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The long-term effects of fire frequency and season on the woody vegetation in the Pretoriuskop Sourveld of The Kruger National Park

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9 APPENDIX 1: WOODY PLANT SPECIES LISTS FOR THE THREE SURVEYS (1954, 1959 AND 1996) CONDUCTED ON THE PRETORIUSKOP EXPERIMENTAL BURN PLOTS

Table 9-1: List of all woody species found on the Pretoriuskop EBPs in the 1954, 1959, and 1996 surveys with the species nomenclature according to Palgrave (1991). The list shows the species codes used when displaying species data in tables and figures through out this document.

Family	Species name	Species code
Anacardiaceae	*Lannea discolor* (Sond.) Engl.	lann disc
	Lannea edulis var. *edulis*	lann edul
	Lannea schweinfurthii (Engl.) Engl. var. *stuhlmannii* (Engl.) Kokwaro	lann schw
	Ozoroa sphaerocarpa R. & A. Fernandes	ozor spha
	Rhus leptodictya Diels	rhus lept
	Rhus pentheri Zahlbr.	rhus pent
	Rhus pyroides Burch.	rhus pyro
	Rhus transvaalensis Engl.	rhus tran
	Sclerocarya birrea (A. Rich.) Hochst. var. *caffra* (Sond.) Kokwaro	scle birr
Annonaceae	*Annona senegalensis* subsp. *senegalensis* Pers.	anno sene
Asteraceae	*Vernonia colorata* (Willd.) Drake	vern colo
Bignoniaceae	*Kigelia africana* (Lam.) Benth.	kige afri
	Markhamia zanzibarica (Bojes ex DC.) K. Schum.	mark zanz
Boraginaceae	*Ehretia obtusifolia* Hochst. ex DC.	ehre obtu
Burseraceae	*Commiphora mollis* (Oliver) Engl.	comm moll
	Commiphora neglecta Veldoorn	comm negl
Caesalpinioideae	*Bauhinia galpinii* N.E. Brown	bauh galp
	Peltophorum africanum Sond.	pelt afri
	Piliostigma thonningii (K. Schum.) Milne-Redh.	pili thon
	Schotia brachypetala Sond.	scho brac
	Senna petersiana (Bolle) Lock	senn pete
Celastraceae	*Cassine aethiopica* Thunb.	cass aeth
	Cassine transvaalensis (Burtt Davy) Codd	cass tran
	Maytenus heterophylla (Eckl. & Zeyh) N.K.B. Robson	mayt hete
	Maytenus senegalensis (Lam.) Exell	mayt sene
	Putterlickia pyracantha (L.) Szyszyl	putt pyra
Combretaceae	*Combretum apiculatum* Sonder. subsp. *apiculatum*	comb apic
	Combretum collinum Fresen.	comb coll
	Combretum hereroense Schinz	comb here
	Combretum imberbe Wawra	comb imbe
	Combretum molle R.Br. ex G. Don	comb moll
	Combretum mossambicense (Klotzsch) Engl.	comb moss
	Terminalia sericea Burch. ex DC.	term seri
Ebenaceae	*Diospyros lycioides* Desf.	dios lyci
	Diospyros mespiliformis Hochst. ex A. DC.	dios mesp
	Diospyros whyteana (Hiern) F. White	dios whyt
	Euclea divinorum Hiern	eucl divi
	Euclea natalensis A. DC. subsp. *natalensis*	eucl nata
Euphorbiaceae	*Antidesma venosum* E. Mey. ex Tul.	anti veno
	Bridelia mollis Hutch.	brid moll
	Croton gratissimus Burch. var. *gratissimus*	crot grat
	Phyllanthus reticulatus Poir.	phyl reti
	Securinega virosa (Roxb. Ex Willd) Pax & K. Hoffm.	secu viro
	Spirostachys africana Sond.	spir afri
Flacourtiaceae	*Flacourtia indica* (N. L. Burm.) Merr.	flac indi
Leguminosae	*Pseudarthria hookeri* Wight & Arn. var. *hookeri*	pseu hook
Loganiaceae	*Strychnos madagascariensis* Poir.	stry mada
	Strychnos spinosa Lam.	stry spin
Meliaceae	*Trichilia emetica* Vahl.	tric emet
	Turraea nilotica Kotschy & Peyr	turr nilo
Mimosoideae	*Acacia caffra* (Thunb.) Willd.	acac caff
	Acacia gerrardii Benth. var. *gerrardii*	acac gerr

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Family	Species name	Species code
	Acacia xanthophloea Benth.	acac xant
	Acacia exuvialis Veldoorn	acac exuv
	Acacia sieberiana DC. var. *woodii* (Burt Davy) Keay & Brenan	acac sieb
	Acacia swazica Burtt Davy	acac swaz
	Albizia harveyi Fourn.	albi harv
	Albizia versicolor Welw. ex Oliver	albi vers
	Dichrostachys cinerea (L.) Wright ex Arn.	dich cine
Moraceae	*Ficus stuhlmannii* Warb.	ficu stuh
	Ficus sycomorus L. subsp. sycomorus	ficu syco
Myrtaceae	*Heteropyxis natalensis* Harv.	hete nata
	Syzygium cordatum Hochst.	syzy cord
	Syzygium guineense (Willd.) DC.	syzy guin
Ochnaceae	*Ochna natalitia* (Meisn.) Walp.	ochn nata
Olacaceae	*Olea europaea* L. subsp. *africana* (Mill.) P.S. Green	olea euro
	Ximenia caffra Sond. var. *caffra*	xime caff
Papilionoideae	*Dalbergia melanoxylon* Guillemin & Perrottet	dalb mela
	Lonchocarpus capassa Rolfe	lonc capa
	Mundulea sericea (Willd.) A. Chev.	mund seri
	Ormocarpum trichocarpum (Taub.) Engl.	ormo tric
	Papilionacea	papi lion
	Pterocarpus angolensis DC.	pter ango
	Pterocarpus rotundifolius (Sond.) Druce subsp. *rotundifolius*	pter rotu
Proteaceae	*Faurea saligna* Harv.	faur sali
Rhamnaceae	*Berchemia zeyheri* (Sonder) Grubov	berc zeyh
	Ziziphus mucronata Willd. subsp. *mucronata*	zizi mucr
Rosaceae	*Parinari curatellifolia* Planch. ex Benth.	pari cura
Rubiaceae	*Canthium* sp.	cant spec
	Catunaregam spinosa (Thunb.) Tirvengadum subsp. *spinosa*	catu spin
	Gardenia volkensii K. Schum. subsp. *spatulifolia*	gard volk
	Hyperacanthus amoenus (Sims) Bridson	hype amoe
	Kraussia floribunda Harv.	krau flor
	Pavetta schumanniana F. Hoffm. ex K. Schum.	pave schu
	Psydrax locuples (K. Schum.) Bridson	psyd locu
	Tarenna supra-axillaris (Hemsl.) Brem.	tare supr
	Vangueria infausta Burch.	vang infa
Rutaceae	*Zanthoxylum capense* (Thunb.) Harv.	zant cape
Sapindaceae	*Hippobromus pauciflorus* (L.f.) Randlk.	hipp pauc
	Pappea capensis Eckl. & Zeyh.	papp cape
Sterculiaceae	*Dombeya rotundifolia* (Hochst.) Planchon	domb rotu
Tiliaceae	*Grewia flavescens* Juss. var. *flavescens*	grew flav
	Grewia hexamita Burret	grew hexa
	Grewia monticola Sond.	grew mont
Ulmaceae	*Chaetachme aristata* Planchon	chae aris
Unidentified	Unidentified	unid enti
Verbenaceae	*Clerodendrum* sp.	cler spec

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Table 9-2: List showing the woody species found on the Pretoriuskop EBPs in the three surveys conducted in 1954, 1959, and 1996. This list links the species code defined in Table 9-1 to the species name used at the time of each of the surveys.

Species code	1954 species name	1959 species name	1996 species name
acac caff			*Acacia caffra*
acac exuv			*Acacia exuvialis*
acac gerr	*Acacia gerrardii*		*Acacia gerrardii*
acac sieb	*Acacia* sp. *Acacia woodii*		*Acacia sieberiana*
acac swaz		*Acacia ataxacantha*	*Acacia swazica*
acac xant			*Acacia xanthophloea*
albi harv			*Albizia harveyi*
albi vers	*Albizia versicolor*		*Albizia versicolor*
anno sene	*Annona chrysophylla*	*Annona chrysophylla*	*Annona senegalensis*
anti veno	*Antidesma venosum*	*Antidesma venosum*	*Antidesma venosum*
berc zeyh			*Berchemia zeyheri*
brid moll	*Bridelia mollis*	*Bridelia mollis*	
bauh galp	*Bauhinia galpinii*	*Bauhinia galpinii*	*Bauhinia galpinii*
cant spec			*Canthium* sp.
cass aeth			*Cassine aethiopica*
cass tran	*Pseudocassine transvaalensis*		*Cassine transvaalensis*
catu spin	*Randia* sp. *Randia vestita*	*Randia* sp.	*Catunaregam spinosa*
chae aris	*Chaetachme aristata*		
cler spec	*Clerodendrum* sp.		
comb apic	*Combretum apiculatum* *Combretum* sp.		*Combretum apiculatum*
comb coll	*Combretum suluense* *Combretum zeyheri*		*Combretum collinum*
comb here	*Combretum transvaalensis*		*Combretum hereroense*
comb imbe			*Combretum imberbe*
comb moll	*Combretum gueinzii*	*Combretum gueinzii*	*Combretum molle*
comb moss			*Combretum mossambiquensis*
comm moll	*Commiphora mollis* *Commiphora* sp.		
comm negl			*Commiphora neglecta*
crot grat			*Croton gratissimus*
dalb mela	*Dalbergia melanoxylon* *Dalbergia* sp.	*Dalbergia melanoxylon*	*Dalbergia melanoxylon*
dich cine	*Dichrostachys glomerata* *Dichrostachys nyassana*	*Dichrostachys nyassana*	*Dichrostachys cinerea*
dios lyci	*Rhus villosa* *Royena lucida* *Royena schlechteri* *Royena sericea* *Royena* sp.	*Royena schlechteri*	*Diospyros lycioides*
dios mesp	*Diospyros mespiliformis*	*Diospyros mespiliformis*	*Diospyros mespiliformis*
dios whyt			*Diospyros whyteana*
domb rotu	*Dombeya rotundifolia*	*Dombeya rotundifolia*	*Dombeya rotundifolia*
ehre obtu	*Ehretia amoena* *Ehretia rigida* *Ehretia* sp.	*Ehretia amoena* *Ehretia* sp.	*Ehretia obtusifolia*
eucl divi	*Euclea divinorum* *Euclea* sp.	*Euclea divinorum*	*Euclea divinorum*
eucl nata	*Euclea multiflora*	*Euclea multiflora*	*Euclea natalensis*
faur sali			*Faurea saligna*
ficu stuh	*Ficus stuhlmannii*		
ficu syco			*Ficus sycomorus*
flac indi	*Flacourtia hirtiuscula*	*Flacourtia hirtiuscula*	*Flacourtia indica*
gard volk			*Gardenia volkensii*
grew flav	*Grewia flavescens*	*Grewia flavescens*	*Grewia flavescens*
grew hexa			*Grewia hexamita*
grew mont	*Grewia monticola*		*Grewia monticola*

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Species code	1954 species name	1959 species name	1996 species name
hete nata			*Heteropyxis natalensis*
hipp pauc			*Hippobromus pauciflorus*
hype amoe			*Hyperacanthus amoenus*
kige afri			*Kigelia africana*
krau flor		*Kraussia schlechteri*	*Kraussia floribunda*
lann schw	*Lannea* sp.		*Lannea schweinfurthii*
lann disc	*Lannea discolor*		*Lannea discolor*
lann edul	*Lannea edulis*	*Lannea edulis*	*Lannea edulis*
lonc capa	*Lonchocarpus capassa*	*Lonchocarpus capassa*	*Lonchocarpus capassa*
mark zanz			*Markhamia zanzibarica*
mayt hete	*Gymnosporia buxifolia*	Gymnosporia buxifolia	*Maytenus heterophylla*
mayt sene	*Gymnosporia senegalensis*	*Gymnosporia senegalensis*	*Maytenus senegalensis*
mund seri	*Mundulea sericea*	*Mundulea sericea*	*Mundulea sericea*
ochn nata	*Ochna natalitia* *Ochna* sp.	*Ochna natalitia*	*Ochna natalitia*
olea euro	*Olea africana*		*Olea europaea*
ormo tric	*Ormocarpum trichocarpum*	*Ormocarpum trichocarpum*	*Ormocarpum trichocarpum*
ozor spha	*Heeria reticulata*		*Ozoroa sphaerocarpa*
papi lion	Papilionacea		
papp cape	*Pappea capensis*		*Pappea capensis*
pari cura	*Parinari mobola*	*Parinari mobola*	*Parinari curatellifolia*
pave schu	*Pavetta schumanniana* *Pavetta* sp.	*Pavetta schumanniana*	*Pavetta schumanniana*
pelt afri	*Peltophorum africanum*	*Peltophorum africanum*	*Peltophorum africanum*
phyl reti	*Phyllanthus reticulatus* *Phyllanthus tuberosa*	*Phyllanthus* sp.	*Phyllanthus reticulatus*
pili thon	*Piliostigma thonningii*	*Piliostigma thonningii*	*Piliostigma thonningii*
pseu hook	*Pseudarthria hookeri*	*Pseudarthria hookeri*	
pter ango	*Pterocarpus angolensis*	*Pterocarpus angolensis*	*Pterocarpus angolensis*
pter rotu	*Pterocarpus rotundifolius*		*Pterocarpus rotundifolius*
putt pyra			*Putterlickia pyracantha*
rhus lept			*Rhus leptodictya*
rhus pent			*Rhus pentheri*
rhus pyro	*Rhus gueinzii* *Rhus pyroides* *Rhus* sp.	*Rhus pyroides*	*Rhus pyroides*
rhus tran	*Rhus transvaalensis*	*Rhus transvaalensis*	*Rhus transvaalensis*
scho brac	*Schotia brachypetala*		*Schotia brachypetala*
scle birr	*Sclerocarya caffra*	*Sclerocarya caffra*	*Sclerocarya birrea*
secu viro	*Flueggea virosa*		*Securinega virosa*
senn pete	*Cassia petersiana*	*Cassia petersiana*	*Senna petersiana*
spir afri			*Spirostachys africana*
stry mada	*Strychnos innocua* *Strychnos* sp.	*Strychnos innocua*	*Strychnos madagascariensis*
stry spin	*Strychnos spinosa*		*Strychnos spinosa*
syzy cord	*Syzygium cordatum*		*Syzygium cordatum*
syzy guin			*Syzygium guineense*
tare supr			*Tarenna supra-axillaris*
term seri	*Terminalia sericea*	*Terminalia sericea*	*Terminalia sericea*
tric emet	*Trichilia emetica*		*Trichilia emetica*
turr nilo	*Turraea* sp.		*Turraea nilotica*
unid enti	Ongeidentifiseerd		
vang infa	*Vangueria infausta*	*Vangueria infausta*	*Vangueria infausta*
veno colo	*Vernonia* sp.		
xime caff	*Ximenia caffra* *Ximenia* sp.	*Ximenia caffra*	*Ximenia caffra*
zant cape	*Fagara capensis*	*Fagara capensis*	*Zanthoxylum capense*
zizi mucr	*Ziziphus mucronata*	*Ziziphus mucronata*	*Ziziphus mucronata*

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10 APPENDIX 2: LIST OF THE PRETORIUSKOP EXPERIMENTAL BURN PLOTS AND TREATMENTS

Table 10-1: List of the Pretoriuskop Experimental Burn Plots, the treatment assigned to the plot in 1954 and 1956, and the plot code used when displaying plot data in tables and figures through out this document. A description of the treatment codes are presented in Table 3-1 (p. 15).

Replicate	Plot Number	Treatment Code	Plot Code
Fayi	1	Aug2	Fa01Aug2
	2	Cont	Fa02Con0
	3	Dec2	Fa03Dec2
	4	Oct2	Fa04Oct2
	5	Apr2	Fa05Apr2
	6	Feb2	Fa06Feb2
	7	Aug1	Fa07Aug1
	8	Dec3	Fa08Dec3
	9	Aug3	Fa09Aug3
	10	Oct3	Fa10Oct3
	11	Feb3	Fa11Feb3
	12	Apr3	Fa12Apr3
Kambeni	1	Cont	Ka01Con0
	2	Dec2	Ka02Dec2
	3	Oct2	Ka03Oct2
	4	Feb2	Ka04Feb2
	5	Aug2	Ka05Aug2
	6	Apr2	Ka06Apr2
	7	Aug1	Ka07Aug1
	8	Feb3	Ka08Feb3
	9	Oct3	Ka09Oct3
	10	Dec3	Ka10Dec3
	11	Aug3	Ka11Aug3
	12	Apr3	Ka12Apr3
Numbi	1	Oct2	Nu01Oct2
	2	Dec2	Nu02Dec2
	3	Feb2	Nu03Feb2
	4	Aug2	Nu04Aug2
	5	Apr2	Nu05Apr2
	6	Aug1	Nu06Aug1
	7	Cont	Nu07Con0
	8	Dec3	Nu08Dec3
	9	Oct3	Nu09Oct3
	10	Feb3	Nu10Feb3
	11	Apr3	Nu11Apr3
	12	Aug3	Nu12Aug3
Shabeni	1	Aug2	Sh01Aug2
	2	Apr2	Sh02Apr2
	3	Aug1	Sh03Aug1
	4	Feb2	Sh04Feb2
	5	Oct2	Sh05Oct2
	6	Dec2	Sh06Dec2
	7	Cont	Sh07Con0
	8	Dec3	Sh08Dec3
	9	Apr3	Sh09Apr3
	10	Aug3	Sh10Aug3
	11	Oct3	Sh11Oct3
	12	Feb3	Sh12Feb3

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11 APPENDIX 3: METADATA FOR THE SURVEYS OF THE WOODY VEGETATION OF THE PRETORIUSKOP EBPS IN 1954, 1959 AND 1996

The survey information in Table 11-1 comprises:

- The year the survey was done (**Year**). For the baseline survey, 1954 was the year even though the surveys were conducted between 1954 and 1958. For the final survey, 1996 was the year even though the surveys were conducted during 1996 and 1997.
- The treatment plot information:
  - The name of the replicate on which the plot occurs (**Replicate**). See Figure 3-3 (p. 18) for the layout of the Pretoriuskop replicates
  - The plot number (**Plot**).
  - The treatment applied to the plot (**Treatment Code**). See Table 3-1 (p. 15) for a definition of the treatment codes.
- The survey transect information:
  - The transect indicator (A or B) (**Transect**). This denotes which diagonal of the plot that was surveyed.
  - The date the transect was surveyed (**Date**). Many of the 1954 survey dates had the same date. These dates are believed to be the date the data was captured into a summarised format and not the date the actual survey was done. A more likely date for the 1954 surveys is believed to be approximately a month before the first application of the treatments on each plot.
  - The direction of the survey transect across the diagonal of the plot (**Direction**).
  - The length of the transect (m) (**Length**). In the 1996 surveys some of the transect lengths are less than 300m. The reasons for the lengths being less than 300m are given in the comments. In some cases, the reason for the length being shorter than 300m was believed to have been valid for the 1954 and 1959 surveys. These survey lengths were then adjusted accordingly, which is why some of the transect lengths in 1954 and 1959 are less than 310m.
  - The width of the transect (m) (**Width**).
  - The area of the transect (m^2) (**Area**).
  - General comments (**Comments**).

Table 11-1: A list showing the information for each of the survey transects that was used to survey the woody vegetation of the Pretoriuskop EBPs in 1954, 1959, and 1996.

Year	Replicate	Plot	Treatment Code	Transect	Date	Direction	Length (m)	Width (m)	Area (m^2)	Comments
1954	Fayi	1	Aug2	A	09 Apr 54		305	1.524	464.82	
1954	Fayi	1	Aug2	B	09 Apr 54		305	1.524	464.82	
1954	Fayi	2	Cont	A	09 Apr 54		305	1.524	464.82	
1954	Fayi	2	Cont	B	09 Apr 54		305	1.524	464.82	
1954	Fayi	3	Dec2	A	09 Apr 54		305	1.524	464.82	
1954	Fayi	3	Dec2	B	09 Apr 54		301	1.524	458.724	Into road (4m)
1954	Fayi	4	Oct2	A	09 Apr 54		305	1.524	464.82	
1954	Fayi	4	Oct2	B	09 Apr 54		305	1.524	464.82	
1954	Fayi	5	Apr2	A	09 Apr 54		305	1.524	464.82	
1954	Fayi	5	Apr2	B	09 Apr 54		305	1.524	464.82	
1954	Fayi	6	Feb2	A	09 Apr 54		305	1.524	464.82	

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Year	Replicate	Plot	Treatment Code	Transect	Date	Direction	Length (m)	Width (m)	Area (m^2)	Comments
1954	Fayi	6	Feb2	B	09 Apr 54		305	1.524	464.82	
1954	Fayi	7	Aug1	A	09 Apr 54		305	1.524	464.82	
1954	Fayi	7	Aug1	B	09 Apr 54		305	1.524	464.82	
1954	Fayi	8	Dec3	A	24 Jun 54		305	1.524	464.82	
1954	Fayi	8	Dec3	B	24 Jun 54		305	1.524	464.82	
1954	Fayi	9	Aug3	A	28 Jul 58		305	1.524	464.82	
1954	Fayi	9	Aug3	B	28 Jul 58		305	1.524	464.82	
1954	Fayi	10	Oct3	A	07 Oct 58		295	1.524	449.58	Into road (10m)
1954	Fayi	10	Oct3	B	07 Oct 58		305	1.524	464.82	
1954	Fayi	11	Feb3	A	21 Nov 57		305	1.524	464.82	
1954	Fayi	11	Feb3	B	21 Nov 57		305	1.524	464.82	
1954	Fayi	12	Apr3	A	26 Mar 58		305	1.524	464.82	
1954	Fayi	12	Apr3	B	26 Mar 58		305	1.524	464.82	
1954	Kambeni	1	Cont	A	08 Apr 54		305	1.524	464.82	
1954	Kambeni	1	Cont	B	08 Apr 54		305	1.524	464.82	
1954	Kambeni	2	Dec2	A	08 Apr 54		305	1.524	464.82	
1954	Kambeni	2	Dec2	B	08 Apr 54		299	1.524	455.676	Telephone road through plot (6m)
1954	Kambeni	3	Oct2	A	16 Nov 54		305	1.524	464.82	
1954	Kambeni	3	Oct2	B	16 Nov 54		305	1.524	464.82	
1954	Kambeni	4	Feb2	A	08 Apr 54		305	1.524	464.82	Not sure of the survey date.
1954	Kambeni	4	Feb2	B	08 Apr 54		305	1.524	464.82	Not sure of the survey date.
1954	Kambeni	5	Aug2	A	08 Apr 54		305	1.524	464.82	
1954	Kambeni	5	Aug2	B	08 Apr 54		305	1.524	464.82	
1954	Kambeni	6	Apr2	A	08 Apr 54		305	1.524	464.82	
1954	Kambeni	6	Apr2	B	08 Apr 54		275	1.524	419.1	Rock outcrop (30m)
1954	Kambeni	7	Aug1	A	08 Apr 54		305	1.524	464.82	
1954	Kambeni	7	Aug1	B	08 Apr 54		305	1.524	464.82	
1954	Kambeni	8	Feb3	A	21 Nov 57		305	1.524	464.82	
1954	Kambeni	8	Feb3	B	21 Nov 57		305	1.524	464.82	
1954	Kambeni	9	Oct3	A	07 Oct 58		305	1.524	464.82	
1954	Kambeni	9	Oct3	B	07 Oct 58		297	1.524	452.628	Road through plot (7.6m)
1954	Kambeni	10	Dec3	A	26 Nov 58		288	1.524	438.912	Into road (17m)
1954	Kambeni	10	Dec3	B	26 Nov 58		305	1.524	464.82	
1954	Kambeni	11	Aug3	A	28 Jul 58		305	1.524	464.82	
1954	Kambeni	11	Aug3	B	28 Jul 58		305	1.524	464.82	
1954	Kambeni	12	Apr3	A	26 Mar 58		305	1.524	464.82	
1954	Kambeni	12	Apr3	B	26 Mar 58		292	1.524	445.008	Into road (12.8m)
1954	Numbi	1	Oct2	A	07 Apr 54		305	1.524	464.82	
1954	Numbi	1	Oct2	B	07 Apr 54		305	1.524	464.82	
1954	Numbi	2	Dec2	A	07 Apr 54		305	1.524	464.82	
1954	Numbi	2	Dec2	B	07 Apr 54		305	1.524	464.82	
1954	Numbi	3	Feb2	A	07 Apr 54		305	1.524	464.82	
1954	Numbi	3	Feb2	B	07 Apr 54		305	1.524	464.82	
1954	Numbi	4	Aug2	A	07 Apr 54		305	1.524	464.82	
1954	Numbi	4	Aug2	B	07 Apr 54		305	1.524	464.82	
1954	Numbi	5	Apr2	A	07 Apr 54		305	1.524	464.82	
1954	Numbi	5	Apr2	B	07 Apr 54		305	1.524	464.82	
1954	Numbi	6	Aug1	A	07 Apr 54		305	1.524	464.82	
1954	Numbi	6	Aug1	B	07 Apr 54		305	1.524	464.82	
1954	Numbi	7	Cont	A	07 Apr 54		305	1.524	464.82	
1954	Numbi	7	Cont	B	07 Apr 54		305	1.524	464.82	
1954	Numbi	8	Dec3	A	26 Nov 58		305	1.524	464.82	

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Year	Replicate	Plot	Treatment Code	Transect	Date	Direction	Length (m)	Width (m)	Area (m^2)	Comments
1954	Numbi	8	Dec3	B	26 Nov 58		305	1.524	464.82	
1954	Numbi	9	Oct3	A	07 Oct 58		305	1.524	464.82	
1954	Numbi	9	Oct3	B	07 Oct 58		305	1.524	464.82	
1954	Numbi	10	Feb3	A	22 Nov 57		305	1.524	464.82	
1954	Numbi	10	Feb3	B	22 Nov 57		305	1.524	464.82	
1954	Numbi	11	Apr3	A	27 Mar 58		305	1.524	464.82	
1954	Numbi	11	Apr3	B	27 Mar 58		305	1.524	464.82	
1954	Numbi	12	Aug3	A	31 Jul 58		305	1.524	464.82	
1954	Numbi	12	Aug3	B	31 Jul 58		281	1.524	428.244	Into road (24m)
1954	Shabeni	1	Aug2	A	09 Apr 54		305	1.524	464.82	Not sure of the survey date.
1954	Shabeni	1	Aug2	B	09 Apr 54		305	1.524	464.82	Not sure of the survey date.
1954	Shabeni	2	Apr2	A	09 Apr 54		305	1.524	464.82	
1954	Shabeni	2	Apr2	B	09 Apr 54		305	1.524	464.82	
1954	Shabeni	3	Aug1	A	09 Apr 54		305	1.524	464.82	
1954	Shabeni	3	Aug1	B	09 Apr 54		305	1.524	464.82	
1954	Shabeni	4	Feb2	A	15 Apr 54		305	1.524	464.82	
1954	Shabeni	4	Feb2	B	15 Apr 54		305	1.524	464.82	
1954	Shabeni	5	Oct2	A	15 Apr 54		305	1.524	464.82	
1954	Shabeni	5	Oct2	B	15 Apr 54		284	1.524	432.816	Into road (13 m)
1954	Shabeni	6	Dec2	A	15 Apr 54		305	1.524	464.82	
1954	Shabeni	6	Dec2	B	15 Apr 54		305	1.524	464.82	
1954	Shabeni	7	Cont	A	15 Apr 54		305	1.524	464.82	
1954	Shabeni	7	Cont	B	15 Apr 54		305	1.524	464.82	
1954	Shabeni	8	Dec3	A	26 Nov 58		305	1.524	464.82	
1954	Shabeni	8	Dec3	B	26 Nov 58		305	1.524	464.82	
1954	Shabeni	9	Apr3	A	27 Mar 58		305	1.524	464.82	
1954	Shabeni	9	Apr3	B	27 Mar 58		305	1.524	464.82	
1954	Shabeni	10	Aug3	A	28 Jul 58		305	1.524	464.82	
1954	Shabeni	10	Aug3	B	28 Jul 58		305	1.524	464.82	
1954	Shabeni	11	Oct3	A	08 Oct 58		305	1.524	464.82	
1954	Shabeni	11	Oct3	B	08 Oct 58		305	1.524	464.82	
1954	Shabeni	12	Feb3	A	21 Nov 57		305	1.524	464.82	
1954	Shabeni	12	Feb3	B	21 Nov 57		299	1.524	455.676	Into road (6m)
1959	Fayi	2	Cont	A	10 Mar 59		305	1.524	464.82	
1959	Fayi	2	Cont	B	10 Mar 59		305	1.524	464.82	
1959	Kambeni	1	Cont	A	10 Mar 59		305	1.524	464.82	
1959	Kambeni	1	Cont	B	10 Mar 59		305	1.524	464.82	
1959	Numbi	7	Cont	A	13 Mar 59		305	1.524	464.82	
1959	Numbi	7	Cont	B	13 Mar 59		305	1.524	464.82	
1959	Shabeni	7	Cont	A	13 Mar 59		305	1.524	464.82	
1959	Shabeni	7	Cont	B	13 Mar 59		305	1.524	464.82	
1996	Fayi	1	Aug2	A	31 Jul 96	SSW	300	2	600	
1996	Fayi	1	Aug2	B	06 Aug 96	NW	300	2	600	
1996	Fayi	2	Cont	A	22 Sep 97	SW	300	2	600	
1996	Fayi	2	Cont	B	23 Sep 97	NW	300	2	600	
1996	Fayi	3	Dec2	A	04 Dec 96	SE	300	2	600	
1996	Fayi	3	Dec2	B	04 Dec 96	NE	296	2	592	Into road (4m)
1996	Fayi	4	Oct2	A	05 Sep 96	SW	300	2	600	
1996	Fayi	4	Oct2	B	05 Sep 96	SE	300	2	600	
1996	Fayi	5	Apr2	A	27 May 97	SW	300	2	600	
1996	Fayi	5	Apr2	B	28 May 97	NW	300	2	600	
1996	Fayi	6	Feb2	A	11 Dec 96	NW	300	2	600	

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Year	Replicate	Plot	Treatment Code	Transect	Date	Direction	Length (m)	Width (m)	Area (m^2)	Comments
1996	Fayi	6	Feb2	B	12 Dec 96	NE	300	2	600	
1996	Fayi	7	Aug1	A	06 Aug 96	N	300	2	600	
1996	Fayi	7	Aug1	B	07 Aug 96	SW	300	2	600	
1996	Fayi	8	Dec3	A	29 Aug 97	SW	300	2	600	
1996	Fayi	8	Dec3	B	09 Sep 97	NW	300	2	600	
1996	Fayi	9	Aug3	A	21 Aug 97	SW	300	2	600	
1996	Fayi	9	Aug3	B	22 Aug 97	NW	300	2	600	
1996	Fayi	10	Oct3	A	24 Sep 97	SW	290	2	580	Into road (10m)
1996	Fayi	10	Oct3	B	24 Sep 97	NW	300	2	600	
1996	Fayi	11	Feb3	A	29 Jan 97	NE	300	2	600	
1996	Fayi	11	Feb3	B	30 Jan 97	SE	300	2	600	
1996	Fayi	12	Apr3	A	26 May 97	NE	300	2	600	
1996	Fayi	12	Apr3	B	27 May 97	SE	300	2	600	
1996	Kambeni	1	Cont	A	19 Sep 97	SW	300	2	600	
1996	Kambeni	1	Cont	B	19 Sep 97	NW	300	2	600	
1996	Kambeni	2	Dec2	A	09 Dec 96	SE	300	2	600	
1996	Kambeni	2	Dec2	B	09 Dec 96	NE	294	2	588	Telephone road through plot (6m)
1996	Kambeni	3	Oct2	A	29 Aug 96	NW	300	2	600	
1996	Kambeni	3	Oct2	B	03 Sep 96	SW	300	2	600	
1996	Kambeni	4	Feb2	A	17 Dec 96	ENE	300	2	600	
1996	Kambeni	4	Feb2	B	22 Jan 97	NW	300	2	600	
1996	Kambeni	5	Aug2	A	19 Jul 96	WNW	300	2	600	
1996	Kambeni	5	Aug2	B	23 Jul 96	SW	300	2	600	
1996	Kambeni	6	Apr2	A	21 May 97	WSW	300	2	600	Excavations for road in segment A6 (30m)
1996	Kambeni	6	Apr2	B	22 May 97	NE	270	2	540	Rock outcrop through segments B2 (11.4m), B3 (17.2m), B4 (1.5m)
1996	Kambeni	7	Aug1	A	14 Aug 96	NW	300	2	600	
1996	Kambeni	7	Aug1	B	14 Aug 96	NE	300	2	600	
1996	Kambeni	8	Feb3	A	23 Jan 97	SE	300	2	600	
1996	Kambeni	8	Feb3	B	24 Jan 97	NE	300	2	600	
1996	Kambeni	9	Oct3	A	26 Aug 97	NW	300	2	600	
1996	Kambeni	9	Oct3	B	27 Aug 97	NE	292	2	584	Road through plot (7.6m)
1996	Kambeni	10	Dec3	A	25 Aug 97	NE	283	2	566	Into road (17m)
1996	Kambeni	10	Dec3	B	26 Aug 97	NW	300	2	600	
1996	Kambeni	11	Aug3	A	20 Aug 97	WNW	300	2	600	
1996	Kambeni	11	Aug3	B	20 Aug 97	NE	300	2	600	
1996	Kambeni	12	Apr3	A	22 May 97	WNW	300	2	600	
1996	Kambeni	12	Apr3	B	23 May 97	SW	287	2	574	Into road (12.8m)
1996	Numbi	1	Oct2	A	27 Aug 96	NNE	300	2	600	
1996	Numbi	1	Oct2	B	27 Aug 96	NW	300	2	600	
1996	Numbi	2	Dec2	A	26 Nov 96	SE	300	2	600	
1996	Numbi	2	Dec2	B	26 Nov 96	NE	300	2	600	
1996	Numbi	3	Feb2	A	23 Jun 97	SSE	300	2	600	
1996	Numbi	3	Feb2	B	24 Jun 97	NE	300	2	600	
1996	Numbi	4	Aug2	A	26 Aug 96	SSE	300	2	600	
1996	Numbi	4	Aug2	B	26 Aug 96	SW	300	2	600	
1996	Numbi	5	Apr2	A	04 Jun 97	NE	300	2	600	
1996	Numbi	5	Apr2	B	05 Jun 97	SE	300	2	600	
1996	Numbi	6	Aug1	A	22 Aug 96	SE	300	2	600	
1996	Numbi	6	Aug1	B	23 Aug 96	SW	300	2	600	

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Year	Replicate	Plot	Treatment Code	Transect	Date	Direction	Length (m)	Width (m)	Area (m^2)	Comments
1996	Numbi	7	Cont	A	11 Sep 97	NE	300	2	600	
1996	Numbi	7	Cont	B	15 Sep 97	SE	300	2	600	
1996	Numbi	8	Dec3	A	12 Jun 97	NW	300	2	600	
1996	Numbi	8	Dec3	B	12 Jun 97	SW	300	2	600	
1996	Numbi	9	Oct3	A	11 Jun 97	NW	300	2	600	
1996	Numbi	9	Oct3	B	11 Jun 97	SW	300	2	600	
1996	Numbi	10	Feb3	A	28 Jan 97	SW	300	2	600	
1996	Numbi	10	Feb3	B	29 Jan 97	NW	300	2	600	
1996	Numbi	11	Apr3	A	03 Jun 97	NW	300	2	600	
1996	Numbi	11	Apr3	B	04 Jun 97	NE	300	2	600	
1996	Numbi	12	Aug3	A	10 Jun 97	NW	300	2	600	
1996	Numbi	12	Aug3	B	10 Jun 97	SW	276	2	552	Into road (24m)
1996	Shabeni	1	Aug2	A	15 Aug 96	SSW	300	2	600	
1996	Shabeni	1	Aug2	B	19 Aug 96	SE	300	2	600	
1996	Shabeni	2	Apr2	A	29 May 97	NE	300	2	600	
1996	Shabeni	2	Apr2	B	29 May 97	SE	300	2	600	
1996	Shabeni	3	Aug1	A	19 Aug 96		300	2	600	
1996	Shabeni	3	Aug1	B	21 Aug 96		300	2	600	
1996	Shabeni	4	Feb2	A	11 Feb 97	NE	300	2	600	
1996	Shabeni	4	Feb2	B	24 Jun 97	SE	300	2	600	Surveyed from 24 Jun 97 to 18 Aug 97 (segments 2 - 6 were surveyed after the fire treatment)
1996	Shabeni	5	Oct2	A	03 Sep 96	NE	300	2	600	
1996	Shabeni	5	Oct2	B	04 Sep 96	SE	279	2	558	Into road (13 m)
1996	Shabeni	6	Dec2	A	27 Nov 96	NE	300	2	600	
1996	Shabeni	6	Dec2	B	28 Nov 96	NW	300	2	600	
1996	Shabeni	7	Cont	A	18 Sep 97	NNE	300	2	600	
1996	Shabeni	7	Cont	B	18 Sep 97	SE	300	2	600	
1996	Shabeni	8	Dec3	A	27 Jun 97	SE	300	2	600	
1996	Shabeni	8	Dec3	B	28 Aug 97	NE	300	2	600	
1996	Shabeni	9	Apr3	A	02 Jun 97	SE	300	2	600	
1996	Shabeni	9	Apr3	B	03 Jun 97	NE	300	2	600	
1996	Shabeni	10	Aug3	A	19 Aug 97	NE	300	2	600	
1996	Shabeni	10	Aug3	B	19 Aug 97	SE	300	2	600	
1996	Shabeni	11	Oct3	A	28 Aug 97	SE	300	2	600	
1996	Shabeni	11	Oct3	B	28 Aug 97	NE	300	2	600	
1996	Shabeni	12	Feb3	A	27 Jan 97	EEN	300	2	600	
1996	Shabeni	12	Feb3	B	28 Jan 97	SSW	294	2	588	Into road (6m)

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12 APPENDIX 4: VEGETATION INDICES CALCULATED TO SUMMARISE THE STRUCTURE AND COMPOSITION OF THE WOODY VEGETATION ON THE PRETORIUSKOP EXPERIMENTAL BURN PLOTS

Table 12-1: Summary of the vegetation indices calculated from the data collected in the 1954 baseline survey.

