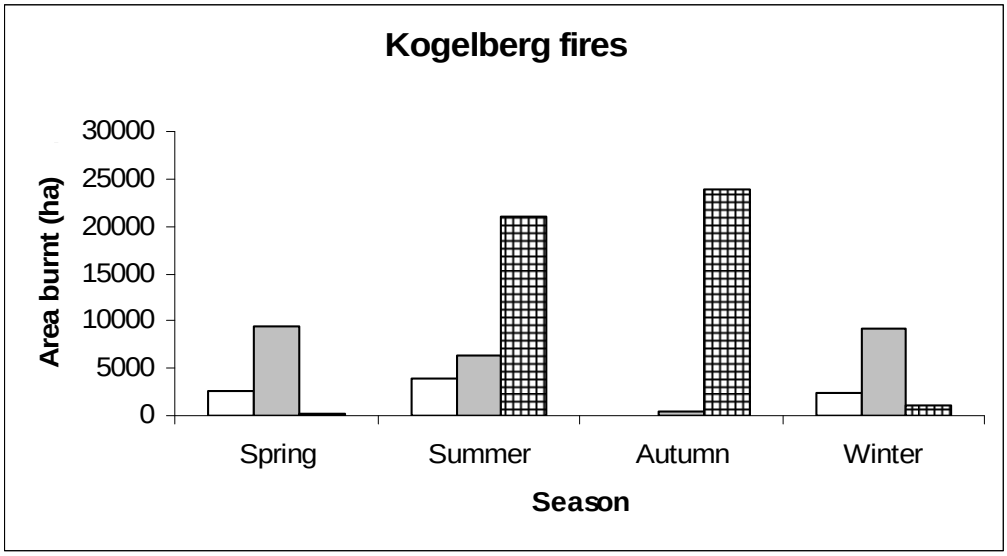


Figure 9. Total area burnt in different seasons in the Kogelberg Nature Reserve during three periods (unshaded bars = 1953 – 1969; shaded bars = 1970 – 1989 and hashed bars = 1990 - 2007).

The mean fire return interval for the whole record was 25.7 years. This ranged from 52.8 years between 1960 - 1969, and decreased to 9.8 years between 1990 and 1999 (*Figure 10*). A relatively small area has burnt in the first half of this decade, resulting in a fire return interval of 38.2 years.

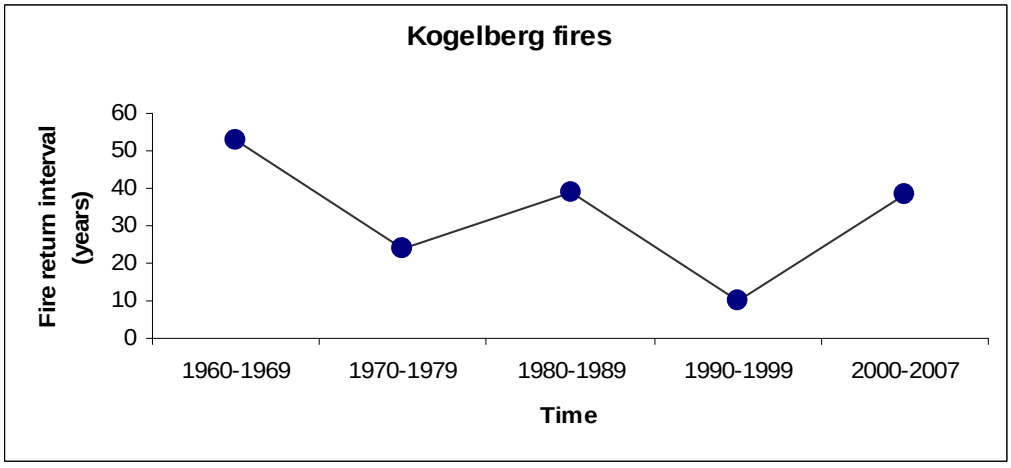


Figure 10. Mean fire return intervals per decade in the Kogelberg Nature Reserve.

Areas subjected to a least one short (≤ 6 years) interval fire amounted to < 1% of the area between 1970 and 1989. This increased to 4.5% between 1990 and 2007. The spatial distribution of these areas is shown in Figure 11.

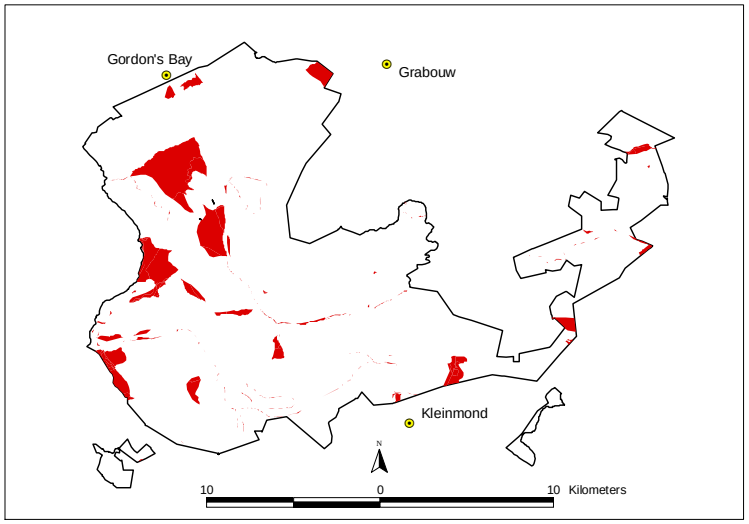


Figure 11 a

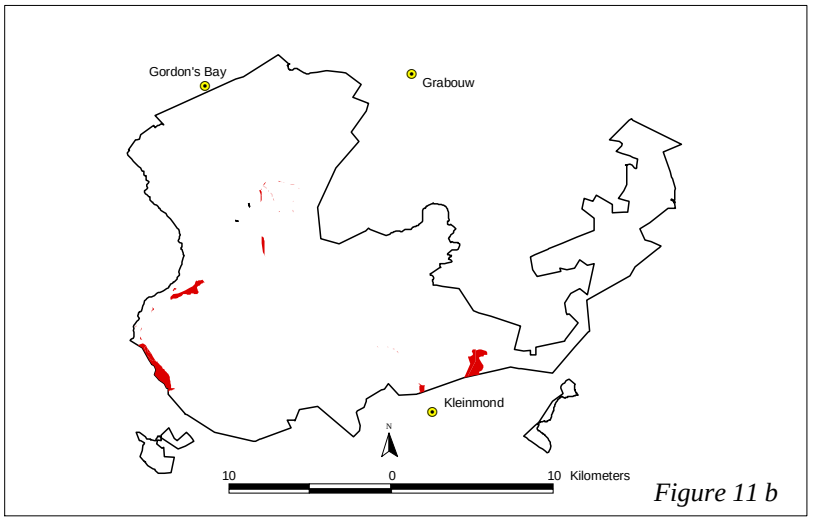


Figure 11 b

Figure 11. The spatial occurrence of short (≤ 6 years) fire return intervals in the Kogelberg Nature Reserve for the periods (a) = 1953 to 2007; (b) = 1970 to 1989; and (c) = 1990 – 2007. Note that some areas depicted in (a) do not appear in either (b) or (c) as the datasets were split, eliminating short fire return intervals that straddled the two datasets.

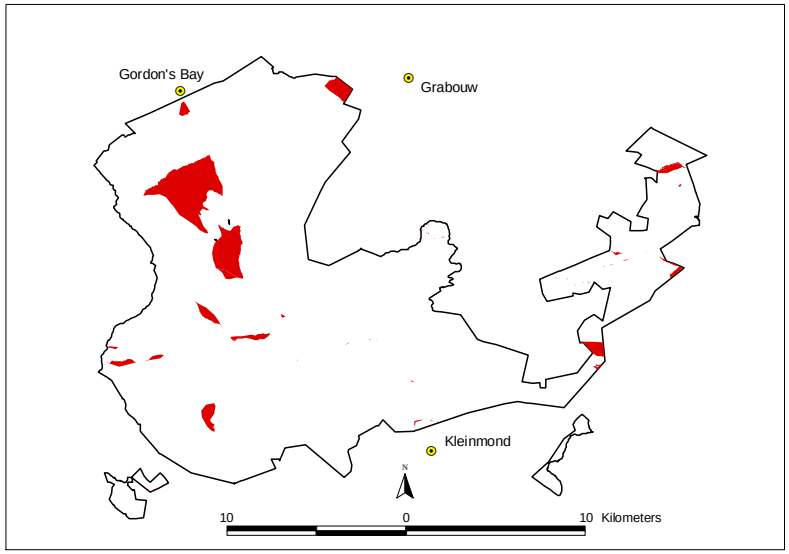


Figure 11 c

Fires of unknown origin accounted for the largest category in terms of area burnt. Lightning and prescribed burning accounted for 16.6 and 19.6 % in terms of area burnt respectively (*Table 4*).

Table 4. The total area burnt in the Kogelberg Nature Reserve by different causes during the period 1953 – 2007.

Cause	Number	Area burnt	% of area burnt
Accidental	24	11 005.2	13.6
Arson	6	395.8	0.5
Lightning	5	13 649.0	16.9
Powerline	4	2 299.6	2.8
Prescribed burn	20	15 892.7	19.6
Unknown	51	37 706.1	46.6
Total	**110**	**80 948.4**	**100**

5.3 Southwestern Coastal Zone: Nuweberg Nature Reserve /…

5.3 Southwestern Coastal Zone: Nuweberg Nature Reserve

The relationship between the number of fires and the area burnt is shown in Figure 12. A small number of fires were responsible for burning most of the area. There has been a tendency for the area burnt in very large fires to increase over time, at the expense of medium-sized fires (*Figure 13*).

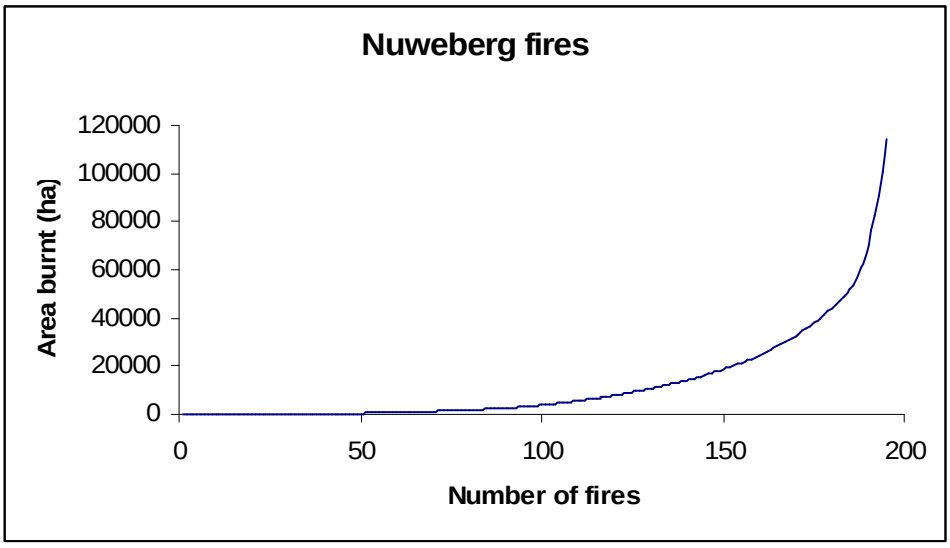


Figure 12. The relationship between the number of fires (195) and area burnt in the Nuweberg Nature Reserve (114 585.3) between 1972 and 2007.

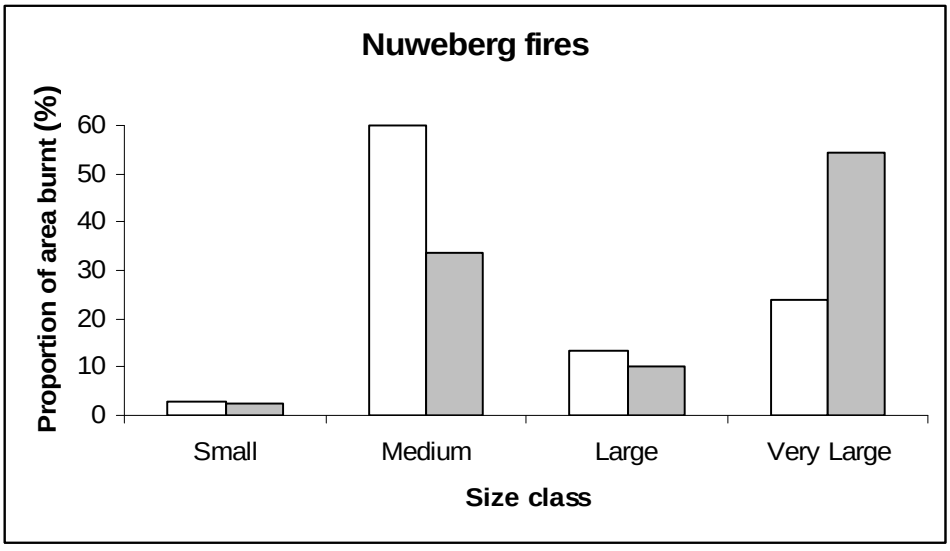


Figure 13. The proportion of the area burnt in fires of different size classes over time in the Nuweberg Nature Reserve. Size classes are small (0 – 100 ha); medium (>100 – 2000 ha); large (>2000 – 5000 ha) and very large (>5000 ha). Un-shaded, shaded and shaded bars are for the periods 1972 – 1989 and 1990 - 2007 respectively.

Most fires were in summer and autumn (*Figure 14*). Close to half (44%) of the area burnt in spring and winter fires between 1972 and 1989 was due to prescribed burning activities.

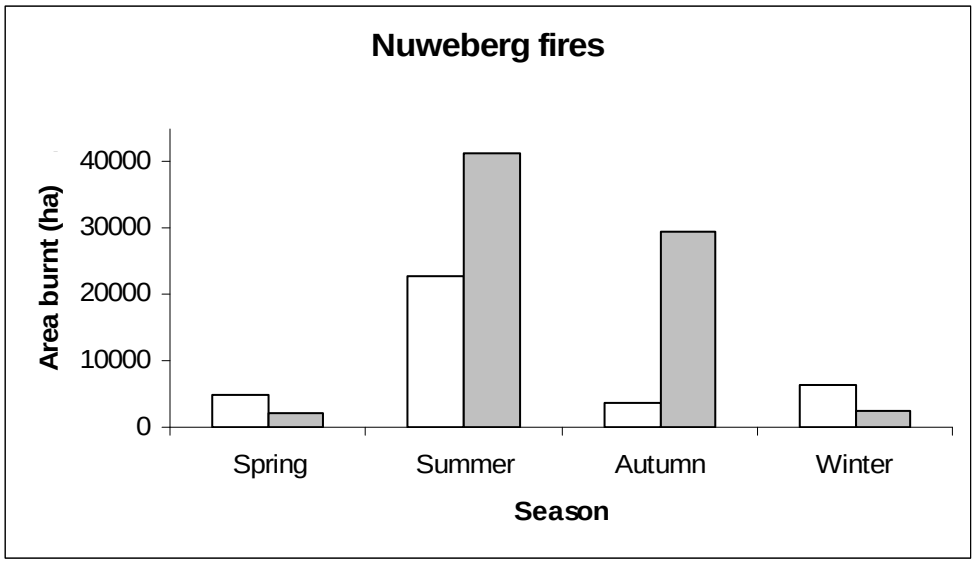


Figure 14. Total area burnt in different seasons in the Nuweberg Nature Reserve during two periods (unshaded bars = 1972 – 1989; shaded bars = 1990 - 2007).

