THE LONG-TERM EFFECTS OF FIRE FREQUENCY AND SEASON ON THE WOODY VEGETATION IN THE PRETORIUSKOP SOURVELD OF THE KRUGER NATIONAL PARK

Sean Patrick O'Regan

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I declare that this dissertation is my own work. It is being submitted for the Degree of Master of Science at the University of Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University.

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Sean Patrick O'Regan

On this ____________________ day of ____________________ 2005

Writing is refined thinking. If your master's thesis is no more organised than a high school essay entitled "Why Shania Twain Turns Me On", you're in big trouble.

Stephen King – On writing: A memoir

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Every traveller on life's journey is a messenger, and every destination is the beginning of a new cycle.

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PREFACE

Sitting here in Johannesburg, it is a glorious summer, full of greens and greys, and balmy afternoon heat, with the ever-present afternoon storm pending. It has been almost nine years since I started this MSc in April 1996.

I can clearly remember December 1995 lying in a large tent in Nwaswitshaka Research Camp listening to the night animals. I had arrived in Skukuza to find out more about a fire experiment that had been running for over forty years. The idea of working on one of the world's longest running ecological research programmes was for me the most exciting thing I had ever embarked on, not to mention the opportunity of working (and living) in the Kruger National Park.

Looking back on my proposal, I find myself smiling. The time plan was ambitions, I started the fieldwork in May 1996, and it was to take 3-5 months. This included resurveying the woody vegetation on the Pretoriuskop plots, scanning archived fixed-point photographs of the plots before the treatments were started, and taking another set of fixed-point photographs as an end reference. I was to complete the data capturing and analysis by mid winter 1997, culminating in final product by early 1998. It was all clear cut and clinical.

The fieldwork took the better part of two years, and it was only completed in September 1997. This set the precedent for a much longer project than I had expected, although I suspect that some people had seen this coming.

I started to work full time in October 1998 already having overshot my proposed completion deadline by ten months with still no real end in sight. For any supervisor this is always a heart wrenching time, to be outwardly excited about the student's good job prospects, but knowing that it spells disaster for the project. Ed was supportive, and I clearly remember assuring him that I would complete my MSc soon.

Doing this MSc has not been as easy as I had imagined when I first started it. For most of the time, I have had all the information but lacked the inspiration. Well, some weddings and funerals later with two solar eclipses and a number of lunar eclipses in between, I am finally completing the circle. I no longer have to hang my head in shame when I go to WITS or KNP, I no longer have to say "It's nearly finished … no really it is". There were times when completing this dissertation really took everything out of me and I thought I would never finish it, on the whole, though it has been good, and I am sad that it is over.

Many thanks to all who supported me while completing this MSc, and even more thanks to those who pushed me to finish this MSc.

ABSTRACT

O'Regan SP, 2005. **The long-term effects of fire frequency and season on the woody vegetation in the Pretoriuskop sourveld of the Kruger National Park**. MSc Dissertation, University of the Witwatersrand, Johannesburg.

The role of fire in the management of conservation areas has historically been a contentious issue in which traditional agricultural principles and ever-changing conservation principles tend to collide. The Kruger National Park (KNP) in the early 1950s was no exception where the appropriate use of fire and its ecosystem consequences were hotly debated. The controversy surrounding the management of fire in the KNP highlighted the significant lack of understanding of fire and its role in the ecosystem and because of this controversy, the Experimental Burn Plot (EBP) experiment was established in 1954. The EBP experiment comprised 12 treatments, and a pseudo-randomised block design was used in which the 12 fire treatments were replicated four times each in four of the six major vegetation zones identified at the time. The EBP experiment originally comprised 192 experimental plots approximately 7 Ha in size each and covered approximately 12 km^2 in the KNP. The twelve fire treatments were an annual burn in August, biennial and triennial burns in February, April, August, October, and December, and a control on which fire was excluded. Despite having been plagued with negative assessments from internal and external researchers from its inception, the EBP experiment was meticulously maintained, and it has now become a valuable research asset in the KNP.

Four replicates of twelve plots each were located in the Pretoriuskop sourveld landscape of the KNP. These replicates were named Fayi, Kambeni, Numbi, and Shabeni after nearby landmarks. The Pretoriuskop region is a moist infertile mesic-savanna, which experiences on average 744mm of rain annually. The dominant tree species in Pretoriuskop are *Dichrostachys cinerea* and *Terminalia sericea* and the dominant grass species is *Hyperthelia dissoluta*. A baseline survey of the woody vegetation was done on all the Pretoriuskop plots in 1954 by HP Van Der Schijff. A second survey of the woody vegetation on all the Pretoriuskop plots was done in 1996 by SP O'Regan. This provided a 42-year period of treatment application over which the effects of fire frequency and season on the woody vegetation of the Pretoriuskop region were studied.