						Taxonomic diversity				Structural diversity			
Replicate	Treatment	Density (plants/Ha)	Mean height (m)	Tree equivalents (per Ha)	Single-stem to Multi stem	Number of species	Species Richness	Species diversity	Species evenness	Number of structural groups	Structure richness	Structure diversity	Structure evenness
Fayi	Aug2	2381	1.277	1830	0.900	18	0.369	1.830	0.633	17	0.348	1.707	0.602
	Con0	1661	1.208	1229	0.805	19	0.466	2.239	0.760	16	0.393	1.816	0.655
	Dec2	2936	1.072	2318	0.900	22	0.406	2.319	0.750	17	0.314	1.719	0.607
	Oct2	2262	1.237	1869	0.866	22	0.463	2.322	0.751	18	0.379	1.848	0.639
	Apr2	2348	1.179	1984	0.825	16	0.330	1.778	0.641	19	0.392	1.974	0.670
	Feb2	3166	1.071	1939	0.922	19	0.338	2.068	0.702	17	0.302	1.313	0.463
	Aug1	2690	1.222	2501	0.752	15	0.289	1.878	0.694	21	0.405	2.151	0.707
	Dec3	1972	1.668	1752	0.388	20	0.450	1.610	0.537	18	0.405	2.044	0.707
	Aug3	1982	0.921	1536	0.429	13	0.292	1.503	0.586	11	0.247	1.728	0.721
	Oct3	833	1.192	823	0.395	18	0.624	2.080	0.720	14	0.485	2.037	0.772
	Feb3	3832	0.939	3079	0.343	18	0.291	1.601	0.554	18	0.291	1.791	0.619
	Apr3	2004	0.909	1616	0.301	19	0.424	1.900	0.645	16	0.358	1.790	0.645
Kambeni	Con0	830	1.370	849	0.624	12	0.417	1.839	0.740	13	0.451	2.200	0.858
	Dec2	990	0.906	562	0.759	15	0.477	2.144	0.792	11	0.350	1.421	0.592
	Oct2	2188	1.254	1668	0.207	21	0.449	2.155	0.708	17	0.364	1.667	0.588
	Feb2	1412	0.953	1114	0.336	12	0.319	1.160	0.467	12	0.319	1.679	0.676
	Aug2	1561	1.047	1370	0.366	9	0.228	1.157	0.527	15	0.380	1.989	0.734
	Apr2	1503	1.147	1252	0.714	15	0.387	1.740	0.643	14	0.361	1.882	0.713
	Aug1	2336	0.914	1840	0.580	14	0.290	1.326	0.502	18	0.372	1.929	0.667
	Feb3	1413	0.993	1096	0.343	16	0.426	2.042	0.737	15	0.399	1.797	0.664
	Oct3	1333	0.923	1014	0.148	22	0.603	2.532	0.819	18	0.494	1.715	0.593
	Dec3	2931	0.932	2705	0.132	16	0.296	1.256	0.453	17	0.314	1.481	0.523
	Aug3	3337	0.867	2597	0.281	26	0.450	2.322	0.713	17	0.294	1.769	0.624
	Apr3	2320	0.914	1651	0.284	24	0.498	2.346	0.738	13	0.270	1.578	0.615
Numbi	Oct2	2141	0.991	1496	0.790	16	0.346	2.004	0.723	18	0.389	1.668	0.577
	Dec2	1658	1.224	1113	0.812	13	0.319	2.047	0.798	16	0.393	1.622	0.585
	Feb2	401	1.639	398	0.783	11	0.549	1.946	0.812	9	0.451	1.642	0.747
	Aug2	2617	1.024	1761	0.765	24	0.469	2.682	0.844	16	0.313	1.869	0.674
	Apr2	2348	1.398	1998	0.785	17	0.351	2.129	0.752	18	0.372	1.933	0.669
	Aug1	2220	0.909	1329	0.830	21	0.446	2.244	0.737	16	0.340	1.561	0.563
	Con0	1897	0.773	1361	0.880	17	0.390	1.987	0.701	19	0.436	1.582	0.537
	Dec3	2177	1.159	1514	0.437	27	0.579	2.537	0.770	13	0.279	1.605	0.626
	Oct3	2067	1.274	1624	0.330	33	0.726	2.880	0.824	16	0.352	1.817	0.655
	Feb3	2809	1.326	2176	0.165	19	0.358	1.919	0.652	14	0.264	1.448	0.549
	Apr3	1650	1.050	1150	0.321	31	0.763	2.828	0.823	14	0.345	1.837	0.696
	Aug3	1880	0.834	1061	0.523	17	0.392	2.247	0.793	8	0.184	1.476	0.710

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Table 12-1 continued.

						Taxonomic diversity				Structural diversity			
Replicate	Treatment	Density (plants/Ha)	Mean height (m)	Tree equivalents (per Ha)	Single-stem to Multi stem	Number of species	Species Richness	Species diversity	Species evenness	Number of structural groups	Structure richness	Structure diversity	Structure evenness
Shabeni	Aug2	3175	0.629	2113	0.658	14	0.248	1.293	0.490	18	0.319	1.626	0.563
	Apr2	2822	0.934	1776	0.496	21	0.395	2.225	0.731	15	0.282	1.641	0.606
	Aug1	2058	1.277	1749	0.671	22	0.485	2.326	0.753	18	0.397	1.948	0.674
	Feb2	4648	1.452	3431	0.368	27	0.396	2.544	0.772	20	0.293	1.764	0.589
	Oct2	2572	0.795	1450	0.657	23	0.454	2.449	0.781	15	0.296	1.500	0.554
	Dec2	1069	0.842	627	0.626	15	0.459	1.772	0.654	10	0.306	1.456	0.632
	Con0	2498	1.113	1822	0.643	21	0.420	2.151	0.707	19	0.380	1.803	0.612
	Dec3	2102	0.908	1323	0.349	25	0.545	2.223	0.691	10	0.218	1.380	0.599
	Apr3	1465	1.000	902	0.449	24	0.627	2.435	0.766	10	0.261	1.556	0.676
	Aug3	895	0.905	683	0.397	9	0.301	1.587	0.722	10	0.334	1.659	0.720
	Oct3	1035	0.958	813	0.313	15	0.466	2.115	0.781	12	0.373	1.629	0.656
	Feb3	2109	1.095	1579	0.304	28	0.610	2.299	0.690	17	0.370	1.799	0.635

Table 12-2: Summary of the vegetation indices calculated from the data collected in the 1959 survey on the No burn plots.

						Taxonomic diversity				Structural diversity			
Replicate	Treatment	Density (plants/Ha)	Mean height (m)	Tree equivalents (per Ha)	Single:Multi stem	Number of species	Species Richness	Species diversity	Species evenness	Number of structural groups	Structure richness	Structure diversity	Structure evenness
Fayi	Con0	2263	0.802	1986	0.529	21	0.441	2.144	0.704	22	0.463	2.183	0.706
Kambeni	Con0	1129	0.783	738	0.573	12	0.357	1.856	0.747	9	0.268	1.656	0.754
Numbi	Con0	3350	0.800	1853	0.479	28	0.484	2.655	0.797	11	0.190	1.466	0.611
Shabeni	Con0	2844	0.785	2024	0.610	19	0.356	1.577	0.536	15	0.281	1.755	0.648

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Table 12-3: Summary of the vegetation indices calculated from the data collected in the 1996 survey.

						Taxonomic diversity				Structural diversity			
Replicate	Treatment	Density (plants/Ha)	Mean height (m)	Tree equivalents (per Ha)	Single:Multi stem	Number of species	Species Richness	Species diversity	Species evenness	Number of structural groups	Structure richness	Structure diversity	Structure evenness
Fayi	Aug2	6805	1.25	4958	0.133	22	0.267	1.605	0.519	21	0.255	1.516	0.498
	Con0	9565	1.185	7137	0.384	30	0.307	2.109	0.62	22	0.225	1.729	0.559
	Dec2	7739	0.981	4962	0.29	35	0.398	2.12	0.596	21	0.239	1.541	0.506
	Oct2	6406	1.101	5084	0.318	29	0.362	2.137	0.635	19	0.237	1.789	0.607
	Apr2	6484	1.347	5235	0.414	26	0.323	1.825	0.56	23	0.286	1.778	0.567
	Feb2	6291	0.759	3200	0.388	30	0.378	2.595	0.763	23	0.29	1.447	0.462
	Aug1	5698	0.891	2602	0.12	27	0.358	1.963	0.596	17	0.225	1.127	0.398
	Dec3	6707	1.491	4981	0.405	35	0.427	2.14	0.602	23	0.281	1.854	0.591
	Aug3	6018	1.196	5932	0.129	27	0.348	1.632	0.495	16	0.206	1.545	0.557
	Oct3	4133	0.93	3950	0.348	14	0.218	1.606	0.609	15	0.233	1.735	0.641
	Feb3	6371	0.959	3974	0.463	31	0.388	1.848	0.538	22	0.276	1.699	0.55
	Apr3	6555	0.912	5179	0.338	31	0.383	1.908	0.556	21	0.259	1.7	0.558
Kambeni	Con0	4983	1.244	4653	0.572	32	0.453	2.64	0.762	19	0.269	2.055	0.698
	Dec2	5958	0.93	3586	0.445	28	0.363	1.755	0.527	14	0.181	1.497	0.567
	Oct2	2655	1.236	2602	0.223	21	0.408	1.868	0.614	15	0.291	1.768	0.653
	Feb2	10409	0.832	7918	0.344	30	0.294	1.938	0.57	22	0.216	1.645	0.532
	Aug2	5548	1.282	6016	0.065	28	0.376	1.481	0.444	19	0.255	1.282	0.435
	Apr2	6469	1.007	5672	0.364	30	0.373	1.729	0.508	19	0.236	1.693	0.575
	Aug1	6515	1.019	4795	0.098	29	0.359	1.848	0.549	19	0.235	1.433	0.487
	Feb3	6208	0.888	3857	0.452	27	0.343	2.127	0.645	18	0.228	1.618	0.56
	Oct3	5893	1.574	5814	0.219	27	0.352	2.011	0.61	15	0.195	1.599	0.59
	Dec3	7157	1.33	6739	0.432	27	0.319	1.772	0.538	24	0.284	1.96	0.617
	Aug3	7381	1.114	7359	0.235	35	0.407	2.229	0.627	21	0.244	1.73	0.568
	Apr3	6196	0.881	5113	0.373	30	0.381	1.952	0.574	16	0.203	1.638	0.591
Numbi	Oct2	3917	1.256	2670	0.332	30	0.479	2.624	0.771	20	0.32	1.716	0.573
	Dec2	5201	0.867	3413	0.331	31	0.43	2.085	0.607	18	0.25	1.619	0.56
	Feb2	3401	0.879	1835	0.245	34	0.583	2.37	0.672	16	0.274	1.328	0.479
	Aug2	5951	0.818	3158	0.151	26	0.337	2.238	0.687	14	0.181	1.319	0.5
	Apr2	5500	0.858	4192	0.323	23	0.31	1.895	0.604	15	0.202	1.553	0.573
	Aug1	7381	0.64	2711	0.095	26	0.303	2.164	0.664	15	0.175	0.912	0.337
	Con0	14163	1.209	10323	0.587	44	0.37	2.725	0.72	22	0.185	1.807	0.585
	Dec3	3489	0.901	2255	0.482	35	0.593	2.849	0.801	16	0.271	1.694	0.611
	Oct3	6788	1.044	4366	0.362	37	0.449	2.618	0.725	19	0.231	1.593	0.541
	Feb3	5803	0.9	4460	0.385	30	0.394	2.26	0.665	21	0.276	1.75	0.575
	Apr3	7465	0.834	4012	0.331	47	0.544	2.646	0.687	19	0.22	1.441	0.489
	Aug3	3889	0.892	2032	0.429	19	0.305	2.082	0.707	12	0.192	1.322	0.532
Shabeni	Aug2	2963	1.183	2268	0.27	29	0.533	2.244	0.667	15	0.275	1.643	0.607
	Apr2	2550	0.954	1551	0.385	19	0.376	1.972	0.67	12	0.238	1.461	0.588
	Aug1	4622	0.886	2098	0.193	28	0.412	2.415	0.725	17	0.25	1.178	0.416
	Feb2	11649	0.914	5922	0.363	37	0.343	2.595	0.719	19	0.176	1.399	0.475
	Oct2	9008	0.922	4661	0.257	26	0.274	2.215	0.68	15	0.158	1.362	0.503
	Dec2	7185	0.882	3285	0.424	40	0.472	2.664	0.722	17	0.201	1.447	0.511
	Con0	6073	1.17	5740	0.613	44	0.565	2.453	0.648	21	0.269	2.081	0.683
	Dec3	2298	1.072	1725	0.232	28	0.584	2.322	0.697	14	0.292	1.542	0.584
	Apr3	4406	1.035	3040	0.384	29	0.437	2.006	0.596	19	0.286	1.657	0.563
	Aug3	3581	1.2	3531	0.179	24	0.401	1.722	0.542	17	0.284	1.612	0.569
	Oct3	3191	1.195	2794	0.247	25	0.443	2.022	0.628	14	0.248	1.599	0.606
	Feb3	3990	1.122	2363	0.426	31	0.491	2.437	0.71	17	0.269	1.551	0.547

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13 APPENDIX 5: DESCRIPTIVE STATISTICAL SUMMARY OF THE DATA USED IN THE ANOVA AND ANCOVA ANALYSES

Table 13-1: Summary of data collected on the Pretoriuskop EBPs in 1954 and 1996. This data was used to test for changes in the woody vegetation structure and composition on the Pretoriuskop EBPs between 1954 and 1996.

						Taxonomic diversity				Structural diversity			
Treatment	Statistic	Density (plants/Ha)	Mean height (m)	Tree equivalents (per Ha)	Single:Multi stem	Number of species	Species Richness	Species diversity	Species evenness	Number of structural groups	Structure richness	Structure diversity	Structure evenness
1954	N	48	48	48	48	48	48	48	48	48	48	48	48
	Min	401	0.629	398	0.132	9	0.228	1.157	0.453	8	0.184	1.313	0.463
	Max	4648	1.668	3431	0.922	33	0.763	2.880	0.844	21	0.494	2.200	0.858
	Mean	2094.458	1.076	1571.729	0.541	18.979	0.431	2.042	0.700	15.271	0.347	1.726	0.641
	SD	817.070	0.217	637.720	0.237	5.444	0.119	0.413	0.099	3.167	0.065	0.199	0.071
1996	N	48	48	48	48	48	48	48	48	48	48	48	48
	Min	2298	0.640	1551	0.065	14	0.218	1.481	0.444	12	0.158	0.912	0.337
	Max	14163	1.574	10323	0.613	47	0.593	2.849	0.801	24	0.320	2.081	0.698
	Mean	6012.667	1.041	4285.896	0.324	29.646	0.396	2.135	0.633	18.083	0.241	1.582	0.549
	SD	2309.038	0.196	1816.365	0.129	6.323	0.086	0.340	0.081	3.134	0.039	0.223	0.069

WitsETD

Table 13-2: Summary of data collected on the Pretoriuskop replicates (Fayi, Kambeni, Numbi, and Shabeni) in 1954. This data was used to test for differences between the EBP replicates in the Pretoriuskop region in 1954.

						Taxonomic diversity				Structural diversity			
Treatment	Statistic	Density (plants/Ha)	Mean height (m)	Tree equivalents (per Ha)	Single:Multi stem	Number of species	Species Richness	Species diversity	Species evenness	Number of structural groups	Structure richness	Structure diversity	Structure evenness
Fayi	N	12	12	12	12	12	12	12	12	12	12	12	12
	Min	833	0.901	872	0.301	13	0.289	1.503	0.537	11	0.247	1.313	0.463
	Max	3832	1.743	3179	0.922	22	0.624	2.322	0.760	21	0.485	2.151	0.772
	Mean	2338.917	1.160	1893.167	0.652	18.250	0.395	1.927	0.665	16.833	0.360	1.826	0.651
	SD	768.851	0.228	600.314	0.254	2.633	0.099	0.281	0.077	2.517	0.064	0.218	0.078
Kambeni	N	12	12	12	12	12	12	12	12	12	12	12	12
	Min	830	0.872	545	0.132	9	0.228	1.157	0.453	11	0.270	1.421	0.523
	Max	3337	1.476	2819	0.759	26	0.603	2.532	0.819	18	0.494	2.200	0.858
	Mean	1846.167	1.041	1521.000	0.398	16.833	0.403	1.835	0.653	15.000	0.364	1.759	0.654
	SD	773.712	0.216	683.800	0.217	5.254	0.105	0.499	0.131	2.412	0.064	0.220	0.087
Numbi	N	12	12	12	12	12	12	12	12	12	12	12	12
	Min	401	0.737	444	0.165	11	0.319	1.919	0.652	8	0.184	1.448	0.537
	Max	2809	2.133	2264	0.880	33	0.763	2.880	0.844	19	0.451	1.933	0.747
	Mean	1988.750	1.215	1449.500	0.618	20.500	0.474	2.287	0.769	14.750	0.343	1.672	0.632
	SD	609.033	0.432	500.376	0.248	6.922	0.150	0.353	0.058	3.415	0.075	0.157	0.069
Shabeni	N	12	12	12	12	12	12	12	12	12	12	12	12
	Min	895	0.603	629	0.304	9	0.248	1.293	0.490	10	0.218	1.380	0.554
	Max	4648	1.721	3520	0.671	28	0.627	2.544	0.781	20	0.397	1.948	0.720
	Mean	2204.000	1.045	1555.583	0.494	20.333	0.451	2.118	0.711	14.500	0.319	1.647	0.626
	SD	1064.933	0.317	799.236	0.148	5.836	0.112	0.378	0.081	3.920	0.054	0.162	0.049

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Table 13-3: Summary of data collected on the Pretoriuskop replicates (Fayi, Kambeni, Numbi, and Shabeni) in 1996. This data was used to test for differences between the EBP replicates in the Pretoriuskop region in 1996.

						Taxonomic diversity				Structural diversity			
Treatment	Statistic	Density (plants/Ha)	Mean height (m)	Tree equivalents (per Ha)	Single:Multi stem	Number of species	Species Richness	Species diversity	Species evenness	Number of structural groups	Structure richness	Structure diversity	Structure evenness
Fayi	N	12	12	12	12	12	12	12	12	12	12	12	12
	Min	4133	0.759	2602	0.120	14	0.218	1.605	0.495	15	0.206	1.127	0.398
	Max	9565	1.491	7137	0.463	35	0.427	2.595	0.763	23	0.290	1.854	0.641
	Mean	6564.333	1.084	4766.167	0.311	28.083	0.346	1.957	0.591	20.250	0.251	1.622	0.541
	SD	1263.696	0.215	1206.902	0.120	5.744	0.059	0.287	0.069	2.832	0.027	0.200	0.066
Kambeni	N	12	12	12	12	12	12	12	12	12	12	12	12
	Min	2655	0.832	2602	0.065	21	0.294	1.481	0.444	14	0.181	1.282	0.435
	Max	10409	1.574	7918	0.572	35	0.453	2.640	0.762	24	0.291	2.055	0.698
	Mean	6281.000	1.111	5343.667	0.318	28.667	0.369	1.946	0.581	18.417	0.237	1.660	0.573
	SD	1777.262	0.225	1568.564	0.152	3.367	0.042	0.293	0.080	3.029	0.034	0.211	0.069
Numbi	N	12	12	12	12	12	12	12	12	12	12	12	12
	Min	3401	0.640	1835	0.095	19	0.303	1.895	0.604	12	0.175	0.912	0.337
	Max	14163	1.256	10323	0.587	47	0.593	2.849	0.801	22	0.320	1.807	0.611
	Mean	6079.000	0.925	3785.583	0.338	31.833	0.425	2.380	0.693	17.250	0.231	1.504	0.530
	SD	2923.552	0.170	2254.297	0.134	8.189	0.107	0.304	0.058	3.049	0.047	0.254	0.073
Shabeni	N	12	12	12	12	12	12	12	12	12	12	12	12
	Min	2298	0.882	1551	0.179	19	0.274	1.722	0.542	12	0.158	1.178	0.416
	Max	11649	1.200	5922	0.613	44	0.584	2.664	0.725	21	0.292	2.081	0.683
	Mean	5126.333	1.045	3248.167	0.331	30.000	0.444	2.256	0.667	16.417	0.246	1.544	0.554
	SD	2864.546	0.128	1475.657	0.125	7.097	0.091	0.281	0.056	2.539	0.045	0.218	0.070

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Table 13-4: Summary of data collected on the Pretoriuskop EBPs to be burnt at different frequencies in 1954 excluding the August annual treatment. This data was used to test for pre-treatment differences between the plots to be burnt at different frequencies in 1954.

						Taxonomic diversity				Structural diversity			
Frequency	Statistic	Density (plants/Ha)	Mean height (m)	Tree equivalents (per Ha)	Single:Multi stem	Number of species	Species Richness	Species diversity	Species evenness	Number of structural groups	Structure richness	Structure diversity	Structure evenness
None	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	830	0.773	849	0.624	12	0.390	1.839	0.701	13	0.380	1.582	0.537
	Max	2498	1.370	1822	0.880	21	0.466	2.239	0.760	19	0.451	2.200	0.858
	Mean	1721.500	1.116	1315.250	0.738	17.250	0.423	2.054	0.727	16.750	0.415	1.850	0.666
	SD	690.938	0.252	401.546	0.125	3.862	0.032	0.178	0.028	2.872	0.034	0.256	0.137
Biennial	N	20	20	20	20	20	20	20	20	20	20	20	20
	Min	401	0.629	398	0.207	9	0.228	1.157	0.467	9	0.282	1.313	0.463
	Max	4648	1.639	3431	0.922	27	0.549	2.682	0.844	20	0.451	1.989	0.747
	Mean	2209.900	1.104	1603.450	0.677	17.500	0.388	1.988	0.698	15.600	0.346	1.696	0.624
	SD	945.569	0.240	683.961	0.212	4.763	0.081	0.423	0.106	3.033	0.044	0.185	0.068
Triennial	N	20	20	20	20	20	20	20	20	20	20	20	20
	Min	833	0.834	683	0.132	9	0.291	1.256	0.453	8	0.184	1.380	0.523
	Max	3832	1.668	3079	0.523	33	0.763	2.880	0.824	18	0.494	2.044	0.772
	Mean	2007.300	1.038	1534.700	0.332	21.000	0.486	2.113	0.701	14.050	0.327	1.697	0.650
	SD	779.754	0.202	665.139	0.100	6.181	0.144	0.442	0.103	3.103	0.081	0.181	0.061

Table 13-5: Summary of data collected on the Pretoriuskop EBPs burnt at different frequencies in 1996 excluding the August annual treatment. This data was used to test for the treatment effects on the plots burnt at different frequencies between 1954 and 1996.

						Taxonomic diversity				Structural diversity			
Frequency	Statistic	Density (plants/Ha)	Mean height (m)	Tree equivalents (per Ha)	Single:Multi stem	Number of species	Species Richness	Species diversity	Species evenness	Number of structural groups	Structure richness	Structure diversity	Structure evenness
None	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	4983	1.170	4653	0.384	30	0.307	2.109	0.620	19	0.185	1.729	0.559
	Max	14163	1.244	10323	0.613	44	0.565	2.725	0.762	22	0.269	2.081	0.698
	Mean	8696.000	1.202	6963.250	0.539	37.500	0.424	2.482	0.688	21.000	0.237	1.918	0.631
	SD	4135.607	0.032	2459.790	0.105	7.550	0.112	0.273	0.065	1.414	0.041	0.176	0.070
Biennial	N	20	20	20	20	20	20	20	20	20	20	20	20
	Min	2550	0.759	1551	0.065	19	0.267	1.481	0.444	12	0.158	1.282	0.435
	Max	11649	1.347	7918	0.445	40	0.583	2.664	0.771	23	0.320	1.789	0.653
	Mean	6104.450	1.013	4109.400	0.303	28.700	0.384	2.098	0.627	17.850	0.238	1.540	0.539
	SD	2411.223	0.182	1629.767	0.101	5.283	0.083	0.349	0.088	3.249	0.045	0.161	0.057
Triennial	N	20	20	20	20	20	20	20	20	20	20	20	20
	Min	2298	0.834	1725	0.129	14	0.218	1.606	0.495	12	0.192	1.322	0.489
	Max	7465	1.574	7359	0.482	47	0.593	2.849	0.801	24	0.292	1.960	0.641
	Mean	5375.950	1.074	4173.800	0.342	29.450	0.410	2.109	0.628	17.950	0.249	1.642	0.572
	SD	1582.418	0.208	1564.979	0.102	6.840	0.092	0.340	0.078	3.300	0.033	0.138	0.034

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Table 13-6: Summary of data collected on the No burn, August annual, August biennial, and August triennial treatments. This data was used to test for pre-treatment differences between the plots to be burnt at different frequencies in 1954.

						Taxonomic diversity				Structural diversity			
Fire Frequency (yr)	Statistic	Density (plants/Ha)	Mean height (m)	Tree equivalents (per Ha)	Single:Multi stem	Number of species	Species Richness	Species diversity	Species evenness	Number of structural groups	Structure richness	Structure diversity	Structure evenness
None	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	830	0.773	849	0.624	12	0.390	1.839	0.701	13	0.380	1.582	0.537
	Max	2498	1.370	1822	0.880	21	0.466	2.239	0.760	19	0.451	2.200	0.858
	Mean	1721.500	1.116	1315.250	0.738	17.250	0.423	2.054	0.727	16.750	0.415	1.850	0.666
	SD	690.938	0.252	401.546	0.125	3.862	0.032	0.178	0.028	2.872	0.034	0.256	0.137
Annual	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	2058	0.909	1329	0.580	14	0.289	1.326	0.502	16	0.340	1.561	0.563
	Max	2690	1.277	2501	0.830	22	0.485	2.326	0.753	21	0.405	2.151	0.707
	Mean	2326.000	1.081	1854.750	0.708	18.000	0.377	1.944	0.671	18.250	0.378	1.897	0.653
	SD	268.114	0.196	484.924	0.107	4.082	0.103	0.456	0.115	2.062	0.029	0.246	0.062
Biennial	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	1561	0.629	1370	0.366	9	0.228	1.157	0.490	15	0.313	1.626	0.563
	Max	3175	1.277	2113	0.900	24	0.469	2.682	0.844	18	0.380	1.989	0.734
	Mean	2433.500	0.994	1768.500	0.672	16.250	0.329	1.740	0.623	16.500	0.340	1.798	0.643
	SD	670.201	0.269	306.225	0.227	6.344	0.112	0.692	0.159	1.291	0.030	0.162	0.076
Triennial	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	895	0.834	683	0.281	9	0.292	1.503	0.586	8	0.184	1.476	0.624
	Max	3337	0.921	2597	0.523	26	0.450	2.322	0.793	17	0.334	1.769	0.721
	Mean	2023.500	0.882	1469.250	0.408	16.250	0.359	1.915	0.703	11.500	0.265	1.658	0.694
	SD	1003.512	0.039	828.881	0.100	7.274	0.076	0.429	0.086	3.873	0.064	0.130	0.047

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Table 13-7: Summary of data collected on the No burn, August annual, August biennial, and August triennial treatments. This data was used to test for the treatment effects on the plots burnt at different frequencies between 1954 and 1996.

						Taxonomic diversity				Structural diversity			
Fire Frequency (yr)	Statistic	Density (plants/Ha)	Mean height (m)	Tree equivalents (per Ha)	Single:Multi stem	Number of species	Species Richness	Species diversity	Species evenness	Number of structural groups	Structure richness	Structure diversity	Structure evenness
None	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	4983	1.170	4653	0.384	30	0.307	2.109	0.620	19	0.185	1.729	0.559
	Max	14163	1.244	10323	0.613	44	0.565	2.725	0.762	22	0.269	2.081	0.698
	Mean	8696.000	1.202	6963.250	0.539	37.500	0.424	2.482	0.688	21.000	0.237	1.918	0.631
	SD	4135.607	0.032	2459.790	0.105	7.550	0.112	0.273	0.065	1.414	0.041	0.176	0.070
Annual	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	4622	0.640	2098	0.095	26	0.303	1.848	0.549	15	0.175	0.912	0.337
	Max	7381	1.019	4795	0.193	29	0.412	2.415	0.725	19	0.250	1.433	0.487
	Mean	6054.000	0.859	3051.500	0.126	27.500	0.358	2.097	0.633	17.000	0.221	1.162	0.409
	SD	1176.267	0.159	1192.608	0.045	1.291	0.045	0.249	0.077	1.633	0.033	0.214	0.062
Biennial	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	2963	0.818	2268	0.065	22	0.267	1.481	0.444	14	0.181	1.282	0.435
	Max	6805	1.282	6016	0.270	29	0.533	2.244	0.687	21	0.275	1.643	0.607
	Mean	5316.750	1.133	4100.000	0.155	26.250	0.378	1.892	0.579	17.250	0.242	1.440	0.510
	SD	1654.366	0.214	1698.117	0.085	3.096	0.113	0.406	0.117	3.304	0.041	0.170	0.071
Triennial	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	3581	0.892	2032	0.129	19	0.305	1.632	0.495	12	0.192	1.322	0.532
	Max	7381	1.200	7359	0.429	35	0.407	2.229	0.707	21	0.284	1.730	0.569
	Mean	5217.250	1.100	4713.500	0.243	26.250	0.365	1.916	0.593	16.500	0.232	1.552	0.557
	SD	1804.123	0.145	2385.523	0.131	6.702	0.048	0.285	0.094	3.697	0.041	0.171	0.017

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Table 13-8: Summary of data collected on the Pretoriuskop EBPs burnt at different times of the year excluding the August annual treatment. This data was used to test for pre-treatment differences between the plots to be burnt at different times of the year in 1954.

						Taxonomic diversity				Structural diversity			
Treatment	Statistic	Density (plants/Ha)	Mean height (m)	Tree equivalents (per Ha)	Single:Multi stem	Number of species	Species Richness	Species diversity	Species evenness	Number of structural groups	Structure richness	Structure diversity	Structure evenness
February	N	8	8	8	8	8	8	8	8	8	8	8	8
	Min	401	0.939	398	0.165	11	0.291	1.160	0.467	9	0.264	1.313	0.463
	Max	4648	1.639	3431	0.922	28	0.610	2.544	0.812	20	0.451	1.799	0.747
	Mean	2473.750	1.184	1851.500	0.446	18.750	0.411	1.947	0.673	15.250	0.336	1.654	0.618
	SD	1406.396	0.259	1029.295	0.261	6.182	0.113	0.421	0.114	3.536	0.064	0.182	0.086
April	N	8	8	8	8	8	8	8	8	8	8	8	8
	Min	1465	0.909	902	0.284	15	0.330	1.740	0.641	10	0.261	1.556	0.606
	Max	2822	1.398	1998	0.825	31	0.763	2.828	0.823	19	0.392	1.974	0.713
	Mean	2057.500	1.067	1541.125	0.522	20.875	0.472	2.173	0.717	14.875	0.330	1.774	0.661
	SD	485.444	0.169	400.494	0.223	5.330	0.151	0.368	0.068	2.850	0.051	0.163	0.037
August	N	8	8	8	8	8	8	8	8	8	8	8	8
	Min	895	0.629	683	0.281	9	0.228	1.157	0.490	8	0.184	1.476	0.563
	Max	3337	1.277	2597	0.900	26	0.469	2.682	0.844	18	0.380	1.989	0.734
	Mean	2228.500	0.938	1618.875	0.540	16.250	0.344	1.827	0.663	14.000	0.303	1.728	0.669
	SD	819.827	0.188	600.185	0.215	6.319	0.090	0.541	0.126	3.780	0.062	0.155	0.064
October	N	8	8	8	8	8	8	8	8	8	8	8	8
	Min	833	0.795	813	0.148	15	0.346	2.004	0.708	12	0.296	1.500	0.554
	Max	2572	1.274	1869	0.866	33	0.726	2.880	0.824	18	0.494	2.037	0.772
	Mean	1803.875	1.078	1344.625	0.463	21.250	0.516	2.317	0.763	16.000	0.391	1.735	0.629
	SD	642.075	0.183	406.314	0.272	5.600	0.123	0.293	0.045	2.204	0.067	0.163	0.069
December	N	8	8	8	8	8	8	8	8	8	8	8	8
	Min	990	0.842	562	0.132	13	0.296	1.256	0.453	10	0.218	1.380	0.523
	Max	2936	1.668	2705	0.900	27	0.579	2.537	0.798	18	0.405	2.044	0.707
	Mean	1979.375	1.089	1489.250	0.550	19.125	0.441	1.988	0.681	14.000	0.322	1.591	0.609
	SD	735.410	0.270	756.590	0.266	5.167	0.099	0.417	0.126	3.381	0.061	0.216	0.052
Control	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	830	0.773	849	0.624	12	0.390	1.839	0.701	13	0.380	1.582	0.537
	Max	2498	1.370	1822	0.880	21	0.466	2.239	0.760	19	0.451	2.200	0.858
	Mean	1721.500	1.116	1315.250	0.738	17.250	0.423	2.054	0.727	16.750	0.415	1.850	0.666
	SD	690.938	0.252	401.546	0.125	3.862	0.032	0.178	0.028	2.872	0.034	0.256	0.137

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Table 13-9: Summary of data collected on the Pretoriuskop EBPs burnt at different times of the year excluding the August annual treatment. This data was used to test for the treatment effects on the plots burnt at different times of the year between 1954 and 1996.

						Taxonomic diversity				Structural diversity			
Treatment	Statistic	Density (plants/Ha)	Mean height (m)	Tree equivalents (per Ha)	Single:Multi stem	Number of species	Species Richness	Species diversity	Species evenness	Number of structural groups	Structure richness	Structure diversity	Structure evenness
February	N	8	8	8	8	8	8	8	8	8	8	8	8
	Min	3401	0.759	1835	0.245	27	0.294	1.848	0.538	16	0.176	1.328	0.462
	Max	11649	1.122	7918	0.463	37	0.583	2.595	0.763	23	0.290	1.750	0.575
	Mean	6765.250	0.907	4191.125	0.383	31.250	0.402	2.271	0.660	19.750	0.251	1.555	0.522
	SD	2872.652	0.106	1963.681	0.070	3.012	0.093	0.282	0.076	2.605	0.040	0.150	0.044
April	N	8	8	8	8	8	8	8	8	8	8	8	8
	Min	2550	0.834	1551	0.323	19	0.310	1.729	0.508	12	0.202	1.441	0.489
	Max	7465	1.347	5672	0.414	47	0.544	2.646	0.687	23	0.286	1.778	0.591
	Mean	5703.125	0.978	4249.250	0.364	29.375	0.391	1.991	0.594	18.000	0.241	1.615	0.563
	SD	1555.412	0.165	1384.033	0.031	8.228	0.073	0.279	0.060	3.505	0.033	0.120	0.032
August	N	8	8	8	8	8	8	8	8	8	8	8	8
	Min	2963	0.818	2032	0.065	19	0.267	1.481	0.444	12	0.181	1.282	0.435
	Max	7381	1.282	7359	0.429	35	0.533	2.244	0.707	21	0.284	1.730	0.607
	Mean	5267.000	1.117	4406.750	0.199	26.250	0.372	1.904	0.586	16.875	0.237	1.496	0.533
	SD	1603.352	0.170	1944.800	0.113	4.833	0.081	0.325	0.098	3.271	0.039	0.169	0.054
October	N	8	8	8	8	8	8	8	8	8	8	8	8
	Min	2655	0.922	2602	0.219	14	0.218	1.606	0.609	14	0.158	1.362	0.503
	Max	9008	1.574	5814	0.362	37	0.479	2.624	0.771	20	0.320	1.789	0.653
	Mean	5248.875	1.157	3992.625	0.288	26.125	0.373	2.137	0.659	16.500	0.239	1.645	0.589
	SD	2145.955	0.212	1208.088	0.058	6.728	0.091	0.350	0.061	2.390	0.050	0.139	0.050
December	N	8	8	8	8	8	8	8	8	8	8	8	8
	Min	2298	0.867	1725	0.232	27	0.319	1.755	0.527	14	0.181	1.447	0.506
	Max	7739	1.491	6739	0.482	40	0.593	2.849	0.801	24	0.292	1.960	0.617
	Mean	5716.750	1.057	3868.250	0.380	32.375	0.448	2.213	0.636	18.375	0.250	1.644	0.568
	SD	1937.417	0.232	1625.638	0.086	4.596	0.098	0.388	0.095	3.889	0.041	0.181	0.042
Control	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	4983	1.170	4653	0.384	30	0.307	2.109	0.620	19	0.185	1.729	0.559
	Max	14163	1.244	10323	0.613	44	0.565	2.725	0.762	22	0.269	2.081	0.698
	Mean	8696.000	1.202	6963.250	0.539	37.500	0.424	2.482	0.688	21.000	0.237	1.918	0.631
	SD	4135.607	0.032	2459.790	0.105	7.550	0.112	0.273	0.065	1.414	0.041	0.176	0.070

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Table 13-10: Summary of data used to test for pre-treatment differences between the plots to be burnt with different fire treatments in 1954.