The mean fire return interval for the whole record was 18.8 years. This ranged from 29.3 years between 1972 - 1979, and decreased to 13.6 years between 1990 and 1999 (*Figure 15*).

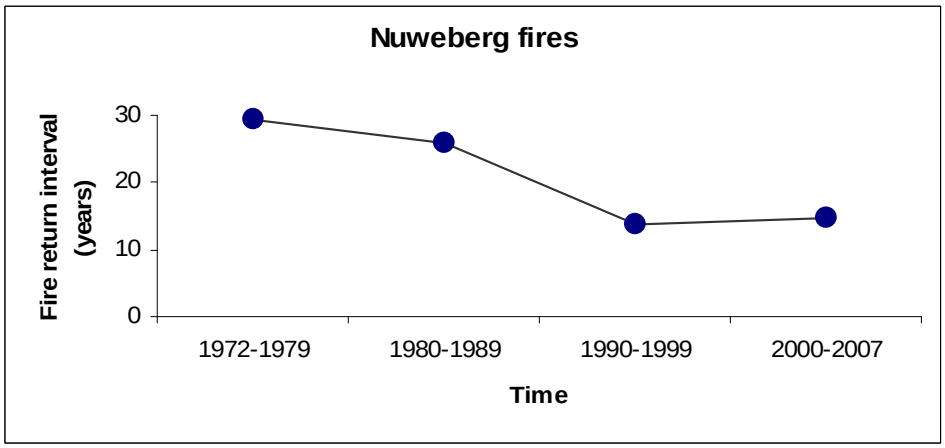


Figure 15. Mean fire return intervals per decade in the Nuweberg Nature Reserve.

Areas subjected to a least one short (≤ 6 years) interval fire amounted to 3.5% of the area between 1972 and 1989. This increased to 18.2% between 1990 and 2007. The spatial distribution of these areas is shown in Figure 16.

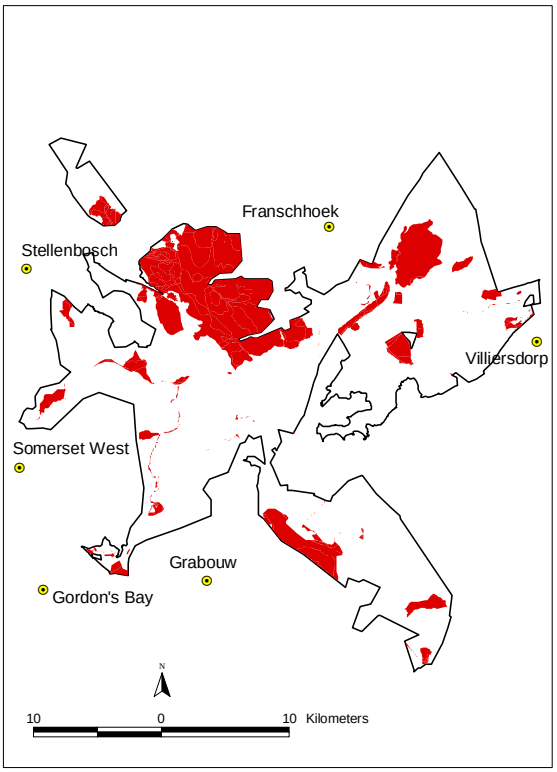


Figure 16 a

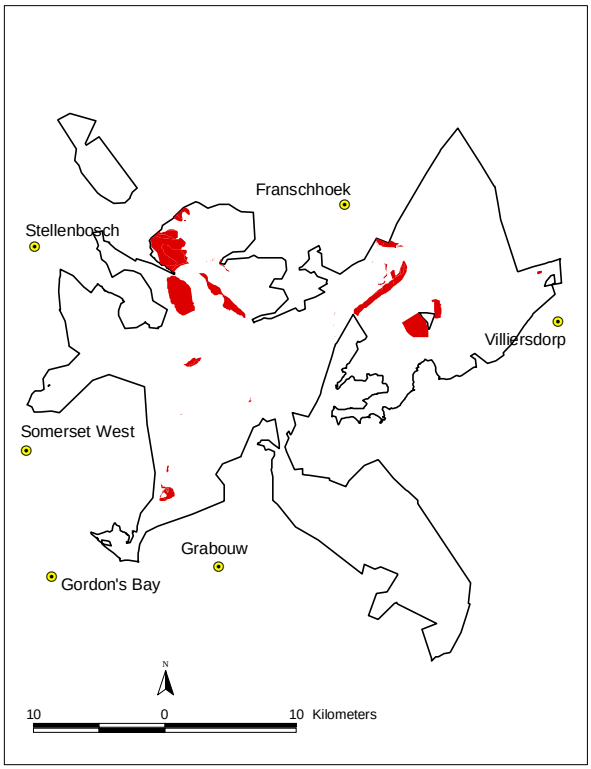


Figure 16 b

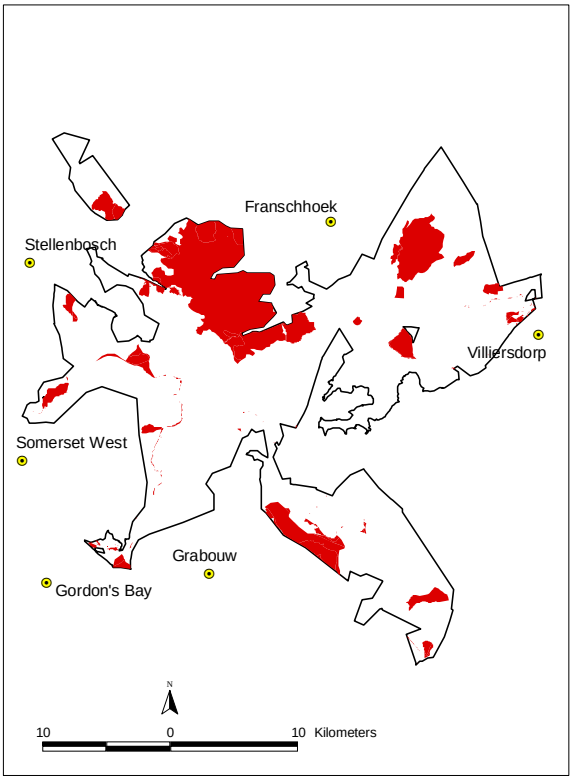


Figure 16 c

Figure 16. The spatial occurrence of short (≤ 6 years) fire return intervals in the Nuweberg Nature Reserve for the periods are (a) = 1972 to 2007; (b) = 1972 to 1989; and (c) = 1990 – 2007. Note that some areas depicted in (a) do not appear in either (b) or (c) as the datasets were split, eliminating short fire return intervals that straddled the two datasets.

Fires of unknown origin accounted for the largest category in terms of area burnt. Lightning and prescribed burning accounted for 14.4 and 6.5 % in terms of area burnt respectively (*Table 5*).

Table 5. The total area burnt in the Nuweberg Nature Reserve by different causes during the period 1972 – 2007.

Cause	Number	Area burnt	% of area burnt
Accidental	35	25 620.0	22.4
Arson	9	1 169.9	1.0
Falling rocks	2	2 76.4	0.2
Lightning	8	16 549.3	14.4
Prescribed burn	17	7 408.9	6.5
Train	3	1 127.6	1.0
Unknown	121	62 433.2	54.5
Total	**195**	**114 585.2**	**100**

5.4 Southwestern Coastal Zone: Riviersonderend Nature Reserve /…

5.4 Southwestern Coastal Zone: Riviersonderend Nature Reserve

The relationship between the number of fires and the area burnt is shown in Figure 17. A small number of fires were responsible for burning most of the area. There has been a tendency for the area burnt in very large fires to increase over time, at the expense of medium and large sized fires (*Figure 18*).

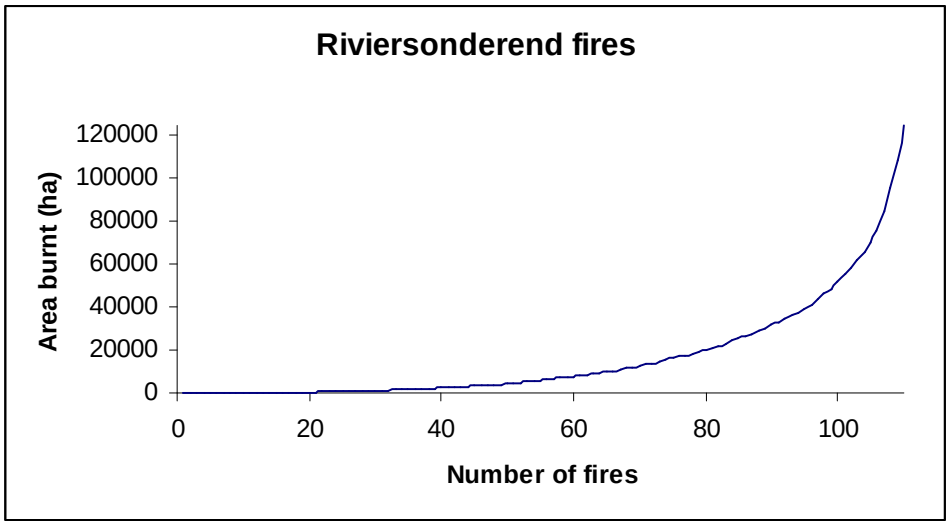


Figure 17. The relationship between the number of fires (110) and area burnt (124 931.0 ha) in the Riviersonderend Nature Reserve between 1970 and 2007.

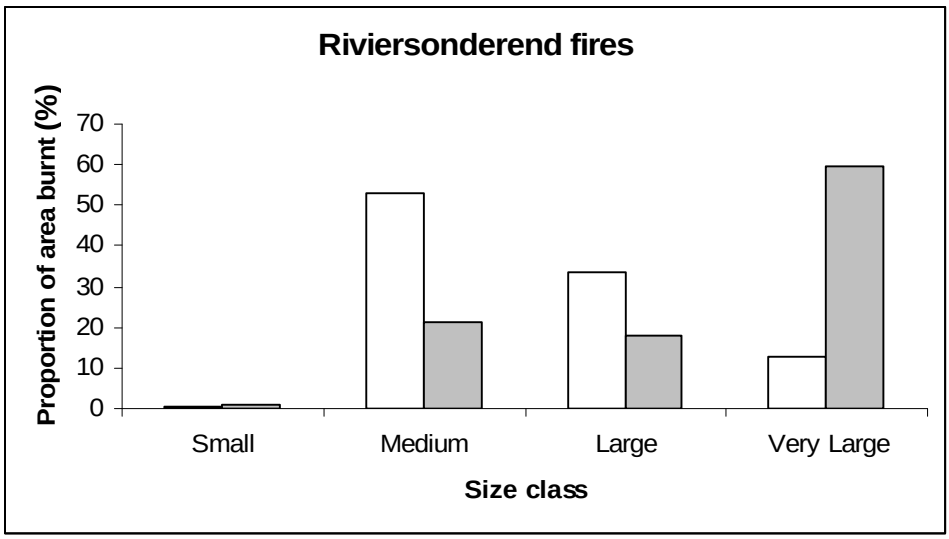


Figure 18. The proportion of the area burnt in fires of different sizes over time in the Riviersonderend Nature Reserve. The size classes are small (0 – 100 ha); medium (>100 – 2000 ha); large (>2000 – 5000 ha) and very large (>5000 ha). Un-shaded and shaded bars are for the periods 1970 – 1989 and 1990 – 2007 respectively.

Most fires were in summer (*Figure 19*).

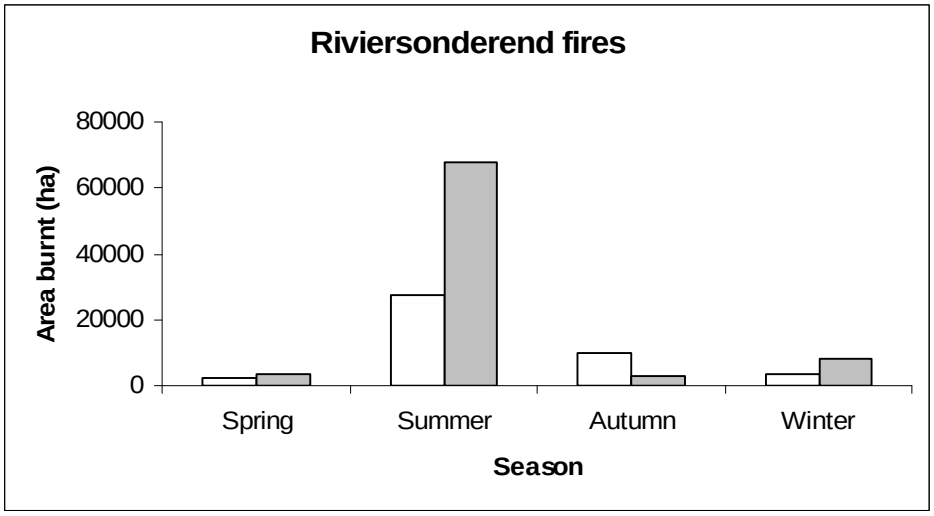


Figure 19. Total area burnt in different seasons in the Riviersonderend Nature Reserve during two periods (unshaded bars = 1970 – 1989; shaded bars = 1990 – 2007).

The mean fire return interval for the whole record was 20.7 years. This mean was however skewed by a value of 93.2 years for the decade 1970 – 1979, which probably has missing fires and was therefore not included in Figure 20. For the remaining decades, little trend was evident (*Figure 20*).

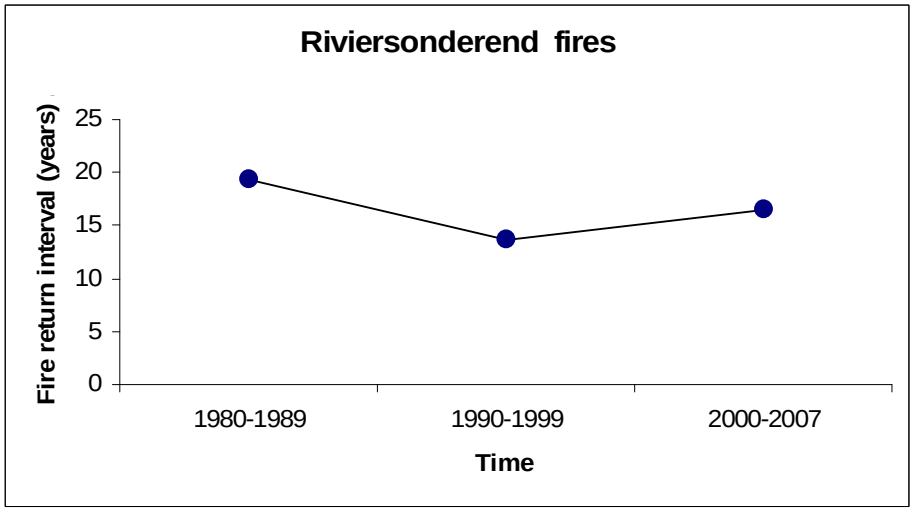


Figure 20. Mean fire return intervals per decade in the Riviersonderend Nature Reserve.

Areas subjected to a least one short (≤ 6 years) interval fire amounted to 4.3% and 5.6% of the area between 1970 and 1989, and between 1990 and 2007 respectively. The spatial distribution of these areas is shown in Figure 21.