The aim of this study was to investigate the long-term effects of the twelve fire treatments on the density, structure, and species composition of the woody vegetation in Pretoriuskop. The objectives of this study were:

1. To carry out a complete re-survey of the trees and shrubs on the Pretoriuskop EBPs using similar methods as those used in the baseline survey in 1954.
2. To capture into a digital format pertinent woody vegetation survey data from surveys that had been conducted on the Pretoriuskop EBPs between 1954 and 1996.
3. To compare the density, structure, and composition of the woody vegetation on the Pretoriuskop EBPs between 1954 and 1996, to determine the effects of fire on the woody vegetation of Pretoriuskop.
4. To investigate the history of the Kruger National Park Experimental Burn Plots experiment.

The four replicates in the Pretoriuskop region were found generally to have very similar woody vegetation traits (density, species composition, and structural composition). However, the EBPs were established and surveyed in two distinct phases, the first phase comprised the control, August Annual, and the Biennial plots, and the second phase comprised the Triennial plots. The baseline structural composition of the plots established in the first phase was different from the structural composition of the plots in the second phase.

Furthermore, the Pretoriuskop EBPs are located in two distinct vegetation types, namely the open and the closed *Terminalia sericea* \ *Combretum* woodlands of the Pretoriuskop region. The Numbi and Shabeni replicates are in the open *Terminalia sericea* \ *Combretum* woodlands, and the Kambeni and Fayi replicates are in the closed *Terminalia sericea* \ *Combretum* woodlands. It was found that the species composition of the plots was influenced by the location of the plots in the different vegetation types.

The exclusion of fire in the Pretoriuskop sourveld results in an increase in the density of the overstorey and understorey woody vegetation, and an increase in the number of species, species diversity, and species evenness. This is because fire sensitive and fire intolerant woody species become more abundant as the period between fires increases. In Pretoriuskop, there is no evidence of relay floristic succession, because fire sensitive and fire intolerant woody species do not replace fire tolerant species. Instead, the floristic succession is accumulative and fire tolerant, fire sensitive, and fire intolerant woody species coexist as the period between fires increases. Woody species tolerant of frequent fires in Pretoriuskop are *Albizia versicolor*, *Catunaregam spinosa*, *Lonchocarpus capassa*, *Pavetta schumanniana*, *Senna petersiana*, *Strychnos madagascariensis*, and *Turraea nilotica*. Woody species that are sensitive or intolerant of fire in Pretoriuskop are *Acacia swazica*, *Bauhinia galpinii*, *Combretum mossambicense*, *Commiphora neglecta*, *Croton gratissimus*, *Dalbergia melanoxylon*, *Diospyros lycioides*, *Diospyros whyteana*, *Euclea natalensis*, *Hyperacanthus amoenus*, *Kraussia floribunda*, *Ochna natalitia*, *Olea europaea*, *Psydrax locuples*, *Putterlickia pyracantha*, *Tarenna supra-axillaris*, and *Zanthoxylum capense*. *Dichrostachys cinerea* and *Terminalia sericea* were found to dominate in areas that had been burnt frequently as well as areas where fire has been excluded. The change in the density of the woody vegetation as the inter-fire period increases is not linear but rather J shaped with an initial decrease in the density as the inter-fire period increases from 1 year to 3 years. This initial decrease in density is the result of a loss of very short (<1m tall) woody individuals. In contrast, there is no initial decrease in the number of tree equivalents (phytomass) of the woody vegetation as the inter-fire period increases. After the initial decrease in the density of the woody vegetation, the density increases as the inter-fire period increases beyond 3 years. Generally in Pretoriuskop, post fire age of the vegetation was found to be an important factor affecting the structure of the woody vegetation, and as the inter-fire period increases the number of structural groups, the structural diversity, and the structural evenness of the woody vegetation increases. As the inter-fire period increases the number of single-stem individuals relative to the number of multi-stem individuals increases, and the average height of the woody vegetation increases. The findings regarding the effects of fire frequency on the Pretoriuskop EBPs were similar to the findings on other fire experiments in mesic African savannas. The finding on the Pretoriuskop EBPs differed from the findings in other fire trials that were in arid savannas in Africa. Generally, the exclusion of fire in moist savannas (> 600 mm of rain annually) results in the woody vegetation becoming denser, while the exclusion of fire in arid to semi-arid savannas (< 600mm of rain annually) does not result in the woody vegetation becoming denser.