						Taxonomic diversity				Structural diversity			
Treatment	Statistic	Density (plants/Ha)	Mean height (m)	Tree equivalents (per Ha)	Single:Multi stem	Number of species	Species Richness	Species diversity	Species evenness	Number of structural groups	Structure richness	Structure diversity	Structure evenness
Apr2	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	1503	0.934	1252	0.496	15	0.330	1.740	0.641	14	0.282	1.641	0.606
	Max	2822	1.398	1998	0.825	21	0.395	2.225	0.752	19	0.392	1.974	0.713
	Mean	2255.250	1.165	1752.500	0.705	17.250	0.366	1.968	0.692	16.500	0.352	1.858	0.665
	SD	549.027	0.190	348.767	0.147	2.630	0.031	0.245	0.058	2.380	0.048	0.149	0.044
Apr3	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	1465	0.909	902	0.284	19	0.424	1.900	0.645	10	0.261	1.556	0.615
	Max	2320	1.050	1651	0.449	31	0.763	2.828	0.823	16	0.358	1.837	0.696
	Mean	1859.750	0.968	1329.750	0.339	24.500	0.578	2.377	0.743	13.250	0.308	1.690	0.658
	SD	379.676	0.069	365.340	0.075	4.933	0.149	0.381	0.074	2.500	0.050	0.144	0.035
Aug1	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	2058	0.909	1329	0.580	14	0.289	1.326	0.502	16	0.340	1.561	0.563
	Max	2690	1.277	2501	0.830	22	0.485	2.326	0.753	21	0.405	2.151	0.707
	Mean	2326.000	1.081	1854.750	0.708	18.000	0.377	1.944	0.671	18.250	0.378	1.897	0.653
	SD	268.114	0.196	484.924	0.107	4.082	0.103	0.456	0.115	2.062	0.029	0.246	0.062
Aug2	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	1561	0.629	1370	0.366	9	0.228	1.157	0.490	15	0.313	1.626	0.563
	Max	3175	1.277	2113	0.900	24	0.469	2.682	0.844	18	0.380	1.989	0.734
	Mean	2433.500	0.994	1768.500	0.672	16.250	0.329	1.740	0.623	16.500	0.340	1.798	0.643
	SD	670.201	0.269	306.225	0.227	6.344	0.112	0.692	0.159	1.291	0.030	0.162	0.076
Aug3	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	895	0.834	683	0.281	9	0.292	1.503	0.586	8	0.184	1.476	0.624
	Max	3337	0.921	2597	0.523	26	0.450	2.322	0.793	17	0.334	1.769	0.721
	Mean	2023.500	0.882	1469.250	0.408	16.250	0.359	1.915	0.703	11.500	0.265	1.658	0.694
	SD	1003.512	0.039	828.881	0.100	7.274	0.076	0.429	0.086	3.873	0.064	0.130	0.047
Con0	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	830	0.773	849	0.624	12	0.390	1.839	0.701	13	0.380	1.582	0.537
	Max	2498	1.370	1822	0.880	21	0.466	2.239	0.760	19	0.451	2.200	0.858
	Mean	1721.500	1.116	1315.250	0.738	17.250	0.423	2.054	0.727	16.750	0.415	1.850	0.666
	SD	690.938	0.252	401.546	0.125	3.862	0.032	0.178	0.028	2.872	0.034	0.256	0.137
Dec2	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	990	0.842	562	0.626	13	0.319	1.772	0.654	10	0.306	1.421	0.585
	Max	2936	1.224	2318	0.900	22	0.477	2.319	0.798	17	0.393	1.719	0.632
	Mean	1663.250	1.011	1155.000	0.774	16.250	0.415	2.070	0.749	13.500	0.341	1.554	0.604
	SD	899.318	0.172	813.381	0.115	3.948	0.071	0.228	0.066	3.512	0.040	0.141	0.021
Dec3	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	1972	0.908	1323	0.132	16	0.296	1.256	0.453	10	0.218	1.380	0.523
	Max	2931	1.668	2705	0.437	27	0.579	2.537	0.770	18	0.405	2.044	0.707
	Mean	2295.500	1.167	1823.500	0.327	22.000	0.467	1.906	0.613	14.500	0.304	1.628	0.614
	SD	432.048	0.353	613.309	0.135	4.967	0.127	0.580	0.144	3.697	0.078	0.293	0.076
Feb2	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	401	0.953	398	0.336	11	0.319	1.160	0.467	9	0.293	1.313	0.463
	Max	4648	1.639	3431	0.922	27	0.549	2.544	0.812	20	0.451	1.764	0.747
	Mean	2406.750	1.279	1720.500	0.602	17.250	0.401	1.930	0.688	14.500	0.341	1.599	0.619
	SD	1880.800	0.321	1302.613	0.295	7.411	0.104	0.574	0.154	4.933	0.074	0.198	0.122

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Table 13-10 continued.

						Taxonomic diversity				Structural diversity			
Treatment	Statistic	Density (plants/Ha)	Mean height (m)	Tree equivalents (per Ha)	Single:Multi stem	Number of species	Species Richness	Species diversity	Species evenness	Number of structural groups	Structure richness	Structure diversity	Structure evenness
Feb3	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	1413	0.939	1096	0.165	16	0.291	1.601	0.554	14	0.264	1.448	0.549
	Max	3832	1.326	3079	0.343	28	0.610	2.299	0.737	18	0.399	1.799	0.664
	Mean	2540.750	1.088	1982.500	0.289	20.250	0.421	1.965	0.658	16.000	0.331	1.709	0.617
	SD	1032.394	0.171	854.098	0.084	5.315	0.137	0.290	0.078	1.826	0.064	0.174	0.049
Oct2	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	2141	0.795	1450	0.207	16	0.346	2.004	0.708	15	0.296	1.500	0.554
	Max	2572	1.254	1869	0.866	23	0.463	2.449	0.781	18	0.389	1.848	0.639
	Mean	2290.750	1.069	1620.750	0.630	20.500	0.428	2.232	0.741	17.000	0.357	1.671	0.590
	SD	194.002	0.219	190.244	0.295	3.109	0.055	0.194	0.032	1.414	0.042	0.142	0.036
Oct3	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	833	0.923	813	0.148	15	0.466	2.080	0.720	12	0.352	1.629	0.593
	Max	2067	1.274	1624	0.395	33	0.726	2.880	0.824	18	0.494	2.037	0.772
	Mean	1317.000	1.087	1068.500	0.296	22.000	0.605	2.402	0.786	15.000	0.426	1.799	0.669
	SD	540.536	0.173	381.707	0.105	7.874	0.107	0.379	0.048	2.582	0.074	0.176	0.074

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Table 13-11: Summary of data used to test for treatment differences between the plots burnt with different fire treatments between 1954 and 1996.

						Taxonomic diversity				Structural diversity			
Treatment	Statistic	Density	Mean height (m)	Tree equivalents (per Ha)	Single:Multi stem	Number of species	Species Richness	Species diversity	Species evenness	Number of structural groups	Structure richness	Structure diversity	Structure evenness
Apr2	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	2550	0.858	1551	0.323	19	0.310	1.729	0.508	12	0.202	1.461	0.567
	Max	6484	1.347	5672	0.414	30	0.376	1.972	0.670	23	0.286	1.778	0.588
	Mean	5250.750	1.041	4162.500	0.371	24.500	0.346	1.855	0.586	17.250	0.240	1.621	0.576
	SD	1858.424	0.213	1848.391	0.038	4.655	0.034	0.103	0.068	4.787	0.034	0.142	0.009
Apr3	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	4406	0.834	3040	0.331	29	0.381	1.908	0.556	16	0.203	1.441	0.489
	Max	7465	1.035	5179	0.384	47	0.544	2.646	0.687	21	0.286	1.700	0.591
	Mean	6155.500	0.915	4336	0.356	34.250	0.436	2.128	0.603	18.750	0.242	1.609	0.550
	SD	1282.807	0.086	1016.361	0.026	8.539	0.076	0.348	0.058	2.062	0.038	0.115	0.043
Aug1	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	4622	0.640	2098	0.095	26	0.303	1.848	0.549	15	0.175	0.912	0.337
	Max	7381	1.019	4795	0.193	29	0.412	2.415	0.725	19	0.250	1.433	0.487
	Mean	6054.000	0.859	3051.500	0.126	27.500	0.358	2.097	0.633	17.000	0.221	1.162	0.409
	SD	1176.267	0.159	1192.608	0.045	1.291	0.045	0.249	0.077	1.633	0.033	0.214	0.062
Aug2	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	2963	0.818	2268	0.065	22	0.267	1.481	0.444	14	0.181	1.282	0.435
	Max	6805	1.282	6016	0.270	29	0.533	2.244	0.687	21	0.275	1.643	0.607
	Mean	5316.750	1.133	4100.000	0.155	26.250	0.378	1.892	0.579	17.250	0.242	1.440	0.510
	SD	1654.366	0.214	1698.117	0.085	3.096	0.113	0.406	0.117	3.304	0.041	0.170	0.071
Aug3	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	3581	0.892	2032	0.129	19	0.305	1.632	0.495	12	0.192	1.322	0.532
	Max	7381	1.200	7359	0.429	35	0.407	2.229	0.707	21	0.284	1.730	0.569
	Mean	5217.250	1.100	4713.500	0.243	26.250	0.365	1.916	0.593	16.500	0.232	1.552	0.557
	SD	1804.123	0.145	2385.523	0.131	6.702	0.048	0.285	0.094	3.697	0.041	0.171	0.017
Con0	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	4983	1.170	4653	0.384	30	0.307	2.109	0.620	19	0.185	1.729	0.559
	Max	14163	1.244	10323	0.613	44	0.565	2.725	0.762	22	0.269	2.081	0.698
	Mean	8696.000	1.202	6963.250	0.539	37.500	0.424	2.482	0.688	21.000	0.237	1.918	0.631
	SD	4135.607	0.032	2459.790	0.105	7.550	0.112	0.273	0.065	1.414	0.041	0.176	0.070
Dec2	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	5201	0.867	3285	0.290	28	0.363	1.755	0.527	14	0.181	1.447	0.506
	Max	7739	0.981	4962	0.445	40	0.472	2.664	0.722	21	0.250	1.619	0.567
	Mean	6520.750	0.915	3811.500	0.373	33.500	0.416	2.156	0.613	17.500	0.218	1.526	0.536
	SD	1152.358	0.052	776.854	0.074	5.196	0.046	0.376	0.081	2.887	0.032	0.073	0.032
Dec3	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	2298	0.901	1725	0.232	27	0.319	1.772	0.538	14	0.271	1.542	0.584
	Max	7157	1.491	6739	0.482	35	0.593	2.849	0.801	24	0.292	1.960	0.617
	Mean	4912.750	1.199	3925.000	0.388	31.250	0.481	2.271	0.659	19.250	0.282	1.762	0.601
	SD	2388.861	0.263	2356.737	0.109	4.349	0.132	0.448	0.115	4.992	0.009	0.183	0.015
Feb2	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	3401	0.759	1835	0.245	30	0.294	1.938	0.570	16	0.176	1.328	0.462
	Max	11649	0.914	7918	0.388	37	0.583	2.595	0.763	23	0.290	1.645	0.532
	Mean	7937.500	0.846	4718.750	0.335	32.750	0.400	2.375	0.681	20.000	0.239	1.455	0.487
	SD	3793.606	0.067	2726.758	0.063	3.403	0.127	0.310	0.083	3.162	0.053	0.136	0.031

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Table 13-11 continued.

						Taxonomic diversity				Structural diversity			
Treatment	Statistic	Density	Mean height (m)	Tree equivalents (per Ha)	Single:Multi stem	Number of species	Species Richness	Species diversity	Species evenness	Number of structural groups	Structure richness	Structure diversity	Structure evenness
Feb3	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	3990	0.888	2363	0.385	27	0.343	1.848	0.538	17	0.228	1.551	0.547
	Max	6371	1.122	4460	0.463	31	0.491	2.437	0.710	22	0.276	1.750	0.575
	Mean	5593.000	0.967	3663.500	0.431	29.750	0.404	2.168	0.639	19.500	0.262	1.654	0.558
	SD	1095.022	0.108	905.458	0.035	1.893	0.062	0.248	0.073	2.380	0.023	0.088	0.012
Oct2	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	2655	0.922	2602	0.223	21	0.274	1.868	0.614	15	0.158	1.362	0.503
	Max	9008	1.256	5084	0.332	30	0.479	2.624	0.771	20	0.320	1.789	0.653
	Mean	5496.500	1.129	3754.250	0.283	26.500	0.381	2.211	0.675	17.250	0.251	1.659	0.584
	SD	2812.281	0.154	1303.036	0.052	4.041	0.086	0.313	0.070	2.630	0.071	0.200	0.063
Oct3	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	3191	0.93	2794	0.219	14	0.218	1.606	0.609	14	0.195	1.593	0.541
	Max	6788	1.574	5814	0.362	37	0.449	2.618	0.725	19	0.248	1.735	0.641
	Mean	5001.250	1.186	4231.000	0.294	25.750	0.365	2.064	0.643	15.750	0.227	1.632	0.595
	SD	1634.886	0.28	1247.403	0.072	9.430	0.108	0.417	0.055	2.217	0.022	0.069	0.041

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Table 13-12: Summary of data used to test the effects of not burning between 1954, 1959, and 1996.

						Taxonomic diversity				Structural diversity			
Treatment	Statistic	Density	Mean height (m)	Tree equivalents (per Ha)	Single:Multi stem	Number of species	Species Richness	Species diversity	Species evenness	Number of structural groups	Structure richness	Structure diversity	Structure evenness
1954	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	830	0.773	849	0.624	12	0.390	1.839	0.701	13	0.380	1.582	0.537
	Max	2498	1.370	1822	0.880	21	0.466	2.239	0.760	19	0.451	2.200	0.858
	Mean	1721.500	1.116	1315.250	0.738	17.250	0.423	2.054	0.727	16.750	0.415	1.850	0.666
	SD	690.938	0.252	401.546	0.125	3.862	0.032	0.178	0.028	2.872	0.034	0.256	0.137
1959	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	1129	0.783	738	0.479	12	0.356	1.577	0.536	9	0.190	1.466	0.611
	Max	3350	0.802	2024	0.610	28	0.484	2.655	0.797	22	0.463	2.183	0.754
	Mean	2396.500	0.792	1650.250	0.548	20.000	0.410	2.058	0.696	14.250	0.300	1.765	0.680
	SD	954.602	0.010	612.570	0.056	6.583	0.064	0.460	0.113	5.737	0.115	0.304	0.063
1996	N	4	4	4	4	4	4	4	4	4	4	4	4
	Min	4983	1.170	4653	0.384	30	0.307	2.109	0.620	19	0.185	1.729	0.559
	Max	14163	1.244	10323	0.613	44	0.565	2.725	0.762	22	0.269	2.081	0.698
	Mean	8696.000	1.202	6963.250	0.539	37.500	0.424	2.482	0.688	21.000	0.237	1.918	0.631
	SD	4135.607	0.032	2459.790	0.105	7.550	0.112	0.273	0.065	1.414	0.041	0.176	0.070

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14 APPENDIX 6: TUKEY STUDENTIZED *POST HOC* ANALYSES ON THE ANOVA AND ANCOVA ANALYSES OF THE VEGETATION INDICES CALCULATED

The coloured cells show the level of the test significance: yellow: α=0.05, and orange: α = 0.10. LS Mean is the least squares mean, SE is the standard error, and N is the number of samples.

Table 14-1: Tukey *post hoc* analyses for the ANOVA analyses testing for differences between the replicates in 1954.

Single:Multi stem	Fayi	Kambeni	Numbi	Shabeni	LS Mean	SE	N
Fayi	1.000				0.652	0.064	12
Kambeni	0.035	1.000			0.398	0.064	12
Numbi	0.982	0.083	1.000		0.618	0.064	12
Shabeni	0.309	0.710	0.520	1.000	0.494	0.064	12

Species diversity	Fayi	Kambeni	Numbi	Shabeni	Mean	SE	N
Fayi	1.000				1.927	0.111	12
Kambeni	0.936	1.000			1.835	0.111	12
Numbi	0.117	0.031	1.000		2.287	0.111	12
Shabeni	0.623	0.288	0.707	1.000	2.118	0.111	12

Species evenness	Fayi	Kambeni	Numbi	Shabeni	Mean	SE	N
Fayi	1.000				0.665	0.026	12
Kambeni	0.990	1.000			0.653	0.026	12
Numbi	0.035	0.016	1.000		0.769	0.026	12
Shabeni	0.589	0.405	0.415	1.000	0.711	0.026	12

Structural diversity	Fayi	Kambeni	Numbi	Shabeni	Mean	SE	N
Fayi	1.000				1.826	0.055	12
Kambeni	0.823	1.000			1.759	0.055	12
Numbi	0.212	0.683	1.000		1.672	0.055	12
Shabeni	0.115	0.486	0.989	1.000	1.647	0.055	12

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Table 14-2: Tukey *post hoc* analyses for the ANOVA analyses testing for differences between the replicates in 1996.

Mean height (m)	Fayi	Kambeni	Numbi	Shabeni	Mean	SE	N
Fayi	1.000				1.084	0.054	12
Kambeni	0.984	1.000			1.111	0.054	12
Numbi	0.181	0.087	1.000		0.925	0.054	12
Shabeni	0.957	0.821	0.414	1.000	1.045	0.054	12

Tree equivalents (per Ha)	Fayi	Kambeni	Numbi	Shabeni	Mean	SE	N
Fayi	1.000				4766.167	482.537	12
Kambeni	0.832	1.000			5343.667	482.537	12
Numbi	0.484	0.118	1.000		3785.583	482.537	12
Shabeni	0.133	0.018	0.860	1.000	3248.167	482.537	12

Species Richness	Fayi	Kambeni	Numbi	Shabeni	Mean	SE	N
Fayi	1.000				0.346	0.023	12
Kambeni	0.897	1.000			0.369	0.023	12
Numbi	0.087	0.324	1.000		0.425	0.023	12
Shabeni	0.021	0.107	0.930	1.000	0.444	0.023	12

Species diversity	Fayi	Kambeni	Numbi	Shabeni	Mean	SE	N
Fayi	1.000				1.957	0.084	12
Kambeni	1.000	1.000			1.946	0.084	12
Numbi	0.005	0.004	1.000		2.38	0.084	12
Shabeni	0.073	0.058	0.725	1.000	2.256	0.084	12

Species evenness	Fayi	Kambeni	Numbi	Shabeni	Mean	SE	N
Fayi	1.000				0.591	0.019	12
Kambeni	0.982	1.000			0.581	0.019	12
Numbi	0.003	0.001	1.000		0.693	0.019	12
Shabeni	0.036	0.014	0.778	1.000	0.667	0.019	12

Number of structural groups	Fayi	Kambeni	Numbi	Shabeni	Mean	SE	N
Fayi	1.000				20.25	0.828	12
Kambeni	0.409	1.000			18.417	0.828	12
Numbi	0.064	0.753	1.000		17.25	0.828	12
Shabeni	0.011	0.332	0.892	1.000	16.417	0.828	12

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Table 14-3: Tukey *post hoc* analyses for the ANCOVA analyses testing for differences between the replicates in 1996 using the baseline data (1954) as covariates.

Mean height (m)	Fayi	Kambeni	Numbi	Shabeni	Mean	SE	N
Fayi	1.000				1.082	0.055	12
Kambeni	0.979	1.000			1.113	0.055	12
Numbi	0.184	0.091	1.000		0.922	0.056	12
Shabeni	0.968	0.825	0.408	1.000	1.046	0.055	12

Tree equivalents (per Ha)	Fayi	Kambeni	Numbi	Shabeni	Mean	SE	N
Fayi	1.000				4624.197	491.428	12
Kambeni	0.692	1.000			5384.931	480.008	12
Numbi	0.696	0.127	1.000		3862.051	482.596	12
Shabeni	0.219	0.016	0.821	1.000	3272.404	479.309	12

Species Richness	Fayi	Kambeni	Numbi	Shabeni	Mean	SE	N
Fayi	1.000				0.352	0.023	12
Kambeni	0.907	1.000			0.373	0.023	12
Numbi	0.197	0.522	1.000		0.418	0.023	12
Shabeni	0.040	0.166	0.887	1.000	0.441	0.023	12

Species Richness	Fayi	Kambeni	Numbi	Shabeni	Mean	SE	N
Fayi	1.000				0.352	0.023	12
Kambeni	0.907	1.000			0.373	0.023	12
Numbi	0.197	0.522	1.000		0.418	0.023	12
Shabeni	0.040	0.166	0.887	1.000	0.441	0.023	12

Species diversity	Fayi	Kambeni	Numbi	Shabeni	Mean	SE	N
Fayi	1.000				1.986	0.081	12
Kambeni	1.000	1.000			1.998	0.083	12
Numbi	0.041	0.062	1.000		2.317	0.084	12
Shabeni	0.149	0.195	0.894	1.000	2.236	0.081	12

Species evenness	Fayi	Kambeni	Numbi	Shabeni	Mean	SE	N
Fayi	1.000				0.598	0.019	12
Kambeni	0.991	1.000			0.591	0.019	12
Numbi	0.039	0.023	1.000		0.678	0.020	12
Shabeni	0.079	0.044	0.960	1.000	0.664	0.019	12

Number of structural groups	Fayi	Kambeni	Numbi	Shabeni	Mean	SE	N
Fayi	1.000				19.761	0.814	12
Kambeni	0.688	1.000			18.501	0.789	12
Numbi	0.187	0.763	1.000		17.413	0.791	12
Shabeni	0.048	0.361	0.905	1.000	16.658	0.794	12

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Table 14-4: Tukey *post hoc* analyses for the ANOVA analyses testing for differences between plots to be burnt at different frequencies in 1954 using the No-August-Annual data grouping.

Single-stem to Multi-stem	None	Biennial	Triennial	Mean	SE	N
None	1.000			0.738	0.082	4
Biennial	0.773	1.000		0.677	0.036	20
Triennial	0.001	0.001	1.000	0.332	0.036	20

Species richness	None	Biennial	Triennial	Mean	SE	N
None	1.000			0.423	0.056	4
Biennial	0.833	1.000		0.388	0.025	20
Triennial	0.572	0.023	1.000	0.486	0.025	20

Structural richness	None	Biennial	Triennial	Mean	SE	N
None	1.000			0.415	0.032	4
Biennial	0.129	1.000		0.346	0.014	20
Triennial	0.039	0.608	1.000	0.327	0.014	20

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Table 14-5: Tukey *post hoc* analyses for the ANOVA analyses testing for differences between plots burnt at different frequencies between 1954 and 1996 using the No-August-Annual data grouping.

Density	None	Biennial	Triennial	Mean	SE	N
None	1.000			8696.000	1129.841	4
Biennial	0.104	1.000		6104.450	505.280	20
Triennial	0.028	0.569	1.000	5375.950	505.280	20

Tree equivalents	None	Biennial	Triennial	Mean	SE	N
None	1.000			6963.250	837.943	4
Biennial	0.009	1.000		4109.400	374.740	20
Triennial	0.011	0.992	1.000	4173.800	374.740	20

Single-stem to Multi-stem	None	Biennial	Triennial	Mean	SE	N
None	1.000			0.539	0.051	4
Biennial	0.001	1.000		0.303	0.023	20
Triennial	0.003	0.449	1.000	0.342	0.023	20

Number of species	None	Biennial	Triennial	Mean	SE	N
None	1.000			37.500	3.114	4
Biennial	0.035	1.000		28.700	1.393	20
Triennial	0.059	0.923	1.000	29.450	1.393	20

Structural diversity	None	Biennial	Triennial	Mean	SE	N
None	1.000			1.918	0.076	4
Biennial	0.001	1.000		1.540	0.034	20
Triennial	0.005	0.098	1.000	1.642	0.034	20

Structural evenness	None	Biennial	Triennial	Mean	SE	N
None	1.000			0.631	0.024	4
Biennial	0.003	1.000		0.539	0.011	20
Triennial	0.080	0.088	1.000	0.572	0.011	20

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Table 14-6: Tukey *post hoc* analyses for the ANCOVA analyses testing for differences between plots burnt at different frequencies between 1954 and 1996 using the baseline data (1954) as covariates. The No-August-Annual data grouping was used in these analyses.

Density	None	Biennial	Triennial	Mean	SE	N
None	1.000			8988.070	1094.947	4
Biennial	0.044	1.000		5991.168	488.688	20
Triennial	0.013	0.699	1.000	5430.818	486.386	20

Tree equivalents	None	Biennial	Triennial	Mean	SE	N
None	1.000			7158.578	804.832	4
Biennial	0.003	1.000		4060.769	358.459	20
Triennial	0.005	0.968	1.000	4183.365	357.821	20

Single-stem to Multi-stem	None	Biennial	Triennial	Mean	SE	N
None	1.000			0.527	0.055	4
Biennial	0.001	1.000		0.295	0.027	20
Triennial	0.041	0.441	1.000	0.353	0.030	20

Number of species	None	Biennial	Triennial	Mean	SE	N
None	1.000			38.287	2.937	4
Biennial	0.022	1.000		29.379	1.333	20
Triennial	0.014	0.918	1.000	28.613	1.346	20

Species diversity	None	Biennial	Triennial	Mean	SE	N
None	1.000			2.481	0.150	4
Biennial	0.087	1.000		2.123	0.067	20
Triennial	0.052	0.917	1.000	2.085	0.067	20

Structural diversity	None	Biennial	Triennial	Mean	SE	N
None	1.000			1.893	0.077	4
Biennial	0.001	1.000		1.543	0.034	20
Triennial	0.014	0.094	1.000	1.644	0.034	20

Structural evenness	None	Biennial	Triennial	Mean	SE	N
None	1.000			0.631	0.025	4
Biennial	0.005	1.000		0.539	0.011	20
Triennial	0.086	0.104	1.000	0.572	0.011	20

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Table 14-7: Tukey *post hoc* analyses for the ANOVA analyses testing for differences between plots to be burnt at different frequencies in 1954 using the August-Control data grouping.

Single-stem to Multi-stem	None	Annual	Biennial	Triennial	Mean	SE	N
None	1.000				0.738	0.074	4
Annual	0.992	1.000			0.708	0.074	4
Biennial	0.922	0.985	1.000		0.672	0.074	4
Triennial	0.037	0.061	0.108	1.000	0.408	0.074	4

Number of structure groups	None	Annual	Biennial	Triennial	Mean	SE	N
None	1.000				16.750	1.350	4
Annual	0.860	1.000			18.250	1.350	4
Biennial	0.999	0.797	1.000		16.500	1.350	4
Triennial	0.073	0.019	0.091	1.000	11.500	1.350	4

Structural richness	None	Annual	Biennial	Triennial	Mean	SE	N
None	1.000				0.415	0.021	4
Annual	0.619	1.000			0.378	0.021	4
Biennial	0.107	0.588	1.000		0.340	0.021	4
Triennial	0.001	0.012	0.107	1.000	0.265	0.021	4

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Table 14-8: Tukey *post hoc* analyses for the ANOVA analyses testing for differences between plots burnt at different frequencies between 1954 and 1996 using the August-Control data grouping.

Mean height (m)	None	Annual	Biennial	Triennial	Mean	SE	N
None	1.000				1.202	0.076	4
Annual	0.035	1.000			0.859	0.076	4
Biennial	0.918	0.103	1.000		1.133	0.076	4
Triennial	0.783	0.168	0.990	1.000	1.100	0.076	4

Tree equivalents	None	Annual	Biennial	Triennial	Mean	SE	N
None	1.000				6963.250	1001.474	4
Annual	0.071	1.000			3051.500	1001.474	4
Biennial	0.234	0.879	1.000		4100.000	1001.474	4
Triennial	0.420	0.654	0.972	1.000	4713.500	1001.474	4

Single-stem to Multi-stem	None	Annual	Biennial	Triennial	Mean	SE	N
None	1.000				0.539	0.048	4
Annual	0.001	1.000			0.126	0.048	4
Biennial	0.001	0.975	1.000		0.155	0.048	4
Triennial	0.005	0.366	0.587	1.000	0.243	0.048	4

Number of species	None	Annual	Biennial	Triennial	Mean	SE	N
None	1.000				37.500	2.659	4
Annual	0.085	1.000			27.500	2.659	4
Biennial	0.048	0.987	1.000		26.250	2.659	4
Triennial	0.048	0.987	1.000	1.000	26.250	2.659	4

Species diversity	None	Annual	Biennial	Triennial	Mean	SE	N
None	1.000				2.482	0.155	4
Annual	0.339	1.000			2.097	0.155	4
Biennial	0.080	0.785	1.000		1.892	0.155	4
Triennial	0.096	0.840	0.999	1.000	1.916	0.155	4

Structural diversity	None	Annual	Biennial	Triennial	Mean	SE	N
None	1.000				1.918	0.092	4
Annual	<0.001	1.000			1.162	0.092	4
Biennial	0.014	0.198	1.000		1.440	0.092	4
Triennial	0.065	0.048	0.822	1.000	1.552	0.092	4

Structural evenness	None	Annual	Biennial	Triennial	Mean	SE	N
None	1.000				0.631	0.030	4
Annual	0.001	1.000			0.409	0.030	4
Biennial	0.056	0.129	1.000		0.510	0.030	4
Triennial	0.326	0.019	0.686	1.000	0.557	0.030	4

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Table 14-9: Tukey *post hoc* analyses for the ANCOVA analyses testing for differences between plots burnt at different frequencies between 1954 and 1996 using the baseline data (1954) as covariates. The August-Control data grouping was used in these analyses.

Mean height (m)	None	Annual	Biennial	Triennial	Mean	SE	N
None	1.000				1.192	0.082	4
Annual	0.048	1.000			0.852	0.080	4
Biennial	0.960	0.113	1.000		1.136	0.079	4
Triennial	0.922	0.183	0.998	1.000	1.115	0.084	4

Tree equivalents	None	Annual	Biennial	Triennial	Mean	SE	N
None	1.000				7313.455	1032.018	4
Annual	0.048	1.000			2742.675	1022.199	4
Biennial	0.153	0.842	1.000		3896.534	1002.484	4
Triennial	0.353	0.487	0.901	1.000	4875.585	996.889	4

Single-stem to Multi-stem	None	Annual	Biennial	Triennial	Mean	SE	N
None	1.000				0.529	0.054	4
Annual	0.001	1.000			0.119	0.052	4
Biennial	0.001	0.970	1.000		0.151	0.051	4
Triennial	0.073	0.435	0.591	1.000	0.263	0.066	4

Number of species	None	Annual	Biennial	Triennial	Mean	SE	N
None	1.000				37.419	2.674	4
Annual	0.084	1.000			27.225	2.689	4
Biennial	0.060	0.997	1.000		26.428	2.680	4
Triennial	0.060	0.997	1.000	1.000	26.428	2.680	4

Species diversity	None	Annual	Biennial	Triennial	Mean	SE	N
None	1.000				2.434	0.139	4
Annual	0.334	1.000			2.087	0.137	4
Biennial	0.135	0.899	1.000		1.951	0.140	4
Triennial	0.091	0.815	0.998	1.000	1.916	0.137	4

Number of structure groups	None	Annual	Biennial	Triennial	Mean	SE	N
None	1.000				20.423	1.180	4
Annual	0.059	1.000			15.557	1.309	4
Biennial	0.181	0.876	1.000		16.817	1.169	4
Triennial	0.893	0.493	0.728	1.000	18.953	1.559	4

Structural diversity	None	Annual	Biennial	Triennial	Mean	SE	N
None	1.000				1.904	0.092	4
Annual	0.001	1.000			1.136	0.094	4
Biennial	0.019	0.152	1.000		1.441	0.091	4
Triennial	0.167	0.037	0.679	1.000	1.592	0.098	4

Structural evenness	None	Annual	Biennial	Triennial	Mean	SE	N
None	1.000				0.631	0.031	4
Annual	0.002	1.000			0.410	0.031	4
Biennial	0.078	0.147	1.000		0.512	0.031	4
Triennial	0.336	0.033	0.782	1.000	0.554	0.031	4

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Table 14-10: Tukey *post hoc* analyses for the ANOVA analyses testing for differences between plots to be burnt at different times of the year in 1954 using the No-August-Annual data grouping.

Species richness	Apr	Aug	Cont	Dec	Feb	Oct	Mean	SE	N
Apr	1.000						0.472	0.04	8
Aug	0.230	1.000					0.344	0.04	8
Cont	0.980	0.856	1.000				0.423	0.056	4
Dec	0.994	0.521	1.000	1.000			0.441	0.04	8
Feb	0.885	0.838	1.000	0.994	1.000		0.411	0.04	8
Oct	0.969	0.044	0.759	0.769	0.438	1.000	0.516	0.04	8

Structural richness	Apr	Aug	Cont	Dec	Feb	Oct	Mean	SE	N
Apr	1.000						0.330	0.021	8
Aug	0.937	1.000					0.303	0.021	8
Cont	0.204	0.039	1.000				0.415	0.030	4
Dec	1.000	0.984	0.135	1.000			0.322	0.021	8
Feb	1.000	0.864	0.275	0.997	1.000		0.336	0.021	8
Oct	0.328	0.051	0.986	0.210	0.444	1.000	0.391	0.021	8

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Table 14-11: Tukey *post hoc* analyses for the ANOVA analyses testing for differences between plots burnt at different times of the year between 1954 and 1996 using the No-August-Annual data grouping.

Mean height (m)	Apr	Aug	Cont	Dec	Feb	Oct	Mean	SE	N
Apr	1.000						0.978	0.062	8
Aug	0.615	1.000					1.117	0.062	8
Cont	0.315	0.967	1.000				1.202	0.087	4
Dec	0.945	0.982	0.752	1.000			1.057	0.062	8
Feb	0.962	0.181	0.087	0.530	1.000		0.907	0.062	8
Oct	0.338	0.997	0.998	0.858	0.068	1.000	1.157	0.062	8

Tree equivalents	Apr	Aug	Cont	Dec	Feb	Oct	Mean	SE	N
Apr	1.000						4249.25	611.684	8
Aug	1.000	1.000					4406.75	611.684	8
Cont	0.132	0.177	1.000				6963.25	865.052	4
Dec	0.998	0.989	0.060	1.000			3868.25	611.684	8
Feb	1.000	1.000	0.118	0.999	1.000		4191.125	611.684	8
Oct	1.000	0.997	0.079	1.000	1.000	1.000	3992.625	611.684	8

Single-stem to Multi-stem	Apr	Aug	Cont	Dec	Feb	Oct	Mean	SE	N
Apr	1.000						0.364	0.028	8
Aug	0.002	1.000					0.199	0.028	8
Cont	0.011	0.001	1.000				0.539	0.040	4
Dec	0.998	0.001	0.026	1.000			0.380	0.028	8
Feb	0.996	0.001	0.031	1.000	1.000		0.383	0.028	8
Oct	0.414	0.236	0.001	0.213	0.185	1.000	0.288	0.028	8

Number of species	Apr	Aug	Cont	Dec	Feb	Oct	Mean	SE	N
Apr	1.000						29.375	2.097	8
Aug	0.896	1.000					26.25	2.097	8
Cont	0.245	0.040	1.000				37.5	2.965	4
Dec	0.911	0.326	0.720	1.000			32.375	2.097	8
Feb	0.988	0.549	0.527	0.999	1.000		31.25	2.097	8
Oct	0.880	1.000	0.036	0.305	0.522	1.000	26.125	2.097	8

Species diversity	Apr	Aug	Cont	Dec	Feb	Oct	Mean	SE	N
Apr	1.000						1.991	0.114	8
Aug	0.994	1.000					1.904	0.114	8
Cont	0.157	0.061	1.000				2.482	0.162	4
Dec	0.743	0.411	0.753	1.000			2.213	0.114	8
Feb	0.521	0.232	0.893	0.999	1.000		2.271	0.114	8
Oct	0.943	0.702	0.516	0.997	0.961	1.000	2.137	0.114	8

Structural diversity	Apr	Aug	Cont	Dec	Feb	Oct	Mean	SE	N
Apr	1.000						1.615	0.055	8
Aug	0.647	1.000					1.496	0.055	8
Cont	0.032	0.001	1.000				1.918	0.078	4
Dec	0.999	0.413	0.066	1.000			1.644	0.055	8
Feb	0.970	0.973	0.006	0.856	1.000		1.555	0.055	8
Oct	0.999	0.406	0.068	1.000	0.850	1.000	1.645	0.055	8

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Structural evenness	Apr	Aug	Cont	Dec	Feb	Oct	Mean	SE	N
Apr	1.000						0.563	0.017	8
Aug	0.805	1.000					0.533	0.017	8
Cont	0.197	0.019	1.000				0.631	0.024	4
Dec	1.000	0.675	0.275	1.000			0.568	0.017	8
Feb	0.531	0.997	0.007	0.393	1.000		0.522	0.017	8
Oct	0.874	0.193	0.696	0.948	0.075	1.000	0.589	0.017	8

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Table 14-12: Tukey *post hoc* analyses for the ANCOVA analyses testing for differences between plots burnt at different times of the year between 1954 and 1996 using the baseline data (1954) as covariates. The No-August-Annual data grouping was used in these analyses.