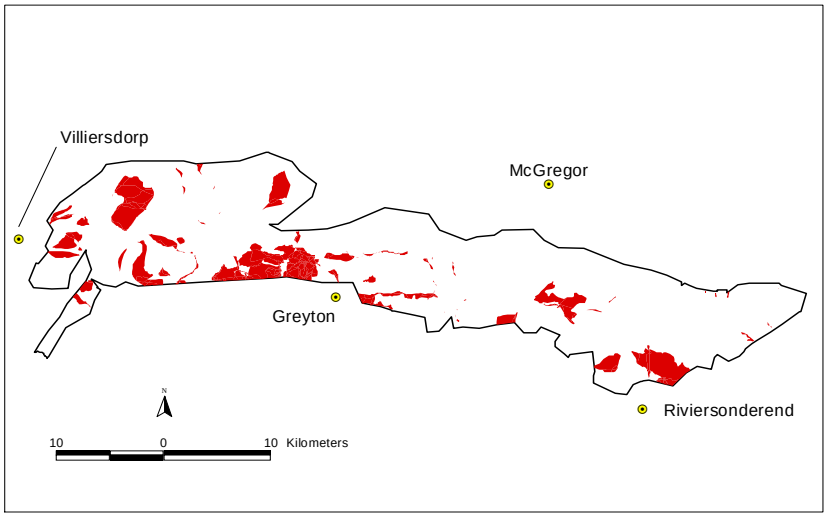


Figure 21 a

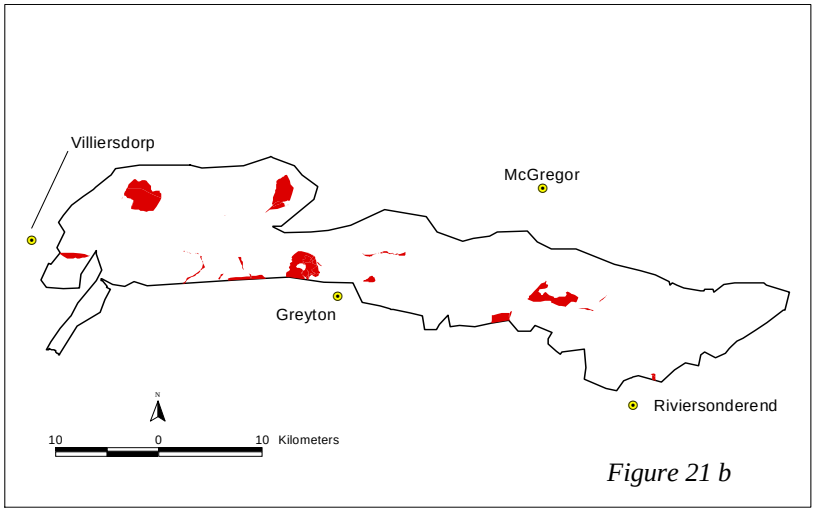


Figure 21 b

Figure 21. The spatial occurrence of short (≤ 6 years) fire return intervals in the Riviersonderend Nature Reserve for the periods (a) = 1970 to 2007; (b) = 1970 – 1989; and (c) = 1990 - 2007. Note that some areas depicted in (a) do not appear in either (b) or (c) as the datasets were split, eliminating short fire return intervals that straddled the two datasets.

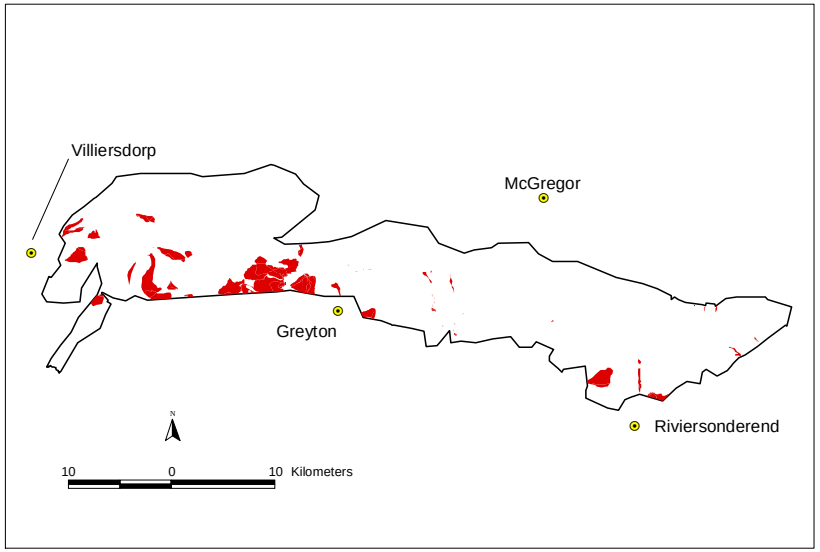


Figure 21 c

Fires of accidental origin accounted for the largest category in terms of area burnt. Prescribed burning was also a dominant cause of fires (*Table 6*).

Table 6. The total area burnt in the Riviersonderend Nature Reserve by different causes during the period 1970 – 2007.

Cause	Number	Area burnt	% of area burnt
Accidental	38	55 943.2	44.8
Arson	11	13 058.1	10.4
Lightning	8	3 738.0	3.0
Powerline	1	1 216.4	1.0
Prescribed burn	26	40 491.4	32.4
Unknown	26	10 483.9	8.4
Total	**110**	**124 931.0**	**100**

5.5 Western Inland Zone: Cedarberg Nature Reserve /…

5.5 Western Inland Zone: Cedarberg Nature Reserve

The relationship between the number of fires and the area burnt is shown in Figure 22. A small number of fires were responsible for burning most of the area. There has been a tendency for the area burnt in very large fires to increase over time, at the expense of medium-sized fires (*Figure 23*).

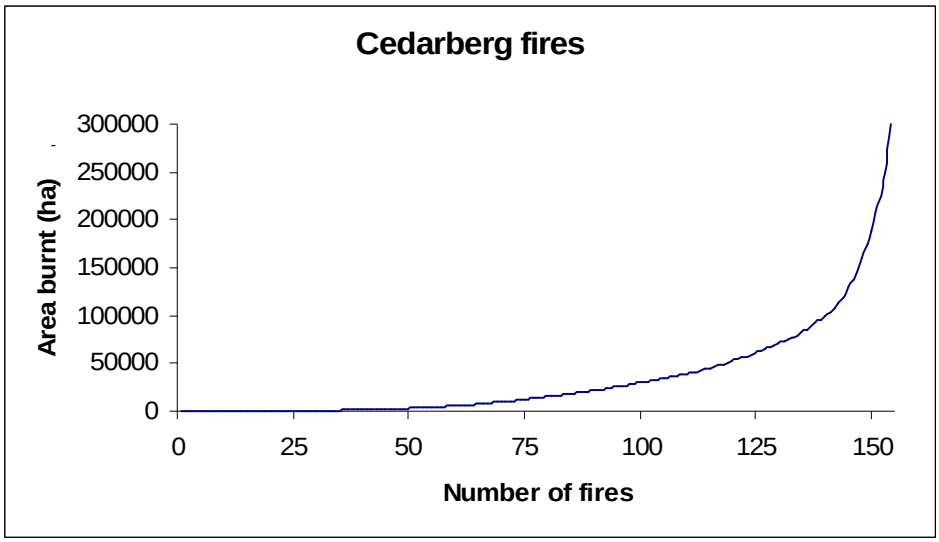


Figure 22. The relationship between the number of fires (154) and area burnt (299 296.9 ha) in the Cedarberg Nature Reserve between 1945 and 2006.

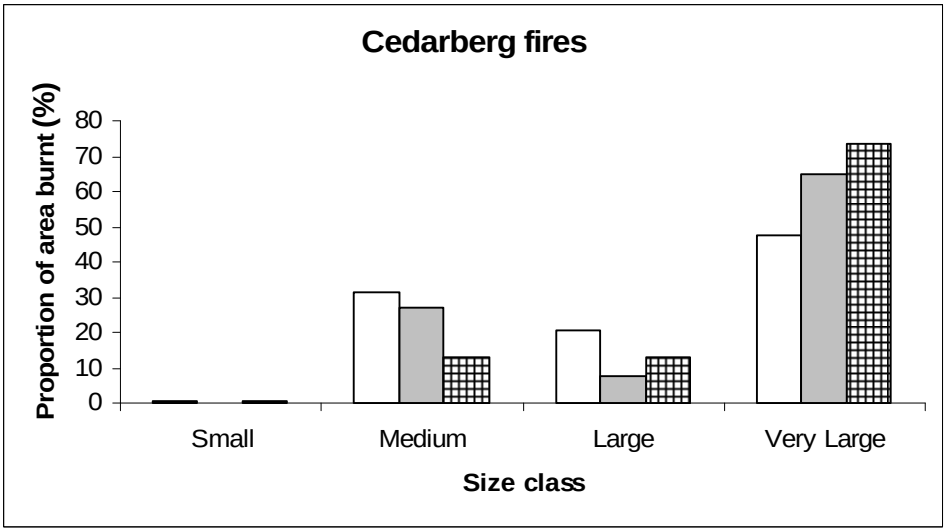


Figure 23. The proportion of the area burnt in fires of different size classes over time in the Cedarberg Nature Reserve. Size classes are small (0 – 100 ha); medium (>100 – 2000 ha); large (>2000 – 5000 ha) and very large (>5000 ha). Un-shaded, shaded and hashed bars are for the periods 1945 – 1969, 1970 – 1989 and 1990 – 2006 respectively.

Most fires were in summer and autumn (*Figure 24*). The incidence of winter fires between 1970 and 1989 was largely due to prescribed burning activities.

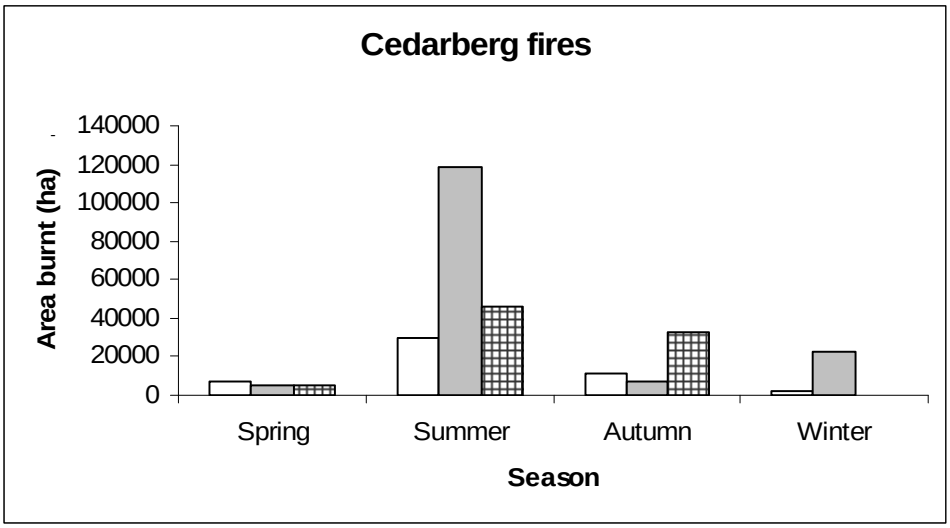


Figure 24. Total area burnt in different seasons in the Cedarberg Nature Reserve during two periods (unshaded bars = 1945 – 1969; shaded bars = 1970 – 1989; hashed bars = 1990 - 2006).

The mean fire return interval for the whole record was 25.4 years. This ranged from 40.9 years between 1945 and 1949, and decreased to 23.6 years between 2000 and 2006 (*Figure 25*). The value of 145.9 years for the period between 1960 and 1969 probably reflects a lack of records.

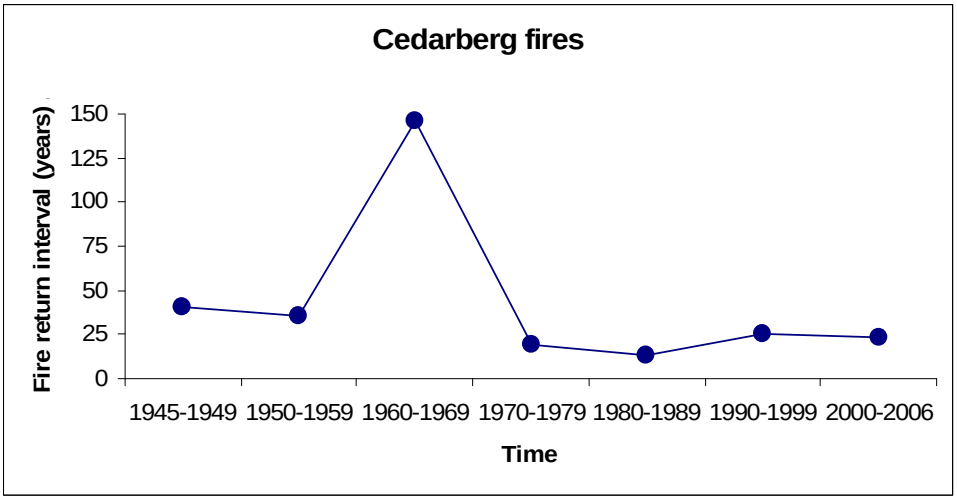
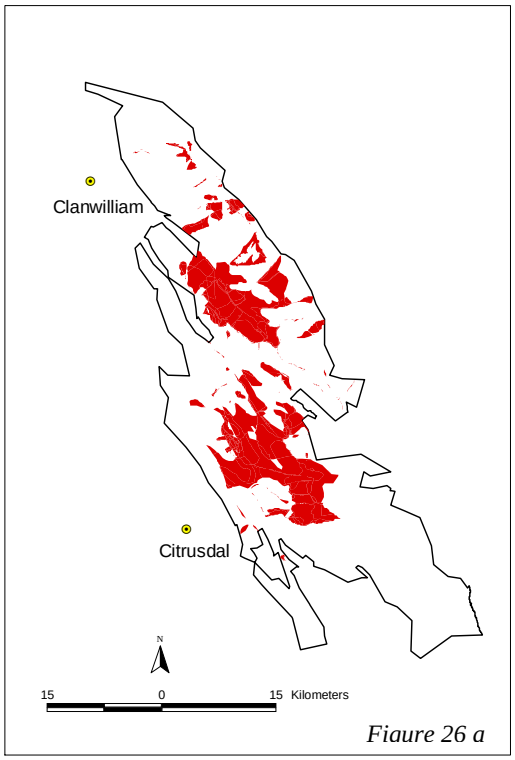


Figure 25. Mean fire return intervals per decade in the Cedarberg Nature Reserve.

Areas subjected to a least one short (≤ 6 years) interval fire amounted to 11.5% and 8.4% of the area between 1970 and 1989, and between 1990 and 2006 respectively. The spatial distribution of these areas is shown in Figure 26.