In Pretoriuskop, fires occurring in summer between December and February have a different impact on the density, species composition, and structure of the woody vegetation than fires occurring in winter between August and October. Furthermore, fires occurring in April have a different impact on the density, species composition, and structure of the woody vegetation in Pretoriuskop. Woody vegetation burnt by summer fires is denser than woody vegetation burnt by winter fires. The number of species and species diversity of the woody vegetation is also higher in vegetation burnt by summer fires in comparison with vegetation burnt by winter fires. The density and species composition of woody vegetation in areas that have been burnt in summer fires is more similar to areas where fire has been excluded than to areas that have been burnt in winter fires. The woody species associated with vegetation burnt in summer fires and where fire has been excluded are *Euclea natalensis*, *Antidesma venosum*, *Diospyros lycioides*, *Phyllanthus reticulatus*, *Grewia flavescens*, *Grewia monticola*, *Ochna natalitia*, *Peltophorum africanum*, *Rhus pyroides*, *Diospyros mespiliformis*, *Rhus transvaalensis*, *Securinega virosa*, *Putterlickia pyracantha*, *Rhus pentheri*, *Commiphora neglecta*, *Heteropyxis natalensis*, and *Olea europaea*. Structurally the average height of the woody vegetation is taller in areas burnt by winter fires than in areas burnt by summer fires. The woody vegetation in areas burnt in summer fires have more single-stem individuals relative to multi-stem individuals than in areas burnt in winter fires. The structural composition of areas burnt in summer fires is more similar to areas where fire has been excluded than with areas burnt in winter fires. The structure of the woody vegetation in areas burnt in winter fires is generally dominated by multi-stem individuals that are 0-1m tall or 3-5m tall. The structure of the woody vegetation in areas burnt in summer fires or where fire has been excluded is dominated by both single-stem and multi-stem individuals of all heights and basal diameters. Findings regarding the effect of early dry season fires (April) in comparison with late dry season fire (August) on the woody vegetation are consistent with the findings on other fire trails in Africa. However, a comparison of all the fire-timing treatments between the Pretoriuskop and Satara EBPs in the KNP reveals that the timing of fires affects the woody vegetation differently in different areas even when the affects at certain times appear similar.

The data collected on the Pretoriuskop EBPs reveals that there have been significant changes in the woody vegetation in Pretoriuskop between 1954 and 1996. The density of the woody vegetation increased between 1954 and 1996 by almost 200%. The number of species and the species diversity of the woody vegetation also increased between 1954 and 1996. In 1954, there were approximately equal numbers of single-stem and multi-stem individuals, while in 1996 there were more multi-stem individuals than single-stem individuals. The increase in atmospheric CO_2 levels between 1954 and 1996 is believed to have been a factor that has driven the changes in the woody vegetation of Pretoriuskop between 1954 and 1996.

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TERMS AND DEFINITIONS

Block – Refers to a string of experimental plots adjacent to one another in the Experimental Burn Plot experiment. There are either 12 or 14 plots in a block (Biggs *et al* 2003). Block is interchangeable with replicate.

Control treatment – Refers to the Experimental Burn Plots treatments in which fire was excluded. Control treatment and no burn treatment are interchangeable.

EBP – Abbreviation for the Experimental Burn Plot experiment. This refers to the fire experiment established in the Kruger National Park in 1954.

Fire frequency –This refers to the regularity with which a fire treatment is applied. Fire frequency is inversely proportional to fire return period (inter-fire period). For example, a treatment that has been applied annually has a higher fire frequency than a treatment that has been applied triennially. Three fire frequencies were applied to the Experimental burn plots, namely Annual (every year), Biennial (every two years), and Triennial (every three years).

Fire return period – This refers to the period, in years, between fire events, namely annual (1 year), biennial (2 years), and triennial (3 years). Fire return period is interchangeable with inter-fire period.

Fire season – This refers to the time of the year of the fire events and is interchangeable with fire timing.

Fire timing – This refers to the time of the year of the fire events, namely February, April, August, October, and December. Fire timing is interchangeable with fire season.

Inter-fire period – This refers to the period, in years, between fire events, and is interchangeable with fire return period.

KNP – Abbreviation for the Kruger National Park.

LS Mean – Abbreviation for the least squares of a mean.

No burn treatment – Refers to the Experimental Burn Plots treatments in which fire was excluded. No burn treatment is interchangeable with control treatment.

Overstorey woody community – Refers to the community of woody individuals taller than 1m.

Plot – Refers to the smallest experimental unit in the Experimental Burn Plot experiment. Each plot is approximately 7ha in size. Treatments are applied to plots, and plots are grouped together in blocks or replicates (Biggs *et al* 2003).

Phytomass – This refers to the amount of vegetation as measured in the number of equivalent 1.5m high savanna trees (Trollope *et al*. 1990). Phytomass is not a measure of biomass. Phytomass is interchangeable with tree equivalents.

Replicate – This refers to a block of plots adjacent to one another in the Experimental Burn Plot experiment. Replicate is interchangeable with block.

ppmv – Abbreviation for parts per million by volume. The concentration of atmospheric CO_2 is measured in these units.

SADF – Abbreviation for the South African Defence Force.

SAFARI 92 – Abbreviation for the South African Fire-Atmosphere Research Initiative (SAFARI) that was conducted during 1992 (Van Wilgen *et al.* 1997).

SCOPE – Abbreviation for Scientific Committee on Problems of the Environment project (SCOPE 1978).

SE – Abbreviation for Standard Error.

SEM – Abbreviation for the Standard Error of the Mean.

SIO – Abbreviation for the Scripps Institution of Oceanography.

Treatment – In the context of the Experimental Burn Plot experiment this refers to a combination of fire timing and fire frequency applied to treatment plots (i.e. Biennial burn in February) (Biggs *et al* 2003).

Tree equivalents – This refers to the measure of the number of equivalent 1.5m high savanna trees there are in a collection. Tree equivalents are interchangeable with phytomass.

Trial – Refers to all the replicates of the Experimental Burn Plots experiment in the Kruger National Park (Biggs *et al* 2003).

Understorey woody community – Refers to the community of woody individuals shorter than 1m.