Mean height (m)	Apr	Aug	Cont	Dec	Feb	Oct	Mean	SE	N
Apr	1.000						0.980	0.062	8
Aug	0.508	1.000					1.135	0.064	8
Cont	0.349	0.993	1.000				1.197	0.088	4
Dec	0.953	0.944	0.770	1.000			1.055	0.062	8
Feb	0.918	0.117	0.073	0.449	1.000		0.892	0.063	8
Oct	0.347	1.000	0.999	0.850	0.051	1.000	1.157	0.062	8

Tree equivalents	Apr	Aug	Cont	Dec	Feb	Oct	Mean	SE	N
Apr	1.000						4253.443	585.254	8
Aug	1.000	1.000					4344.073	585.995	8
Cont	0.070	0.087	1.000				7161.710	832.929	4
Dec	0.998	0.995	0.032	1.000			3917.059	585.702	8
Feb	0.999	0.996	0.038	1.000	1.000		3928.375	598.186	8
Oct	1.000	1.000	0.056	1.000	1.000	1.000	4165.820	590.906	8

Single-stem to Multi-stem	Apr	Aug	Cont	Dec	Feb	Oct	Mean	SE	N
Apr	1.000						0.364	0.028	8
Aug	0.003	1.000					0.199	0.028	8
Cont	0.012	0.001	1.000				0.543	0.042	4
Dec	0.998	0.001	0.028	1.000			0.381	0.028	8
Feb	0.998	0.001	0.036	1.000	1.000		0.381	0.029	8
Oct	0.410	0.272	< 0.001	0.210	0.198	1.000	0.287	0.029	8

Number of species	Apr	Aug	Cont	Dec	Feb	Oct	Mean	SE	N
Apr	1.000						28.569	1.947	8
Aug	0.999	1.000					27.508	1.977	8
Cont	0.067	0.029	1.000				38.311	2.739	4
Dec	0.738	0.507	0.490	1.000			32.350	1.926	8
Feb	0.905	0.720	0.325	0.999	1.000		31.392	1.927	8
Oct	0.807	0.960	0.005	0.117	0.233	1.000	25.151	1.957	8

Species diversity	Apr	Aug	Cont	Dec	Feb	Oct	Mean	SE	N
Apr	1.000						1.937	0.097	8
Aug	0.997	1.000					2.004	0.099	8
Cont	0.027	0.075	1.000				2.481	0.136	4
Dec	0.256	0.523	0.707	1.000			2.242	0.096	8
Feb	0.088	0.223	0.923	0.993	1.000		2.318	0.097	8
Oct	0.991	1.000	0.092	0.612	0.304	1.000	2.018	0.101	8

Number of structure groups	Apr	Aug	Cont	Dec	Feb	Oct	Mean	SE	N
Apr	1.000						18.061	0.954	8
Aug	0.995	1.000					17.362	0.964	8
Cont	0.810	0.576	1.000				20.148	1.371	4
Dec	0.991	0.873	0.973	1.000			18.862	0.964	8
Feb	0.852	0.562	1.000	0.993	1.000		19.628	0.955	8
Oct	0.662	0.922	0.151	0.326	0.106	1.000	16.013	0.964	8

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Structural diversity	Apr	Aug	Cont	Dec	Feb	Oct	Mean	SE	N
Apr	1.000						1.601	0.054	8
Aug	0.710	1.000					1.492	0.054	8
Cont	0.044	0.002	1.000				1.887	0.078	4
Dec	0.951	0.227	0.269	1.000			1.670	0.056	8
Feb	0.998	0.922	0.023	0.754	1.000		1.567	0.054	8
Oct	0.996	0.394	0.117	0.999	0.931	1.000	1.640	0.054	8

Structural evenness	Apr	Aug	Cont	Dec	Feb	Oct	Mean	SE	N
Apr	1.000						0.561	0.017	8
Aug	0.797	1.000					0.531	0.017	8
Cont	0.208	0.020	1.000				0.629	0.024	4
Dec	0.999	0.597	0.380	1.000			0.571	0.017	8
Feb	0.644	1.000	0.012	0.385	1.000		0.524	0.017	8
Oct	0.837	0.169	0.764	0.964	0.086	1.000	0.590	0.017	8

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Table 14-13: Tukey post hoc analyses for the ANOVA analyses testing for differences between plots to be burnt with different fire treatments in 1954.

Single-stem to Multi-stem	Apr2	Apr3	Aug1	Aug2	Aug3	Con0	Dec2	Dec3	Feb2	Feb3	Oct2	Oct3	Mean	SE	N
Apr2	1.000												0.705	0.084	4
Apr3	0.127	1.000											0.339	0.084	4
Aug1	1.000	0.120	1.000										0.708	0.084	4
Aug2	1.000	0.221	1.000	1.000									0.672	0.084	4
Aug3	0.371	1.000	0.355	0.543	1.000								0.408	0.084	4
Con0	1.000	0.068	1.000	1.000	0.231	1.000							0.738	0.084	4
Dec2	1.000	0.033	1.000	0.999	0.127	1.000	1.000						0.774	0.084	4
Dec3	0.101	1.000	0.095	0.181	1.000	0.053	0.025	1.000					0.327	0.084	4
Feb2	0.999	0.549	0.999	1.000	0.883	0.990	0.946	0.481	1.000				0.602	0.084	4
Feb3	0.049	1.000	0.046	0.093	0.997	0.024	0.011	1.000	0.297	1.000			0.289	0.084	4
Oct2	1.000	0.401	1.000	1.000	0.768	0.999	0.985	0.341	1.000	0.194	1.000		0.630	0.084	4
Oct3	0.057	1.000	0.053	0.107	0.998	0.029	0.013	1.000	0.330	1.000	0.219	1.000	0.296	0.084	4

Species richness	Apr2	Apr3	Aug1	Aug2	Aug3	Con0	Dec2	Dec3	Feb2	Feb3	Oct2	Oct3	Mean	SE	N
Apr2	1.000												0.366	0.050	4
Apr3	0.143	1.000											0.578	0.050	4
Aug1	1.000	0.198	1.000										0.377	0.050	4
Aug2	1.000	0.043	1.000	1.000									0.329	0.050	4
Aug3	1.000	0.115	1.000	1.000	1.000								0.359	0.050	4
Con0	0.999	0.556	1.000	0.966	0.998	1.000							0.423	0.050	4
Dec2	1.000	0.481	1.000	0.982	1.000	1.000	1.000						0.415	0.050	4
Dec3	0.945	0.906	0.976	0.704	0.916	1.000	1.000	1.000					0.467	0.050	4
Feb2	1.000	0.355	1.000	0.996	1.000	1.000	1.000	0.998	1.000				0.401	0.050	4
Feb3	1.000	0.536	1.000	0.971	0.999	1.000	1.000	1.000	1.000	1.000			0.421	0.050	4
Oct2	0.999	0.597	1.000	0.954	0.997	1.000	1.000	1.000	1.000	1.000	1.000		0.428	0.050	4
Oct3	0.062	1.000	0.091	0.016	0.049	0.326	0.268	0.720	0.182	0.310	0.361	1.000	0.605	0.050	4

Structural richness	Apr2	Apr3	Aug1	Aug2	Aug3	Con0	Dec2	Dec3	Feb2	Feb3	Oct2	Oct3	Mean	SE	N
Apr2	1.000												0.352	0.027	4
Apr3	0.992	1.000											0.308	0.027	4
Aug1	1.000	0.808	1.000										0.378	0.027	4
Aug2	1.000	0.999	0.997	1.000									0.340	0.027	4
Aug3	0.540	0.992	0.178	0.734	1.000								0.265	0.027	4
Con0	0.887	0.247	0.998	0.734	0.020	1.000							0.415	0.027	4
Dec2	1.000	0.999	0.997	1.000	0.724	0.743	1.000						0.341	0.027	4
Dec3	0.983	1.000	0.745	0.998	0.997	0.200	0.998	1.000					0.304	0.027	4
Feb2	1.000	0.999	0.998	1.000	0.714	0.753	1.000	0.998	1.000				0.341	0.027	4
Feb3	1.000	1.000	0.984	1.000	0.857	0.586	1.000	1.000	1.000	1.000			0.331	0.027	4
Oct2	1.000	0.981	1.000	1.000	0.458	0.930	1.000	0.965	1.000	1.000	1.000		0.357	0.027	4
Oct3	0.749	0.144	0.984	0.556	0.009	1.000	0.566	0.114	0.578	0.409	0.819	1.000	0.426	0.027	4

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Table 14-14: Tukey post hoc analyses for the ANOVA analyses testing for differences between plots to be burnt with different fire treatments between 1954 and 1996.

Mean height (m)	Apr2	Apr3	Aug1	Aug2	Aug3	Con0	Dec2	Dec3	Feb2	Feb3	Oct2	Oct3	Mean	SE	N
Apr2	1.000												1.041	0.084	4
Apr3	0.994	1.000											0.915	0.084	4
Aug1	0.918	1.000	1.000										0.859	0.084	4
Aug2	1.000	0.785	0.483	1.000									1.133	0.084	4
Aug3	1.000	0.911	0.664	1.000	1.000								1.100	0.084	4
Con0	0.964	0.418	0.184	1.000	0.999	1.000							1.202	0.084	4
Dec2	0.994	1.000	1.000	0.783	0.910	0.415	1.000						0.915	0.084	4
Dec3	0.970	0.436	0.195	1.000	0.999	1.000	0.434	1.000					1.199	0.084	4
Feb2	0.877	1.000	1.000	0.413	0.591	0.147	1.000	0.156	1.000				0.846	0.084	4
Feb3	1.000	1.000	0.998	0.956	0.991	0.700	1.000	0.719	0.996	1.000			0.967	0.084	4
Oct2	1.000	0.806	0.508	1.000	1.000	1.000	0.804	1.000	0.437	0.963	1.000		1.129	0.084	4
Oct3	0.984	0.505	0.239	1.000	1.000	1.000	0.503	1.000	0.194	0.783	1.000	1.000	1.186	0.084	4

Single-stem to Multi-stem	Apr2	Apr3	Aug1	Aug2	Aug3	Con0	Dec2	Dec3	Feb2	Feb3	Oct2	Oct3	Mean	SE	N
Apr2	1.000												0.371	0.038	4
Apr3	1.000	1.000											0.356	0.038	4
Aug1	0.003	0.007	1.000										0.126	0.038	4
Aug2	0.013	0.027	1.000	1.000									0.155	0.038	4
Aug3	0.443	0.622	0.589	0.885	1.000								0.243	0.038	4
Con0	0.122	0.066	0.001	0.001	0.001	1.000							0.539	0.038	4
Dec2	1.000	1.000	0.003	0.012	0.429	0.128	1.000						0.373	0.038	4
Dec3	1.000	1.000	0.001	0.006	0.275	0.224	1.000	1.000					0.388	0.038	4
Feb2	1.000	1.000	0.020	0.071	0.853	0.025	1.000	0.997	1.000				0.335	0.038	4
Feb3	0.992	0.959	0.001	0.001	0.050	0.698	0.993	1.000	0.816	1.000			0.431	0.038	4
Oct2	0.880	0.962	0.187	0.451	1.000	0.002	0.871	0.724	0.997	0.241	1.000		0.283	0.038	4
Oct3	0.949	0.989	0.121	0.326	0.998	0.003	0.943	0.841	1.000	0.348	1.000	1.000	0.294	0.038	4

Number of species	Apr2	Apr3	Aug1	Aug2	Aug3	Con0	Dec2	Dec3	Feb2	Feb3	Oct2	Oct3	Mean	SE	N
Apr2	1.000												24.500	2.792	4
Apr3	0.389	1.000											34.250	2.792	4
Aug1	1.000	0.852	1.000										27.500	2.792	4
Aug2	1.000	0.674	1.000	1.000									26.250	2.792	4
Aug3	1.000	0.674	1.000	1.000	1.000								26.250	2.792	4
Con0	0.080	0.999	0.353	0.203	0.203	1.000							37.500	2.792	4
Dec2	0.508	1.000	0.925	0.788	0.788	0.996	1.000						33.500	2.792	4
Dec3	0.852	1.000	0.998	0.978	0.978	0.904	1.000	1.000					31.250	2.792	4
Feb2	0.633	1.000	0.969	0.880	0.880	0.985	1.000	1.000	1.000				32.750	2.792	4
Feb3	0.969	0.990	1.000	0.999	0.999	0.714	0.998	1.000	1.000	1.000			29.750	2.792	4
Oct2	1.000	0.714	1.000	1.000	1.000	0.228	0.821	0.985	0.904	0.999	1.000		26.500	2.792	4
Oct3	1.000	0.591	1.000	1.000	1.000	0.158	0.714	0.957	0.821	0.996	1.000	1.000	25.750	2.792	4

Structural diversity	Apr2	Apr3	Aug1	Aug2	Aug3	Con0	Dec2	Dec3	Feb2	Feb3	Oct2	Oct3	Mean	SE	N
Apr2	1.000												1.621	0.076	4
Apr3	1.000	1.000											1.609	0.076	4
Aug1	0.007	0.009	1.000										1.162	0.076	4
Aug2	0.864	0.909	0.331	1.000									1.440	0.076	4
Aug3	1.000	1.000	0.037	0.995	1.000								1.552	0.076	4
Con0	0.242	0.195	0.001	0.004	0.063	1.000							1.918	0.076	4
Dec2	0.999	1.000	0.066	1.000	1.000	0.035	1.000						1.526	0.076	4
Dec3	0.972	0.950	0.001	0.152	0.721	0.946	0.563	1.000					1.762	0.076	4
Feb2	0.918	0.950	0.260	1.000	0.999	0.006	1.000	0.201	1.000				1.455	0.076	4
Feb3	1.000	1.000	0.003	0.695	0.998	0.403	0.986	0.997	0.779	1.000			1.654	0.076	4
Oct2	1.000	1.000	0.003	0.670	0.997	0.427	0.982	0.998	0.757	1.000	1.000		1.659	0.076	4
Oct3	1.000	1.000	0.005	0.817	1.000	0.287	0.997	0.984	0.882	1.000	1.000	1.000	1.632	0.076	4

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Structural evenness	Apr2	Apr3	Aug1	Aug2	Aug3	Con0	Dec2	Dec3	Feb2	Feb3	Oct2	Oct3	Mean	SE	N
Apr2	1.000												0.576	0.022	4
Apr3	1.000	1.000											0.550	0.022	4
Aug1	0.001	0.004	1.000										0.409	0.022	4
Aug2	0.637	0.977	0.103	1.000									0.510	0.022	4
Aug3	1.000	1.000	0.002	0.937	1.000								0.557	0.022	4
Con0	0.831	0.337	0.001	0.021	0.456	1.000							0.631	0.022	4
Dec2	0.980	1.000	0.013	0.999	1.000	0.147	1.000						0.536	0.022	4
Dec3	1.000	0.899	0.001	0.194	0.957	0.998	0.661	1.000					0.601	0.022	4
Feb2	0.220	0.692	0.398	1.000	0.560	0.003	0.916	0.039	1.000				0.487	0.022	4
Feb3	1.000	1.000	0.002	0.926	1.000	0.482	1.000	0.965	0.534	1.000			0.558	0.022	4
Oct2	1.000	0.994	0.001	0.468	0.999	0.932	0.927	1.000	0.131	0.999	1.000		0.584	0.022	4
Oct3	1.000	0.956	0.001	0.278	0.986	0.989	0.781	1.000	0.062	0.989	1.000	1.000	0.595	0.022	4

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Table 14-15: Tukey post hoc analyses for the ANCOVA analyses testing for differences between plots to be burnt with different fire treatments between 1954 and 1996 using the baseline data (1954) as covariates.

Mean height (m)	Apr2	Apr3	Aug1	Aug2	Aug3	Con0	Dec2	Dec3	Feb2	Feb3	Oct2	Oct3	Mean	SE	N
Apr2	1.000												1.033	0.085	4
Apr3	0.999	1.000											0.926	0.085	4
Aug1	0.942	1.000	1.000										0.858	0.084	4
Aug2	0.999	0.803	0.453	1.000									1.141	0.085	4
Aug3	1.000	0.891	0.597	1.000	1.000								1.119	0.088	4
Con0	0.958	0.521	0.203	1.000	1.000	1.000							1.198	0.084	4
Dec2	0.998	1.000	1.000	0.781	0.878	0.487	1.000						0.921	0.085	4
Dec3	0.971	0.582	0.236	1.000	1.000	1.000	0.544	1.000					1.190	0.085	4
Feb2	0.845	1.000	1.000	0.353	0.515	0.128	1.000	0.141	1.000				0.826	0.088	4
Feb3	1.000	1.000	0.999	0.941	0.979	0.722	1.000	0.768	0.989	1.000			0.966	0.084	4
Oct2	1.000	0.856	0.511	1.000	1.000	1.000	0.835	1.000	0.380	0.962	1.000		1.129	0.084	4
Oct3	0.978	0.589	0.249	1.000	1.000	1.000	0.557	1.000	0.167	0.788	1.000	1.000	1.185	0.084	4

Single-stem to Multi-stem	Apr2	Apr3	Aug1	Aug2	Aug3	Con0	Dec2	Dec3	Feb2	Feb3	Oct2	Oct3	Mean	SE	N
Apr2	1.000												0.361	0.04	4
Apr3	1.000	1.000											0.369	0.041	4
Aug1	0.003	0.010	1.000										0.116	0.040	4
Aug2	0.016	0.029	1.000	1.000									0.146	0.040	4
Aug3	0.768	0.583	0.497	0.802	1.000								0.251	0.040	4
Con0	0.138	0.356	0.001	0.001	0.003	1.000							0.526	0.041	4
Dec2	1.000	1.000	0.004	0.020	0.831	0.123	1.000						0.358	0.042	4
Dec3	1.000	1.000	0.002	0.008	0.247	0.690	1.000	1.000					0.401	0.042	4
Feb2	1.000	1.000	0.017	0.064	0.951	0.046	1.000	0.985	1.000				0.331	0.039	4
Feb3	0.962	0.948	0.001	0.001	0.043	0.982	0.964	0.999	0.717	1.000			0.447	0.043	4
Oct2	0.918	0.907	0.167	0.430	1.000	0.003	0.940	0.623	0.997	0.212	1.000		0.277	0.039	4
Oct3	0.999	0.993	0.126	0.288	0.995	0.063	1.000	0.861	1.000	0.350	1.000	1.000	0.309	0.043	4

Number of species	Apr2	Apr3	Aug1	Aug2	Aug3	Con0	Dec2	Dec3	Feb2	Feb3	Oct2	Oct3	Mean	SE	N
Apr2	1.000												25.209	2.613	4
Apr3	0.828	1.000											31.986	2.744	4
Aug1	1.000	0.994	1.000										27.902	2.603	4
Aug2	1.000	0.987	1.000	1.000									27.369	2.635	4
Aug3	1.000	0.987	1.000	1.000	1.000								27.369	2.635	4
Con0	0.045	0.892	0.222	0.168	0.168	1.000							38.209	2.613	4
Dec2	0.340	1.000	0.795	0.707	0.707	0.997	1.000						34.619	2.635	4
Dec3	0.977	1.000	1.000	1.000	1.000	0.570	0.984	1.000					30.011	2.643	4
Feb2	0.531	1.000	0.927	0.876	0.876	0.975	1.000	0.998	1.000				33.459	2.613	4
Feb3	0.993	1.000	1.000	1.000	1.000	0.418	0.945	1.000	0.990	1.000			29.229	2.606	4
Oct2	1.000	0.883	1.000	1.000	1.000	0.075	0.470	0.991	0.663	0.999	1.000		25.876	2.610	4
Oct3	1.000	0.676	0.999	1.000	1.000	0.034	0.283	0.932	0.441	0.976	1.000	1.000	24.511	2.643	4

Species diversity	Apr2	Apr3	Aug1	Aug2	Aug3	Con0	Dec2	Dec3	Feb2	Feb3	Oct2	Oct3	Mean	SE	N
Apr2	1.000												1.89	0.133	4
Apr3	1.000	1.000											1.971	0.138	4
Aug1	0.966	0.999	1.000										2.144	0.134	4
Aug2	1.000	1.000	1.000	1.000									2.033	0.137	4
Aug3	1.000	1.000	0.999	1.000	1.000								1.976	0.134	4
Con0	0.120	0.297	0.826	0.485	0.293	1.000							2.476	0.133	4
Dec2	0.967	0.999	1.000	1.000	0.999	0.823	1.000						2.143	0.133	4
Dec3	0.458	0.772	0.996	0.901	0.750	1.000	0.996	1.000					2.334	0.134	4
Feb2	0.203	0.464	0.929	0.640	0.435	1.000	0.929	1.000	1.000				2.427	0.134	4
Feb3	0.871	0.985	1.000	0.999	0.985	0.946	1.000	1.000	0.987	1.000			2.204	0.133	4
Oct2	0.984	1.000	1.000	1.000	1.000	0.767	1.000	0.992	0.898	1.000	1.000		2.121	0.135	4
Oct3	1.000	1.000	0.977	1.000	1.000	0.144	0.975	0.533	0.256	0.902	0.986	1.000	1.896	0.139	4

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Number of structure groups	Apr2	Apr3	Aug1	Aug2	Aug3	Con0	Dec2	Dec3	Feb2	Feb3	Oct2	Oct3	Mean	SE	N
Apr2	1.000												16.518	1.326	4
Apr3	0.813	1.000											19.953	1.347	4
Aug1	1.000	0.456	1.000										15.226	1.386	4
Aug2	1.000	0.813	1.000	1.000									16.518	1.326	4
Aug3	0.992	1.000	0.871	0.992	1.000								18.745	1.429	4
Con0	0.728	1.000	0.309	0.728	1.000	1.000							20.119	1.332	4
Dec2	0.994	1.000	0.868	0.994	1.000	0.999	1.000						18.555	1.340	4
Dec3	0.858	1.000	0.488	0.858	1.000	1.000	1.000	1.000					19.709	1.318	4
Feb2	0.629	1.000	0.269	0.629	0.999	1.000	0.996	1.000	1.000				20.459	1.318	4
Feb3	0.962	1.000	0.668	0.962	1.000	1.000	1.000	1.000	1.000	1.000			19.066	1.318	4
Oct2	1.000	0.737	1.000	1.000	0.981	0.627	0.985	0.785	0.536	0.923	1.000		16.220	1.338	4
Oct3	1.000	0.590	1.000	1.000	0.939	0.532	0.953	0.663	0.404	0.859	1.000	1.000	15.911	1.314	4

Structural diversity	Apr2	Apr3	Aug1	Aug2	Aug3	Con0	Dec2	Dec3	Feb2	Feb3	Oct2	Oct3	Mean	SE	N
Apr2	1.000												1.588	0.075	4
Apr3	1.000	1.000											1.618	0.074	4
Aug1	0.004	0.002	1.000										1.120	0.077	4
Aug2	0.898	0.770	0.190	1.000									1.422	0.074	4
Aug3	1.000	1.000	0.009	0.957	1.000								1.569	0.074	4
Con0	0.194	0.346	0.001	0.004	0.157	1.000							1.887	0.075	4
Dec2	1.000	1.000	0.015	0.965	1.000	0.191	1.000						1.568	0.077	4
Dec3	0.787	0.888	0.001	0.057	0.629	0.998	0.630	1.000					1.787	0.074	4
Feb2	0.998	0.979	0.077	1.000	1.000	0.031	1.000	0.188	1.000				1.486	0.075	4
Feb3	1.000	1.000	0.001	0.517	0.999	0.582	0.999	0.983	0.880	1.000			1.659	0.073	4
Oct2	1.000	1.000	0.001	0.444	0.997	0.677	0.997	0.993	0.816	1.000	1.000		1.672	0.074	4
Oct3	1.000	1.000	0.002	0.783	1.000	0.302	1.000	0.885	0.986	1.000	1.000	1.000	1.613	0.074	4

Structural evenness	Apr2	Apr3	Aug1	Aug2	Aug3	Con0	Dec2	Dec3	Feb2	Feb3	Oct2	Oct3	Mean	SE	N
Apr2	1.000												0.574	0.023	4
Apr3	1.000	1.000											0.549	0.023	4
Aug1	0.001	0.005	1.000										0.408	0.023	4
Aug2	0.681	0.982	0.104	1.000									0.510	0.023	4
Aug3	1.000	1.000	0.004	0.969	1.000								0.553	0.023	4
Con0	0.837	0.357	0.001	0.027	0.430	1.000							0.629	0.023	4
Dec2	0.994	1.000	0.012	0.999	1.000	0.227	1.000						0.539	0.023	4
Dec3	0.999	0.867	0.001	0.181	0.922	0.999	0.685	1.000					0.603	0.023	4
Feb2	0.292	0.765	0.369	1.000	0.721	0.005	0.907	0.040	1.000				0.489	0.023	4
Feb3	1.000	1.000	0.002	0.910	1.000	0.585	1.000	0.965	0.540	1.000			0.560	0.023	4
Oct2	1.000	0.986	0.001	0.420	0.995	0.978	0.919	1.000	0.123	0.999	1.000		0.588	0.023	4
Oct3	1.000	0.963	0.001	0.323	0.981	0.989	0.879	1.000	0.096	0.996	1.000	1.000	0.592	0.023	4

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Table 14-16: Tukey post hoc analyses for the ANOVA analyses testing for differences in the plots that were not burnt between 1954, 1959, and 1996.

Density	1954	1959	1996	LS Mean	SE	N
1954	1.000			1721.5	1241.367	4
1959	0.922	1.000		2396.5	1241.367	4
1996	0.008	0.015	1.000	8696	1241.367	4

Mean height (m)	1954	1959	1996	LS Mean	SE	N
1954	1.000			1.116	0.073	4
1959	0.030	1.000		0.792	0.073	4
1996	0.695	0.009	1	1.202	0.073	4

Tree equivalents	1954	1959	1996	LS Mean	SE	N
1954	1.000			1315.25	740.892	4
1959	0.946	1.000		1650.25	740.892	4
1996	0.001	0.002	1.000	6963.25	740.892	4

Single-stem to Multi-stem	1954	1959	1996	LS Mean	SE	N
1954	1.000			0.738	0.050	4
1959	0.057	1.000		0.548	0.050	4
1996	0.047	0.991	1.000	0.539	0.050	4

Number of species	1954	1959	1996	LS Mean	SE	N
1954	1.000			17.25	3.099	4
1959	0.809	1.000		20	3.099	4
1996	0.003	0.008	1.000	37.5	3.099	4

Number of structure groups	1954	1959	1996	LS Mean	SE	N
1954	1.000			16.750	1.897	4
1959	0.635	1.000		14.250	1.897	4
1996	0.301	0.077	1.000	21.000	1.897	4

Structural richness	1954	1959	1996	LS Mean	SE	N
1954	1.000			0.415	0.037	4
1959	0.122	1.000		0.300	0.037	4
1996	0.018	0.470	1.000	0.237	0.037	4

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15 APPENDIX 7: THE WEIGHTED EIGENVECTOR SAMPLE SCORES FROM THE FIRST FOUR ORDINATION AXES FROM CORRESPONDENCE ANALYSES (CA) ON THE 1954 AND 1996 SPECIES AND STRUCTURE DATA

Table 15-1: Weighted eigenvector plot scores from the CA on the 1954 species by plot data. The table also shows the plot weights and the effective number of species that occur on the plots (N2 species diversity of plots) (Hill 1973). The codes for the treatment plots are defined in Table 10-1 (p. 214).

Plot	Axis 1	Axis 2	Axis 3	Axis 4	Weight	N2
Fa01Aug2	-0.1072	-1.2281	-0.2465	0.0475	2381	4.12
Fa02Con0	0.2851	-1.1915	-0.6005	0.5331	1661	6.33
Fa03Dec2	0.3671	-0.8789	-0.1698	0.3240	2936	6.7
Fa04Oct2	-0.0378	-0.6832	0.3516	-0.0796	2262	6.83
Fa05Apr2	-0.0450	-1.0751	-0.2512	-0.1190	2348	4.05
Fa06Feb2	4.9733	0.8584	0.7310	-0.3985	3166	5.21
Fa07Aug1	-0.0686	-0.7166	-0.5224	-0.1908	2690	4.44
Fa08Dec3	-0.0378	-1.2246	-0.7809	-0.5237	1972	2.65
Fa09Aug3	-0.2486	-1.0310	-0.0914	-0.3771	1982	3.02
Fa10Oct3	0.0314	-0.9620	-0.1479	-0.4126	833	4.76
Fa11Feb3	0.0636	-1.0569	0.1325	-0.1783	3832	3.61
Fa12Apr3	-0.0748	-0.9736	-0.0859	-0.0991	2004	4.23
Ka01Con0	-0.2913	-0.6069	0.3114	-0.4479	830	4.45
Ka02Dec2	-0.2838	0.8324	-1.4618	-1.4272	990	5.97
Ka03Oct2	0.0013	-0.4721	-0.6241	-0.2462	2188	5.86
Ka04Feb2	-0.2778	-1.1725	-0.3348	-0.5786	1412	2.14
Ka05Aug2	-0.2641	-1.1528	-0.4847	-0.7233	1561	2.33
Ka06Apr2	-0.0680	-0.4859	-0.8095	-0.9366	1503	3.21
Ka07Aug1	-0.3293	-1.0109	-0.4849	-0.7089	2336	2.63
Ka08Feb3	-0.4973	0.0124	1.1770	-1.9109	1413	5.71
Ka09Oct3	-0.1056	-0.7307	1.2717	2.3530	1333	8.36
Ka10Dec3	-0.3341	-1.2215	0.0477	-0.4391	2931	2.53
Ka11Aug3	1.0715	-0.6209	0.5216	1.1477	3337	5.97
Ka12Apr3	0.0091	-0.1662	-0.4706	0.0712	2320	6.23
Nu01Oct2	-0.5211	0.9776	-0.4759	-0.1207	2141	4.39
Nu02Dec2	-0.7314	1.7140	-0.8810	0.0713	1658	6.17
Nu03Feb2	-0.4882	0.2881	-0.3855	-0.2170	401	4.94
Nu04Aug2	-0.8851	2.0524	1.9361	1.0904	2617	10.62
Nu05Apr2	-0.8131	1.5742	0.5785	-0.5449	2348	6.42
Nu06Aug1	-0.6431	1.3965	-0.7974	1.9265	2220	6.44
Nu07Con0	-0.4955	0.4234	0.1180	0.2242	1897	4.77
Nu08Dec3	-0.5785	1.2176	-0.0039	-0.2885	2177	8.04
Nu09Oct3	-0.3342	0.3769	1.2099	2.7472	2067	10.6
Nu10Feb3	-0.8600	0.1585	4.1738	-1.9268	2809	4.04
Nu11Apr3	0.0042	0.1300	0.5533	1.4063	1650	10.02
Nu12Aug3	-0.6112	1.7451	-0.1664	-0.8658	1880	6.58
Sh01Aug2	-0.4160	-0.9065	0.2358	-0.2870	3175	2.21
Sh02Apr2	0.2175	0.5864	-0.6783	0.9229	2822	6.7
Sh03Aug1	-0.1796	-0.2398	-0.1765	0.6965	2058	5.98
Sh04Feb2	-0.2071	0.0964	-0.3519	1.8871	4648	8.33
Sh05Oct2	0.1831	1.5084	-1.2568	-0.7298	2572	8.29
Sh06Dec2	-0.4341	1.5220	-1.5311	-1.6049	1069	3.78
Sh07Con0	-0.4025	0.8604	-0.9900	-0.7742	2498	5.77
Sh08Dec3	-0.1002	1.3617	-1.5654	-1.3654	2102	5.57
Sh09Apr3	1.7122	1.3015	-0.2430	-0.8270	1465	7.32
Sh10Aug3	-0.1718	-0.1287	-0.7071	-0.0745	895	3.54
Sh11Oct3	0.0859	0.0592	0.3722	-0.0609	1035	5.53
Sh12Feb3	-0.1736	-0.1020	0.8550	-0.5033	2109	5.48

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Table 15-2: Weighted eigenvector species scores from the CA on the 1954 species by plot data. The table shows the species weights and the effective number of occurrences of the species (N2 diversity of species) (Hill 1973). The codes for the species are defined in Table 9-1 (p. 210).

Species	Axis 1	Axis 2	Axis 3	Axis 4	Weight	N2
acac exuv	1.7120	1.3015	-0.2429	-0.8267	11	1
acac gerr	2.9036	0.6517	0.2836	-0.1073	2221	3.31
acac sieb	0.0092	-0.1662	-0.4702	0.0716	11	1
albi vers	-0.2146	0.3232	-0.4820	0.2557	132	8
anno sene	-0.4557	0.8841	0.2699	0.0340	2038	16.52
anti veno	-0.0354	-0.3582	-0.1083	0.3543	371	14.96
brid moll	-0.0473	1.1078	-1.4069	-1.1736	97	1.25
bauh galp	-0.5489	1.0123	0.9306	0.8099	108	2.79
cass tran	-0.0376	-0.6833	0.3517	-0.0795	11	1
catu spin	-0.1776	0.2962	0.8199	1.9223	216	2.2
chae aris	-0.1894	-0.0934	-0.2436	1.2106	174	2.95
cler spec	0.1828	1.5083	-1.2569	-0.7298	56	1
comb apic	-0.1947	0.5935	-0.4656	-0.0584	33	3
comb coll	-0.3639	0.7799	0.2418	0.5968	669	9.29
comb here	3.8226	0.9727	0.2102	-0.6178	97	1.54
comb moll	-0.1350	0.4047	-0.1066	0.6012	1409	9.27
comm moll	-0.4447	1.1937	-0.5123	-0.5159	44	2.67
dalb mela	-0.1400	-0.3783	-0.0932	-0.1720	284	9.5
dich cine	-0.0893	-0.3208	-0.1876	-0.1632	24229	36.65
dios lyci	0.1473	-0.2641	0.2813	1.1575	1093	7.63
dios mesp	0.2135	0.0857	0.3772	1.1886	530	5.54
domb rotu	-0.1535	0.1385	0.1166	0.4643	197	7.8
ehre obtu	0.3150	-0.4465	-0.0029	0.2118	555	10.94
eucl divi	0.2373	0.3648	0.2155	0.5186	294	10.38
eucl nata	0.0581	-0.2553	-0.1012	0.6179	800	13.52
ficu stuh	0.0316	-0.9623	-0.1480	-0.4127	11	1
flac indi	0.1766	-0.1647	0.6715	1.0663	120	5.82
grew flav	0.3370	-0.6524	-0.2050	0.3323	240	10.64
grew mont	-0.2803	0.4316	0.0312	-0.1157	482	15.66
lann disc	-0.5783	1.3835	0.9782	0.5190	87	2.94
lann edul	-0.2281	-0.1681	0.1974	-0.1996	238	4.28
lann schw	-0.4161	-0.9064	0.2355	-0.2873	32	1
lonc capa	-0.1442	0.8511	-0.4658	-0.3613	1561	10.92
mayt hete	0.1883	0.3967	-0.0365	0.0683	987	21.92
mayt sene	0.4508	-0.2365	-0.0099	0.0966	6357	17.73
mund seri	0.3732	-0.5694	-0.1995	-0.0307	1503	15.7
ochn nata	0.1499	-0.4601	-0.0731	0.7552	725	10
olea euro	-0.5787	1.2177	-0.0040	-0.2888	11	1
ormo tric	2.8321	0.2754	0.3595	-0.2276	758	2.93
ozor spha	0.7692	0.5999	0.3060	-0.6650	22	2
papi lion	-0.8079	1.6422	1.6473	0.8783	173	1.29
papp cape	0.2296	0.0744	0.7382	1.6195	75	2.59
pari cura	-0.5611	0.7773	1.3739	-0.0151	2107	8.03
pave schu	-0.1584	0.4504	-0.2422	0.6317	3358	10.89
pelt afri	0.3013	-0.4861	0.1129	0.1792	575	7.17
phyl reti	0.1493	-0.3673	-0.2045	0.4609	358	8.08
pili thon	-0.2126	-0.5012	0.2589	-0.3948	99	7.36
pseu hook	-0.3345	0.3767	1.2099	2.7472	43	1
pter ango	-0.5817	1.1073	0.1851	-0.4036	249	4.06
pter rotu	-0.1652	0.2534	0.8817	2.0769	22	2
rhus pyro	-0.1670	0.2560	0.2420	0.5945	328	15.62
rhus tran	0.2075	0.6652	0.2897	0.5297	185	4.53
scho brac	-0.3345	0.3767	1.2099	2.7472	32	1
scle birr	-0.0576	-0.0850	-0.1470	-0.2482	2792	32.89
secu viro	-0.2543	-0.3967	1.0647	0.3341	132	7.2
senn pete	-0.2270	0.8355	-0.4850	-0.4534	8123	20.92
stry mada	0.1159	-0.1574	-0.2268	0.2689	2563	19.16
stry spin	-0.0829	-0.8952	0.5878	1.3941	33	1.8
syzy cord	-0.4973	0.0126	1.1769	-1.9110	11	1
term seri	-0.1581	-0.2564	0.1643	-0.0277	26618	29.98
tric emet	-0.0576	-0.7337	0.6740	1.2827	98	2.82

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Species	Axis 1	Axis 2	Axis 3	Axis 4	Weight	N2
turr nilo	-0.5573	1.1428	-0.3403	0.8112	1725	6.07
unid enti	-0.5639	-0.0090	2.6903	-1.3702	173	2.38
vang infa	-0.0290	0.9855	1.1251	-0.4254	207	4.24
vern colo	-0.7667	0.1213	3.4031	-1.9226	420	1.62
xime caff	-0.0602	-0.4297	-0.1508	0.0019	587	15.26
zant cape	-0.0431	-0.3330	-0.4346	1.4359	33	1.8
zizi mucr	0.1487	-0.4807	-0.2724	-0.2393	601	16.75
acac exuv	1.7120	1.3015	-0.2429	-0.8267	11	1

WitsETD

Table 15-3: Weighted eigenvector plot scores from the CA on the 1996 species by plot data. The table also shows the plot weights and the effective number of species that occur on the plots (N2 species diversity of plots) (Hill 1973). The codes for the treatment plots are defined in Table 10-1 (p. 214).