Fiaure 26 a

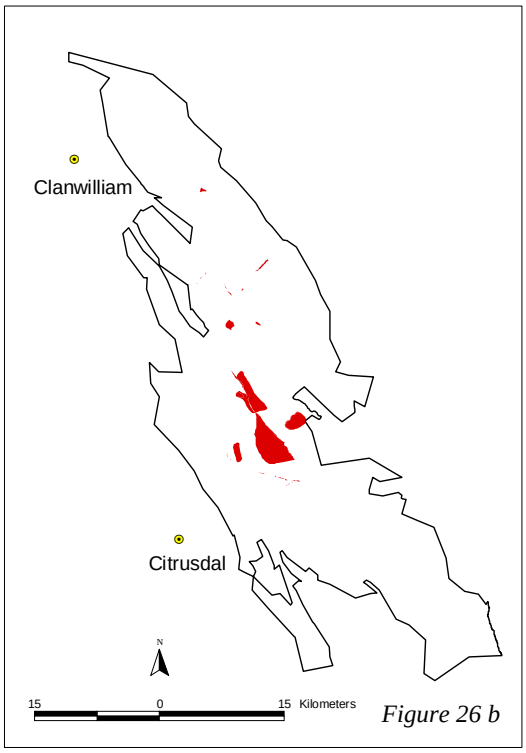
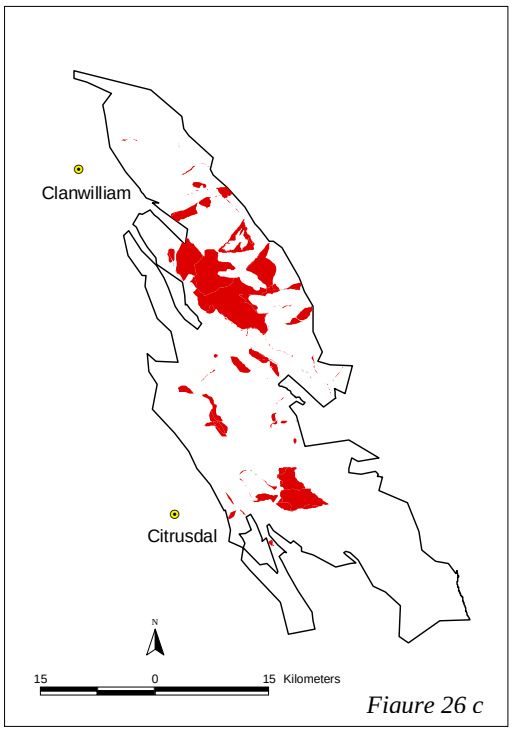


Figure 26 b



Fiaure 26 c

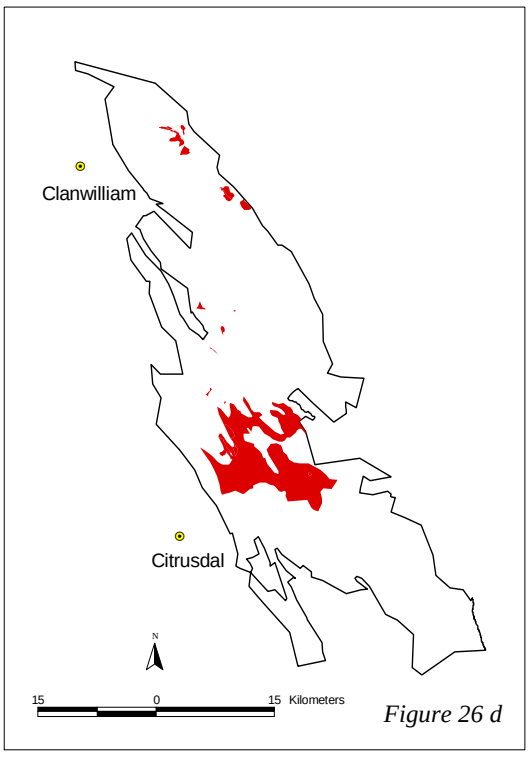


Figure 26 d

Figure 26. The spatial occurrence of short (≤ 6 years) fire return intervals in the Cedarberg Nature Reserve for the periods (a) = 1945 to 2006; (b) = 1945 – 1969; (c) = 1970 – 1989; and (d) = 1990 – 2006.

In Figure 26 (above) some areas depicted in (a) do not appear in either (b), (c) or (d) as the datasets were split, eliminating short (≤ 6 years) fire return intervals that straddled the three datasets.

Fires of unknown origin accounted for the largest category in terms of area burnt. Lightning and prescribed burning accounted for 28.6 and 9.5 % in terms of area burnt respectively (*Table 7*).

Table 7. The total area burnt in the Cedarberg Nature Reserve by different causes during the period 1945 – 2006.

Cause	Number	Area burnt	% of area burnt
Accidental	21	38 734.5	12.9
Arson	2	3 89.6	0.1
Escaped prescribed burn	1	705.1	0.2
Falling rocks	11	42 319.7	14.1
Lightning	24	85 273.9	28.6
Prescribed burn	39	28 312.8	9.5
Unknown	56	103 561.4	34.6
Total	**154**	**299 296.9**	**100**

5.5 Western Inland Zone: Limietberg Nature Reserve /…

5.6 Western Inland Zone: Limietberg Nature Reserve

The relationship between the number of fires and the area burnt is shown in Figure 27. A small number of fires were responsible for burning most of the area. It appears that fires in the very large category have been increasing in importance over the last decade or two (*Figure 28*).

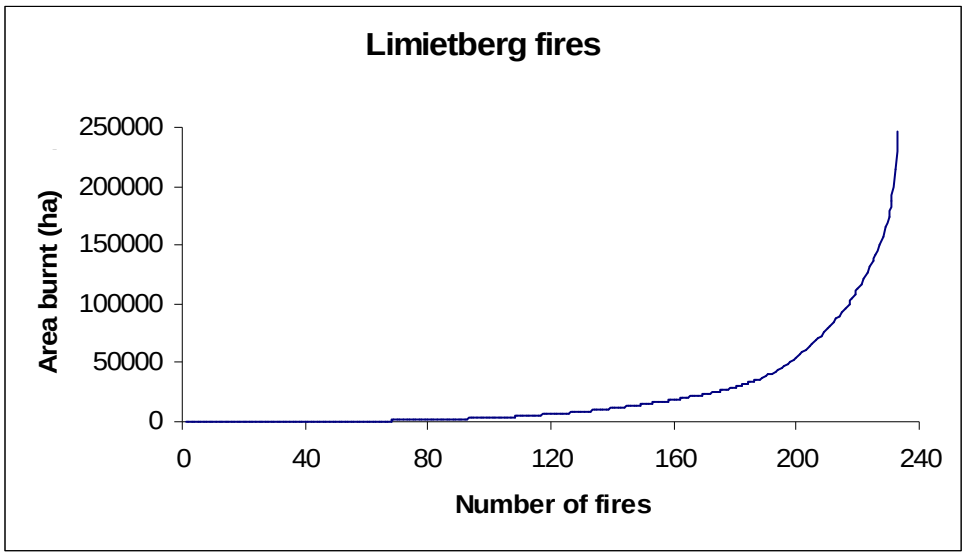


Figure 27. The relationship between the number of fires (233) and area burnt (245 831.4 ha) in the Limietberg Nature Reserve between 1966 and 2006.

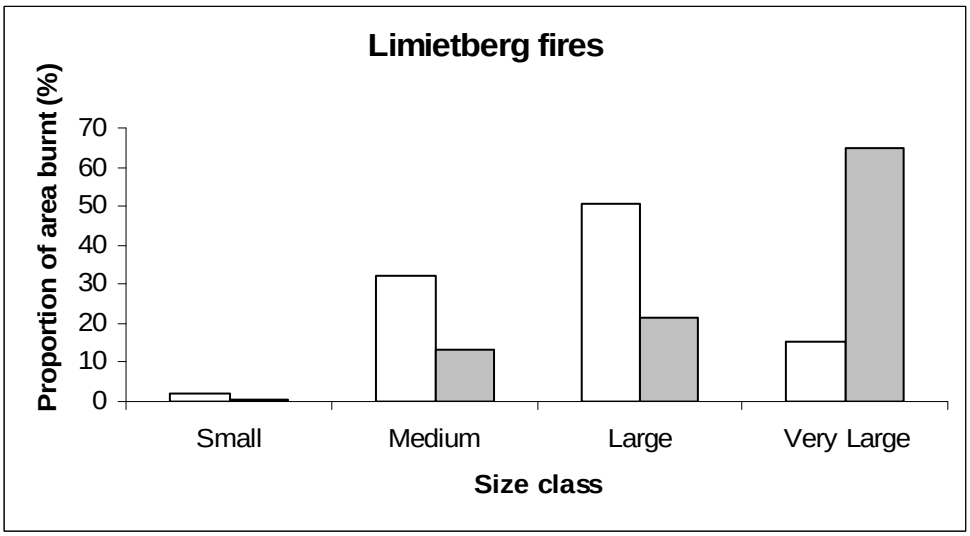


Figure 28. The proportion of the area burnt in fires of different sizes over time in the Limietberg Nature Reserve. Size classes are small (0 – 100 ha); medium (>100 – 2000 ha); large (>2000 – 5000 ha) and very large (>5000 ha). Un-shaded and shaded bars are for the periods 1966 – 1989 and 1990 – 2006 respectively.

Most fires were in summer, especially more recently (*Figure 29*).

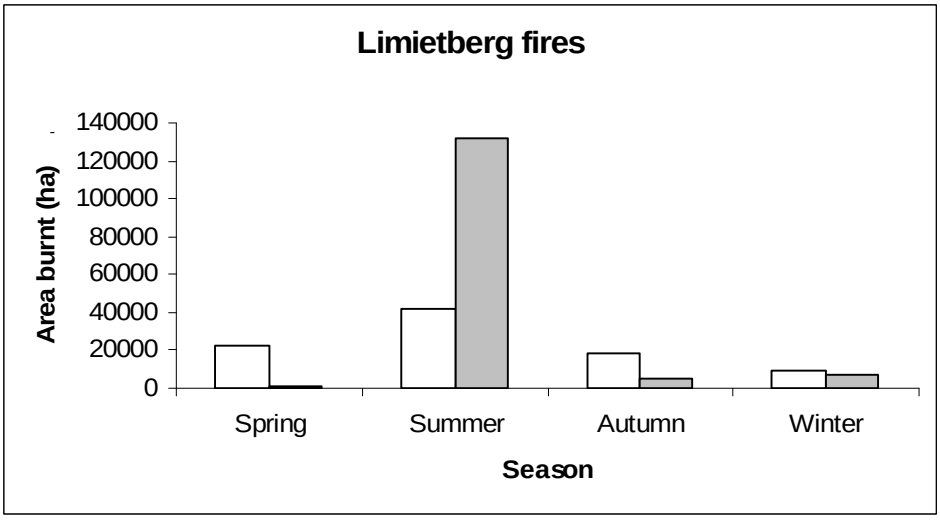


Figure 29. Total area burnt in different seasons in the Limietberg Nature Reserve during two periods (unshaded bars = 1966 – 1989; shaded bars = 1990 – 2006).

The mean fire return interval for the whole record was 15 years. This ranged from 22.2 years between 1966 and 1969 (not included in Figure 30), and decreased to 13.7 years between 2000 and 2006 (*Figure 30*). This indicates a clear tendency of increasing fire frequency.

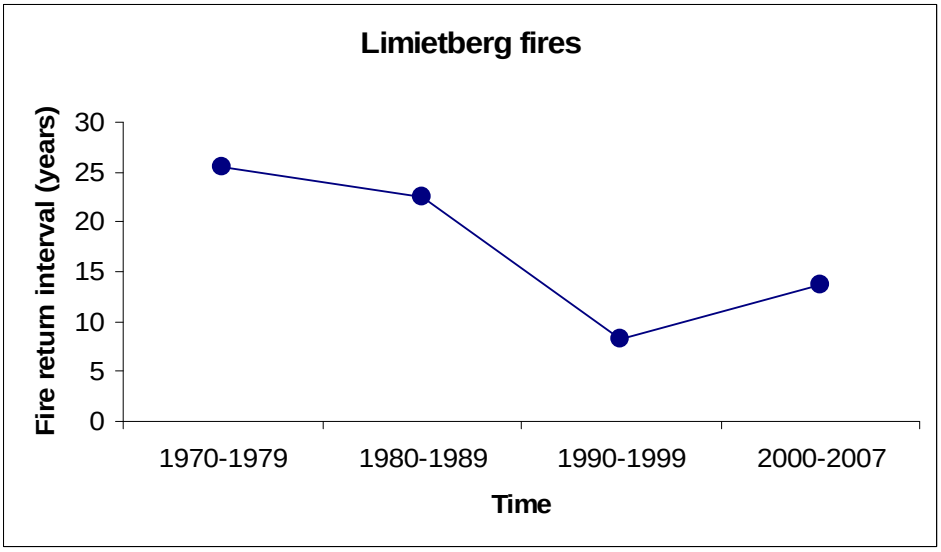


Figure 30. Mean fire return intervals per decade in the Limietberg Nature Reserve.

Areas subjected to a least one short (≤ 6 years) interval fire amounted to 6.4% between 1966 and 1989, but this increased to 21.9% of the area between 1990 and 2006. The spatial distribution of these areas is shown in Figure 31.

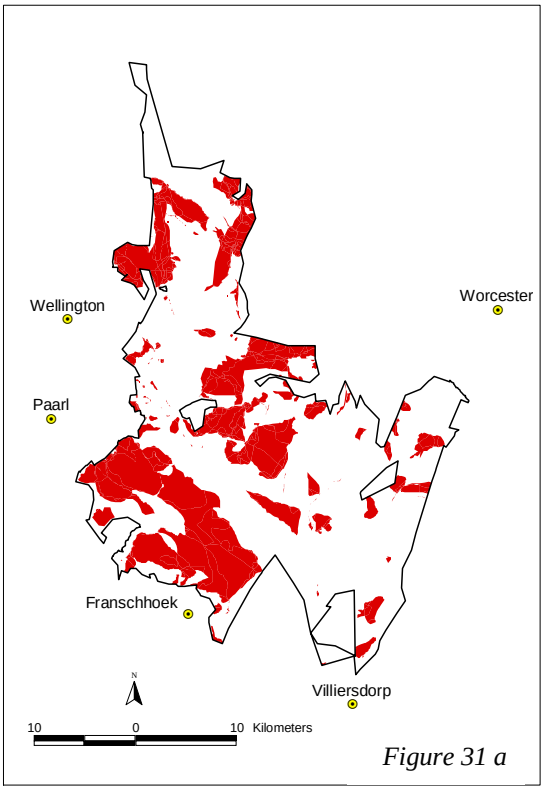


Figure 31 a

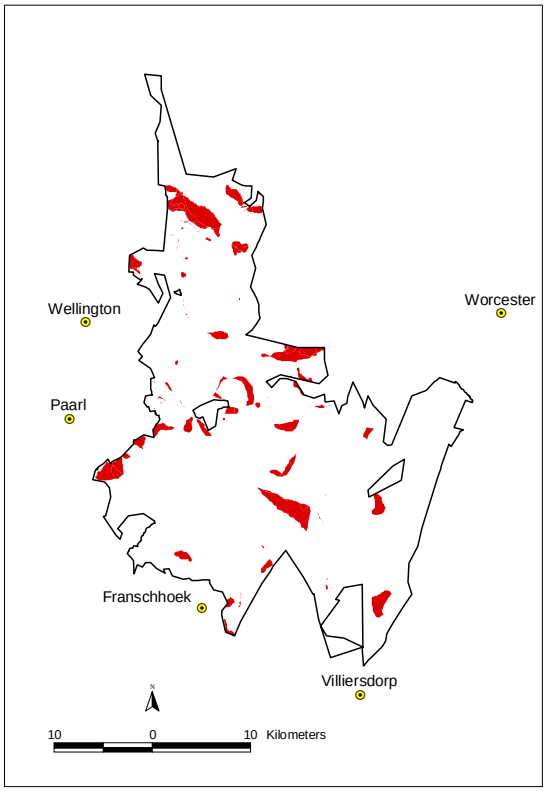


Figure 31 b

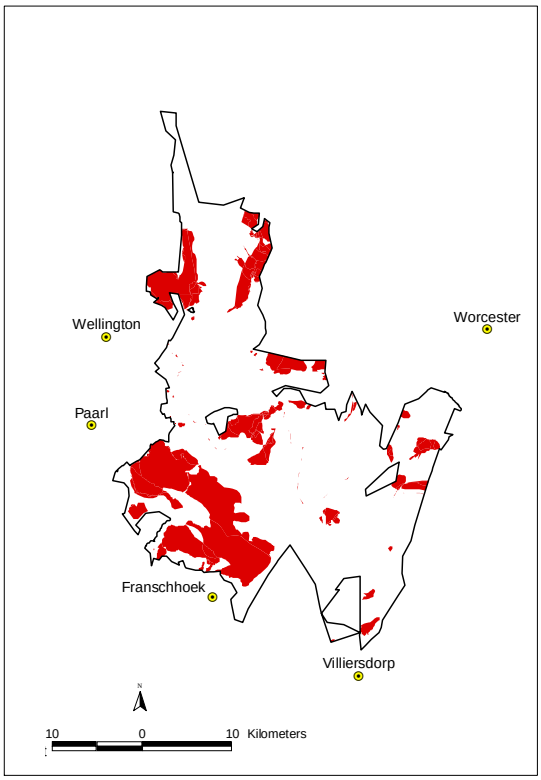


Figure 31. The spatial occurrence of short (≤ 6 years) fire return intervals in the Limietberg Nature Reserve for the periods (a) = 1966 to 2006; (b) = 1970 – 1989; and (c) = 1990 – 2006. Note that some areas depicted in (a) do not appear in either (b) or (c) as the datasets were split, eliminating short fire return intervals that straddled the two datasets.

Figure 31 c

Fires of unknown origin accounted for most fires in terms of area burnt. Lightning and prescribed burning accounted for 2.6 and 11.2 % in terms of area burnt respectively (*Table 8*).

Table 8. The total area burnt in the Limietberg Nature Reserve by different causes during the period 1966 – 2006.

Cause	Number	Area burnt	% of area burnt
Accidental	50	39 490.8	16.1
Arson	15	22 418.8	9.1
Falling rocks	1	2 972.7	1.2
Lightning	14	6 361.9	2.6
Powerline	6	25 86.2	1.1
Prescribed burn	43	27 671.7	11.2
Unknown	104	144 329.4	58.7
Total	**233**	**245 831.4**	**100**

5.7 Western Inland Zone: Waterval Nature Reserve /…

5.7 Western Inland Zone: Waterval Nature Reserve

The relationship between the number of fires and the area burnt is shown in Figure 32. A small number of fires were responsible for burning most of the area. The proportion of the area burnt by the different fire size classes has been relative stable over time (*Figure 33*).

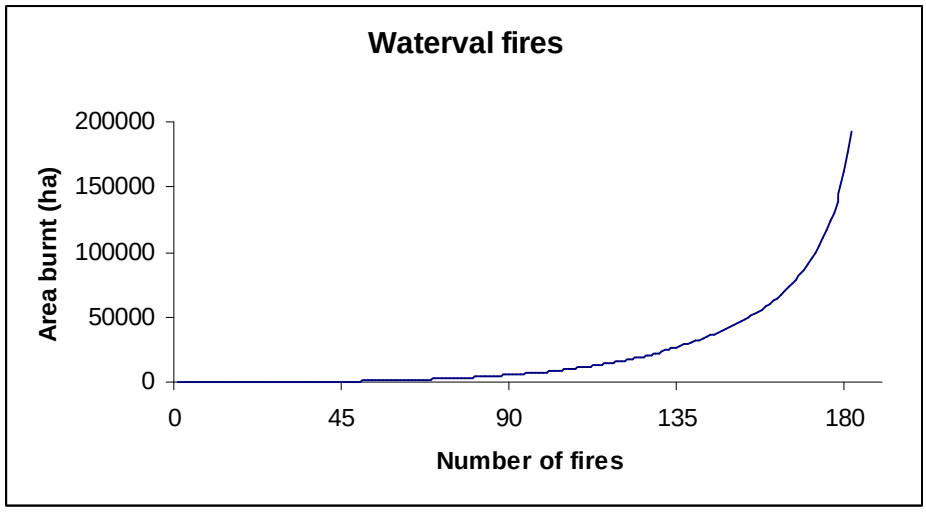


Figure 32. The relationship between the number of fires (182) and area burnt in Waterval Nature Reserve (192 063.8 ha) between 1974 and 2007.

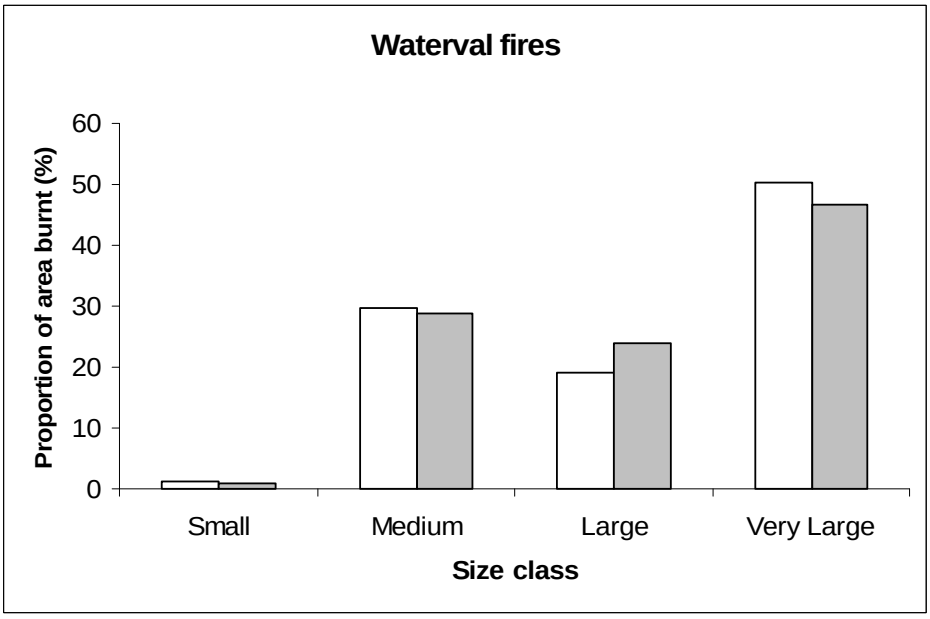


Figure 33. The proportion of the area burnt in fires of different sizes over time in Waterval Nature Reserve. Size classes are small (0 – 100 ha); medium (>100 – 2000 ha); large (>2000 – 5000 ha) and very large (>5000 ha). Un-shaded and shaded bars are for the periods 1974 – 1989 and 1990 – 2007 respectively.

Most fires were in summer and autumn, with autumn fires been more prevalent recently (*Figure 34*).

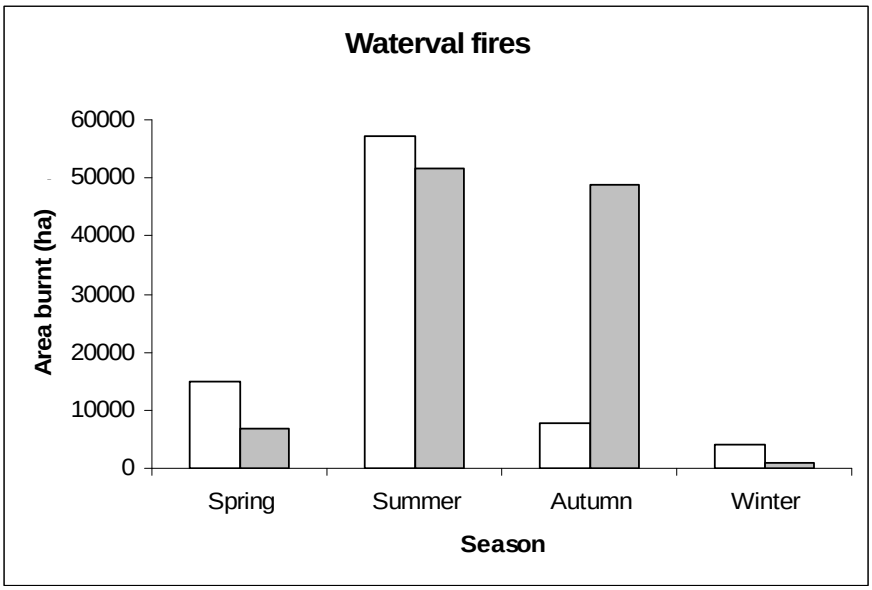


Figure 34. Total area burnt in different seasons in Waterval Nature Reserve during two periods (unshaded bars = 1974 – 1989; shaded bars = 1990 – 2007).

The mean fire return interval for the whole record was 19.1 years. This ranged from 14.4 years between 1980 and 1989, increased to 17.9 between 1990 and 1999 and decreased again to 16.9 years between 2000 and 2007 (*Figure 35*).

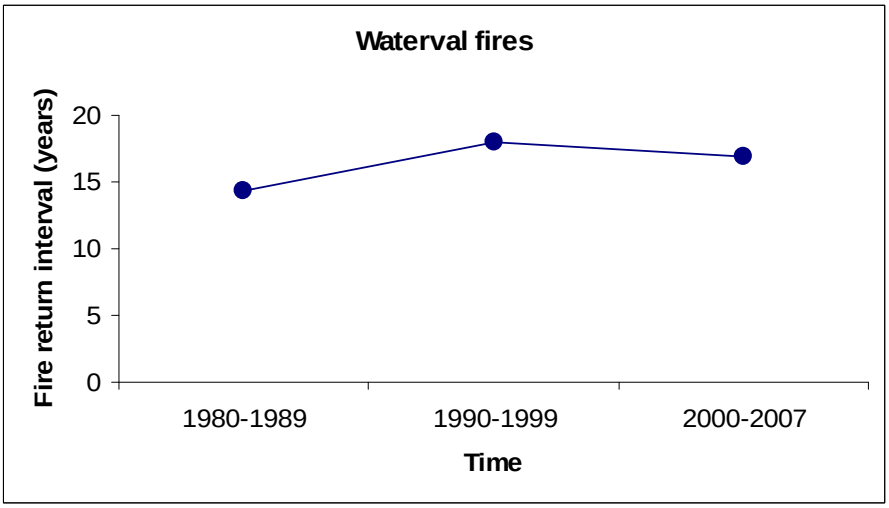


Figure 35. Mean fire return intervals per decade in Waterval Nature Reserve.

Areas subjected to a least one short (≤ 6 years) interval fire amounted to 5.5% between 1974 and 1989, and increased slightly to 6.3% of the area between 1990 and 2007. The spatial distribution of these areas is shown in Figure 36.

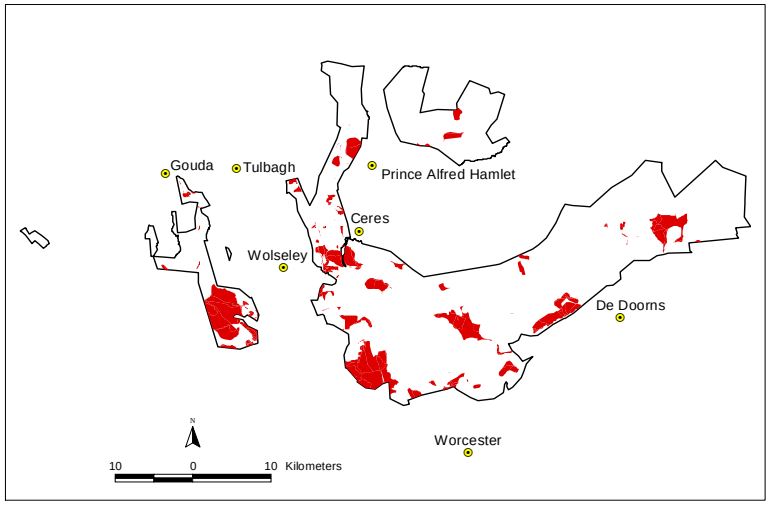


Figure 36 a

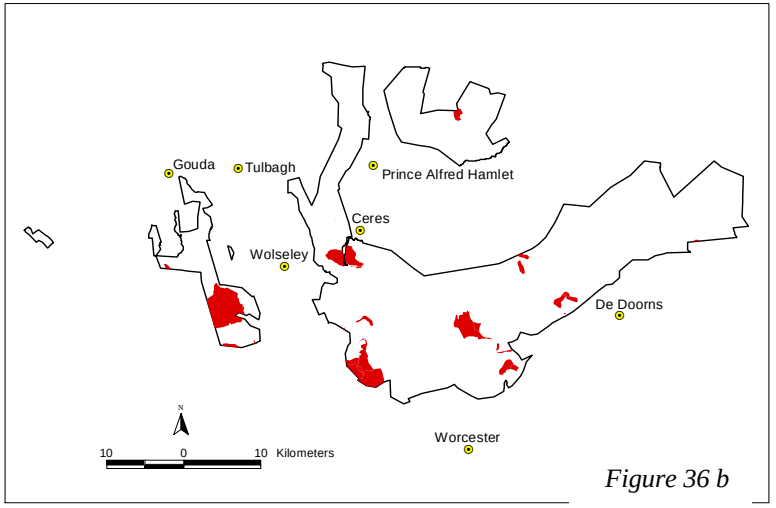


Figure 36 b

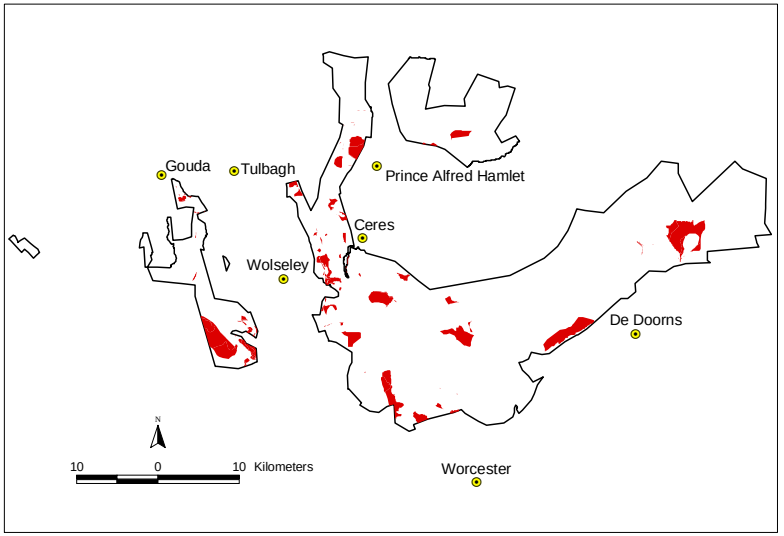


Figure 36 c

Figure 36 The spatial occurrence of short (≤6 years) fire return intervals in Waterval Nature Reserve for the periods. (a) = 1974 to 2007; (b) = 1974 – 1989; and (c) = 1990 – 2007. Note that some areas depicted in (a) do not appear in either (b) or (c) as the datasets were split, eliminating short fire return intervals that straddled the two datasets.