Plot	Axis 1	Axis 2	Axis 3	Axis 4	Weight	N2
Fa01Aug2	-0.1955	0.3039	-1.1159	-0.3963	6805	3.51
Fa02Con0	1.6728	0.4704	-0.6129	-0.1237	9565	6.1
Fa03Dec2	-0.0961	0.1992	-0.6706	-0.5335	7739	4.62
Fa04Oct2	-0.1949	-0.0350	-0.1941	-0.7490	6406	5.63
Fa05Apr2	-0.3012	0.2603	-1.0343	-0.4654	6484	4.08
Fa06Feb2	-0.1046	5.5640	3.0665	-0.9710	6291	9.36
Fa07Aug1	-0.3181	-0.0509	-0.6110	0.0601	5698	4.8
Fa08Dec3	0.5135	0.4979	-0.7705	-0.5908	6707	5.13
Fa09Aug3	-0.3841	0.2381	-1.0266	-0.2742	6018	3.26
Fa10Oct3	-0.4660	0.2330	-1.0056	-0.4172	4133	3.39
Fa11Feb3	-0.2066	0.3041	-0.9016	-0.2775	6371	4.5
Fa12Apr3	-0.2780	0.2365	-0.8631	-0.5893	6555	4.22
Ka01Con0	0.8062	-0.1723	-0.4506	-0.1361	4983	9.65
Ka02Dec2	-0.3891	0.1568	-0.8222	0.0821	5958	3.03
Ka03Oct2	-0.2601	0.0414	-0.4373	-0.2715	2655	4.19
Ka04Feb2	-0.1083	0.1666	-1.1365	-0.5212	10409	4.26
Ka05Aug2	-0.4841	0.3053	-0.8299	-0.1804	5548	2.44
Ka06Apr2	-0.3589	0.0920	-0.7067	0.0594	6469	3.21
Ka07Aug1	-0.2467	0.2124	-0.6814	-0.1036	6515	3.33
Ka08Feb3	-0.3436	-0.1958	-0.3495	0.3019	6208	5.57
Ka09Oct3	-0.2405	-0.1450	-0.7704	-0.1152	5893	4.43
Ka10Dec3	-0.2135	-0.0272	-0.5568	-0.8544	7157	4.07
Ka11Aug3	-0.1365	0.8762	-0.4757	0.2370	7381	4.93
Ka12Apr3	-0.4012	0.0632	-0.6158	0.9479	6196	3.9
Nu01Oct2	-0.4972	-0.8077	0.7664	-0.2725	3917	9.57
Nu02Dec2	-0.6543	-0.6658	0.1335	0.1799	5201	4.75
Nu03Feb2	-0.3198	-0.1318	0.1723	-0.9023	3401	5.35
Nu04Aug2	-0.5315	-0.8933	1.0503	-0.5958	5951	6.07
Nu05Apr2	-0.4806	-0.2485	-0.4679	-0.1611	5500	4.02
Nu06Aug1	-0.4252	-1.3415	1.9515	-1.3604	7381	5.47
Nu07Con0	3.9319	-0.3967	0.4590	0.4257	14163	9.5
Nu08Dec3	-0.0041	-0.8474	0.6092	-0.2901	3489	11.77
Nu09Oct3	-0.5248	-0.9244	0.6943	-0.1484	6788	8.31
Nu10Feb3	-0.5769	-0.7457	0.2392	-0.3206	5803	5.75
Nu11Apr3	-0.3068	-0.6637	1.7127	-2.0656	7465	7.64
Nu12Aug3	-0.7340	-1.0453	1.4309	3.4831	3889	5.04
Sh01Aug2	-0.5398	-0.2508	0.0911	1.2855	2963	6
Sh02Apr2	-0.6956	0.5881	0.2013	2.1837	2550	4.71
Sh03Aug1	-0.6289	-1.0176	1.4538	2.3238	4622	7.78
Sh04Feb2	0.1308	-0.5047	0.6194	0.4033	11649	10.09
Sh05Oct2	-0.3474	-1.4206	1.9828	-1.1722	9008	5.3
Sh06Dec2	-0.3853	0.2801	1.0877	2.3250	7185	10.05
Sh07Con0	0.4586	0.0687	-0.4785	0.3201	6073	6.78
Sh08Dec3	-0.3909	0.3373	-0.5116	0.9344	2298	6.8
Sh09Apr3	-0.6837	1.0795	0.5846	3.2428	4406	4.15
Sh10Aug3	-0.6011	0.6531	-0.4831	0.6767	3581	2.83
Sh11Oct3	-0.4136	0.3621	-0.6906	0.1964	3191	4.33
Sh12Feb3	-0.5013	-0.1687	-0.2345	1.1251	3990	6.94

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Table 15-4: Weighted eigenvector species scores from the CA on the 1996 species by plot data. The table shows the species weights and the effective number of occurrences of the species (N2 diversity of species) (Hill 1973). The codes for the species are defined in Table 9-1 (p. 210).

Species	Axis 1	Axis 2	Axis 3	Axis 4	Weight	N2
acac caff	-0.4157	-0.7941	1.2035	-1.1069	34	2
acac exuv	-0.6837	1.0796	0.5849	3.2428	8	1
acac gerr	-0.3492	1.1488	0.7468	1.4218	2742	5.33
acac sieb	-0.4055	-0.0961	-0.2840	0.4471	100	5.52
acac swaz	3.9319	-0.3966	0.4591	0.4256	83	1
acac xant	-0.2135	-0.0272	-0.5569	-0.8545	9	1
albi harv	-0.4013	0.0633	-0.6158	0.9479	68	1
albi vers	-0.2685	-0.9263	1.1003	-0.5493	1081	6.74
anno sene	0.0074	-0.6167	0.5124	-0.1091	1559	10.77
anti veno	0.3859	-0.1863	-0.0332	-0.0728	893	17.29
berc zeyh	-0.3066	-0.6638	1.7126	-2.0653	8	1
bauh galp	2.2744	-0.3977	0.4809	-0.1028	284	2.38
cant spec	3.4139	-0.3557	0.3097	0.3416	458	1.39
cass aeth	0.8899	-0.1529	0.2144	-0.5197	192	6.49
cass tran	0.0455	1.6432	1.3174	-0.9559	174	5.15
catu spin	-0.1244	-0.6341	0.9560	-0.5486	17264	11.28
comb apic	-0.2854	0.2080	-0.2428	0.5898	207	2.61
comb coll	-0.4240	-0.2388	0.8678	0.9094	1669	4.73
comb here	-0.1167	5.2342	2.9371	-0.9636	1066	1.12
comb imbe	-0.6011	0.6531	-0.4830	0.6768	8	1
comb moll	-0.3219	0.1021	0.0710	0.3809	1623	12.82
comb moss	3.9319	-0.3966	0.4591	0.4256	42	1
comm negl	0.6190	0.3987	0.0454	0.7785	42	2.75
crot grat	0.8060	-0.1725	-0.4506	-0.1360	17	1
dalb mela	-0.0579	-0.1373	-0.1374	-0.1235	4285	16.03
dich cine	-0.1840	0.1158	-0.2368	-0.0121	81817	39.27
dios lyci	0.5293	-0.3532	0.2949	0.2577	3492	10.49
dios mesp	0.2412	0.1338	-0.0509	0.0726	1457	15.6
dios whyt	3.9319	-0.3966	0.4591	0.4256	208	1
domb rotu	-0.1552	-0.3103	0.0885	-0.3291	408	6.59
ehre obtu	-0.2086	0.6643	-0.0537	-0.0658	2199	10.38
eucl divi	-0.1579	3.2773	1.7352	-0.4045	748	2.87
eucl nata	1.4436	-0.1113	-0.0379	0.0808	10283	7.58
faur sali	-0.4252	-1.3416	1.9513	-1.3605	8	1
ficu syco	-0.1955	0.3039	-1.1160	-0.3963	8	1
flac indi	-0.2126	-0.4754	1.0687	-1.1316	801	2.97
gard volk	-0.1137	0.4140	-0.7610	-0.2727	24	3
grew flav	0.8753	0.1909	-0.2459	-0.0036	1192	13.13
grew hexa	0.1286	0.2199	-0.6574	-0.7303	17	1.99
grew mont	-0.2034	0.0728	0.0920	-0.1921	825	19.89
hete nata	0.6882	-0.5966	0.4841	-0.0301	125	2.63
hipp pauc	-0.3222	-0.5413	1.2401	-1.4563	1008	2.08
hype amoe	1.3006	-0.0442	-0.2512	0.3457	33	1.58
kige afri	0.1061	0.3790	-0.9025	-0.5279	16	2
krau flor	3.7812	-0.3858	0.4153	0.3985	166	1.1
lann disc	-0.4768	-0.8199	0.8170	-0.5650	100	3.56
lann edul	-0.3225	0.5558	0.0263	-0.5363	82	6.17
lann schw	-0.3644	0.0422	0.3691	1.3134	16	2
lonc capa	-0.4429	-0.4203	0.5595	0.6909	2759	15.24
mark zanz	-0.3853	0.2802	1.0877	2.3248	8	1
mayt hete	-0.2338	0.1050	0.2293	-0.2791	2249	22.52
mayt sene	0.0816	0.1257	-0.1625	-0.1955	23449	24.74
mund seri	-0.3530	-0.0994	0.1634	0.1923	570	8.42
ochn nata	1.7685	0.2924	0.0023	0.0145	7003	4.85
olea euro	3.7968	-0.3950	0.4483	0.3923	1083	1.08
ormo tric	-0.4066	1.5640	0.5229	0.7648	1133	7.1
ozor spha	-0.4227	-0.1105	-0.0108	-0.0131	33	3.99
papp cape	-0.3142	-0.0540	0.2741	-0.2300	173	7.1
pari cura	-0.3606	-0.4805	0.1076	0.3168	2186	8.88
pave schu	-0.3186	-0.5204	0.5280	0.0034	7684	14.77
pelt afri	0.5806	0.0455	-0.2480	0.0188	1152	9.92

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Species	Axis 1	Axis 2	Axis 3	Axis 4	Weight	N2
phyl reti	0.3581	0.2552	-0.4356	-0.1501	1060	13.36
pili thon	-0.3838	-0.2128	-0.1536	0.2389	148	10.59
psyd locu	0.4586	0.0686	-0.4785	0.3202	25	1
pter ango	-0.4832	-0.4264	-0.0812	-0.2322	536	4.76
pter rotu	-0.3132	-0.3978	0.9425	-1.4836	16	2
putt pyra	2.7413	-0.4717	0.8112	-0.2741	267	1.68
rhus lept	-0.2419	0.6746	-0.2923	-0.5672	82	4.46
rhus pent	0.2803	2.0132	0.7733	-0.3225	315	5.84
rhus pyro	-0.0900	0.0493	-0.7051	-0.2547	1126	3.38
rhus tran	0.0045	-0.2587	-0.1233	-0.2192	1212	12.92
scho brac	-0.0372	-0.4677	1.0843	-1.4979	74	2.03
scle birr	-0.3068	-0.0684	-0.0319	0.2685	4303	20.12
secu viro	0.3756	0.3502	-0.0441	-0.1083	1102	14.85
senn pete	-0.2915	-0.2608	0.5171	1.1878	10815	15.72
spir afri	0.2272	-0.3895	0.0654	0.0150	16	2
stry mada	-0.0802	-0.0181	-0.1603	0.0890	12537	22.14
stry spin	-0.0947	-0.6047	0.4523	-0.1733	123	5.33
syzy cord	-0.5213	-1.1087	1.5243	0.3380	42	2.75
syzy guin	-0.3181	-0.0508	-0.6111	0.0601	8	1
tare supr	0.4586	0.0686	-0.4785	0.3202	8	1
term seri	-0.1639	0.0132	-0.3192	-0.1049	59298	34.49
tric emet	-0.2868	-0.0929	-0.1994	0.2994	82	6.17
turr nilo	-0.4857	-0.7163	0.7494	0.1997	4813	13.02
vang infa	-0.3458	0.0386	0.0185	0.7617	58	5.37
xime caff	-0.0234	0.0513	-0.2987	0.0738	620	23.99
zant cape	2.9397	-0.2405	0.2341	0.3800	635	1.76
zizi mucr	-0.1544	0.3005	-0.4657	0.0596	856	17.63

WitsETD

Table 15-5: Weighted eigenvector plot scores from the CA on the 1996 species by plot data with the first eight weighted eigenvector axes of the CA on the 1954 species by plot data as covariables. The table also shows the plot weights and the effective number of species that occur on the plots (N2 species diversity of plots) (Hill 1973). The codes for the treatment plots are defined in Table 10-1 (p. 214).

Plot	Axis 1	Axis 2	Axis 3	Axis 4	Weight	N2
Fa01Aug2	-0.4204	-0.3054	-0.1137	-0.5282	6805	3.51
Fa02Con0	1.9062	0.2820	-0.8471	-0.9175	9565	6.1
Fa03Dec2	-0.3525	0.1351	-0.0120	0.1957	7739	4.62
Fa04Oct2	-0.2530	0.9969	-0.0352	-0.1085	6406	5.63
Fa05Apr2	-0.4944	-0.1293	-0.2146	-0.2651	6484	4.08
Fa06Feb2	-0.0403	-0.1151	-1.2094	0.9705	6291	9.36
Fa07Aug1	-0.2634	-0.3037	-0.5374	-0.8962	5698	4.8
Fa08Dec3	0.6732	0.4327	-1.0972	-0.5001	6707	5.13
Fa09Aug3	-0.6842	-0.2326	0.2513	-0.3552	6018	3.26
Fa10Oct3	-0.6576	-0.3315	-0.2024	-0.0686	4133	3.39
Fa11Feb3	-0.6494	-0.0240	0.3325	-0.4243	6371	4.5
Fa12Apr3	-0.5852	-0.1394	-0.3266	-0.2662	6555	4.22
Ka01Con0	0.8338	0.4451	-0.7477	0.4159	4983	9.65
Ka02Dec2	-0.1691	-0.8052	-1.5118	1.1263	5958	3.03
Ka03Oct2	-0.2918	0.3024	0.0399	0.3003	2655	4.19
Ka04Feb2	-0.1865	-0.3724	-0.9011	0.7155	10409	4.26
Ka05Aug2	-0.6188	-0.1194	0.5640	0.2462	5548	2.44
Ka06Apr2	-0.3187	-0.2450	0.0832	0.7685	6469	3.21
Ka07Aug1	-0.3314	-0.1369	0.4878	0.2488	6515	3.33
Ka08Feb3	0.1517	0.8090	0.0148	0.0388	6208	5.57
Ka09Oct3	-0.6011	-0.9091	0.0737	-0.1361	5893	4.43
Ka10Dec3	-0.6532	0.4872	-0.1257	0.0164	7157	4.07
Ka11Aug3	-0.3158	-0.6310	1.5039	-1.4621	7381	4.93
Ka12Apr3	0.0851	-0.9208	0.7449	1.1127	6196	3.9
Nu01Oct2	-0.9635	0.0122	-0.2946	-0.1745	3917	9.57
Nu02Dec2	-0.9311	-1.7536	-0.9905	0.5613	5201	4.75
Nu03Feb2	-0.2815	0.8609	0.5812	0.2497	3401	5.35
Nu04Aug2	-0.4505	-0.1872	-0.1970	-0.7133	5951	6.07
Nu05Apr2	-0.6894	-1.2538	-0.5614	-0.0056	5500	4.02
Nu06Aug1	-1.6589	0.8356	-0.1219	-0.9012	7381	5.47
Nu07Con0	3.5345	-0.1480	0.4628	0.3545	14163	9.5
Nu08Dec3	-0.0989	-0.2491	-1.7850	0.2536	3489	11.77
Nu09Oct3	-0.1185	-1.4038	-2.0340	0.1455	6788	8.31
Nu10Feb3	-0.0098	0.6605	-0.6256	-0.5632	5803	5.75
Nu11Apr3	-0.0047	3.5756	1.5703	0.1875	7465	7.64
Nu12Aug3	0.0703	-0.9440	2.2855	3.5636	3889	5.04
Sh01Aug2	-1.0129	-0.5143	1.8813	1.4237	2963	6
Sh02Apr2	0.1867	-1.2422	1.3161	2.2758	2550	4.71
Sh03Aug1	-0.6205	0.0525	2.8251	2.4766	4622	7.78
Sh04Feb2	0.4927	0.2742	-0.2734	0.0447	11649	10.09
Sh05Oct2	-0.4814	2.9924	-0.9822	0.5800	9008	5.3
Sh06Dec2	0.1393	-0.2882	1.2959	-3.2021	7185	10.05
Sh07Con0	0.5670	-0.3637	-0.7526	0.3245	6073	6.78
Sh08Dec3	0.2514	-0.4238	-0.6467	-1.2590	2298	6.8
Sh09Apr3	0.2884	-1.4326	2.7893	-2.2095	4406	4.15
Sh10Aug3	-0.0638	-1.0564	0.6253	-0.4246	3581	2.83
Sh11Oct3	-0.2344	-0.5913	0.3247	-1.1555	3191	4.33
Sh12Feb3	-0.3997	-0.6666	1.2515	0.6181	3990	6.94

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Table 15-6: Weighted eigenvector species scores from the CA on the 1996 species by plot data with the first eight weighted eigenvector axes of the CA on the 1954 species by plot data as covariables. The table shows the species weights and the effective number of occurrences of the species (N2 diversity of species) (Hill 1973). The codes for the species are defined in Table 9-1 (p. 210).

Species	Axis 1	Axis 2	Axis 3	Axis 4	Weight	N2
acac caff	-0.0616	1.0857	-0.2318	0.1665	34	2
acac exuv	0.2883	-1.4321	2.7891	-2.2093	8	1
acac gerr	0.1050	-0.4809	1.2502	-1.5815	2742	5.33
acac sieb	-0.5102	-0.6819	0.2783	0.5177	100	5.52
acac swaz	3.5345	-0.1478	0.4628	0.3546	83	1
acac xant	-0.6531	0.4870	-0.1259	0.0164	9	1
albi harv	0.0851	-0.9211	0.7448	1.1127	68	1
albi vers	-0.5809	0.4966	-0.6945	-0.0774	1081	6.74
anno sene	-0.0484	-0.2789	-0.3632	0.1230	1559	10.77
anti veno	0.3840	0.0564	-0.0957	0.0463	893	17.29
berc zeyh	-0.0050	3.5752	1.5703	0.1871	8	1
bauh galp	2.0482	0.2293	0.4482	0.2286	284	2.38
cant spec	3.0875	-0.0648	0.2645	0.3630	458	1.39
cass aeth	0.8617	0.7870	0.3001	0.0042	192	6.49
cass tran	0.0419	0.7737	-0.2192	0.3145	174	5.15
catu spin	-0.3026	0.9988	-0.0838	-0.0250	17264	11.28
comb apic	0.1457	-0.0980	-0.2740	-0.7540	207	2.61
comb coll	-0.3097	-0.0723	0.6597	-1.3841	1669	4.73
comb here	-0.0459	-0.0445	-1.1234	0.9248	1066	1.12
comb imbe	-0.0640	-1.0560	0.6253	-0.4246	8	1
comb moll	-0.1319	-0.4194	0.4396	-0.4372	1623	12.82
comb moss	3.5345	-0.1478	0.4628	0.3546	42	1
comm negl	0.9562	0.0799	-0.0273	-1.7627	42	2.75
crot grat	0.8338	0.4455	-0.7476	0.4158	17	1
dalb mela	-0.0268	0.3424	-0.1947	0.1874	4285	16.03
dich cine	-0.1727	-0.0900	0.1155	-0.0441	81817	39.27
dios lyci	0.5843	0.1939	-0.2337	0.0226	3492	10.49
dios mesp	0.2041	-0.1893	0.1794	-0.0023	1457	15.6
dios whyt	3.5345	-0.1478	0.4628	0.3546	208	1
domb rotu	-0.0690	-0.2821	-0.7920	-0.0086	408	6.59
ehre obtu	-0.2864	-0.1539	0.4955	-0.2522	2199	10.38
eucl divi	-0.1177	-0.1146	-0.4287	0.0599	748	2.87
eucl nata	1.3560	0.0255	-0.0677	0.0579	10283	7.58
faur sali	-1.6588	0.8355	-0.1220	-0.9012	8	1
ficu syco	-0.4203	-0.3055	-0.1137	-0.5283	8	1
flac indi	0.0144	1.7476	0.5934	0.0586	801	2.97
gard volk	-0.2850	-0.2893	0.1969	-0.1837	24	3
grew flav	0.8562	0.0160	-0.0617	-0.2229	1192	13.13
grew hexa	-0.0289	0.4614	-0.5830	-0.2266	17	1.99
grew mont	-0.1414	-0.1522	-0.3466	-0.0107	825	19.89
hete nata	0.8475	-0.7015	-0.9303	0.1251	125	2.63
hipp pauc	-0.1413	2.5295	1.2764	0.3008	1008	2.08
hype amoe	1.2865	-0.3119	-0.4581	0.3316	33	1.58
kige afri	0.0895	0.1517	-0.6559	-0.3826	16	2
krau flor	3.4043	-0.1192	0.4045	0.3575	166	1.1
lann disc	-0.3638	0.3547	-0.3064	-0.4347	100	3.56
lann edul	-0.3085	0.1127	-0.2170	0.0525	82	6.17
lann schw	0.1455	0.2602	0.6553	-1.5817	16	2
lonc capa	-0.2870	-0.2863	0.2801	0.4049	2759	15.24
mark zanz	0.1393	-0.2881	1.2959	-3.2022	8	1
mayt hete	-0.1805	0.3808	0.2652	0.0474	2249	22.52
mayt sene	0.0464	0.1260	-0.1735	-0.1576	23449	24.74
mund seri	-0.1944	0.3537	0.1008	0.5856	570	8.42
ochn nata	1.7369	0.0706	-0.3053	-0.2009	7003	4.85
olea euro	3.4172	-0.1134	0.4264	0.3533	1083	1.08
ormo tric	0.0026	-0.7238	0.2298	0.4489	1133	7.1
ozor spha	-0.2249	0.4250	1.0240	0.5584	33	3.99
papp cape	-0.2668	0.6806	1.0575	-0.0332	173	7.1
pari cura	-0.2512	-0.5388	0.0226	0.3602	2186	8.88
pave schu	-0.2697	-0.2108	-0.4511	0.0777	7684	14.77

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Species	Axis 1	Axis 2	Axis 3	Axis 4	Weight	N2
pelt afri	0.4956	-0.0468	-0.0154	0.1629	1152	9.92
phyl reti	0.2945	-0.0622	-0.2002	-0.3293	1060	13.36
pili thon	-0.4042	-0.5423	-0.1099	-0.0665	148	10.59
psyd locu	0.5672	-0.3645	-0.7528	0.3243	25	1
pter ango	-0.3983	-0.5352	-0.8335	-0.0285	536	4.76
pter rotu	-0.1433	2.2179	1.0758	0.2182	16	2
putt pyra	2.5402	0.8979	0.7739	0.3075	267	1.68
rhus lept	-0.3875	0.1565	-0.3643	0.0231	82	4.46
rhus pent	0.3625	-0.0939	-0.6977	0.1088	315	5.84
rhus pyro	-0.1044	-0.2048	-0.5673	0.4074	1126	3.38
rhus tran	0.0146	-0.0710	-0.5268	0.3206	1212	12.92
scho brac	0.1539	2.4338	0.7752	0.0758	74	2.03
scle birr	-0.1897	-0.1428	0.1312	0.2054	4303	20.12
secu viro	0.3963	0.0845	-0.3816	0.1668	1102	14.85
senn pete	-0.0216	-0.1817	0.9129	0.7606	10815	15.72
spir afri	0.2342	-0.3067	-1.2688	0.2888	16	2
stry mada	-0.0627	-0.0529	-0.0707	-0.4458	12537	22.14
stry spin	0.0247	0.3868	-0.1307	-0.1643	123	5.33
syzy cord	-1.1062	0.3623	1.0382	0.6046	42	2.75
syzy guin	-0.2633	-0.3033	-0.5373	-0.8962	8	1
tare supr	0.5672	-0.3645	-0.7528	0.3243	8	1
term seri	-0.2065	-0.1695	-0.1997	0.0619	59298	34.49
tric emet	-0.2604	-0.3617	0.1958	0.0491	82	6.17
turr nilo	-0.4295	0.0853	0.1317	0.4085	4813	13.02
vang infa	-0.2613	-0.0289	0.6150	-0.8236	58	5.37
xime caff	-0.0581	-0.1287	0.0424	-0.0586	620	23.99
zant cape	2.6549	-0.1735	0.4587	0.2294	635	1.76
zizi mucr	-0.1573	-0.2215	0.1947	0.0156	856	17.63

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Table 15-7: Weighted eigenvector plot scores from the CA on the 1954 structure by plot data. The table also shows the plot weights and the effective number of structural groups that occur on the plots (N2 structural diversity of plots) (Hill 1973). The codes for the treatment plots are defined in Table 10-1 (p. 214).

Plot	Axis 1	Axis 2	Axis 3	Axis 4	Weight	N2
Fa01Aug2	-1.4636	-1.1334	0.2559	-1.0090	2380	3.13
Fa02Con0	-1.1600	0.0741	0.7975	-0.1494	1658	3.51
Fa03Dec2	-1.4590	-0.4693	0.1875	-0.0874	2934	3.03
Fa04Oct2	-1.3008	-1.2027	0.2395	0.4741	2260	3.52
Fa05Apr2	-1.2047	-1.3435	1.5120	-0.8944	2347	3.97
Fa06Feb2	-1.5471	0.1418	-1.3498	-0.7114	3165	2.08
Fa07Aug1	-0.7757	-2.2766	1.0212	-0.3603	2693	5.61
Fa08Dec3	0.5709	0.3380	0.9811	0.1488	1972	5.34
Fa09Aug3	0.5640	-0.8481	-0.3779	-0.5965	1980	4.49
Fa10Oct3	0.6225	-1.5887	0.6778	1.9661	833	5.43
Fa11Feb3	0.8984	-2.1054	0.4228	-1.5144	3832	4.19
Fa12Apr3	1.0354	0.1729	0.1275	-0.3661	2002	4.17
Ka01Con0	-0.3392	-1.4346	2.0477	4.2887	830	7.25
Ka02Dec2	-0.9294	1.7003	-0.9206	0.0670	989	2.47
Ka03Oct2	1.3203	0.1481	0.1896	1.3058	2185	3.47
Ka04Feb2	0.8453	0.3729	0.1181	-1.0656	1411	4.16
Ka05Aug2	0.5786	1.8538	3.6962	-1.5023	1562	5.33
Ka06Apr2	-0.7533	0.7841	0.7994	0.8286	1504	3.98
Ka07Aug1	-0.3689	2.5492	3.3111	-1.5463	2337	4.29
Ka08Feb3	0.8067	0.0828	0.0221	0.2490	1411	4.3
Ka09Oct3	1.4691	0.6858	1.4434	0.8142	1330	3.29
Ka10Dec3	1.7511	0.2683	0.0935	0.4487	2931	3.05
Ka11Aug3	1.0938	-0.5494	0.1611	0.1706	3338	4.1
Ka12Apr3	1.0281	0.3901	-0.4327	0.2403	2320	3.66
Nu01Oct2	-1.0410	0.9041	-0.4090	1.0430	2143	2.77
Nu02Dec2	-1.0957	1.0050	-0.1879	1.1141	1659	2.66
Nu03Feb2	-0.9317	0.3774	-1.1207	-0.0980	399	3.34
Nu04Aug2	-0.9445	-0.9396	0.0226	0.1468	2614	3.84
Nu05Apr2	-1.0299	-0.2457	0.4377	3.5015	2347	3.77
Nu06Aug1	-1.2180	0.4260	-0.6833	-0.4801	2218	2.6
Nu07Con0	-1.4348	0.6461	-0.4104	0.4126	1897	2.4
Nu08Dec3	0.4561	0.5563	-1.0630	-0.2865	2175	3.8
Nu09Oct3	0.8232	0.0318	0.0528	0.8677	2068	4.24
Nu10Feb3	1.6378	-0.6014	-0.6419	-0.0794	2809	3.01
Nu11Apr3	0.7664	0.2970	0.3991	0.7131	1648	4.56
Nu12Aug3	0.0966	-0.0188	-1.4362	-1.1266	1881	3.57
Sh01Aug2	-0.4683	1.1403	-0.8208	-0.9220	3175	3.19
Sh02Apr2	0.1778	-0.0978	-1.1053	-0.8882	2821	3.61
Sh03Aug1	-0.4827	-1.0386	-0.2055	0.0659	2057	4.53
Sh04Feb2	0.6717	0.3363	-0.4862	0.3144	4650	4
Sh05Oct2	-0.6049	1.5454	-0.6919	0.4880	2572	2.79
Sh06Dec2	-0.4064	1.0929	-1.1783	-0.5657	1066	2.97
Sh07Con0	-0.3835	0.7190	-0.4946	-0.1852	2498	3.65
Sh08Dec3	0.8342	0.2664	-1.5045	-0.4439	2099	3.2
Sh09Apr3	0.3135	0.6686	-0.6261	0.3686	1463	3.69
Sh10Aug3	0.6351	-0.4288	-0.2673	-1.0243	895	4.2
Sh11Oct3	0.9822	0.3192	-0.4310	-0.1171	1035	3.74
Sh12Feb3	1.0028	-0.3900	-0.0891	0.7173	2108	4.03

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Table 15-8: Weighted eigenvector structure scores from the CA on the 1954 structure by plot data. The table shows the structure weights and the effective number of occurrences of the structures (N2 diversity of structures) (Hill 1973). The codes for the structure groups are defined in Table 5-3 (p. 34).

Structure	Axis 1	Axis 2	Axis 3	Axis 4	Weight	N2
H01_S01	0.5360	-0.0196	-0.0762	-0.0087	25029	30.43
H01_S13	0.0442	0.0492	0.1910	0.4418	709	24.06
H01_S3	-0.0565	0.0215	-0.0984	-0.1285	349	15.2
H01_T01	-0.4785	0.1260	-0.1001	-0.0186	35183	33.88
H01_T13	-0.4990	-0.5174	-0.1129	0.0429	1343	21.79
H01_T35	-0.6466	-0.0935	0.0766	0.0822	165	13.24
H01_T57	0.2073	0.1075	0.0266	-0.1974	209	17.19
H01_T7	-0.1594	0.4617	0.0441	0.0107	251	14.49
H13_S01	0.5985	0.0236	0.0317	-0.0144	16224	29.58
H13_S13	0.0684	0.3276	0.4812	0.2846	2071	30.35
H13_S3	0.2442	0.1013	0.5683	-0.0585	760	22.66
H13_T01	-0.5119	0.0256	0.2112	-0.1936	3954	29.41
H13_T13	-0.3470	-0.5550	0.1343	-0.1294	6300	25.92
H13_T35	-0.4441	-0.2086	0.1703	0.6383	1873	26.02
H13_T57	-0.2555	-0.0362	0.1519	0.0396	239	8.43
H13_T7	-0.6520	-0.3874	1.2179	0.0219	66	4.5
H35_S01	0.8857	0.0056	0.1178	-0.1044	814	16.81
H35_S13	-0.2117	0.9512	1.0088	0.2862	132	10.29
H5_S3	-0.0333	1.8511	2.6464	-1.0163	130	3.3
H35_T13	-0.4636	-1.6894	0.6647	-0.7442	109	5.05
H35_T35	-0.4702	-0.4217	0.2332	0.1632	1278	24.57
H35_T57	-0.2166	-0.1792	0.2395	0.3238	954	27.49
H35_T7	-0.4791	0.0833	0.5229	-0.2819	479	18.81
H5_S01	1.2886	-0.1365	-0.2184	0.2126	44	4
H5_T01	-1.5471	0.1419	-1.3497	-0.7154	11	1
H5_T35	-0.5386	-0.6492	0.1643	-0.0975	143	11.27
H5_T57	-0.3802	-0.1407	-0.0302	0.3531	165	11.84
H5_T7	-0.1384	-0.0843	-0.0161	0.3069	1517	32.52

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Table 15-9: Weighted eigenvector plot scores from the CA on the 1996 structure by plot data. The table also shows the plot weights and the effective number of structural groups that occur on the plots (N2 structural diversity of plots) (Hill 1973). The codes for the treatment plots are defined in Table 10-1 (p. 214).

Plot code	Axis 1	Axis 2	Axis 3	Axis 4	Weight	N2
Fa01Aug2	-1.3514	0.2488	1.7999	-0.1233	6808	2.91
Fa02Con0	0.476	-0.081	0.1822	0.0805	9567	4.11
Fa03Dec2	-0.358	-0.4344	0.5258	0.0501	7743	3.2
Fa04Oct2	-0.151	0.3764	-0.5065	0.7144	6407	4.36
Fa05Apr2	0.6854	0.0872	0.0526	-0.1335	6479	4.32
Fa06Feb2	-0.2363	-1.298	-0.7769	0.0501	6290	2.95
Fa07Aug1	-2.032	-1.074	1.5428	-0.223	5699	1.93
Fa08Dec3	0.6545	-0.0915	0.5357	0.6091	6710	4.43
Fa09Aug3	-0.7225	2.2731	-0.0085	-0.5253	6015	3.14
Fa10Oct3	0.6819	1.0772	-0.1045	0.0737	4135	4.28
Fa11Feb3	0.6467	-0.7801	-0.2676	-0.8046	6372	3.84
Fa12Apr3	0.2884	0.4751	-0.0136	0.7573	6559	4.07
Ka01Con0	2.3077	-0.0462	2.577	-2.0352	4986	5.87
Ka02Dec2	0.4942	-0.5663	-1.2284	0.1264	5958	3.57
Ka03Oct2	-0.2448	1.9363	-0.693	-0.4338	2659	4.14
Ka04Feb2	0.1294	0.1864	-0.739	0.292	10409	3.88
Ka05Aug2	-0.9914	3.0379	-0.0033	-1.1085	5549	2.43
Ka06Apr2	0.7032	0.8666	-0.2193	0.1317	6466	4.2
Ka07Aug1	-1.6155	0.6745	0.9058	-0.6527	6515	2.88
Ka08Feb3	0.4104	-0.7096	-1.0622	-0.134	6206	3.75
Ka09Oct3	0.0196	2.0542	-0.2595	0.3381	5893	3.53
Ka10Dec3	1.3411	0.387	2.5936	4.8397	7154	5.22
Ka11Aug3	0.0362	1.6554	0.2831	0.462	7381	3.93
Ka12Apr3	0.7082	0.75	-0.4115	-0.0731	6195	4.07
Nu01Oct2	-0.3698	-0.2262	-0.6597	-0.245	3914	3.91
Nu02Dec2	-0.3627	-0.3227	-0.4211	0.0489	5200	3.6
Nu03Feb2	-0.6686	-0.4936	0.6385	-0.1032	3399	2.73
Nu04Aug2	-1.4697	-0.0831	0.3411	-0.3756	5951	2.69
Nu05Apr2	0.2515	0.7666	-0.568	-0.0629	5498	3.78
Nu06Aug1	-2.2473	-1.3338	1.6843	-0.1856	7381	1.68
Nu07Con0	1.782	-0.7164	-0.0366	-0.3426	14166	4.45
Nu08Dec3	0.873	-0.6641	-0.5434	-0.1516	3489	4.16
Nu09Oct3	-0.1393	-0.3549	-0.8629	0.1942	6790	3.66
Nu10Feb3	0.3247	-0.0243	-0.2037	-0.09	5799	4.13
Nu11Apr3	-0.2421	-0.5522	-0.5271	0.2105	7464	3.21
Nu12Aug3	0.1074	-0.7145	-2.1277	0.7743	3890	3.12
Sh01Aug2	-0.6016	0.3176	-0.1842	-0.4869	2965	3.76
Sh02Apr2	0.0014	-0.5061	-0.867	-0.1841	2550	3.41
Sh03Aug1	-1.7778	-1.4619	1.3137	-0.0783	4624	2.06
Sh04Feb2	-0.3514	-1.0126	-0.8992	0.4089	11649	3.02
Sh05Oct2	-1.0844	-0.6931	-0.5129	0.0105	9009	2.86
Sh06Dec2	-0.0098	-1.2954	-1.0772	0.2938	7184	3.09
Sh07Con0	2.2809	-0.6805	2.3034	-2.968	6074	5.59
Sh08Dec3	-0.5216	0.479	0.1102	-0.6521	2301	3.47
Sh09Apr3	0.4058	-0.1981	-0.0997	-0.7386	4405	3.93
Sh10Aug3	-0.4	2.4412	-0.8288	-1.0943	3581	3.46
Sh11Oct3	-0.2488	1.3889	-0.9564	0.109	3190	3.81
Sh12Feb3	0.2492	-0.5293	-1.5448	0.2104	3989	3.57

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Table 15-10: Weighted eigenvector structure scores from the CA on the 1996 structure by plot data. The table shows the structure weights and the effective number of occurrences of the structures (N2 diversity of structures) (Hill 1973). The codes for the structure groups are defined in Table 5-3 (p. 34).