Fires of unknown origin accounted for most fires in terms of area burnt. Lightning and prescribed burning accounted for 18.7 and 4.6 % in terms of area burnt respectively (*Table 9*).

Table 9. The total area burnt in Waterval Nature Reserve by different causes during the period 1974 – 2007.

Cause	Number	Area burnt	% of area burnt
Accidental	48	35 153.2	18.3
Arson	5	445.0	0.2
Falling rocks	5	17 423.4	9.1
Lightning	10	35 823.0	18.7
Powerline	5	309.6	0.2
Prescribed burn	9	8 882.2	4.6
Train	2	5.6	0
Unknown	98	9 4021.9	48.9
Total	**182**	**192 063.8**	**100**

5.8 Southeastern Coastal Inland Zone: Outeniqua Nature Reserve /…

5.8 Southeastern Coastal Zone: Outeniqua Nature Reserve

The relationship between the number of fires and the area burnt is shown in Figure 37. As in other areas, a few fires were responsible for burning most of the area. However, most of the area burnt in medium sized fires with very large fires becoming more prevalent (*Figure 38*).

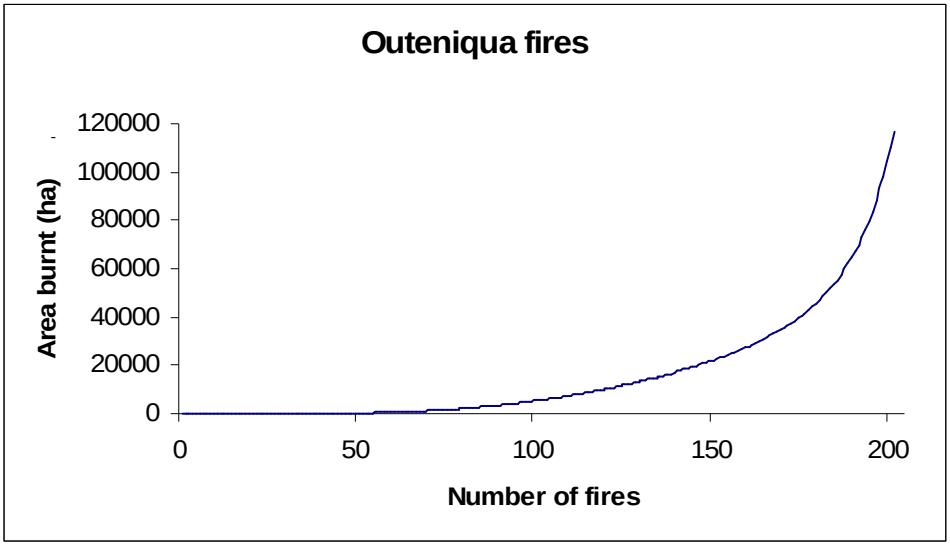


Figure 37. The relationship between the number of fires (202) and area burnt (117 154 ha) in the Outeniqua Nature Reserve between 1938 and 2006.

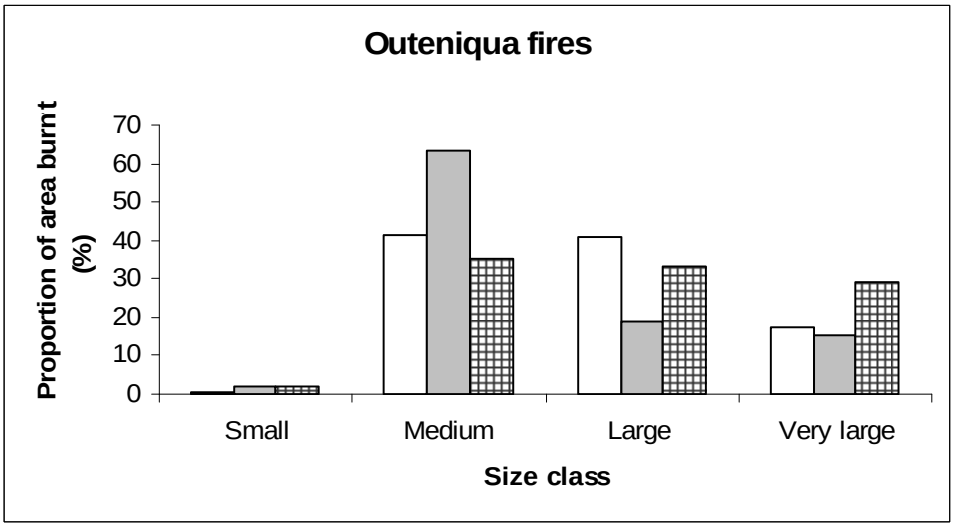


Figure 38. The proportion of the area burnt in fires of different size classes over time in the Outeniqua Nature Reserve. Size classes are small (0 – 100 ha); medium (>100 – 2000 ha); large (>2000 – 5000 ha) and very large (>5000 ha). Un-shaded, shaded and hashed bars are for the periods 1938 – 1969; 1970 - 1989 and 1990 – 2006 respectively.

Most fires were in summer and autumn (*Figure 39)*, but winter and spring fires form a significant part of the fire regime. This is due to very different climatic conditions in this zone.

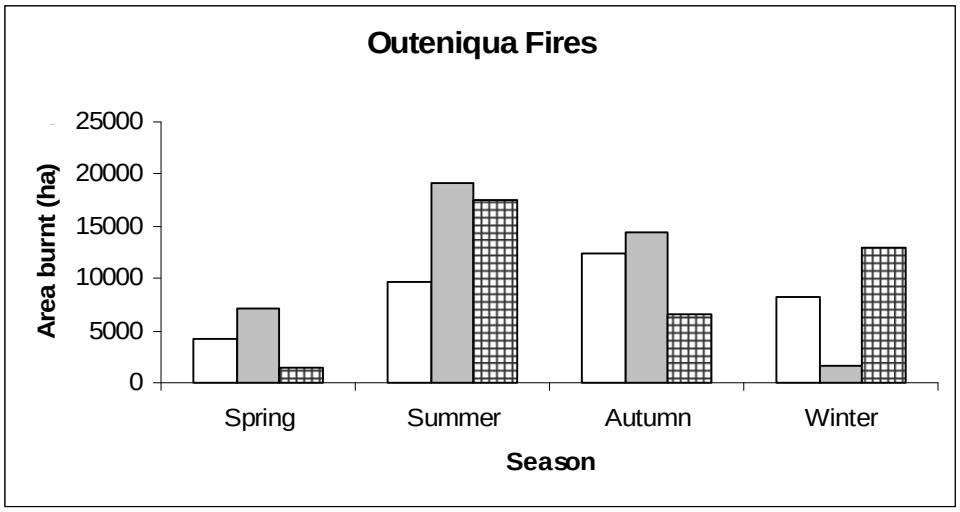


Figure 39. Total area burnt in different seasons in the Outeniqua Nature Reserve during two periods (unshaded bars = 1938 – 1969; shaded bars = 1970 – 1989 and hashed bars = 1990 – 2006).

The mean fire return interval for the whole record was 24.7 years. This ranged from 31.4 years between 1950 and 1959, and decreased to 18.3 years between 2000 and 2006 (*Figure 40*).

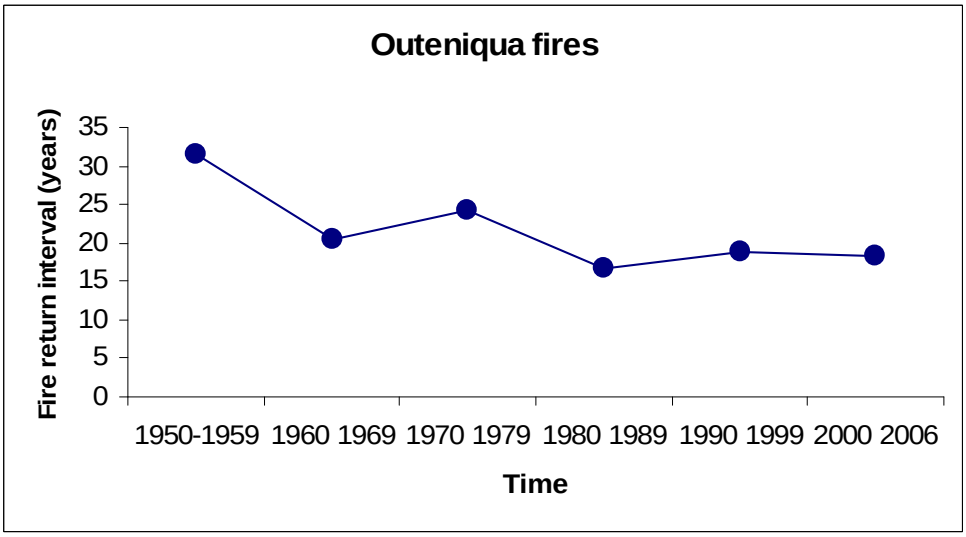


Figure 40. Mean fire return intervals per decade in the Outeniqua Nature Reserve.

Areas subjected to a least one short (≤6 years) interval fire amounted to 4.3 and 8.7% of the area between 1970 and 1989, and between 1990 and 2006 respectively. The spatial distribution of these areas is shown in Figure 41.

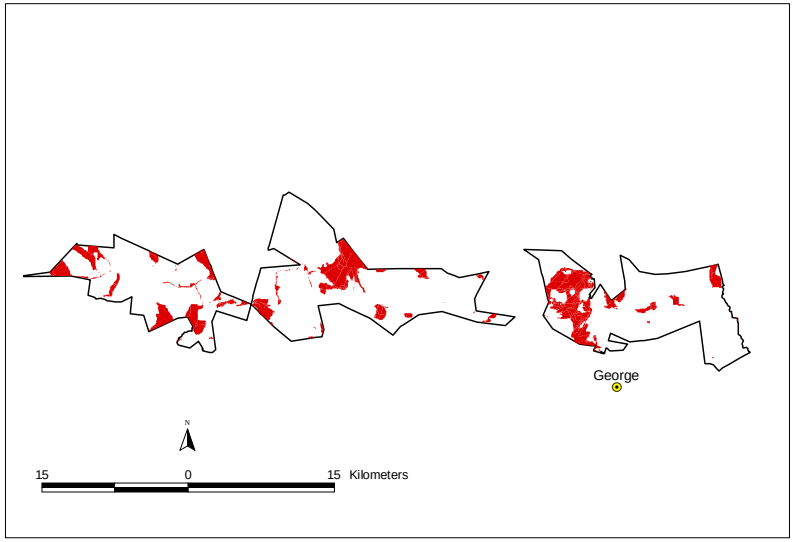


Figure 41 a

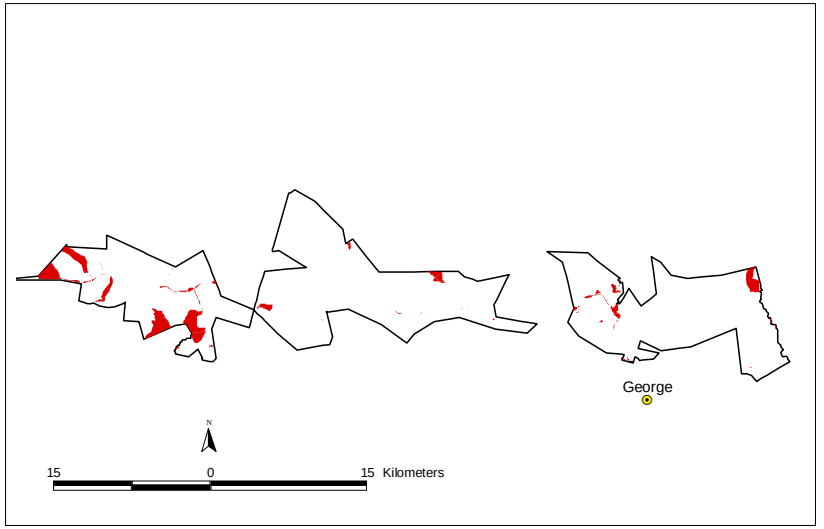


Figure 41 b

Figure 41. The spatial occurrence of short (≤ 6 years) fire return intervals in the Outeniqua Nature Reserve for the periods (a) = 1938 to 2006; (b) = 1970 – 1989; and (c) = 1990 – 2006. Note that some areas depicted in (a) do not appear in either (b) or (c) as the datasets were split, eliminating short fire return intervals that straddled the two datasets.

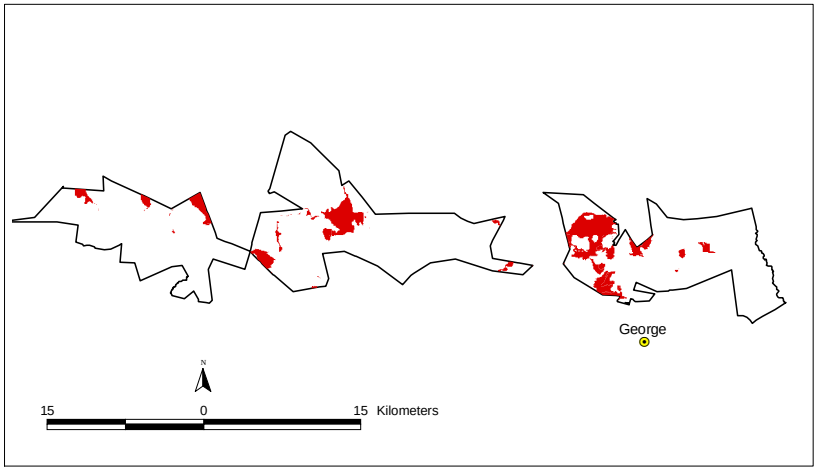


Figure 41 c

Accidental fires accounted for the largest category in terms of area burnt. Lightning and prescribed burning accounted for 14.6 and 18.7 % in terms of area burnt respectively (*Table 10*).

Table 10. The total area burnt in the Outeniqua Nature Reserve by different causes during the period 1938 – 2006.

Cause	Number	Area burnt	% of area burnt
Accidental	40	46 318.4	39.5
Escaped prescribed burn	7	10 200.2	8.7
Lightning	31	17 067.1	14.6
Prescribed burn	75	21 889.3	18.7
Steam train	7	2 127.5	1.8
Unknown	42	19 551.5	16.7
Total	**202**	**117 154.0**	**100**

5.9 Eastern Inland Zone: Kammanassie Nature Reserve /…

5.9 Eastern Inland Zone: Kammanassie Nature Reserve

The relationship between the number of fires and the area burnt is shown in Figure 42. A small number of fires were responsible for burning most of the area. There has been a tendency for the area burnt in large and very large fires to increase over time, at the expense of medium-sized fires (*Figure 43*).

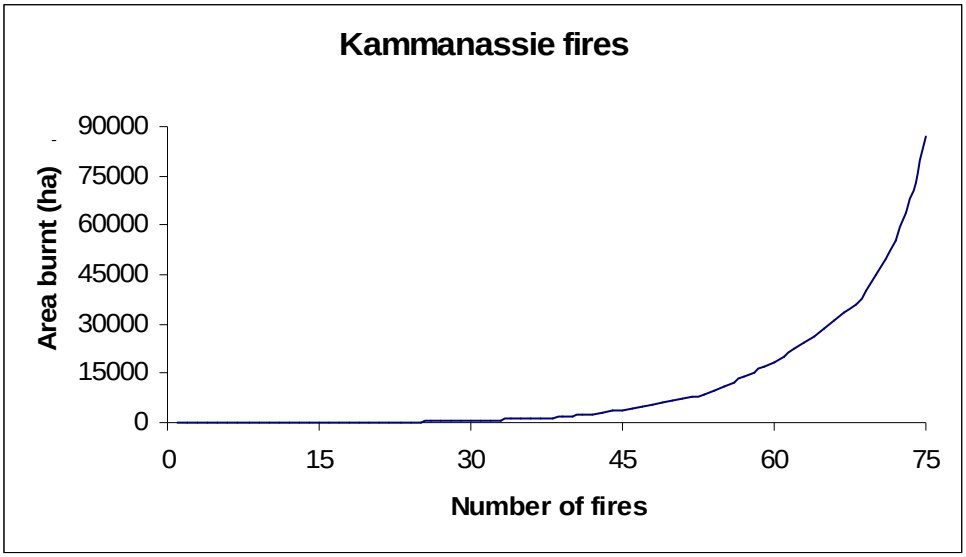


Figure 42. The relationship between the number of fires (75) and area burnt (86 656.9 ha) in the Kammanassie Nature Reserve between 1970 and 2006.

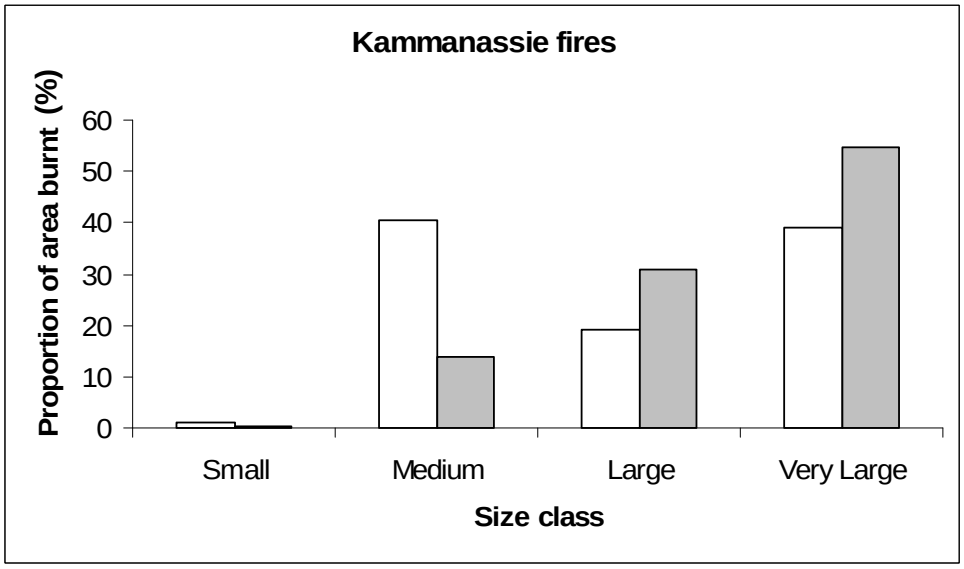


Figure 43. The proportion of the area burnt in fires of different sizes over time in the Kammanassie Nature Reserve. Size classes are small (0 – 100 ha); medium (>100 – 2000 ha); large (>2000 – 5000 ha) and very large (>5000 ha). Unshaded and shaded bars are for the periods 1970 – 1989 and 1990 – 2006 respectively.

Most fires were in summer and autumn (*Figure 44*).

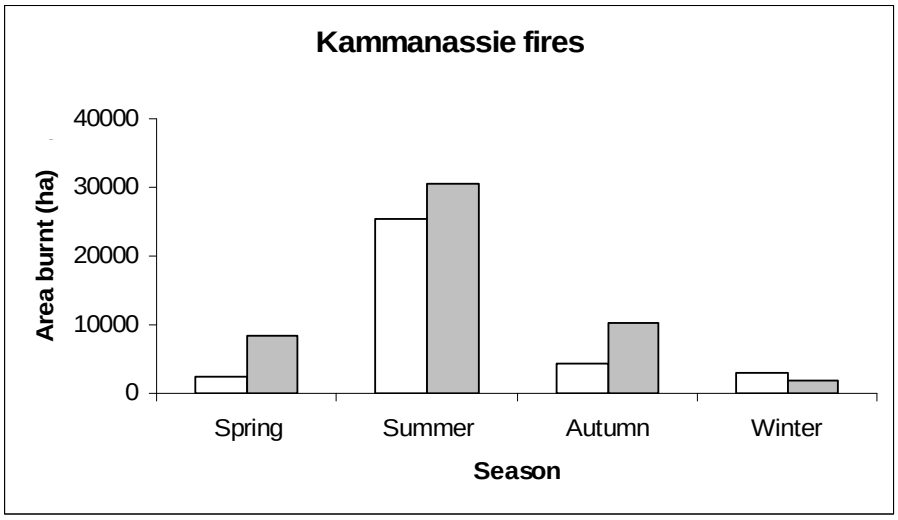


Figure 44. Total area burnt in different seasons in the Kammanassie Nature Reserve during two periods (unshaded bars = 1970 – 1989; shaded bars = 1990 – 2006).

The mean fire return interval for the whole record was 21.2 years. This ranged from 15.6 years between 1980 and 1989, and decreased slightly to 13.3 years between 2000 and 2006 (*Figure 45)*. The value of 145.9 years for the period between 1960 and 1969 probably reflects a lack of records, and is not included in Figure 45.

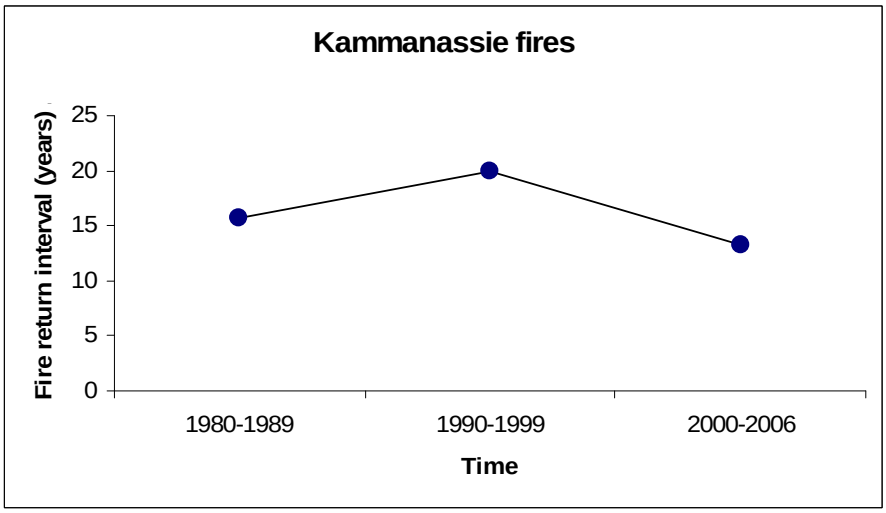


Figure 45. Mean fire return intervals per decade in the Kammanassie Nature Reserve.

Relatively small areas were subjected to short-interval (≤ 6 years) fires. This area amounted to 1% between 1970 and 1989, and 6.9% between 1990 and 2006. The spatial distribution of these areas is shown in Figure 46.

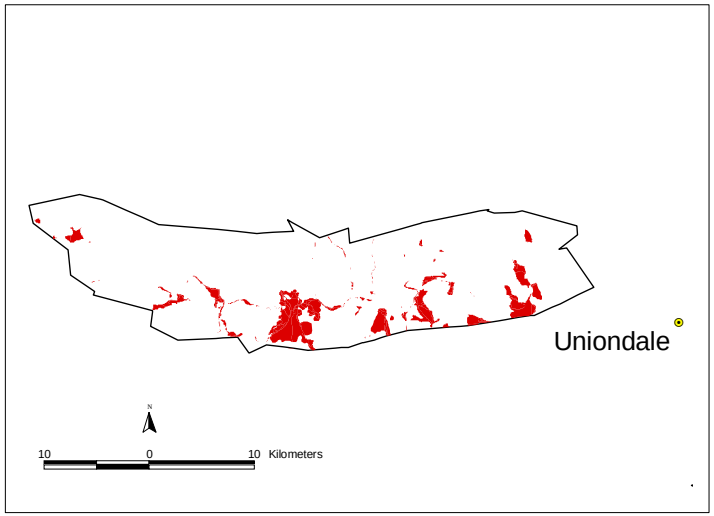


Figure 46 a

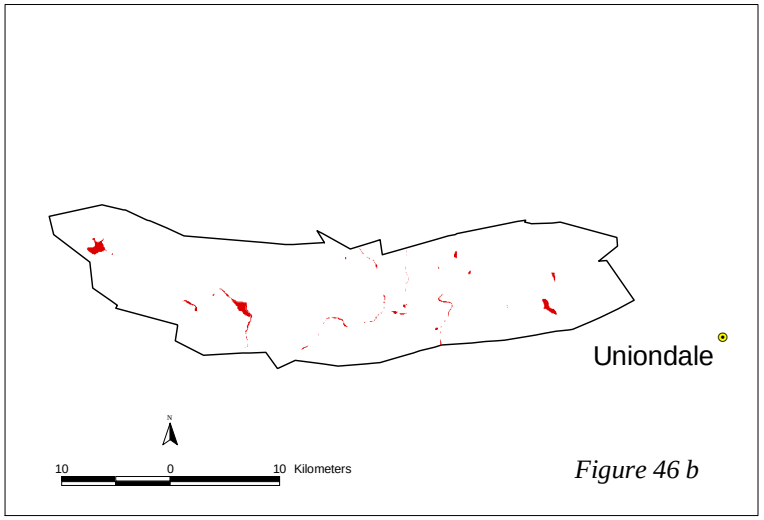


Figure 46 b

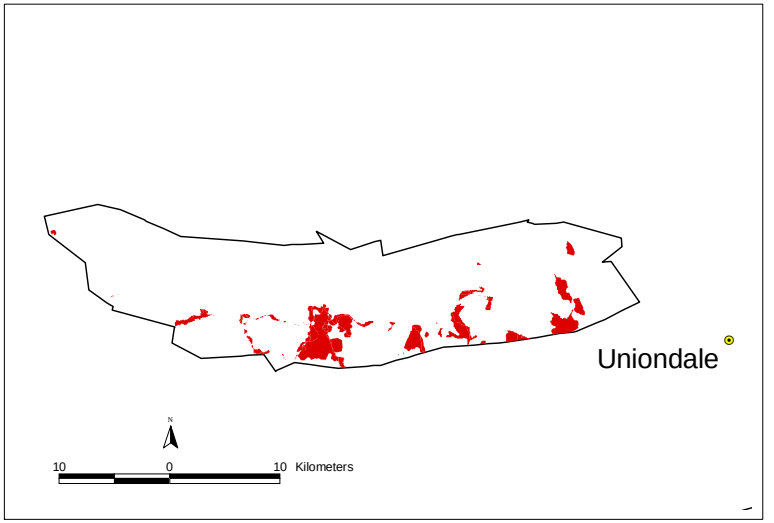


Figure 46 c

Figure 46. The spatial occurrence of short (≤ 6 years) fire return intervals in the Kammanassie Nature Reserve for the periods (a) = 1970 – 2006; (b) = 1970 – 1989; and (c) = 1990 – 2006. Note that some areas depicted in (a) do not appear in either (b) or (c) as the datasets were split, eliminating short fire return intervals that straddled the two datasets.

Fires caused by lightning accounted for the largest category in terms of area burnt. Prescribed burning only accounted for 4.2 % in terms of area burnt (*Table 11*).

Table 11. The total area burnt in the Kammanassie Nature Reserve by different causes during the period 1970 – 2006.

Cause	Number	Area burnt	% of area burnt
Accidental	8	2 499.1	2.9
Escaped prescribed burn	4	144.4	0.2
Lightning	33	43 529.5	50.2
Prescribed burn	2	3 603.5	4.2
Unknown	28	36 880.4	42.5
Total	**75**	**86 656.9**	**100**

5.10 Eastern Inland Zone: Swartberg Nature Reserve /…

5.10 Eastern Inland Zone: Swartberg Nature Reserve

The relationship between the number of fires and the area burnt is shown in Figure 47. Unlike other areas, medium-sized fires accounted for almost as much area burnt as large fires, although large and very large fires have recently become more prevalent. (*Figure 48*).

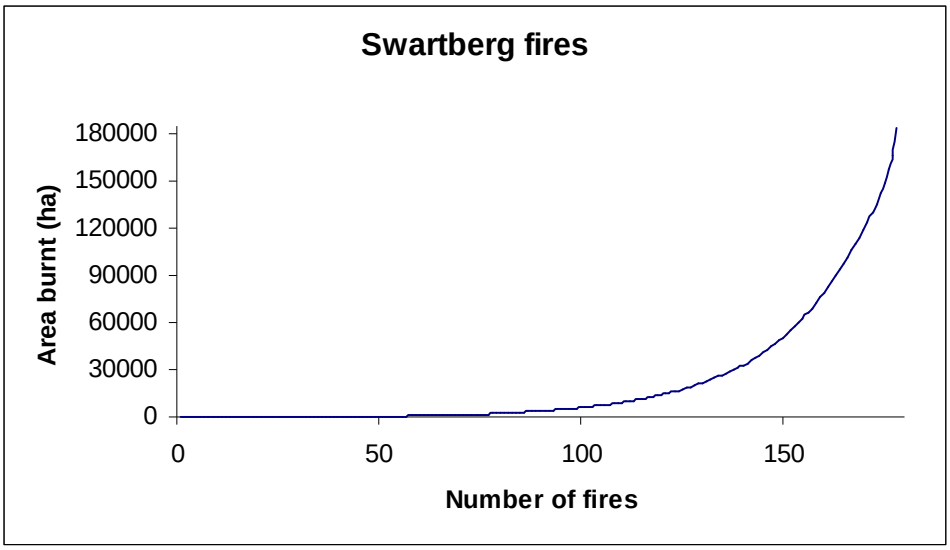


Figure 47. The relationship between the number of fires (177) and area burnt (183 510.7 ha) in the Swartberg Nature Reserve between 1944 and 2006.

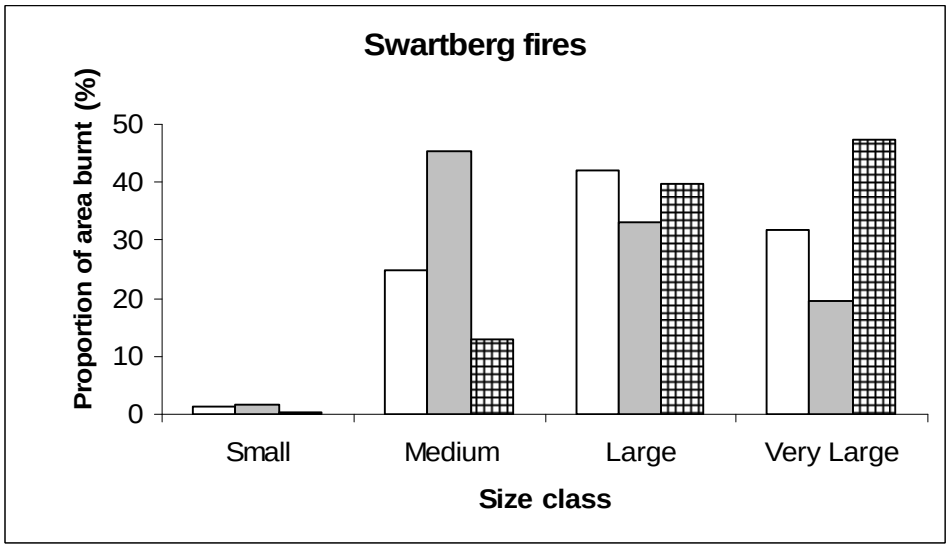


Figure 48. The proportion of the area burnt in fires of different size classes over time in the Swartberg Nature Reserve. Size classes are small (0 – 100 ha); medium (>100 – 2000 ha); large (>2000 – 5000 ha) and very large (>5000 ha). Un-shaded, shaded and hashed bars are for the periods 1944 – 1969 and 1970 – 1989 and 1990 - 2007 respectively.