Structure code	Axis 1	Axis 2	Axis 3	Axis 4	Weight	N2
H01_S01	-0.2659	-0.1729	0.0637	0.0063	110183	38.13
H01_S13	-0.8594	-0.1838	0.3302	-0.1028	2239	21.09
H01_S3	-1.0549	-0.2747	0.3823	-0.1341	334	14.39
H01_T01	0.2461	-0.2259	-0.1762	0.0282	67226	34.11
H01_T13	0.2855	-0.104	-0.0213	-0.1866	1311	30.25
H01_T35	0.8247	0.2793	1.3353	0.2284	91	6.3
H01_T57	1.3412	0.3865	2.5936	4.837	9	1
H01_T7	-0.8293	-0.2669	0.5341	0.0311	73	7.23
H13_S01	-0.0189	0.4489	-0.0429	-0.0152	66335	38.51
H13_S13	-0.3687	0.4499	-0.1525	-0.1449	6275	30.74
H13_S3	-0.2044	0.2122	-0.2768	0.0193	649	24.14
H13_T01	0.6291	-0.0144	0.054	0.0516	9441	20.57
H13_T13	0.6611	0.0146	0.1935	-0.0624	10478	26.62
H13_T35	0.8196	-0.1599	0.4992	-0.6037	1418	15.9
H13_T57	0.5892	-0.3911	0.0323	-0.3747	332	13.95
H13_T7	0.7077	-0.2927	0.5244	0.0499	183	13.29
H35_S01	0.276	0.4475	0.3333	0.3485	3854	25.61
H35_S13	-0.0938	0.4281	0.0342	0.1512	1332	26.82
H35_S3	0.195	-0.4428	-0.1406	-0.0461	91	6.98
H35_T01	0.5001	0.3017	0.1929	-0.1317	49	4.41
H35_T13	1.0929	0.1867	1.4116	1.6891	512	4.94
H35_T35	0.8429	-0.1064	0.6671	-0.443	1218	14.27
H35_T57	0.8648	-0.2401	0.7208	-0.7662	1092	13.63
H35_T7	0.4954	-0.104	0.4296	-0.3543	599	20.34
H5_S01	0.0311	0.1734	0.0239	0.4568	425	14.65
H5_S13	-0.2301	0.2479	-0.0799	0.176	467	19.21
H5_S3	-0.8791	0.2962	0.527	0.1286	16	2
H5_T01	0.3988	0.0114	0.226	1.1181	41	4.99
H5_T13	0.7637	-0.3779	-0.0038	0.2312	16	2
H5_T35	0.7788	-0.0943	0.209	0.0184	200	5.31
H5_T57	0.0938	0.306	0.423	-0.0634	599	13.41
H5_T7	0.0207	0.1662	0.1536	-0.1286	1529	32.76

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Table 15-11: Weighted eigenvector plot scores from the CA on the 1996 structure by plot data with the first eight weighted eigenvector axes of the 1954 CA of the structure data as covariables. The table also shows the plot weights and the effective number of structural groups that occur on the plots (N2 structural diversity of plots) (Hill 1973). The codes for the treatment plots are defined in Table 10-1 (p. 214).

Plot code	Axis 1	Axis 2	Axis 3	Axis 4	Weight	N2
Fa01Aug2	-1.0476	0.5754	1.613	-0.4608	6808	2.91
Fa02Con0	0.1842	0.0809	0.1037	0.212	9567	4.11
Fa03Dec2	-0.4197	-0.1715	-0.2136	0.2296	7743	3.2
Fa04Oct2	0.0114	1.0127	-0.5575	2.2382	6407	4.36
Fa05Apr2	1.7381	0.5422	-0.2599	0.9447	6479	4.32
Fa06Feb2	0.5001	-0.4869	-0.4013	0.2607	6290	2.95
Fa07Aug1	-1.9003	-1.5635	-0.1247	-0.2762	5699	1.93
Fa08Dec3	0.2019	-0.2184	-0.2296	1.6543	6710	4.43
Fa09Aug3	-0.7777	2.4159	0.6147	-0.68	6015	3.14
Fa10Oct3	0.3202	0.6619	-0.5385	0.4088	4135	4.28
Fa11Feb3	1.965	-1.1893	-0.3726	-0.7767	6372	3.84
Fa12Apr3	-0.0003	-0.1048	0.1622	-0.0945	6559	4.07
Ka01Con0	1.0965	-1.1796	0.698	-2.5829	4986	5.87
Ka02Dec2	0.515	-0.0539	-0.5448	-0.2119	5958	3.57
Ka03Oct2	-1.3235	2.0432	-0.0727	-0.0143	2659	4.14
Ka04Feb2	-0.0557	-0.3132	-1.499	-0.2904	10409	3.88
Ka05Aug2	-0.0509	0.771	-0.9935	-1.0955	5549	2.43
Ka06Apr2	-0.43	0.8726	-0.726	-0.1915	6466	4.2
Ka07Aug1	-0.3562	-1.1633	0.402	-0.0843	6515	2.88
Ka08Feb3	0.0025	-0.8531	-1.4196	-0.3247	6206	3.75
Ka09Oct3	-0.0152	1.9625	1.4275	1.1487	5893	3.53
Ka10Dec3	0.5151	-1.884	3.1089	2.9952	7154	5.22
Ka11Aug3	-0.1741	1.4209	1.0281	0.4006	7381	3.93
Ka12Apr3	0.4894	0.9634	0.298	-0.5018	6195	4.07
Nu01Oct2	-1.0139	0.0137	-0.5319	-0.4097	3914	3.91
Nu02Dec2	-0.3846	0.1707	-1.3784	1.2998	5200	3.6
Nu03Feb2	-0.6441	0.5793	-0.2107	-0.0548	3399	2.73
Nu04Aug2	-1.1426	0.3913	-0.0527	0.4935	5951	2.69
Nu05Apr2	-0.2703	0.6991	-1.1438	-0.0014	5498	3.78
Nu06Aug1	-1.7502	-1.2382	1.7324	-0.7878	7381	1.68
Nu07Con0	2.2108	0.0685	0.4601	0.3799	14166	4.45
Nu08Dec3	1.1664	-0.4362	-0.0378	-0.138	3489	4.16
Nu09Oct3	-0.3725	-0.6869	-0.3968	-0.1935	6790	3.66
Nu10Feb3	0.4303	-1.0588	-0.6954	-1.6043	5799	4.13
Nu11Apr3	-0.5317	-0.5829	-0.1148	0.1916	7464	3.21
Nu12Aug3	0.7829	0.0002	-1.9587	1.4716	3890	3.12
Sh01Aug2	-0.9455	0.8431	0.1552	-1.189	2965	3.76
Sh02Apr2	0.4063	0.6961	-0.3039	0.0614	2550	3.41
Sh03Aug1	-1.7586	-1.41	1.0511	-0.7211	4624	2.06
Sh04Feb2	-0.5032	-1.0157	-0.6757	0.0886	11649	3.02
Sh05Oct2	-1.2029	-0.2833	0.5085	-0.2102	9009	2.86
Sh06Dec2	0.1435	-0.438	-0.4824	0.5787	7184	3.09
Sh07Con0	2.4061	0.5236	1.6267	-2.6023	6074	5.59
Sh08Dec3	-0.5148	1.0976	1.3861	-1.318	2301	3.47
Sh09Apr3	0.4329	0.14	0.8194	-1.3276	4405	3.93
Sh10Aug3	-0.5368	3.0119	-0.2314	-0.54	3581	3.46
Sh11Oct3	-0.8414	1.7812	-0.1009	0.0987	3190	3.81
Sh12Feb3	-0.0493	-0.9383	-2.3309	0.2263	3989	3.57

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Table 15-12: Weighted eigenvector structure scores from the CA on the 1996 data with the first eight weighted eigenvector axes of the 1954 CA of the structure data as covariables. The table shows the structure weights and the effective number of occurrences of the structures (N2 diversity of structures) (Hill 1973). The codes for the structure groups are defined in Table 5-3 (p. 34).

Structure code	Axis 1	Axis 2	Axis 3	Axis 4	Weight	N2
H01_S01	-0.2176	-0.1523	0.0323	-0.0172	110183	38.13
H01_S13	-0.7061	-0.2304	0.2052	-0.1157	2239	21.09
H01_S3	-0.8669	-0.3202	0.2163	-0.1735	334	14.39
H01_T01	0.2335	-0.1209	-0.1454	0.0452	67226	34.11
H01_T13	0.1824	-0.0602	-0.1485	-0.2341	1311	30.25
H01_T35	0.3493	-0.4656	0.767	-0.2604	91	6.3
H01_T57	0.5151	-1.8843	3.1089	2.994	9	1
H01_T7	-0.5545	-0.3593	0.4349	0.1326	73	7.23
H13_S01	-0.0507	0.3299	-0.0092	-0.0039	66335	38.51
H13_S13	-0.3171	0.3806	-0.0289	-0.0025	6275	30.74
H13_S3	-0.2499	0.2643	-0.1891	0.1279	649	24.14
H13_T01	0.5497	0.0469	0.1005	0.1256	9441	20.57
H13_T13	0.5393	0.0074	0.1627	-0.0947	10478	26.62
H13_T35	0.7753	0.0081	0.3048	-0.5024	1418	15.9
H13_T57	0.7234	-0.0812	0.0407	-0.131	332	13.95
H13_T7	0.6127	-0.4405	0.2221	-0.0407	183	13.29
H35_S01	0.1127	0.2535	0.3897	0.2502	3854	25.61
H35_S13	-0.1806	0.3212	0.0928	0.2506	1332	26.82
H35_S3	0.1241	-0.2086	-0.4152	0.101	91	6.98
H35_T01	0.5235	0.0971	-0.016	0.2774	49	4.41
H35_T13	0.7044	-0.6805	1.4495	1.2169	512	4.94
H35_T35	0.8744	-0.1342	0.4158	-0.4302	1218	14.27
H35_T57	0.8679	-0.0528	0.4025	-0.7006	1092	13.63
H35_T7	0.4774	-0.0885	0.2202	-0.3148	599	20.34
H5_S01	-0.0479	-0.0322	-0.0334	0.2624	425	14.65
H5_S13	-0.1935	0.0708	-0.0234	0.1531	467	19.21
H5_S3	-0.8869	0.2765	1.2393	0.2138	16	2
H5_T01	0.2611	-0.6042	0.3921	0.4091	41	4.99
H5_T13	0.6842	-0.3277	-0.1336	0.7624	16	2
H5_T35	0.8618	-0.3331	-0.1225	-0.3844	200	5.31
H5_T57	0.1451	-0.0403	0.0351	-0.2015	599	13.41
H5_T7	0.0588	0.1085	0.0707	-0.1685	1529	32.76

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16 APPENDIX 8: ATMOSPHERIC CO_2 RECORDS FROM SITES IN THE SCRIPPS INSTITUTION OF OCEANOGRAPHY (SIO) AIR SAMPLING NETWORK FROM 1958 TO 2003

The data presented in Table 16-1 was compiled from ten SIO sites where atmospheric CO_2 levels have been monitored over the past half a century (Keeling and Whorf 2004). The SIO data is available on the web at the Carbon Dioxide Information Analysis Center (CDIAC) (http://cdiac.esd.ornl.gov), which is considered the primary centre for global-change data and information analysis (Anon. 2004). The data comprises the annual average concentration of atmospheric CO_2 in parts per million by volume (ppmv) as determined using flask samples collected at each of the sites (Keeling and Whorf 2004).

Table 16-1: The mean annual atmospheric CO_2 levels (ppmv) at ten Scripps Institution of Oceanography (SIO) air sampling sites between 1958 and 2003 (Keeling and Whorf 2004).

Year	Alert	American Samoa	Baring Head	Point Barrow	Cape Kumukahi	Christmas Island	Kermadec Islands	La Jolla Pier	Mauna Loa	South Pole	Average
1958										314.78	314.78
1959									316.00	315.64	315.82
1960									316.91	316.45	316.68
1961									317.63	317.08	317.36
1962									318.46	317.62	318.04
1963									319.02	318.35	318.69
1964									319.52	318.68	319.10
1965									320.09	319.42	319.76
1966									321.34	320.72	321.03
1967									322.13	321.32	321.73
1968									323.11	321.91	322.51
1969									324.60	323.12	323.86
1970								326.86	325.65	324.32	325.61
1971								327.49	326.32	325.12	326.31
1972								328.15	327.52	326.00	327.22
1973						329.96		330.20	329.61	327.62	329.35
1974				332.77		330.54		331.49	330.29	328.49	330.72
1975				333.28		331.60		332.14	331.16	329.50	331.54
1976				334.15		332.58		333.16	332.18	330.60	332.53
1977				335.31		334.26		334.79	333.88	332.03	334.05
1978			333.79	336.99		335.68		336.30	335.52	333.69	335.33
1979			335.16	338.42		337.33		338.02	336.89	335.03	336.81
1980			336.85	340.15	339.10	339.17		339.58	338.67	336.98	338.64
1981			338.26	341.39	340.27	340.32		341.08	339.95	338.26	339.93
1982		340.58	339.39	342.51	341.32	341.43		341.88	341.09	339.39	340.95
1983		342.11	340.95	344.07	342.84	343.33	341.39	343.48	342.75	341.17	342.45
1984		343.83	342.19	345.65	344.58	344.73	342.86	345.36	344.44	342.58	344.02
1985		345.28	343.48	346.98	345.91	345.94	344.10	346.51	345.86	343.82	345.32
1986	348.47	346.37	345.10	348.60	347.45	347.18	345.54	347.74	347.14	345.32	346.89
1987	349.94	347.97	346.82	350.05	349.33	349.07	347.57	349.64	348.99	346.99	348.64
1988	352.71	350.11	348.72	352.94	351.67	351.46	349.52	352.35	351.44	348.95	350.99
1989	355.05	351.59	350.37	355.34	353.14	352.95	350.86	353.56	352.94	350.44	352.62

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Year	Alert	American Samoa	Baring Head	Point Barrow	Cape Kumukahi	Christmas Island	Kermadec Islands	La Jolla Pier	Mauna Loa	South Pole	Average
1990	355.86	353.02	351.58	356.26	354.87	354.13	352.26	354.86	354.19	351.77	353.88
1991	357.30	354.28	352.84	357.38	356.04	355.32	353.55	356.38	355.62	353.12	355.18
1992	357.91	355.23	354.04	357.88	356.73	356.33	354.71	356.80	356.36	354.24	356.02
1993	358.15	356.11	354.97	358.28	357.53	357.41	355.56	357.66	357.10	355.16	356.79
1994	359.84	357.74	356.44	359.78	359.30	359.15	357.08	359.38	358.86	356.48	358.41
1995	361.83	359.69	357.95	362.09	361.18	361.13	358.89	361.26	360.90	358.35	360.33
1996	363.77	361.23	359.63	364.07	362.9	363.09	360.27	363.02	362.58	359.99	362.06
1997	364.73	362.28	361.13	365.06	364.34	364.15	361.82	364.12	363.84	361.2	363.27
1998	367.27	364.79	363.61	367.36	366.92	366.72	364.23	366.89	366.58	363.7	365.81
1999	369.34	366.99	365.4	369.76	368.44	368.54	366.29	368.75	368.3	365.65	367.75
2000	370.79	368.21	366.61	370.82	370.12	370.05	367.19	369.84	369.47	367.05	369.02
2001	372.11	369.91	368.17	372.38	371.64	371.51	368.78	371.4	371.03	368.34	370.53
2002	374.09	371.94	370.57	374.49	373.39	373.79	371.33	373.28	373.07	370.66	372.66
2003	377.05	374.17		376.99	376.04	375.93		375.98	375.61	372.77	375.57

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17 APPENDIX 9: CONFERENCE TALKS, POSTERS, AND PAPERS PUBLISHED

Four talks and one poster were presented at various research conferences on the woody vegetation data collected on the Pretoriuskop EBPs. These papers and posters are presented below in chronological order from the first presentation in January 1998 to the last presentation in February 2003. One peer-reviewed paper was collaborated on regarding the fire history of the KNP between 1941 and 1996. This paper is presented last.

17.1 THE LONG-TERM EFFECT OF FIRE FREQUENCY AND SEASON ON THE TREES AND SHRUBS IN THE SOURVELD SAVANNAS OF THE KRUGER NATIONAL PARK.

This paper was presented as a talk at the South African Association of Botanists (SAAB) Conference. Cape Town, January 1998.

SP O'Regan & ETF Witkowski

Abstract

In the Kruger National Park (KNP), a fire experiment has been running since 1954. The experimental layout was a randomised block design in which twelve treatments were replicated four times each in four of the six major veld types defined in by Van Der Schijff (1958). One of the distinct veld types is the sourveld bushveld of Pretoriuskop in which this study was conducted. Twelve fire treatments comprising a control (no burn), and annual, biennial and triennial burns at different times of the year were applied to 6 hectare plots for 42 years. The trees and shrubs each plot were surveyed using belt transects before the commencement of the experiment. This data serves as a baseline and control to the experiment. All plots were re-surveyed between May 1996 and September 1997. The effects of the different fire frequencies on the structure of the tree and shrub community within the lowveld sourveld will be presented. Furthermore, the significance of these data in interpreting the effects of past fire management policies in the Pretoriuskop region will also be discussed.

Introduction

Savannas are tropical grasslands with scattered trees (Bourliere and Hadley 1970). They are dynamic in their structure and composition, and are affected by fluctuations in rainfall, levels of herbivory, and the fire regime. The role of fire in savannas is generally accepted as being one of mediating the co-existence between trees and grass (Scholes and Walker 1993). In terms of savanna management, though the role of fire has historically been a controversial topic. This is primarily because it has been traditionally viewed and applied as powerful management tool instead of as an ecosystem process.

In the KNP in the early 1950's controversy surrounded the formulation and implementation of a fire management policy (Annual report 1951). In response to the evident lack in understanding the role of fire in the lowveld savannas, the National Parks Board initiated a fire research experiment (Annual report 1953).

An introduction to the KNP fire research experiment

The primary objective of the KNP fire research experiment when it was started was to provide a "scientific" basis for the fire management policies in the Park. Specifically, the aim was to determine the fire regime,

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based on frequency and season of fire occurrence, most appropriate to maintaining the desired vegetation structure within four major veld types defined at the time within the KNP.

The four major veld types in which the experiment was laid out were:

1. The *Terminalia* - *Dichrostachys* sourveld with long grass of Pretoriuskop.
2. The *Combretu*m veld between Skukuza and Pretoriuskop.
3. The Knob-thorn - Marula veld near Satara.
4. The Mopane veld between Shingwedzi and Letaba.

The experimental design

The experimental design was a randomised block design in which 12 treatments were replicated four times within each veld type. The twelve treatments comprised a control and combinations of three frequencies (namely annual, biennial, and triennial burns) burnt at five different times of the year, namely February, April, August, October, and December. The treatments were applied to plots approximately 6ha in size.

For clarity, “block” refers to a replicate of treatment plots, while “plot” refers to the area within each block to which each treatment was applied.

This study was concerned with the plots located in the sourveld savanna of Pretoriuskop.

Aims and Objectives

The aim of this study was to investigate the long-term effects of different fire treatments on the tree and shrub community structure and composition in the Pretoriuskop sourveld savannas of the Kruger National Park (KNP).

The objectives of this study can be divided into two broad categories, working objectives and analytical objectives. The working objectives involve the collection and capturing of data. The analytical objectives involve the analysis, and assimilation of the data.

Study area

Area description

The Pretoriuskop area is located in the south-west of the KNP, and experiences relatively high average annual rainfall of 744mm (Gertenbach 1980a). The terrain is moderately undulating, with the vegetation on the watersheds being open woodland, while the low-lying areas and drainage lines are more densely covered with trees and shrubby vegetation (Gertenbach 1983, Munnick *et al.* 1990). The dominant tree species in this area are *Terminalia sericea* and *Dichrostachys cinerea* subsp. *nyassana* (Gertenbach 1983). The dominant grass species is *Hyperthelia dissoluta* (Gertenbach 1983).

The layout of plots in the Pretoriuskop area

Four blocks of twelve plots were located in the Pretoriuskop sourveld. They were spread out within this veld type, one being placed on the Fayi, loop, another below Kambeni Hill, the third near Shabeni koppie and the last near Numbi Gate (Figure 17-1).

Methods and materials

A number of surveys of the woody vegetation were done on the plots between 1954 and 1996. The data collected in 1954 and in 1996 are presented here.

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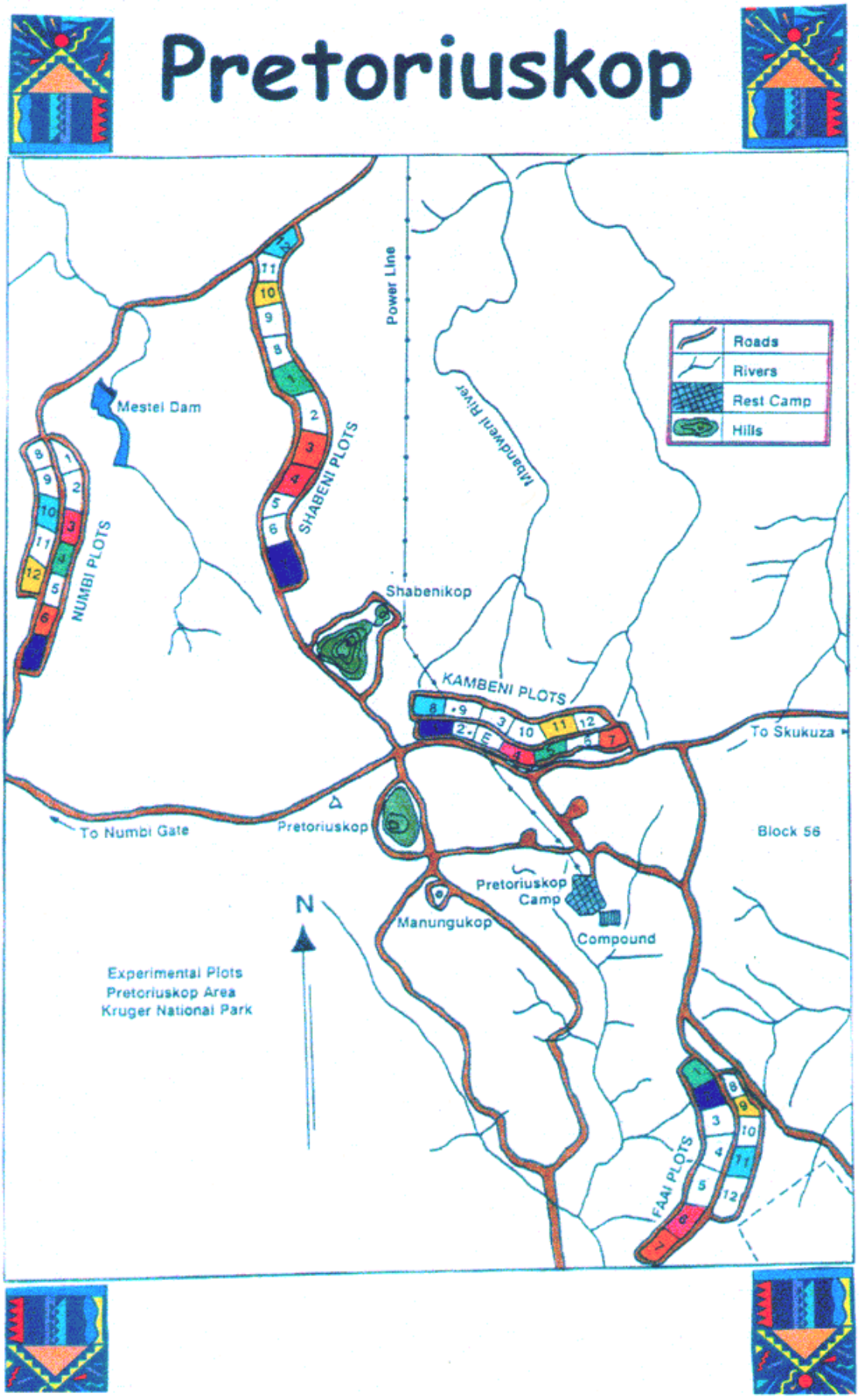


Figure 17-1: Layout of the four blocks of plots in the Pretoriuskop landscape, showing the placement of the six treatments focused on in this presentation.

The 1954 and 1996 surveys were conducted in a similar fashion namely transects were placed along the diagonals of each of the plots. The surveys comprised the measuring the height and coppice or stem diameters for each individual within each transect. However, the height measurements were not recorded in 1954.

These data represent the start and end of a period covering some 42 years of treatment application.

In this presentation six of the twelve treatments are focused on, namely the control, the August annual, biennial, and triennial treatments, and the February biennial and triennial treatments. These treatments comprise four different fire return periods (no fire, annual fires, biennial fires, and triennial fires) at two different times of the year (February and August).

Characteristics of the fire treatments and anecdotal post fire regeneration notes

Generally, the August treatments tend to be clean-burnt intense fires. *Panicum maximum* (Buffalo grass) found under large trees is dry in August and so these fires tend to scorch the trunks and the lower branches of large trees. Topkill of shrubs in August treatments is very high. Grazing, browsing, and trampling of shoots (both herbaceous and woody) is higher after the August treatments than a February treatments, because the first rains usually occur in October, and post fire regeneration and recovery of vegetation is slower than in February.

Generally, the February treatments are less intense than the August burns, they tend to be slow burning and range from patchy to relatively clean, and topkill of shrubs is low but can be high. Buffalo grass (*Panicum maximum*) growing under the large trees is green this time of the year and so the trees and under canopy seedlings are protected from the fires. Regeneration and recovery is relatively quick if rains continue into the autumn. If the rains end early in the wet season the plots are then heavily grazed and browsed through out the dry season and only gain a grass sward in the following wet season.

The frequency of the treatments affects the fire intensity because the longer inter-fire period (i.e. 3 years) the greater the build up of moribund plant material (fuel load). Therefore, treatments with an inter-fire period of 3 years tend to be more intense than treatments with an inter-fire period of 2 years at the same time of the year.

Analyses

Conceptual framework for the analyses

The KNP revised their management mission, vision, and objectives in between 1994 and 1996. The resultant mission or vision was “To maintain biodiversity in all its natural facets and fluxes …” (Braack 1997). Dr. Reed Noss’s (1990) conceptual framework for biodiversity was adopted during this process for defining and monitoring biodiversity. The framework comprised three primary elements being structure, function, and composition at four scales, namely genetic, species (community), habitat (landscape), and region. It is expected that biodiversity will change as species performances (resilience, competitiveness, persistence etc.) respond differently to resource gradients in space and time. Therefore, it is expected that consistent differences in fire regimes will result in differences in biodiversity. This provides a convenient framework with in which the effects of the different treatments on the woody vegetation can be studied, namely the effects of the treatments on the biodiversity of the woody vegetation of the plots at the species and community level (i.e. community structure and composition).

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Indices used to summarise the species and structural characteristics of the woody vegetation on the plots

The data available are height (m), basal diameter (cm), and whether the individual is single-stem or multi-stem for each individual surveyed. Since the heights of the plants were only recorded in 1996, they were not used in these analyses. At the community level (or plot level), we can look at both structural and compositional biodiversity. The structural and compositional components are:

- Density: Is defined as the number of individuals per unit area per plot.
- Physiognomy: Is defined as the number of single stemmed individuals relative to the number of coppicing individuals per plot.
- Diversity: Is defined as the number of individuals per species relative to the total number of individuals. Simpson's Index was used to calculate diversity.
- Composition: Is defined as the occurrence (and abundance) or absence of each species, and the species distribution in time and space. Variation in species composition in space is determined by their presence or absence on a plot. Variation in species composition over time is determined by their presence or absence in a survey (1954 or 1996).

Analyses

Randomised block ANOVA's and ANCOVA's were done on the density, physiognomy and diversity components.

Correspondence Analyses (CA) were done on the composition data, with the four block factors (Fayi, Numbi, Kambeni, and Shabeni) as covariables.

Results and Discussion

The effect of fire on the density of the woody vegetation.

In terms of fire frequency, the density of the woody vegetation on the control plots was significantly higher than on the burnt plots. This is consistent with other research findings regarding "bush encroachment" in savannas, where in the absence of fire, woody plant density tends to increase.

In terms of fire timing, there was no significant difference in the density of the woody vegetation between the August treatments and the February treatments.

Looking at a height class distribution of relative abundances of woody plants between treatments revealed some interesting results regarding the August and February treatments in 1996 (Figure 17-2). Five height classes were defined, namely 0-1m, 1-3m, 3-5m, 5-10m and >10m. There were a large number of woody plants shorter than 1m on the August annual treatments and on the February biennial and triennial treatments. This was expected for the August Annual treatment because frequent intense fires often prevent woody plants from emerging from the herbaceous layer by constantly burning the individuals back, which explains for high number of woody plants that were shorter than 1m on the August Annual treatments. The explanation for the high relative abundance of woody individuals shorter than 1m in the February treatments was not quit as obvious. In February *Panicum maximum*, which is frequently found under large trees, is still green. This provides a safe site for seedlings and saplings, as fire does not often burn into the sward of green grass. The individuals under the tree canopies often persist and remain stunted and so their numbers make up the bulk of the less than 1m height category.

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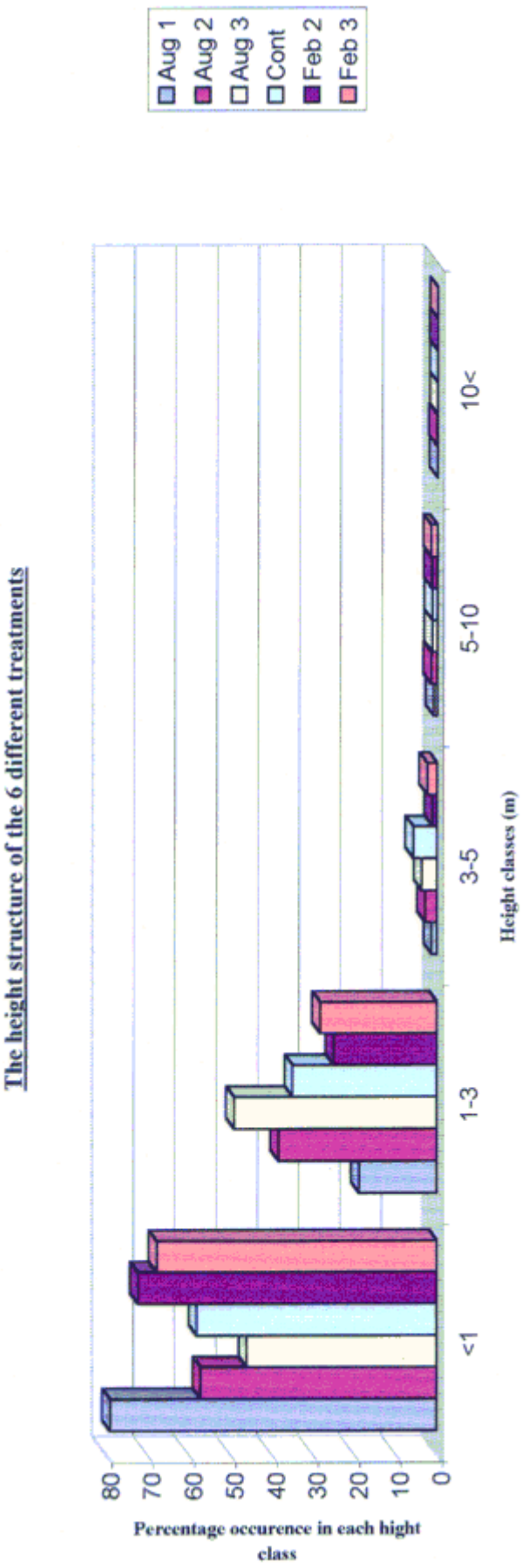


Figure 17-2: Graph showing the relative abundances of woody individuals in each of the five height classes for each of the six treatments.

The effect of fire on the physiognomy of the woody vegetation

There were significantly more single stem individuals on the control plots in comparison to the burnt plots. This was expected since most woody savanna plants have the capacity to sprout either from epicormic buds or from basal coppice buds when damaged. After a fire, plants that are burnt back often sprout from basal coppice buds, and these plants are typically multi-stemmed individuals. In the absence of fire, there is no top kill from fire and only mechanical damage to the plants may cause them to coppice from the base. It is for this reason that there were significantly more single stem individuals on the control plots relative to multi-stem individuals. Many savanna species are by nature multi-stemmed though and so it does not imply that in the absence of fire there will be no multi-stemmed individuals.

There were significantly more single stem individuals relative to multi-stem individuals on the February plots than on the August plots. This was because fires in August tend to be more intense than fires in February resulting in a higher percentage top kill of woody individuals and thus more individuals that sprout from basal coppice buds after the fire.

What is interesting is that the February biennial and triennial treatments are significantly different to the August annual and biennial treatments and not significantly different to the August triennial treatment. This may be a result of the fact that in the first year (and possibly the second year) after a fire individuals that sprouted from basal coppice buds often direct nutrient resources into the growth of many stems. However, it appears that after a certain height is reached resources may then be channelled into the growth of one or two primary stems. The other stems (depending on the species and time since last fire) become moribund and die or they remain reduced. This may explain why the August triennial burns do not have significantly less single stem individuals compared to the February burns.

The effect of fire on the diversity of woody vegetation

It is useful to view the diversity of the woody vegetation in Pretoriuskop within the paradigm of disturbance-mediated co-existence between woody species. Within this paradigm, the intermediate disturbance hypothesis postulates that diversity will be at a maximum at an intermediate frequency of disturbance. Looking at the diversity of the woody vegetation on the plots burnt at different frequencies, there is no significant differences between the Simpson's diversity indices of the plots burnt at different frequencies. This indicates that possibly none of the frequencies at which the plots were burnt can be considered intermediate within the fire disturbance regime of the Pretoriuskop region.

There is a significant difference, though, between the treatments burnt at different times of the year. The control plots have a significantly higher diversity than the burnt plots, and the February treatments have significantly higher diversity than the August plots. In terms of fire intensity, the August burns would generally represent an extreme because of dry climatic conditions and dry fuel. The February burns would generally be less intense, because of moister climatic and fuel conditions. The actual intermediate might be at some other intensity or timing however, the intermediate disturbance hypothesis does help interpreting the data in terms of disturbance gradients.

The control has a significantly higher diversity because more species occur on these plots. This is because fire sensitive species occur on these plots as well as fire tolerant species.

The effect of fire on the composition of the woody vegetation

Correspondence Analyses (CA) were used to determine the effect of fire on the species composition of the plots. The species densities for the 1954 and 1996 data sets were subjected to CA's with the blocks (replicates) as covariates. The Eigenvalues for the first axes of the 1954 and 1996 data sets were 0.3784 and 0.3413, accounting for 25.7% and 24.9% of the variation respectively. Bi-plots of the species-plot scores show that most plots were centrally located with most species being ubiquitously associated with the plots in 1954. Four plots stand out:

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- The Fayi Feb2 treatment was associated with high densities of *Ormocarpum trichocarpum*, *Acacia gerardii*, and *Combretum hereoensis*.
- The Numbi Aug1 and Aug3 treatments were associated with *Turraea nilotica*.
- The Numbi Feb3 treatment was associated with *Pterocarpus angolensis* and *Vernonia* species.

There were no apparent associations between the treatment plots in ordinal space prior to the start of the experiment.

For the 1996 data, variation on the first axis separates the burnt plots from the plots that were not burnt (control plots). The control plots were associated with high densities of *Bauhinia galpinii*, *Olea europaea*, *Zanthoxylum capensis*, *Ochna natalensis*, *Putterlickia pyracantha*, and *Bridelia mollis*. Some of these species were only associated with the control plots, namely, *Bridelia mollis*, *Olea europaea*, *Putterlickia pyracantha*, *Canthium inerme*, and *Kraussia floribunda*. These species are more than likely fire intolerant. The occurrence of fire sensitive or intolerant species on the control plots depends upon the proximity of the nearest fire refuge in which these species are found. Fire refuges are generally large termite hills, rock outcrops, and drainage lines. The control plots acted like natural fire refuges with the exception that they did not have hard, rocky or water logged soil. For this reason, the species associated with the burnt plots were also found in high densities on the control plots.

A long absence of fire can result in changes in the species composition of an area. However at this point it is unclear as to the species compositional changes that may occur because of the prolonged exclusion of fire in the Pretoriuskop region.

Change in density and diversity over time

What is quit interesting is that density on the plots in 1996 is significantly higher than on the plots in 1954. Furthermore, the diversity is also higher on the plots in 1996 than in 1954, though this is not significant ($p = 0.061$). People have often made anecdotal observations about the encroachment of *Dichrostachys cinerea* and other woody species in the Pretoriuskop area. Furthermore, some photographic evidence seems to support these observations.