Most fires were in summer and autumn, and the relative prevalence of summer fires has increased in recent times (*Figure 49*).

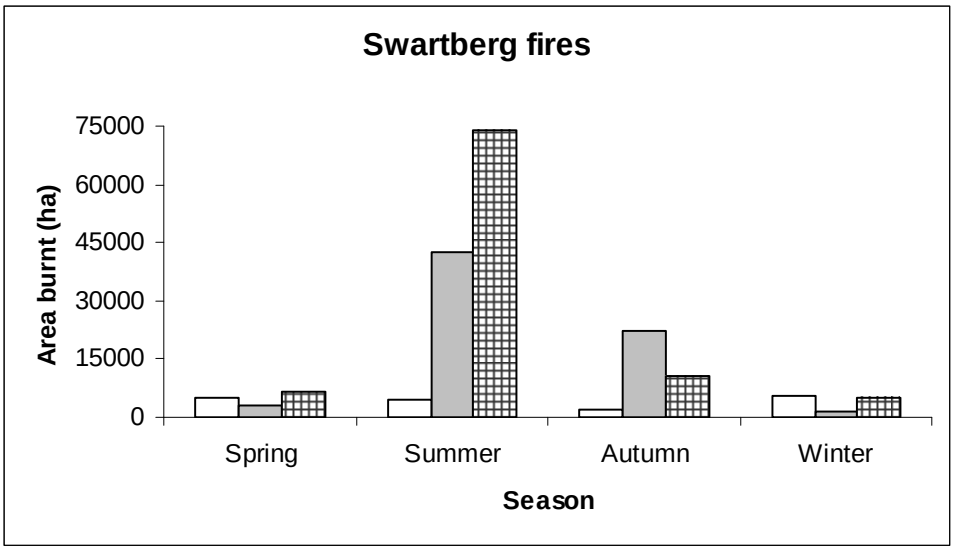


Figure 49. Total area burnt in different seasons in the Swartberg Nature Reserve during three periods (unshaded bars = 1944 – 1969; shaded bars = 1970 – 1989 and hashed bars = 1990 - 2006).

The mean fire return interval for the whole record was 41.3 years. This ranged from 18.1 years between 1980 and 1989, and increased to 25.4 years between 2000 and 2006 (*Figure 50*). Values for earlier decades were 300 – 400 years, almost certainly indicating a lack of records rather than a lack of fire and are not included in Figure 50.

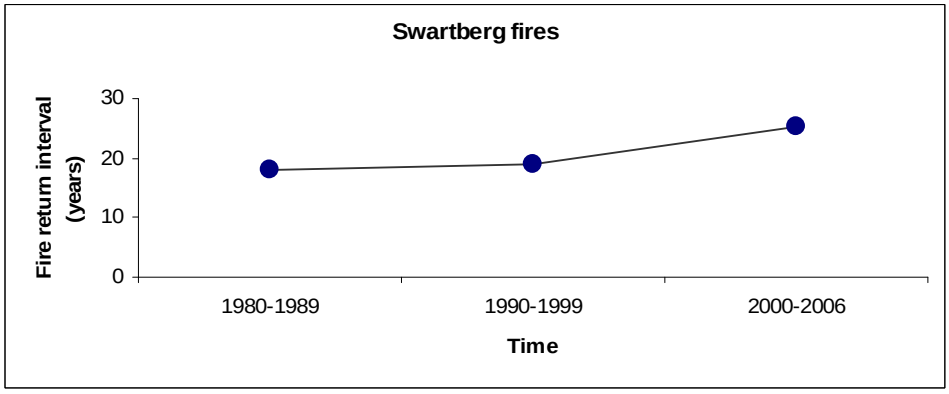


Figure 50. Mean fire return intervals per decade in the Swartberg Nature Reserve.

Areas subjected to a least one short (≤ 6 years) interval fire amounted to 3.5% and 3.3% of the area between 1970 and 1989, and between 1990 and 2006 respectively. The spatial distribution of these areas is shown in Figure 51.

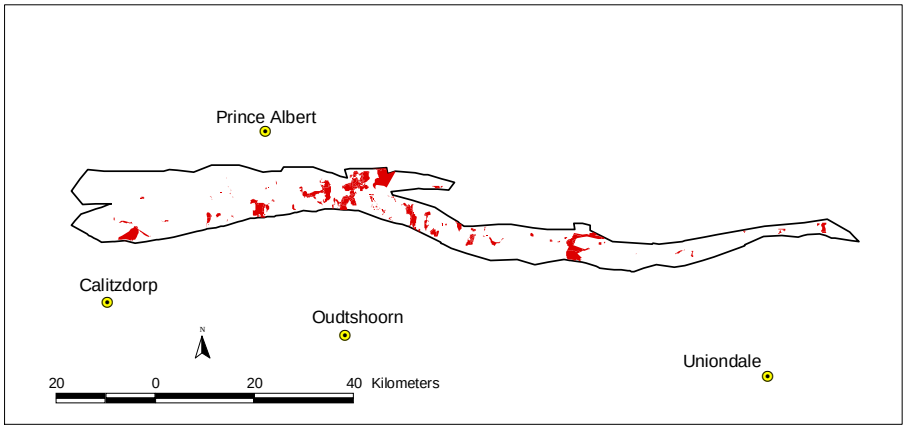


Figure 51 a

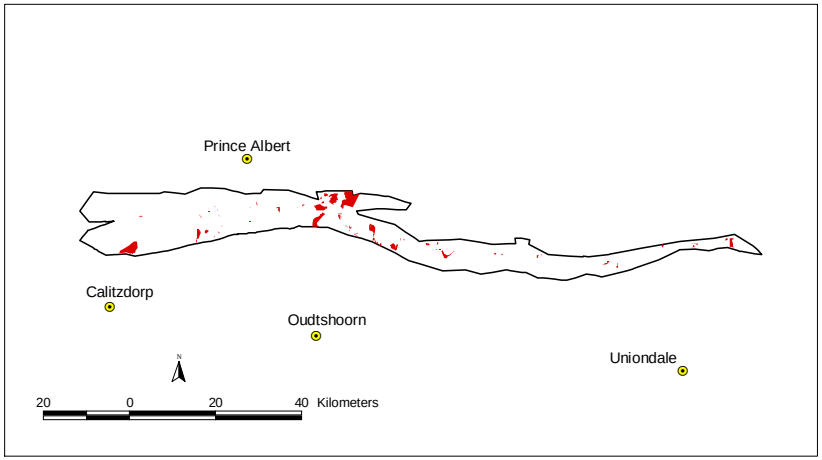


Figure 51 b

Figure 51. The spatial occurrence of short (≤ 6 years) fire return intervals in the Swartberg Nature Reserve for the periods (a) = 1944 to 2006; (b) = 1970 – 1989; and (c) = 1990 – 2006. Note that some areas depicted in (a) do not appear in either (b) or (c) as the datasets were split, eliminating short fire return intervals that straddled the two datasets.

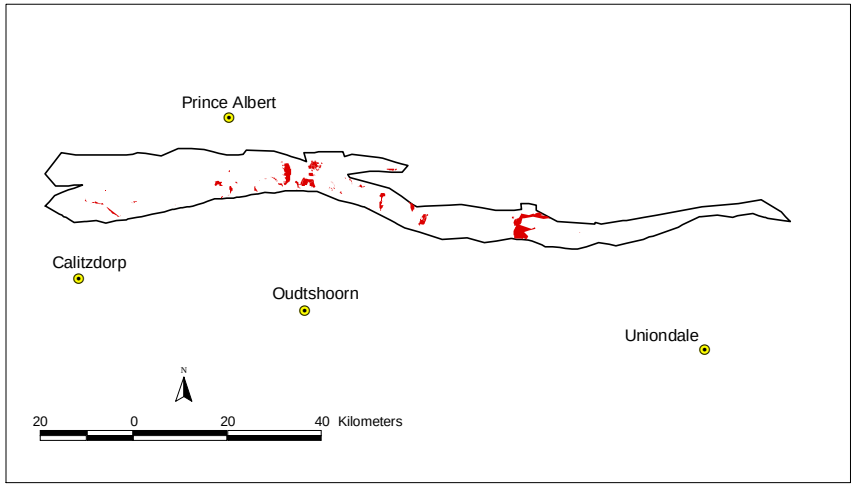


Figure 51 c

Lightning fires accounted for the majority of area burnt. Prescribed burning is not practiced in the Swartberg (*Table 12*).

Table 12. The total area burnt in the Swartberg Nature Reserve by different causes during the period 1944 – 2006.

Cause	Number	Area burnt	% of area burnt
Accidental	12	9 845.3	5.4
Arson	3	980.6	0.5
Falling rocks	1	42.1	0
Lightning	96	99 315.3	54.1
Unknown	65	73 327.4	40.0
Total	**177**	**183 510.7**	**100**

6. Discussion /…

6. Discussion

A number of points arise out of the above analysis, and these are listed briefly here. The ecological implications of these findings will be examined in the next phase of this project and presented in a further report.

***Data accuracy*:** The fire occurrence data appear to be more complete in recent years than in the record. This is reflected in more credible estimates of fire return intervals in recent decades compared to earlier decades. We thus do not have much confidence in fire regime assessments before 1970.

In the case of the Swartberg, we are aware that another dataset exists. The findings from this dataset (Seydack *et al*. 2007) are more complete than ours, for example in terms of fire return intervals. We recommend that this dataset be obtained to augment the existing dataset for the Swartberg.

Fire intensity: Fire intensity records were not analysed, as no records are kept by Cape Nature in this regard. It may be possible to associate individual fire records with a surrogate fire intensity measure. This could be done, for example, by multiplying the fire danger index on the day concerned with some measure of post-fire age (related to fuel load), but this would at best only provide a rough indication of the potential fire intensity within a fire. Actual fire intensity would also be very variable within a given fire; it would vary with time of day (or night), whether the fire was burning upslope or downslope, with or against the wind, and with changes in wind speed relative to the direction in which the fire was burning. Obtaining an accurate surrogate measure would be further complicated in cases where fires burnt over more than one day. At best, therefore, a ranked estimate of fire intensity (low, medium or high) could be assigned to a fire record. However, it is not clear how this would be useful. Given that such estimates would be crude approximations that did not account for variability within fires, and given that there does not (yet) appear to be any useful purpose for such measures, we recommend that this aspect should not be investigated further.

Short-interval fires: We found that short-interval (≤ 6 years) fires are becoming more common. Over the past 16 years (1990 – 2006), short-interval fires have covered between 3.3 and 21.9% of individual reserves, and collectively have burnt across just over 67 000 ha of land. In most cases (except in the Cedarberg and Swartberg Nature Reserves), this represents an increase over the previous 16-year period (when only ~ 38 000 ha burnt in this way).

Fire return intervals: Fire return intervals, measured on a decade-by-decade basis, decreased markedly (i.e. fire frequency increased) in the Table Mountain National Park, and in the Nuweberg and Limietberg Nature Reserves. In other areas, no marked decreases were noted.

Prescribed burning: Fynbos fire regimes are dominated by unplanned wildfires (all fires other than prescribed burns), which accounted for between 4.2 and 32.4% of the area burnt in individual protected areas. This does not include the Swartberg, which is managed as a "natural fire zone", and prescribed burning is not practiced. Prescribed burning accounted for roughly 11% of area burnt in all reserves except Riviersonderend Nature Reserve (where prescribed burning accounted for 32.4% of the area burnt).

Fire season: Fynbos fires take place predominantly in summer, or summer and autumn. In the Outeniqua Nature Reserve, the seasonal pattern of fires is more evenly distributed, with winter fires becoming more prevalent. A small proportion of the fires have occurred in winter and spring in the past, and many of these fires (37.6 and 27.6% of the area burnt in winter and spring respectively) have been due to prescribed fires, or escaped fires from the burning of firebreaks.

Causes of shifts in fire regimes: It is currently difficult to pinpoint the causes of shifts in cases where fire patterns have changed. The decrease in winter burning is probably due to abandonment of prescribed burning in these months. Increases in fire frequency, and in the incidence of short-interval fires, could be due either to shifts in climate (which could result in an increase in the incidence of severe fire weather), or an increase in sources of ignition, or both. As we have not yet analysed fire weather data, we cannot be more precise about this at this stage but will address it in our next report. It does appear that the incidence of short-interval burning could well be associated with increased human populations, and therefore ignitions in some areas. The more remote areas tend to have less short-interval fires.

Lightning as a cause of fires: Lightning is an important source of fires ignition, and it accounted for between 1.2 and 54.1% of the area burnt in different reserves. In total, fires caused by lightning burnt 272 000 ha (22.5% of the area burnt in all fires), and its influence was greatest in remote areas (for example the Swartberg, Cedarberg and Kammanassie Nature Reserves).

Fire size: The 20 largest fires on record were responsible for burning 24.2% of the total area of 1 490 736 ha burnt. There seems to be some evidence that fires are becoming larger with time. An assessment of the ten largest fires in each of the protected areas shows that, with the exception of the Cedarberg and Outeniqua Nature Reserves, the majority of the area burnt post-1990.

7. References

De Klerk, H., Schutte-Vlok, A., Vlok, J., Shaw, K., Palmer, G., Martens, C., Viljoen, P., Marshall, T., van Ross, G., Forsyth, A.T., Wessels, N., Geldenhuys.D, Wolfaardt, A. and Kirkwood, D. (2007) Ecological Fire Monitoring Manual. CapeNature: Internal Report. pp 47.

Noble, I.R. & Slatyer, R.O. (1980) The use of vital attributes to predict successional changes in plant communities subject to recurrent disturbances. *Vegetatio 43*, 5 – 21.

Seydack, A.H.W., Bekker, S.J. & Marshall, A.H. (2007) Shrubland fire regime scenarios in the Swartberg Mountain Range, South Africa: implications for fire management. *International Journal of Wildland Fire* 16, 81 – 95.

Van Wilgen, B.W. (1984) Fire climates in the southern and western Cape Province and their potential use in fire control and management. *South African Journal of Science* 80, 358-362.

van Wilgen, B.W. & Forsyth, G.G. (1992) Regeneration strategies in fynbos plants and their influence on the stability of community boundaries after fire. *Fire in South African Mountain Fynbos: Species, community and ecosystem response in Swartboskloof.* (eds B.W. van Wilgen, D.M. Richardson, D.M, F.J. Kruger & H.J. van Hensbergen, pp 54 - 80. Springer-Verlag, Heidelberg.

van Wilgen, B.W., Biggs, H.C.,Mare, N and O'Regan, S.P. (2000) A fire history of the savanna ecosystems in the Kruger National Park, South Africa, between 1941 and 1996. *South African Journal of Science* 96: 4, 167-178.