What might be the driving force behind an increase in the density and diversity of woody species in the Pretoriuskop area? People were still living within the park boundaries in the Pretoriuskop region and practising small scale agricultural up until at least 1925. Furthermore, a KNP Scientific Services field assistant Maxim Signwane remembered his family being remove from the Numbi area when he was a young boy. So some 70 years ago the Pretoriuskop region was still inhabited. These people harvested trees and fruit they practised agriculture and they kept livestock (Baloye pers. com. 1997). This increase in density and diversity may be a direct result of the exclusion of man inhabiting the area.

Conclusion

The two aspects of a fire regime held constant (frequency and timing) in this experiment affect the woody vegetation composition and diversity differentially. A greater understanding of these impacts will enhance our understanding of fire as an ecosystem process. What is important is translating these results to the landscape level. The fire history of the KNP has been recently captured into onto a spatial database. With this data, results from the KNP experiment can be extrapolated to the landscape level and can be tested.

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17.2 THE ROLE OF THE EXPERIMENTAL BURN PLOTS (EBP) IN VALIDATING WOODY VEGETATION THRESHOLDS FOR POTENTIAL CONCERN (TPC) WITH RESPECT TO THE MONITORING OF MANAGEMENT STRATEGIES IN THE KRUGER NATIONAL PARK (KNP).

This paper was presented as a talk at the Kruger National Park Research Conference. Skukuza, August 1998.

SP O'Regan & ETF Witkowski

Introduction

The management of land for conservation purposes is and has long been a controversial issue. At one end, there are those who advocate intervention - which often benefits a few key species - and on the other end those who advocate non-intervention - called the Wilderness conservation ethic. There are gradients of different approaches between these two extremes. However, irrespective of the management strategy one problem often still remains, which is that of not having enough precise information. Fire management in most conservation areas is no exception to this.

Often a lot of emphasis is placed on trying to assess the so-called "natural" fire regime in an area. The rationale being that in the absence of more precise information about the ecological effects of different fire regimes, the best management can do is to emulate nature.

Along this vein, attempts can be made to estimate historic fire frequencies over various time spans -like pre-human or pre-industrial. However, other equally important components of fire regimes like areas burnt in past fires, fire intensity, season of fire, and type are much more difficult to estimate. Also without the aid of humans, fire regimes almost certainly varied widely over time and that variation in the fire regime itself is likely to have been ecologically important.

Robert Whelan (1995) suggests that a profitable approach to fire research might be to place more emphasis on understanding how organisms, populations, and communities respond to experimentally imposed fire regimes, than on trying to determine the historical fire regimes for an area.

The Kruger National Park (KNP) is in a position in which not only have there been studies into the history of fire in the Lowveld area, but there is also a small-scale fire experiment, which was established in the KNP in 1954. This experiment provides a long-term database that few other wilderness parks, nature reserves, or conservation areas posses.

How can data from this experiment be used for meaningful assessment of management initiatives in the KNP?

With the recent restructuring and reworking of the Mission, Vision, and Objectives of the KNP, the monitoring strategy within the park has also been reshaped. As part of the new approach to monitoring biodiversity, Thresholds of Potential Concern (TPC) have also been set for different ecosystem characteristics within the KNP. TPCs are warning lights indicating changes in monitored biodiversity that should be a cause for concern and warrant some attention.

Each TPC has both spatial and temporal bounds. The TPCs for the density of woody vegetation in the KNP are summarized in Figure 17-3. This is a change over area graph, showing the percentage of acceptable change in woody vegetation density varying with the spatial extent of that change.

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For example in any one landscape an increase in woody plant density of up to 100 percent would be acceptable, if the area in which that amount of change occurred covered less that 10 percent of the area of that landscape. For an entire landscape, an increase of only 20 percent in the density of woody plants would be accepted before there would be cause for concern.

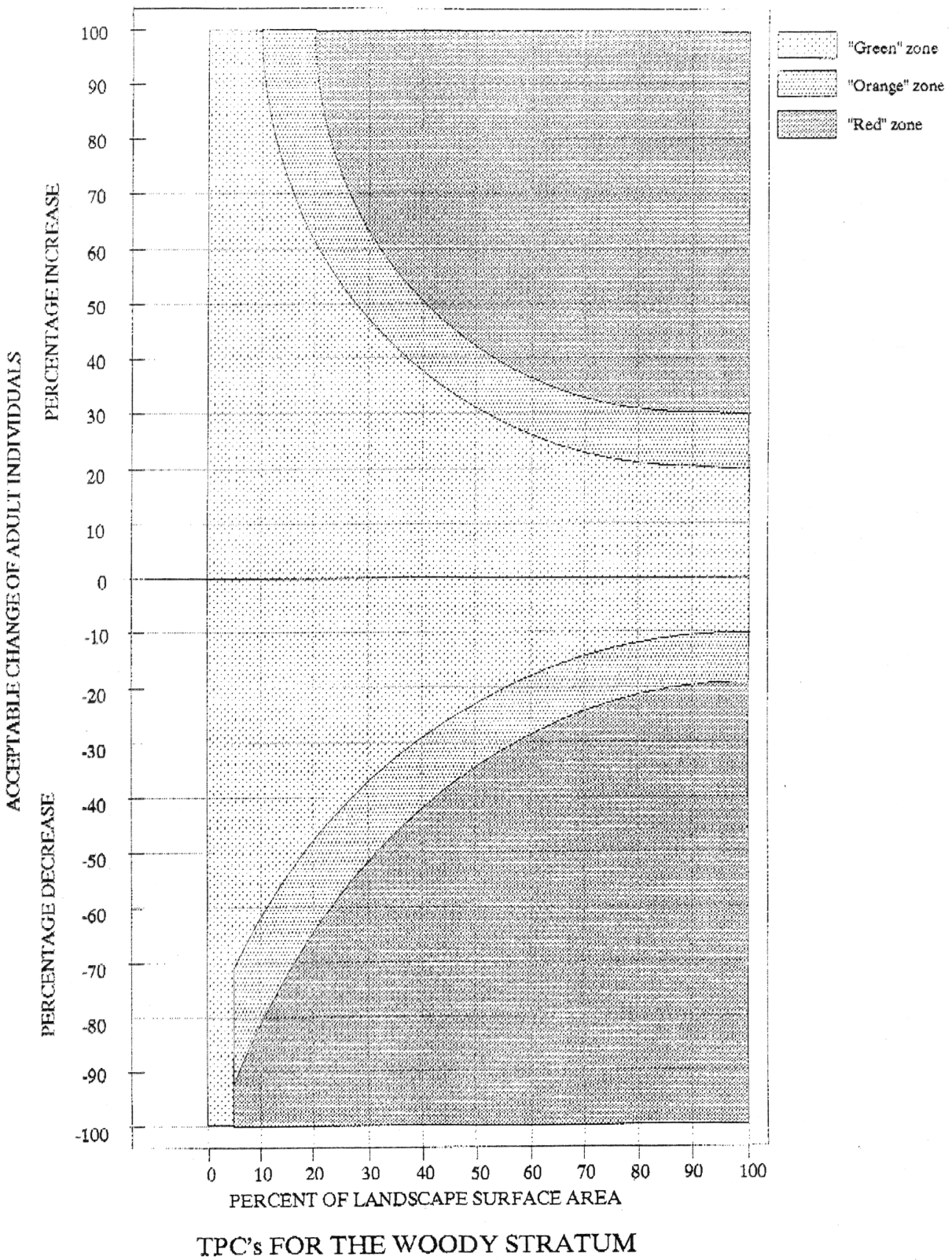


Figure 17-3: Change over area graph modelling the suggested Thresholds of Potential Concern for the density of the woody vegetation in the KNP (Provided by N Zambatis KNP Scientific Services).

The benchmark from which change is measured is any points in time at which accurate measurements have been made that are relevant to any particular TPC. In other words, there should be potential concern if a threshold level of change has been exceeded from any point in the history of quantitative monitoring within the KNP.

The Experimental Burn Plots were set up in 1954. In the Pretoriuskop Sourveld region, forty-eight plots were laid out in four replicates in different parts of the landscape. A baseline vegetation survey was conducted on each plot. The woody vegetation survey's were done with belt transects placed along the diagonals of each plot. In addition, twelve burning treatments were applied to the plots, at three return periods, namely annual, biennial, and triennial burns, and at five different times of the year, with one of the treatments being a control (no burn). A survey similar to the baseline was conducted in 1996. This provides a 42-year period over which woody vegetation change can be analysed.

What changes have there been over this 42-year period?

In almost all cases regardless of the burning treatment applied to a plot the woody plant density has increased since 1954. On only two plots out of 48 has the density decreased and in both cases by only a few percent. The trend since 1954 has been an increase in the density of woody vegetation on the plots in Pretoriuskop Sourveld. The magnitude of this increase in density ranges from 10 percent to over 700 percent since 1954. The average increase in woody plant density on these plots has been over 200 percent, which far exceeds the thresholds of potential concern that have been suggested for the woody vegetation in the KNP.

Can these trends be seen as being applicable to the entire Sourveld landscape?

The median inter-fire period for the whole Pretoriuskop landscape is 2 years, and the inter-fire periods of the different treatments are 1 year, 2 years, and 3 years. The fire return periods of the treatments applied to the EBPs are comparable to the median fire return period of the Pretoriuskop landscape. The timing of the experimental fires is also comparable to those in the rest of the landscape. What is important though is that an increase in density has occurred regardless of the treatments applied to the plots.

Anecdotal observations made by research staff and section rangers seem to support this evidence, and suggest that this increase in woody plant density on the EBPs to some extent reflects what has occurred at the landscape level in the Pretoriuskop Sourveld. Photographic evidence also appears to support these observations.

The Threshold for Potential Concern for an increase or decrease in density of trees and shrubs at the landscape level is 20 percent. Since 1954 the density of woody vegetation in the Pretoriuskop Sourveld has increased, and appears to exceed the suggested TPCs, by at least eight times.

Should there be eight times as much potential for concern then?

Along with the increase in density, there has been an increase in the number of species recorded on the plots, from 68 species in 1954 to 88 in 1996. There was however no significant increase in the species diversity between 1954 and 1996. This is because the species diversity was calculated using Shannon and Simpson's Diversity Indices. These indices calculated species diversity as the number of species relative to the total number of individuals surveyed. In 1996, eighty-eight species were recorded in a survey of over 35000 individuals, and in 1954, sixty-eight species were recorded from over 9000 individuals. Therefore, the calculated species diversity in 1954 is similar to the species diversity calculated for 1996. This is a mathematical issue though; the point being that previously rare and unrecorded species on these plots are now being found in higher numbers and are being recorded.

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What might be the driving force behind this increase in density of the woody species in the Pretoriuskop area?

The Pretoriuskop area was still inhabited by humans less than 75 years ago. People living in the area utilised trees to build houses and animal shelters. In addition, the fruits and seed of many tree species were harvested. Small-scale agriculture was practised both near homestead's and further away in special areas that were well suited for growing certain crops, and livestock was kept. Furthermore, towards the latter half of last century and the beginning of this century, white farmers used the Pretoriuskop area as a winter pasture for sheep and cattle, and the area was burnt almost annually to provide green palatable grass for grazing. The increase in density and numbers of some uncommon species since 1954 may be a direct result of the exclusion any one or all of these human activities from the Pretoriuskop area.

William Bond (1998) suggests that an increase in global CO_2 levels may be another possible reason for the increase in woody plant density in the Pretoriuskop area. Savanna ecosystems appeared in the late Miocene period some 5 to 23 million years ago. The Miocene was a time of warmer global climates than those in the proceeding Oligocene, or the following Pliocene, and atmospheric CO_2 levels dropped below 500ppm during this period. This drop in CO_2 favoured the expansion of C_4 grass dominated ecosystems. There is evidence that global CO_2 levels are increasing and it is predicted that the CO_2 levels will return to above 500ppm by 2050.

How can an increase CO_2 levels favour woody species in fire prone environments?

In savanna ecosystems, many woody species respond vegetatively to fire damage by resprouting. Often individuals remain in a stunted multi-stemmed condition for many years, as they are unable to escape the herbaceous layer between fire events. Individuals caught in this danger zone are classified as either sprouters or Gullivers. These individuals sprout from the base and often form a lignotuber below ground. The difference between sprouters and gullivers is in their strategy for surviving within the danger zone.

Gullivers form obscenely large underground storage organs, and in between fire events, they put all their energy and resources into trying to escape the fire danger zone. Invariably gullivers do not become sexually mature until they have reached a critical height at which point they have escapes the fire danger zone. Sprouters on the other hand have much smaller below ground storage organs, and in between fires, resources are allocated to both growth and reproduction.

It seems that these below ground storage organs are carbohydrate sinks, containing mainly starch. They can almost be seen "large potatoes" supporting the plants through rough times and continual fire damage. The bigger the storage organ the more competitive an individual will be in a fire prone environment.

Under elevated CO_2 conditions, potato plants (*Solanum tuberosum*) and sweet potato plants (*Ipomoea batatas*) produce more and larger tubers than those under CO_2 depleted conditions (Bhattacharya *et al.* 1985, Ludewig *et al.* 1998, Miglietta *at al.* 1998). If elevated CO_2 conditions result in more carbon allocation to below ground storage organs then this may result in an increase in the long-term competitiveness of some woody species. Individuals may be able to persist beyond their previous potential and thus resulting in a larger viable population of fire retarded woody plants than there may have been in the past.

CO2 levels have been increasing since the industrial revolution, however since the 1950's the CO_2 levels have increased at a much more rapid rate.

Can this partially explain for the relatively quick increase in woody plant density since 1954?

In all likely hood both explanations for the increase in density of the trees and shrubs in the Sourveld hold some ground. What is not known though is the relative importance of each. Studies into the potential

magnitude of anthropogenic impacts on the environment have and are still being conducted. Furthermore, the future and prospective continuance of the EBPs appears to lie in their ability to provide data that may be useful for monitoring the effects of global climate change on the vegetation structure in the KNP.

When managing biodiversity in all its natural facets and fluxes it is essential that we understand what these facets and fluxes are. For example, a flux at one spatial or temporal scale may have directionality at another scale.

Long-term databases can be used to provide a context for the management of certain aspects of biodiversity. Management practices are often implemented based on the assumption that certain long-term processes are operating in a community. However, there is often not enough information or data against which we can test for these long-term processes or trends. Furthermore, many organisms have long life spans, and effects of even single disturbance events on their lives are often not evident for many years.

Long-term studies like the EBPs are rare, and are often started with a particular question in mind, that question or purpose, though, does not restrict their applicability in other areas. The relatively controlled nature and well-documented histories inherited with long-term studies are invaluable for assessing current and historical management initiatives.

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17.3 RESPONSES OF THE WOODY VEGETATION, IN THE PRETORIUSKOP SOURVELD SAVANNAS OF THE KRUGER NATIONAL PARK (KNP), TO FIRES BURNT AT DIFFERENT FREQUENCIES.

This paper was presented as a poster at the Grassland Society of Southern Africa (GSSA) Conference. Warm Baths, February 1999.

SP O'Regan & ETF Witkowski

Abstract

Fire plays an important role in the maintenance of both the structure and function of savanna ecosystems. In the early 1950's, controversy surrounded the formulation and implementation of a fire management policy in the Kruger National Park (KNP). This controversy highlighted the lack of understanding of the role fire played in this predominantly arid savanna ecosystem. In 1954, a fire experiment was started in the KNP the aim of the experiment was to provide a scientific basis for fire management policies. The original objective of the experiment was to determine which fire regime would best produce a desirable vegetation structure and composition for different parts of the park.

The experimental layout was a randomised block design in which twelve fire treatments were replicated four times in each of four major vegetation zones that had been defined in the KNP by Van Der Schijff (1958). The twelve treatments were a no burn, an annual August burn, and biennial and triennial burns at five different times of the year, namely February, April, August, October, and December. Prior to the start of the experiment, a baseline vegetation survey was done on each plot. The woody vegetation was surveyed with a belt transect (1.5mX310m) placed along the two diagonals of each plot. Individuals in each transect were identified and classified as either single or multi-stem. In 1996, a similar survey was conducted on the plots in the Pretoriuskop sourveld vegetation zone of the KNP. This provides us with a 42-year period over which the woody vegetation responses to the fire treatments in this area can be analysed. The effects of the different fire frequencies on the structure of the tree and shrub community within the lowveld sourveld will be presented. Furthermore, the significance of these data for interpreting the effects of past fire management policies in this area will also be discussed

Introduction to the KNP fire experiment

The KNP fire experiment is a large field experiment in which twelve fire treatments have been applied to four different vegetation types within the park over the past 45 years. The twelve treatments comprised four fire frequencies or return periods namely annual, biennial, and triennial and no burn. Before starting the experiment, a baseline vegetation survey was conducted on the experimental plots in 1954. In 1996, a similar survey was done on the plots in the Pretoriuskop sourveld. This provided a 42-yr period over which the fire treatment effects on the woody vegetation in the Pretoriuskop area were analysed.

The Pretoriuskop sourveld savannas

The Pretoriuskop sourveld is located in the south-western region of the KNP. It is a mesic savanna experiencing a relatively high annual rainfall of 744mm (Gertenbach 1983, Venter and Gertenbach 1986). It is also a nutrient poor savanna in which the soils on the watersheds are deeply leached (Gertenbach 1983). Post fire grass and herbaceous vegetation recovery tends to be relatively quick and the fire return periods range from annual to triennial burns. The median fire return period in the Pretoriuskop sourveld between 1953 and 1996 was 1.9yrs (Van Wilgen *et al.* 2000)

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Woody savanna species response to fire

Most woody savanna species respond to fire damage by vegetatively resprouting. If the canopies are burnt severely, individuals will often sprout from the base. These woody individuals often remain stunted, because they compete with grasses and herbs, and they are heavily browsed. These individuals can remain in a stunted multi-stemmed condition for many years if consecutive fires are intense and the intervals between fires are too short to allow them to escape to a fire resistant height.

Many studies have shown that a reduction in fire frequency or intensity in savanna ecosystems results in an increase in the number of woody plants and their height, canopy volume and biomass (Scholes and Walker 1993). The converse has also been found to be true and an increase in fire frequency or intensity has been found to cause reductions of woody plant density, canopy volume, and biomass.

Similar trends have been recorded in the KNP for the woody vegetation of the Pretoriuskop sourveld.

The effect of fire return period on the vegetation structure of the woody vegetation of the Pretoriuskop sourveld

The vegetation structure on the experimental plots can be quantified and analysed in three major categories, namely density, composition, and phenology.

- Density is calculated as the number of individuals per hectare on each plot.
- Composition is the species compliment and abundance on the plots. This is assessed in a number of ways ranging from species richness (Menhinick's) and diversity (Simpson's) indices to Canonical analyses of the species on the experimental plots.
- Phenology describes the physical structure of the woody vegetation. Ratios of the number of single stemmed individuals to the number of multi-stemmed individuals were calculated and further analyses on the height structure of each plot were done.

The effect of fire frequency on the density of the woody vegetation

Woody plant density is significantly higher on the plots that were not burnt than on the plots that were burnt ($p = 0.037$). This is consistent with hypothesis on “bush encroachment” in savannas ecosystems, where in the absence of fire, woody plant density tends to increase.

The mean height of the plants on plots burnt annually is significantly lower than plots burnt triennially and not burnt ($p = 0.021$ and $p = 0.029$ respectively). As the inter-fire period increases, the numbers of individuals that escape to a fire resistant height increases, and these plants no longer remain in a stunted form not escaping the herbaceous and grass layer.

The effect of fire frequency on the physiognomy of the woody vegetation

There are significantly more single stem individuals on the plots that were not burnt than on the plots that were burnt ($p < 0.000$). This is expected since most woody savanna plants sprout in response to fire damage from either epicormic or basal coppice buds depending on the severity of the fire damage to the plants. Plants resprouting from basal coppice buds typically become multi-stemmed individuals. In the absence of fire, there is no top kill from fire and only mechanical damage to the plants may cause them to coppice from the base. It is for this reason that there are significantly more single stem individuals on the control plots relative to multi-stem individuals.

There are also significantly higher numbers of single stem individuals on the plots burnt triennially than on those burnt annually ($p = 0.017$). This is because in the first year (and possibly the second year) after a fire, individuals coppicing from the base often channel resources into the growth of a number of stems. However,

it appears that after a certain height is reached resources are then be channelled into the growth of one or two primary stems. Either the other stems become moribund or they remain reduced depending on the species and time since the last fire event.

The effect of fire frequency on the composition of woody vegetation

Species richness and diversity are significantly higher on plots that were not burnt than on the plots that were burnt. This is because fire intolerant and fire sensitive species occur on these plots as well as fire tolerant species.

Fire sensitive and intolerant species usually occur on or near fire refuges like large termite hills, rocky outcrops, koppies, and drainage lines. The unburned plots are fire refuges, however, unlike natural fire refuges they do not have hard, rocky or water logged soil. For this reason, fire tolerant species associated with the burnt plots also occur on the unburned plots.

A Canonical Analysis was performed on the species by plot densities from the 1996 data set. The first four plot score axes of a Correspondence Analysis on the baseline data (1954) were used as covariates during the analysis, and the ranked treatment return periods were used as environmental variables.

The Eigenvalue for the first axis of the canonical analysis is 0.232 accounting for 16.3% of the variation. The species environmental correlation is 0.871 and is statistically significant (p=0.001 - tested by a 999 permutation Monte Carlo test). The first canonical axis separated the plots burnt at different frequencies. This axis was used to describe differences in species compliment under different fire frequencies in the model below (Figure 17-4).

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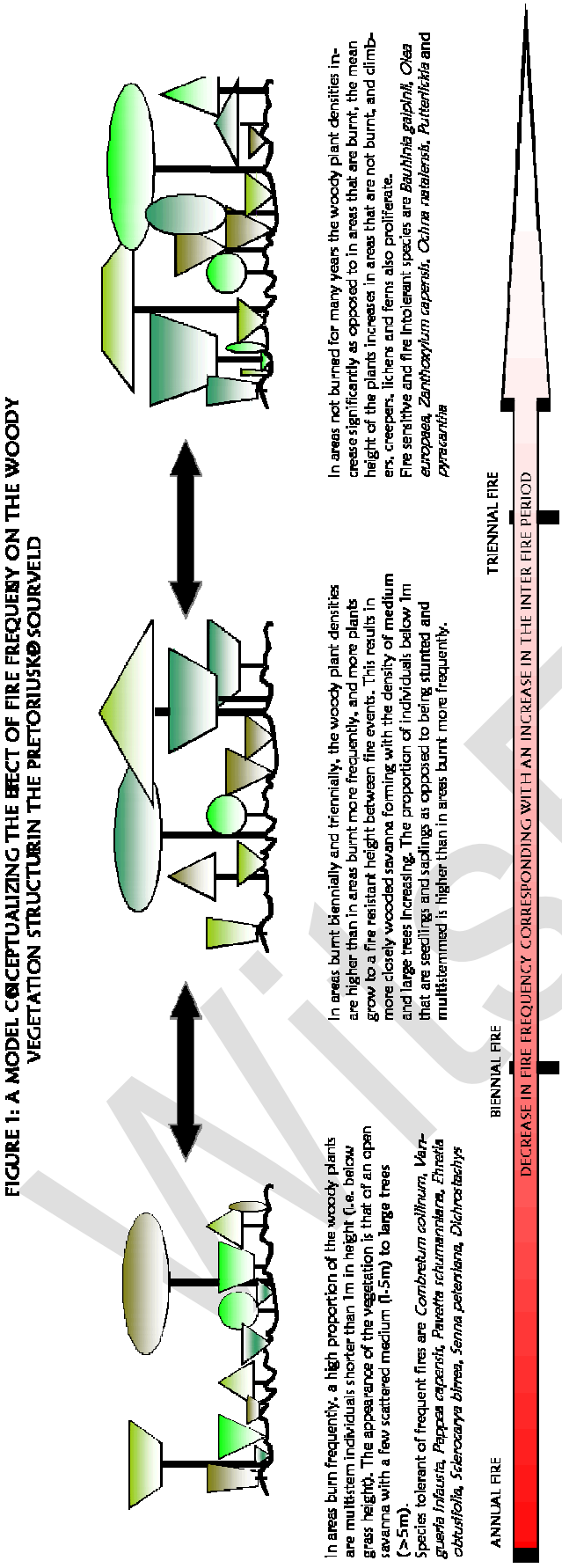


Figure 17-4: Model showing the effect of fire frequency on the structure and composition of the woody vegetation of the Pretoriuskop sourveld.

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17.4 THE EFFECT OF DIFFERENT FIRE RETURN PERIODS ON THE STRUCTURE AND COMPOSITION OF WOODY VEGETATION IN THE PRETORIUSKOP SOURVELD

This paper was presented as a talk at the Kruger National Park Research Conference. Skukuza, April 2000.

This paper is almost identical to the poster presented at the 1998 GSSA conference in Warm baths.

SP O'Regan & ETF Witkowski

Pretoriuskop is classified as a nutrient poor mesic savanna with an average annual rainfall of about 744ml (Gertenbach 1983, Venter and Gertenbach 1986). The soils on the watersheds of the Pretoriuskop region are deep, sandy, and leached (Gertenbach 1983).

Post fire grass and herbaceous vegetation recovery in the Pretoriuskop landscape tends to be relatively quick and the inter-fire periods range from 1 year to 3 years. The median inter-fire period over the past 50yrs is 1.9yrs (Van Wilgen *et al.* 2000).

Woody savanna species response to fire

Most woody savanna species respond to fire damage by vegetatively resprouting. If the canopies are burnt severely, individuals often sprout from the base. These individuals often become stunted as they compete with grass and herbaceous plants, and are heavily browsed. These individuals can remain in a stunted multi-stemmed condition for many years if consecutive fires are too intense or the intervals are too short to allow them to escape to a fire resistant height.

Many studies have shown that a reduction in fire frequency or intensity in savanna ecosystems results in an increase in the number of woody plants and their height, canopy volume and biomass. The converse has also been found to be true in that an increase in fire frequency or intensity results in reductions of woody plant density, canopy volume, and biomass.

Similar trends have been recorded in the KNP for the woody vegetation of the Pretoriuskop sourveld.

The effect of fire return period on the vegetation structure of the woody vegetation of the Pretoriuskop sourveld

Using the data available, vegetation structure on the experimental plots can be quantified into three main categories, namely density, composition, and phenology.

Density is calculated as the number of individuals per hectare on each plot.

Composition is the species compliment and abundance on the plots. This is assessed in a number of ways ranging from species richness (Menhinick's) and diversity (Simpson's) indices to Canonical analyses of the species on the experimental plots.

Phenology describes the physical structure of the woody vegetation. Ratios of the number of single stemmed individuals to the number of multi-stemmed individuals were calculated and further analyses on the height structure of each plot were done.

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The effects of fire return period, on the density of the woody vegetation.

Woody plant density is significantly higher on the plots that were not burnt than on the plots that were burnt ($p = 0.012$). This is not surprising, since it is consistent with hypothesis on "bush encroachment" in savannas ecosystems, where in the absence of fire, woody plant density tends to increase.

The densities between the plots that were burnt at different frequencies did not differ significantly. However, plots burnt annually did tend to be denser than the plots burn biennially and triennially.

It is difficult to make any substantial statements regarding the effect of increasing inter-fire period on the density of woody vegetation in the Pretoriuskop sourveld since. This is because the density of the woody vegetation on almost all plots regardless of treatment applied increased between 1954 and 1996.

The effect of fire frequency on the physiognomy of the woody vegetation

There are significantly more single stem individuals on the plots that were not burnt than on the plots that were burnt (0.000). This is expected since most woody savanna plants sprout from either epicormic or basal coppice buds in response to fire damage depending on the severity of the damage to the plants. Plants resprouting from basal coppice buds typically become multi-stemmed individuals. In the absence of fire, there is no top kill from fire and only mechanical damage to the plants may cause them to coppice from the base. It is for this reason that there are significantly more single stem individuals on the control plots relative to multi-stem individuals.

There are also a significantly higher number of single stem individuals on the plots burnt triennially than on those burnt annually ($p = 0.017$). This is because in the first year (and possibly the second year) after fire individuals that coppice from the base often allocate resources into the growth of a number of stems. However, after a certain height is reached resources are then channelled into the growth of one or two primary stems. Either the other stems become moribund or they remain reduced depending on the species and time since last fire.

The effect of increasing the inter-fire period on the height structure of the woody vegetation is also quite evident. The mean height of the plants on plots burnt annually is significantly shorter than plots burnt triennially and not burnt ($p = 0.021$ and $p = 0.029$ respectively). As the inter-fire period increases, the numbers of woody individuals that escape to a fire resistant height increases and they are no longer trapped stunted below the grass height.

The effect of fire frequency on the composition of woody vegetation

Species richness and diversity are significantly higher on the plots not burnt than on the plots that were burnt. This is because fire intolerant and fire sensitive species occur on these plots as well as fire tolerant species.

Fire sensitive and intolerant species usually occur on or near fire refuges like large termite hills, rocky outcrops, koppies, and drainage lines. The unburned plots are fire refuges, however, unlike natural fire refuges they do not have hard, rocky or water logged soil. For this reason, fire tolerant species associated with the burnt plots also occur on the unburned plots.

A canonical analysis was done on the species by plot densities from the 1996 data set. The first four plot score axes of a correspondence analysis on the baseline data (1954) were used as covariates for the analysis, and the ranked treatment return periods were used as environmental variables.

The Eigenvalue for the first axis of the canonical analysis is 0.232 accounting for 16.3% of the variation. The species environmental correlation is 0.871 and is statistically significant ($p=0.001$ - tested by a 999

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permutation Monte Carlo test). The first ordination axis separated the plots burnt at different frequencies. This axis was used primarily to describe changes in species compliment under different fire frequencies.

The linear axis in Figure 17-5 represents an increase in the fire return period. The axis representing inter-fire period does not correspond to once off fire events but rather the mean (or median) inter-fire period over a long time (i.e. 42 yrs), and the timing and intensity of fires at these return periods are not constant.

A high frequency fire regime (i.e. annual) causes a decrease in the density of woody plants, and changes the physical structure of the woody vegetation. Woody plants that are well established often cannot escape the grass and herbaceous layer between fire events, and they are often burnt back at each fire event. These individuals remain in a stunted multi-stemmed form until they can escape the grass layer and reach a fire resistant height, or until they die. Many savanna species, although fire tolerant, cannot persist when the inter-fire periods are too short. However, some species such as *Turraea nilotica* and *Catunaregam spinosa* are tolerant of frequent fires (i.e. Annual fire). Other species tolerant of frequent fires are listed in Figure 17-5.

Areas burnt biennially and triennially have a higher woody plant density than areas burnt more frequently. In areas burnt annually and biennially interval between fires is also long enough for plants to grow to a fire resistant height. Furthermore, the proportion of seedlings relative to stunted multi-stemmed individuals below 1m tall is also higher in areas burnt less frequently. The result is that the vegetation becomes more closely wooded and the density of medium and large trees increases.

This trend continues as the period between successive fires is increased. Areas not burned for many years (the data base time span being 42 years) become woodland savannas. The woody plant density and mean plant height increases significantly in comparison with burnt areas. Fire sensitive species like *Bauhinia galpinii*, *Olea europaea*, *Zanthoxylum capensis*, *Ochna natalensis*, and *Putterlickia pyracantha* are found on these plots and climbers (creepers), ferns and lichen proliferate.

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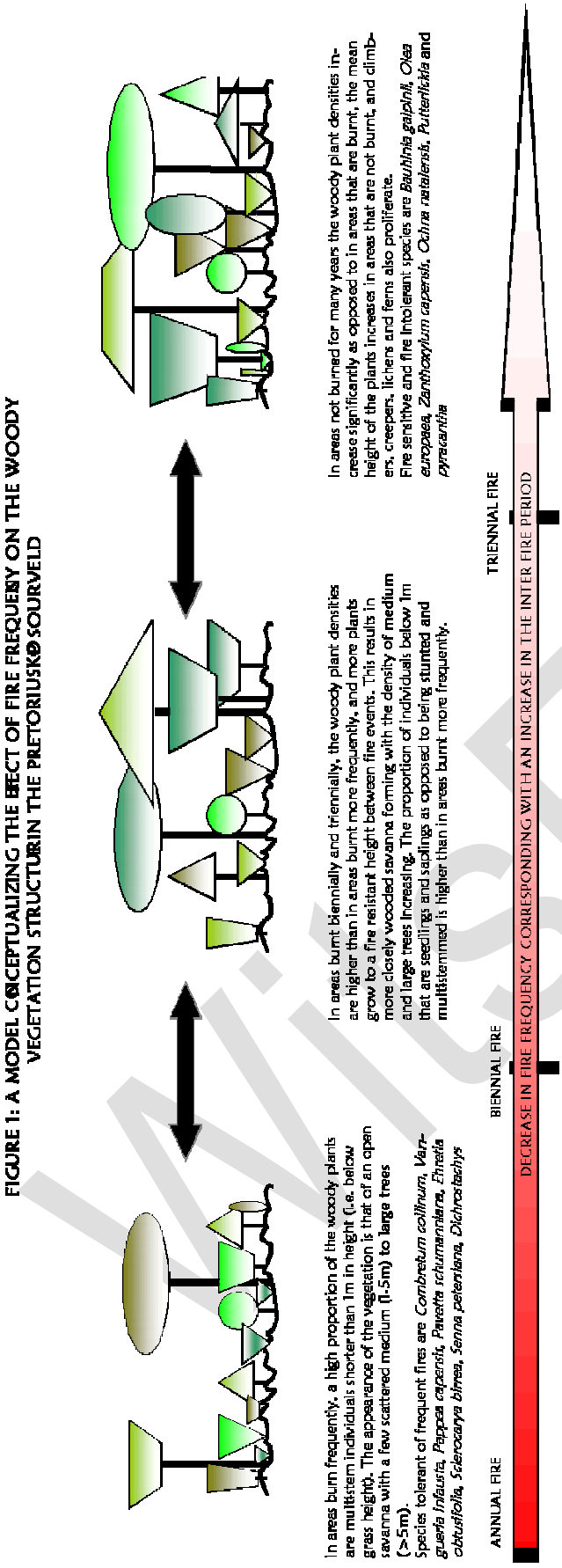


Figure 17-5: Model showing the effect of fire frequency on the structure and composition of the woody vegetation of the Pretoriuskop sourveld.

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17.5 LONG-TERM EFFECTS OF FIRE ON THE SPECIES AND STRUCTURAL DIVERSITY OF THE TREES AND SHRUBS IN THE SOURVELD BUSHVELD OF THE KRUGER NATIONAL PARK

This paper was presented as a talk at the Kruger National Park Research Conference. Skukuza, April 2003.

SP O'Regan & ETF Witkowski

Introduction

The formulation and implementation of a fire management policy in the Kruger National Park (KNP) in the early 1950's was characterised by controversy and disagreement (Annual report 1951). The controversy highlighted the lack of data and understanding of the role that fire played in this predominantly arid savanna ecosystem. In 1954 in response to this controversy the Experimental Burn Plot experiment was started, the aim of the experiment being to provide a scientific basis for fire management policies within the KNP.

The experimental design of the fire experiment was a pseudo-randomised block design in which 12 fire treatments were replicated four times each, in each of the four major veld types defined in the KNP by Van Der Schijff (1958). The four veld types were, the sourveld of Pretoriuskop, the Combretum veld surrounding Skukuza, the Knob-thorn - Marula veld near Satara, and the Mopane veld between Shingwedzi and Letaba. The twelve treatments were no fire, annual fire in August, and biennial and triennial fires at five different times of the year, namely February, April, August, October, and December.

Four replicates of twelve plots each were laid out in the Pretoriuskop sourveld. The four replicates, named after nearby landmarks, are Numbi, Shabeni, Kambeni, and Fayi. The twelve treatments were randomly assigned to the plots within each replicate. These treatments were applied between fastidiously between 1954 and 1996.

There is an extra plot in the Kambeni replicate. This is because soil was used from this plot to construct the road between Numbi gate and Pretoriuskop rest camp in 1954 (Annual report 1955). The affected treatment (October biennial) was relocated to the second row of the replicate in 1956.

Methods

Data collection

In 1954 a baseline survey on each of the plots was done. The woody vegetation was surveyed by means of two belt transects placed along the diagonals of each plot. In 1996, a similar survey was done on the Pretoriuskop set of plots.

The data recorded in 1996:

- Plants within each line were identified.
- The height was measured.
- Whether the individual was live or dead
- Whether the individual had a single stem or multi stems.
- Stem diameter in centimetres for single stem individuals was measured.
- Base diameter in centimetres (coppice diameter) for multi-stem individuals was measured.

Estimating height for the 1954 data

The heights of the plants were not measured during the 1954 survey; the plant heights were estimated using the 1996 survey data.

Estimating height class

1. Each individual in the 1996 survey was classified into one of eight stem or coppice diameter classes, which were used in the 1954 surveys (Table 17-1).

Table 17-1: The single-stem and multi-stem diameter classes used to classify individuals during the 1954 baseline survey (Van Der Schijff 1958).

Basal stem class	Diameter class (cm)	Diameter class code
Multi	0.00 – 30.48	**S01**
	30.48 – 91.44	**S13**
	> 91.44	**S3**
Single	0.00 – 2.54	**T01**
	2.54 – 7.62	**T13**
	7.62 – 12.7	**T35**
	12.7 – 17.78	**T57**
	> 17.78	**T7**

2. Each individual in the 1996 survey was also classified into one of four height classes (Table 17-2).

Table 17-2: The height classes used to classify individuals in the 1996 survey.

Height class (m)	Height class code
0 – 1	**H01**
1 – 3	**H13**
3 – 5	**H35**
> 5	**H5**

3. Estimating the height class for species common to the 1954, 1959, and 1996 surveys:

The relative number of individuals per height class for each diameter class was calculated from the 1996 data. These ratios were used to estimate the number of individuals in each height class within each diameter class for each species in the 1954 and 1959 data.

4. Estimating the height class for species present in the 1954 and 1959 surveys but not present in 1996:

The height class ratios for each diameter class were calculated for the entire 1996 dataset. These ratios were used to estimate the number of individuals in each height class within each diameter class for those species present in the 1954 and 1959 surveys and not in the 1996 survey.

Estimating height

The mean height for each of the four height classes (0-1 m, 1-3 m, 3-5 m and >5 m) was calculated using the 1996 data. These mean heights were used to estimate the height of each individual in the 1954 and 1959 surveys based on the individuals estimated height class.

Analysis

Diversity is a measure of the variability of composition (Pielou 1975). Composition can be any categorization or grouping used to classify a collection of individuals. Diversity has two distinct components: 1) the number of different groups in a collection, and 2) the relative amount of each group in a collection (Huston 1994).

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Two aspects of woody vegetation diversity were investigated, namely taxonomic diversity and structural diversity

Taxonomic diversity

Taxonomic diversity was measured at the species level. The designation of what represented a species unit was taken to be the classification of woody species according to Palgrave (1991).

Structural diversity

The woody individuals in each survey were grouped using two structural classifications, namely the single and multi stem diameter classes (Table 17-1) and the height classes (Table 17-2). The height and diameter classifications were combined into a single structural classification. Therefore the height, diameter, and whether the individual was single-stemmed or multi-stemmed were represented in a single combined structural classification. This structural classification comprised 32 structural groups.

Indices of diversity

The diversity of the woody vegetation on the Pretoriuskop EBPs was measured for each plot using four indices that quantify the different components of diversity. The indices used were:

- The number of species of structural groups.
- Menhinick's species of structural richness index.
- Shannon's species or structural diversity index.
- Shannon's species or structural evenness index.

Number of species or structure groups

The number of groups (s_j) is a count of the number of species or structural groups on plot *j*. This index is used to quantify the first component of diversity.

Menhinick's species or structural richness

Menhinick's index of richness (sm_j) calculates the number of species or structural groups (s_j) relative to the square root of the number of individuals (n_j) on a plot *j* (Brower and Zar 1977).

$$sm_j = \frac{s_j}{\sqrt{n_j}}$$ **Menhinick's richness index.**

This index quantifies the first component of diversity relative to the sample size, and consequently standardises the estimation for different collection sizes.

Shannon's species or structural diversity index

Shannon's index of diversity is a measure of the uncertainty of predicting the identity (class) of an individual chosen randomly from a population (Brower and Zar 1977). It quantifies the combined components of diversity, namely the number of groups and relative abundance of each group in a collection of individuals.

$$H'_j = -\sum p_i \ln p_i$$ **Shannon's diversity index.**

Where H'_j is Shannon's diversity, and p_i is calculated as $p_i = \frac{n_i}{n_j}$, where n_i is the number of individuals in species or structural group *i* and n_j is the number of individuals on plot *j*.

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Shannon's species or structural evenness index

Shannon's evenness is a measure of the nearness of the calculated diversity index to the maximum possible diversity, where maximum diversity occurs when all species are evenly proportioned (Brower and Zar 1977).

$$J'_j = \frac{H'_j}{H\max'_j}$$ **Shannon's evenness index.**

Where J'_j is Shannon's evenness and H'_j is Shannon's diversity. $H\max'_j$ is calculated as $H\max'_j = \ln s_j$, where s_j is the number of species or structural groups on plot *j*.

Analysis of variance (ANOVA) and analysis of covariance (ANCOVA)

ANOVA and ANCOVA analyses were used to test for the effects of the different treatments on various measures of species and structural diversity calculated.

The size of the tests

The size (α) of the ANOVA, ANCOVA, and Tukey tests was set at 0.10. That is the probability of rejecting a null hypothesis was set at 0.10.

The data groupings testing the treatment effects

The effect of fire frequency on the woody vegetation of the Pretoriuskop sourveld

Two different plot groupings were used to test for the effects of fire frequency on the wood vegetation of the Pretoriuskop sourveld. This was because the experimental design of the Experimental Burn Plot (EBP) experiment was not symmetrical. Five fire treatments were burnt biennially and triennially each in February, April, August, October, and December. However, only one fire treatment was burnt annually in August.

The two plot groups were:

- Frequency (no Aug1): in which the annual August treatments were excluded from the analyses so as not to confound frequency effects with timing effects because there were no annual treatments at any other time of the year.
- Frequency (Aug and Cont): in which only the August annual, biennial, and triennial treatments and the control treatments were used in the analyses.

The effect of fire timing on the woody vegetation of the Pretoriuskop sourveld:

- In the testing the effects of fire timing on the woody vegetation of Pretoriuskop the annual August treatment was excluded. This was so as not to confound the timing effects with frequency effects because there was only one annual treatment in August and at no other time of the year.

The combined effect of fire frequency and timing on the woody vegetation of the Pretoriuskop sourveld:

- This analysis tests each fire treatment as individuals irrespective of the treatment frequency and timing.

The effect of not burning on the woody vegetation of the Pretoriuskop sourveld:

- This analysis tests the effect of not burning on the woody vegetations of the Pretoriuskop sourveld. The data collected on the control plots in the 1954, 1959, and 1996 surveys were used in this analysis.

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Changes in the woody vegetation density, structure, and composition in the Pretoriuskop region since 1954:

This analyses tests for changes in the woody vegetation of the Pretoriuskop sourveld at the landscape level between 1954 and 1996.

The covariates for the ANCOVA's

In the Analyses of Covariance (ANCOVA), the 1954 data were used as the covariates when performing the analyses on the 1996 data.

Post hoc analyses

The Tukey Student's t statistic was used for post hoc comparisons to determine which pairs of means differed significantly in the ANOVA's and ANCOVA's

Horn's index of community similarity

Horn's index of community similarity was calculated to compare the similarity of woody vegetation species diversity and structural diversity between treatment plots.

Horn's index of community similarity is based on Shannon's diversity index. The similarity of two communities is calculated by comparing their combined diversity, with their potential maximum and minimum diversity. Horn's index is 0 when the two communities have no species in common and 1 when the species composition and relative abundances are identical (Brower and Zar 1977).

Cluster analyses of Horn's similarity indices

The Horn's similarity indices were subjected to hierarchical cluster analyses to detect natural groupings in data. The distance was computed using Pearson distance measure, and the cluster-linking algorithm used was Ward's method (Ward 1963).

Mapping cluster groups in space

Using a map of the treatment plots the clusters derived in the cluster analyses were mapped onto the treatment plots. This with a background of a vegetation classification of the Pretoriuskop landscape created by the SADF in the mid 1980's provides an effective means for interpreting the results.

Results

Testing the effects of fire timing in the woody vegetation

(The August annual treatments were excluded from these analyses.)

- The mean height on plots burnt in February is significantly lower than on plots not burnt and plot burnt in October.
- Tree equivalents index is significantly higher on plots not burnt than on plots that were burnt.
- The single stem ratio is significantly higher on plots not burnt than on plots burnt. Furthermore, it is significantly lower on plots burnt in August than on plots burnt in April, December, and February.
- The number of species is significantly higher on plots not burnt than on plots burnt in April, August, and October.
- Species diversity is significantly higher on plots not burnt than on plots burnt in April, August, and October. Furthermore, plots burnt in February have significantly higher species diversity than those burnt in April.
- The post hoc analyses were not able to elucidate any significant differences in the number of structure groups between plots burnt at different times of the year.

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- Structural diversity is significantly higher on plots not burnt than on plots burnt in April, August, and February.
- Structural evenness is significantly higher on plots not burnt than on those burnt in August and February. Furthermore, plot burnt in October have a significantly higher structural evenness than those burnt in February.

Testing the effects of fire frequency on the woody vegetation (part 1)

(The August annual treatments were excluded from these analyses.)

- Density is significantly lower on the plots burnt biennially and triennially than on those not burnt.
- Tree equivalents indices are significantly higher on plots that are not burnt than on those that are burnt. The general trend is that as the return period between fires increases so the phytomass of the woody vegetation increases.
- The ratio of single stem individuals is significantly higher on the plots not burnt than on the plots that were burnt. The general trend is that the single-stem to multi-stem index increases as the inter-fire period increases.
- The number of species is significantly higher on the plots not burnt than on those that are burnt.
- Species diversity is significantly higher on the plots not burnt than on those that were burnt.
- Structural diversity is significantly higher on the plots not burnt than on the plots that were burnt. Furthermore, the structural diversity on the plots burnt triennially was significantly higher than on those burnt biennially.
- Structural evenness is significantly higher on the plots not burnt than on the plots that were burnt.

Testing the effects of fire frequency on the woody vegetation (part 2)

(Only the Control and August annual, biennial, and triennial treatments included in these analyses)

- Mean height is significantly taller on the plots not burnt than on those burnt annually. The trend indicates that as the inter-fire period between fires increases so the mean height of the woody vegetation increases.

- Tree equivalents increases significantly between the plots burnt annually and those not burnt. The trend indicates that as the inter-fire period between fires increases so the phytomass (tree equivalents) of the woody vegetation increases.

- The ratio of single stem individuals is significantly higher on the plots not burnt than on those burnt. This is expected since many savanna trees and shrubs respond to fire damage by resprouting from the base. However once they have reached a critical height most often one stem dominates and the others die off as resources are channelled into the growth of a single stem. The trend is one of an increasing ratio of single stem individuals as the return period between fires increases.

- The number of species is significantly higher on the plots not burnt than on those burnt. The trend is one of an increase in the number of woody species as the return period between fires increases.

- Species diversity is significantly higher on the plots not burnt than on those burnt triennially. This is an interesting result since the general trend seems to be an initial decrease in species diversity as inter-fire period increases from 1 year to 3 years. The species diversity then increases as inter-fire period increases beyond 3 years.

- There are significantly less structural groups on the plots burnt annually in comparison with those not burnt. The general trend is an increase in structure groups as inter-fire period increases.

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- The plots burnt annually and biennially have a significantly lower structural diversity in comparison with those not burnt. The plots burnt triennially have a significantly higher structural diversity in comparison with those burnt annually.

- The plots burnt annually and biennially have a significantly lower structural evenness in comparison with those not burnt. The plots burnt triennially have a significantly higher structural evenness in comparison with those burnt annually.

- The general trend for structural diversity and evenness is that as the inter-fire period increases the structural diversity and evenness of the woody vegetation increases.

Testing the combined effects of fire timing and frequency

- The post hoc analyses were not able to elucidate any significant differences in the woody vegetation density between plots burnt at different times of the year.
- The number of species is significantly higher on plots not burnt than on those burnt biennially in April, biennially on October and triennially in October.
- The single stem ratio is significantly higher on plots not burnt than on plots burnt annually in August, biennially in August, triennially in August, biennially in February, biennially in October and triennially in October. Plots burnt annually and biennially in August have significantly lower single stem ratios than those burnt biennially and triennially in April, December, and February. Plots burnt triennially in August have a significantly lower single stem ratio than those burnt triennially in February.
- The post hoc analyses were not able to elucidate any significant differences in the species diversity between plots burnt at different times of the year.
- The post hoc analyses were not able to elucidate any significant differences in the number of structure groups between plots burnt at different times of the year.
- Structural diversity is significantly higher on plots not burnt than on those burnt annually in August, biennially in August and biennially in February. Structural diversity on plots burnt annually in August is significantly lower than on those burnt triennially in August, and biennially and triennially in April, December, February, and October. The plots burnt biennially in August have a significantly lower structural diversity than those burnt triennially in December.
- Structural evenness is significantly higher on plots not burnt than on those burnt annually in August, biennially in August and biennially in February. Structural evenness on plots burnt annually in August is significantly lower than on those burnt triennially in August, triennially in February, and biennially and triennially in April, December and October. The plots burnt biennially in February have a significantly lower structural evenness than those burnt triennially in December and those burnt triennially in October.

Testing the effects of the absence of fire on the woody vegetation

- Density increases significantly between 1954 and 1996 and 1959 and 1996.
- Mean height anomalously decreases significantly between 1954 and 1959 and then increases significantly between 1959 and 1996. There is no significant increase in mean height between 1954 and 1996.
- The number of tree equivalents increases significantly between 1954 and 1996, and 1959 and 1996. This indicates an increase in phytomass or woody biomass in the absence of fire.
- The ratio of single stem individuals decreases significantly between 1954 and 1959, and 1954 and 1996. This is not expected since we would expect a significant increase in single stem individuals with an increase in inter-fire period.
- Number of species increases significantly between 1954 and 1996 and 1959 and 1996. However, species richness does not differ significantly between the tree surveys. This is because the sample size on the control plots was 639 in 1954, 890 in 1959, and 4175 in 1996. The Menhinick's richness

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quantifies the number of species relative to the sample size, and consequently standardises the estimation.

- The number of structure groups significantly increases between 1959 and 1996. However, there is no significant increase between 1954 and 1996.
- Structural richness decreases significantly between 1954 and 1996. This is a mathematical artefact based in the differences in sample size between 1954 and 1996 since Menhinick's richness index is affected by sample size.
- There are no significant differences in the species and structural diversity and evenness between 1954, 1959, and 1996.

Plots grouped based on horn's index of similarity

Species overlap between plots

- The plots not burnt were grouped together with similar species diversities.
- Some plots whose diversities were similar in 1954 were also found to be similar in 1996:

Structural overlap between

- The plots not burnt were grouped together with similar structural diversities.

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

This paper was presented as a talk at the Kruger National Park Research Conference. Skukuza, April 2005.

SP O'Regan & ETF Witkowski

This is a summary of the findings from this MSc, in which the effects of fire frequency and season on the woody vegetation in Pretoriuskop were studied using the Experimental Burn Plot framework.

WHAT ARE THE EFFECTS OF THE FREQUENCY OF FIRE ON THE WOODY VEGETATION IN PRETORIUSKOP?

The exclusion of fire in Pretoriuskop generally results in an increase in the density, species diversity, species evenness, structural diversity, and structural evenness of the woody vegetation.

Post fire succession in Pretoriuskop is not relay floristic succession, where fire sensitive woody species replace fire tolerant species as the period between fires increases.

Instead, the post fire floristic succession is accumulative and as the period between fires increases, fire tolerant and fire intolerant woody species coexist.

The increase in the density of the woody vegetation as the period between fires increases is not linear but rather J shaped with an initial decrease in the density as the period between fires increases from 1 year to 3 years. The initial decrease in density is the result of a loss of very short woody individuals, less than 1m tall. In contrast, there is no initial decrease in the number of tree equivalents (which is a measure of phytomass of the woody vegetation) as the period between fires increases.

Under a high frequency fire regime, the woody vegetation in Pretoriuskop is made up of a high proportion of multi-stem individuals shorter than 1m tall, which are below grass height. The appearance of vegetation is an open savanna with a few scattered medium to large trees.

Under a medium frequency fire regime, the woody plant density is slightly lower than in areas burnt more frequently, and more plants grow to fire resistant heights between fire events. The appearance of the vegetation is a more closely wooded savanna with the density of medium and large trees being greater than in areas burnt more frequently.

When fire is excluded in Pretoriuskop, the woody plant density is significantly higher than in areas that have been burnt, and the average height of the woody vegetation is taller than in areas that have been burnt. The appearance of the vegetation is a closed savanna woodland in which climbers, creepers, lichens, and ferns proliferate.

The findings regarding the effect of fire frequency on the density of the woody vegetation in Pretoriuskop are similar to findings from other fire experiments in mesic African savannas. However, they are different from the findings in fire experiments in semi-arid to arid savannas in Africa.

Generally, it seems that the exclusion of fire in moist or mesic savannas (which experience more than 600 mm of rain annually) results in the woody vegetation becoming denser as well as the woody biomass increasing. However, the exclusion of fire in semi-arid to arid savannas (which experience less than 600mm of rain annually) does not necessarily result in the woody vegetation becoming more dense, even though the woody biomass does increase.

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WHAT ARE THE EFFECTS OF THE TIMING OF FIRE ON THE WOODY VEGETATION IN PRETORIUSKOP?

Generally, under a winter fire regime, in which fires occur between August and October, the woody vegetation is less dense and has a lower species diversity than under a summer fire regime. And, the structure of the woody vegetation under a winter fire regime is generally dominated by multi-stem individuals that are 0-1m tall and 3-5m tall.

Under a summer fire regime, in which fires occur between December and February, the woody vegetation is more dense and has a higher species diversity than under a winter fire regime. And, The structure of the woody vegetation under a summer fire regime is dominated by both single-stem and multi-stem individuals of all heights and basal diameters.

In Pretoriuskop, woody vegetation burnt in the early dry season (i.e. in April) is more dense than woody vegetation burnt in late dry season (i.e. in August). This is consistent with findings in fire experiments else where in Africa where late dry season fires result in a decrease in the density of the woody vegetation.

Generally, the density, species composition, and structural composition of the 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.

WHAT CHANGES HAVE OCCURRED IN THE WOODY VEGETATION OF PRETORIUSKOP BETWEEN THE 1950'S AND THE 1990'S

The density and species diversity of the woody vegetation has increased between 1954 and 1996. With the density of the woody vegetation increasing by almost 200%.

Two main factors are believed to have driven these changes:

1. The exclusion of human habitation of the KNP.

2. The increased atmospheric CO2 levels between 1954 and 1996.

Up until 1926, the human impact on the vegetation in the Pretoriuskop region was significant. As early as 1944, James Stevenson-Hamilton commented in a report to the National Board of trustees that a factor contributing toward bush encroachment in the KNP was that there was no "native population" in the park. The people who had lived in the area before the proclamation of the Nature Reserve had harvested trees and fruit, they practised agriculture, and they kept livestock. And, Stevenson-Hamilton believed that their agricultural practices tended keep the bushveld open to a greater extent than one might expect. Furthermore, up until 1926 Sheep farmers bought their sheep to graze in the Pretoriuskop region annually in the winter. It is reported that they would always burn the old grass in the area to create pastures for gazing.

Regarding atmospheric CO2. As the atmospheric CO2 levels increase the water use efficiency of the many woody plants increases. Furthermore, many woody plants experience increased rates of photosynthesis and a greater production of carbohydrates. So generally, as the atmospheric CO2 levels increase, perennial woody species loose less water while producing more biomass, and it is expected that they will become more dominant relative to annual herbaceous species.

These two factors are believed to be driving the densification of the woody vegetation in Pretoriuskop.

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17.7 A FIRE HISTORY OF THE SAVANNA ECOSYSTEMS IN THE KRUGER NATIONAL PARK, SOUTH AFRICA, BETWEEN 1941 AND 1996.

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A fire history of the savanna ecosystems in the Kruger National Park, South Africa, between 1941 and 1996

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This paper analyses the fire history of the Kruger National Park (1.9 million ha), South Africa, for different periods in the park's history, where fire protection was followed by prescribed burning and then a 'natural' (lightning) fire policy. Fires covering 16.79 million ha occurred between 1941 and 1996 (16% of the area burning each year on average). Of this area, 5.15 million ha was burnt between 1941 and 1957, when limited prescribed burning and protection from fire took place (16% burning each year on average). Between 1957 and 1991, 2213 prescribed burns covering 5.1 million ha (46.3% of the 10.98 million ha burnt during that period) were carried out. Lightning fires affected 2.5 million ha between 1957 and 1996, or 21.6% of the area. The mean fire return period was 4.5 years, with intervals between fires from 1 to 34 years. The distribution around the mean was not symmetrical and the median fire interval was 3.1 years. Some areas burnt more often than others, and mean fire return periods ranged from 2.7 to 7.1 years in the 11 major land systems of the park. Fires occurred in all months, but 59% of them took place from September to November. Prescribed burns were concentrated late in the dry season (September to November). Lightning fires were later, with 84.7% of the area burning between September and January. The implications of the analysis for the management of the park are discussed.

Savannas are tropical grasslands with scattered trees; they occupy about 20% of the land surface of the Earth, and 40% of Africa. These ecosystems are dynamic in their structure and composition, which changes in response to fluctuations in rainfall, levels of herbivory and occasional fires that burn through the grass swards. The role of fire in the maintenance of structure and function in African savannas is probably the oldest issue in savanna ecology[1] and remains contentious. In conservation areas, where early ideas were formed around equilibrium theory, fire was regarded first as something to be avoided, and was later applied at a fixed return period, when it was realized that fire was an integral part of the system. However, with the development of non-equilibrium theories of savanna dynamics, policy and practice in fire management have shifted towards burning under diverse rather than fixed conditions.[2,3]

Fire management in the Kruger National Park has followed a similar trend. After the proclamation of the park in 1926, occasional and limited burning was used until 1948 only to provide green grazing for wildlife. Between 1948 and 1956, prescribed burning was stopped and firebreaks were established to assist in the control of wildfires. This policy was changed in 1957 to a formal system of burning once every three years in spring on fixed management areas (termed 'blocks') ranging in size from 50 to 20 000 ha. In 1975, this policy was amended to allow for longer periods between fires in drier areas, with the season of burn varied between late winter, mid-summer and autumn.[4] In 1992, the policy was again changed to one of allowing natural (lighting-ignited) fires to burn freely, but where prescribed burning would not be carried out, and all other fires of human origin were suppressed. For the sake of analysis, we recognized three periods in this paper. The period prior to 1956 was one of protection from fire, from 1957 to 1991, prescribed burning was actively practised, and from 1992 only lightning fires were permitted to burn.

The shift away from rigid prescribed burning on a fixed cycle was in response to several recent concerns. For example, Trollope and co-workers[5] concluded that a dominance of grass species characteristic of poorly managed pastures and overgrazing was a result of 'excessively frequent burning'. In addition, there was concern over putative trends in woody vegetation structure.[6] It appears (for example, from examining early aerial photographs) that large areas have been homogenized, possibly due to the rigid application of a policy of burning at three-year intervals. Tree densities have declined, greatly for some species, and this decline may be due to an 'unnatural' fire regime (in combination with other factors, such as browsing by ever-increasing numbers of elephants). In a revision of the research objectives for the park, developing an understanding of the attributes of natural fire regimes has been identified as a priority.

The Kruger National Park has a comprehensive set of fire records spanning five decades. These data have only partially been analysed. For example, the records for fires between 1980 and 1993 showed that most (90%) fires were of human origin, while lightning fires affected only 10% of the park. Lightning fires, however, took place in spring and summer (September to February), whereas other fires were predominantly in late winter and spring (June to October).[7] While that analysis is useful, the available records span a much longer period and can also be evaluated spatially to provide information about the historical influences of fire on vegetation patterns and trends in the park.

This study reports on an analysis of fire patterns in the Kruger National Park based on fire records that date back to 1941, to quantify the nature of the fire regime that existed during the period of formal management. This record is probably the longest fire history for any savanna ecosystem in the world, and provides an important benchmark for interpreting the changes in vegetation structure that have taken place.

The study area

The Kruger National Park is situated in the low-lying savannas of the eastern parts of the Northern and Mpumalanga provinces of South Africa, adjacent to Mozambique in the east and Zimbabwe in the north (Fig. 1). The park was established in 1926, and covers 1 948 528 ha. Elevations range from 260 to 839 m

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above sea level. Mean annual rainfall varies from around 750 mm in the south to approximately 350 mm in the north (Fig. 2), but variations about the mean can be marked from year to year (Fig. 3).[8] The pattern of rainfall over the past century has been characterized by extended wet and dry periods, in which the rainfall tended to be either higher or lower than the long-term mean for between 6 and 12 consecutive years (Table 1).[9] These wet and dry periods have marked effects on the dynamics of the ecosystem, and on the occurrence of fires.

The park is crossed by seven perennial or seasonal rivers (the Crocodile, Sabie, Olifants, Letaba, Shingwidzi, Luvuvhu and Limpopo), which run from west to east. Geologically, the park can be divided into western and eastern halves. In the west, granites and their erosion products dominate, while the eastern sector is predominantly underlain by basalt, but includes the Lebombo Hills (primarily rhyolite formations) running from north to south. Two important areas of sandveld (on recent sands) also occur in the north, around Punda Maria and Pafuri.

Several studies have sought to classify the landscapes and vegetation formations of the park. One such study has divided the park into 35 'landscapes' based on geomorphology and vegetation.[10] Another subdivided the park into 56 'land types' on the basis of soil and vegetation patterns and landform characteristics.[11] These land types were combined into 11 'land systems' on the basis of geological, geomorphological and climatic characteristics. The boundaries of these divisions have been captured on a geographic information system (GIS) and provided a framework for the examination of fire regimes in this study.

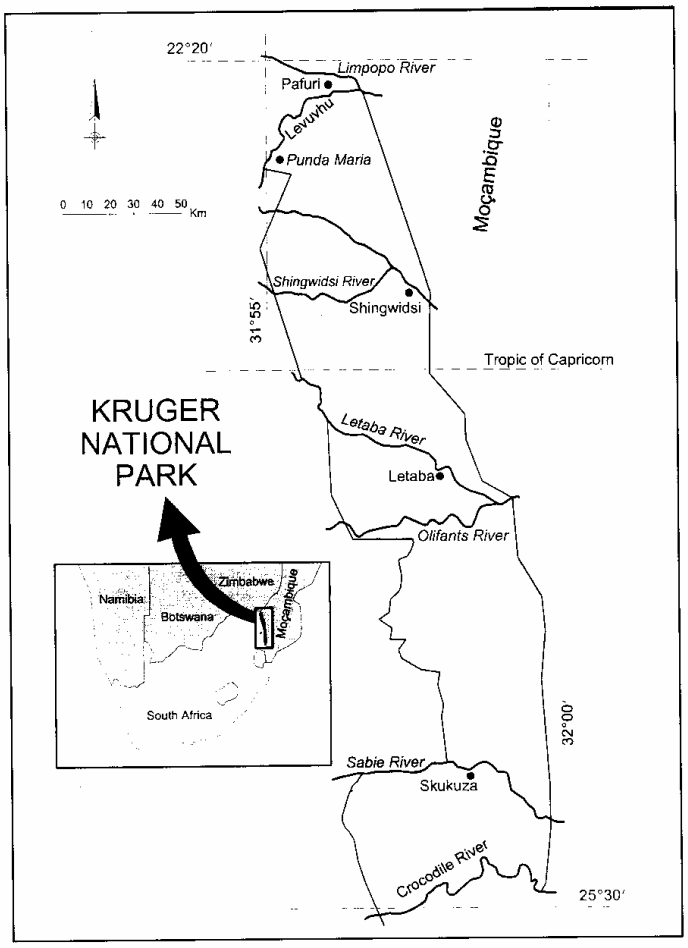


Fig. 1. Map of South Africa showing the location and topographical features of the Kruger National Park.

The flora of the park comprises 1983 species (N. Zambatis, pers. comm.), including over 400 tree and shrub species,[12] and over 220 grasses. Broadly speaking, there are four dominant vegetation types in the park. In the southwest, the low nutrient status of the soils results in a relatively low grazing pressure, and grass fuels accumulate during the growing season; rainfall is also higher, and as a result of these factors fires tend to be relatively frequent in these areas. The area is well wooded, and important tree species include the red bushwillow *(Combretum apiculatum)*, knobthorn *(Acacia nigrescens)*, tamboti *(Spirostachys africana)* and marula *(Sclerocarya birrea)*. In the southeast, on basalt substrates, grasses are more palatable and tend to be heavily grazed. Important tree species include the knobthorn, leadwood *(Combretum imberbe)* and marula. North of the Olifants River, the granite areas in the west are poorly grassed; mopane *(Colophospermum mopane)* and red bushwillow are dominant trees. The northeastern areas on basalt are dominated by multi-stemmed mopane shrubs about 1 to 2 m in height.

The fauna of the park is also diverse, including 147 species of mammals[13] and 492 species of birds.[14] Important herbivores include elephant *(Loxodonta africana)*, buffalo *(Syncerus caffer)*, impala *(Aepyceros melampus)*, zebra *(Equus burchelli)*, wildebeest *(Connochaetes taurinus)*, waterbuck *(Kobus ellipsiprymnus)*, kudu *(Tragelaphus strepsiceros)*, giraffe *(Giraffa camelopardalis)*, white and black rhinoceros *(Ceratotherium simum* and *Diceros bicornis)* and hippopotamus *(Hippopotamus amphibius)*. Herbivory, particularly by grazers, has an important influence on fires through the consumption of grass fuels. In addition, browsing (particularly by elephants) has a strong impact on subsequent tree mortality after fires.

The fire record

Fires in the Kruger National Park were traditionally recorded in ranger's diaries prior to the introduction of a programme of prescribed burning in 1957. When prescribed burning was introduced, the park was subdivided into over 400 management areas, or 'blocks', ranging in size from 50 to 23 800 ha (mean = 4198 ha, Fig. 4). The boundaries of the 453 blocks that existed at

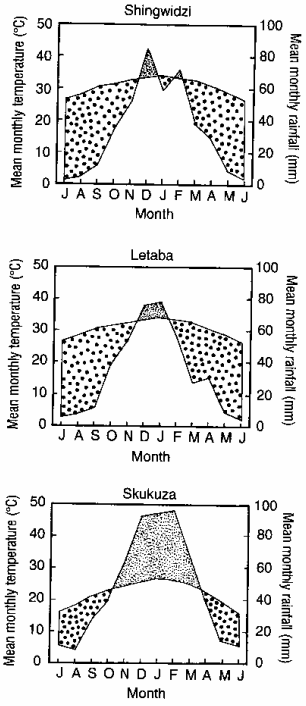


Fig. 2. Climate diagrams for three locations in the Kruger National Park (see Fig. 1 for the localities of stations).

the time of this study were captured on a GIS, and formed the basis of our analysis. The fire records for different periods were in three formats, as follows:

(i) Sketch maps of the distribution of fires for each year from 1941 to 1956, available from a previous analysis of ranger's diaries.[15] These were digitized, and overlaid on the boundaries of existing fire blocks to establish the percentage of the block that was burnt in each year. These fires were recorded at a coarse scale (1:500 000), resulting in partially burnt blocks only providing a crude estimate of percentage burnt.

(ii) The board controlling the park took a decision to institute prescribed burning in fixed blocks on a three-year cycle in 1957.[15] Fire records for each of these blocks, giving the dates and causes of fires, and in some cases an estimate of the percentage of the block that burned, were available from 1957 to 1991. These records were extracted from the management files for each block.

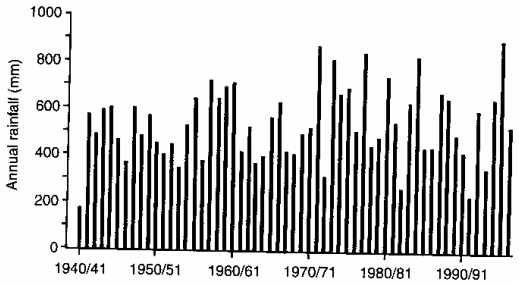


Fig. 3. Total annual rainfall at Skukuza, Kruger National Park, between 1940/41 and 1996/97. Data are for climatic years (1 July to 30 June).

(iii) As from 1992, all prescribed burns were stopped. Natural (lightning) fires were allowed to burn in line with a management policy, although other fires did occur. These fires were mapped (using fire reports and satellite images to establish boundaries on 1:50 000 topographical maps) and added to the database by allocating a date, percentage burnt, and cause of each fire to the existing fire management blocks.

Between 1957 and 1988, numerous adjustments were made to the boundaries of blocks. We established the extent and dates of these changes by comparing older maps to the existing set of blocks. Where necessary, fire records were re-allocated to the existing blocks by assigning the date of the fire and its cause, together with an estimate of the percentage of the existing block that would have burnt in that fire.

The cause of fires was recorded in seven categories: prescribed fires (where the whole block was intentionally burnt); firebreak fires (where the boundaries of the block were ignited under conditions where the fire would not progress very far, with the intention of creating a buffer strip — we refer to these strips as 'firebreaks' throughout); fires caused by lighting; escape fires (where prescribed or firebreak fires unintentionally spread to the block concerned, or where any fires originating outside the park burnt a block inside the park); other fires of human origin (poachers or trans-border migrants being the most common causes); other fires of known cause; and fires of unknown origin.

The fire record consisted of 5512 individual burns between 1957 and 1992, that burnt an area of 10.97 million ha. The total number of fires between 1941 and 1956 is not known (only the annual extent of fires was available), but during this period burnt 5.15 million ha. The period between 1992 and 1996 was initially characterized by a severe drought, and not many fires occurred. However, extensive lightning fires occurred in 1996, following good rains in 1995, burning 359 424 (50.4%) of the 712 055 ha burnt between 1992 and 1996.

Table 1. Cyclical patterns of rainfall from available recording stations in the Kruger National Park, showing the extent and duration of wet and dry periods between 1919/20 and 1992/93.[9] The mean annual rainfall for all stations was 534.2 mm.

Dates	Number of recording stations	Length of period (years)	Type of period	Mean rainfall for period (mm)
1919/20–1924/25	1–2	6	Wet	650.2
1925/26–1935/36	3–7	10	Dry	462.3
1936/37–1942/43	8–11	6	Wet	590.1
1943/44–1952/53	9	9	Dry	510.6
1953/54–1960/61	9–14	7	Wet	586.4
1961/62–1970/71	14–17	9	Dry	457.5
1971/72–1981/82	17–19	10	Wet	638.7
1982/83–1994/94	19–27	12	Dry	450.0
1994/95–1996/97	29–34	2	Wet?	560.7

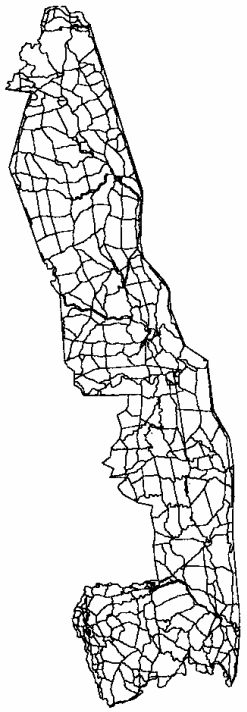


Fig. 4. Distribution of management units ('blocks') which formed the basis for a spatial analysis of fire regimes in the Kruger National Park. See Fig. 1 for scale.

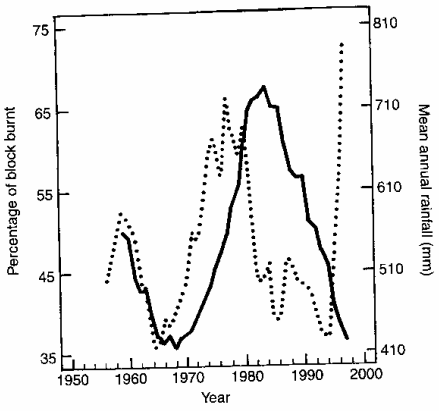


Fig. 5. Trends in percentage burn recorded in fires between 1957 and 1992 (5-year running mean, solid line), and annual rainfall (3-year running mean, dotted line). There is a significant relationship between percentage burn and annual rainfall five years before the fires ($y = 29.95$, $x = 0.034$, where y is the percentage of the block burnt and x is the annual rainfall five years prior to the burn; $r^2 = 0.17$, $P < 0.012$).

Data analysis

Estimation of percentage of block burnt

The 1137 records for individual fires between 1980 to 1993 were complete in terms of estimates of the percentage area of the blocks that burnt.[7] Many (60%) of the fire records from 1957 to 1979 did not have these estimates; however, the cause of fires was consistently recorded. To fill in missing values of percentage burn, we assumed that firebreak burns (743 of the 4375 records between 1957 and 1979) burnt 20% of the block concerned, based on the estimates for fires from this source (firebreak burns were usually ignited to create a fuel-break around the periphery of the block, under conditions that would normally cause the fire to die out at night). Where more than one firebreak burn occurred in a block in the same year, we assumed that the total area of all firebreak burns that year was 20%, and reduced the estimates for individual burns proportionally.

For those records where the percentage area of the block burnt was recorded (73% of the 5512 fires between 1957 and 1992), a clear annual trend was evident. This trend was significantly correlated with annual rainfall five years earlier (Fig. 5). We used this relationship to estimate percentage burn for the fires where this was not recorded, excluding the firebreak burns (where we assumed that 20% of the area of the block was burned). In order to obtain an estimate, we first subtracted the extent of firebreak burns that occurred before the burn in question in the same year from the area of the block. We then used the relationship to estimate the proportion of the remainder of the block that would have burnt. Where more than one non-firebreak burn occurred in a block in the same year, we assumed that the total area of all non-firebreak burns that year was equal to the estimate, and reduced the estimates for individual burns proportionally.

Frequency of fires

Fire frequency was examined in three ways. First, where we wished to test for significant differences in fire return periods between areas of interest, the mean return period was calculated as

$$RP = \frac{\left(\sum i_j a_j\right)}{\left(\sum n_j a_j\right)},$$

where RP is the return period in years, j is the number of blocks in the area of interest, i is the inter-fire period in years, a is the area of block j, and n is the number of inter-fire periods (the number of fires minus 1). Using this method, we were able to test for differences between areas using one-way analysis of variance.

Secondly, where return periods were determined for short intervals, cases arose where only one fire had occurred in some blocks in the period concerned (that is, there was no inter-fire period on record). This precluded the use of the above formula, and we used $RP = y/(b/a)$, where RP is the return period in years, y is the number of years over which fires were recorded, b is the extent of all fires recorded over y years, and a is the area over which fires were recorded. In this case, only one number is produced, and it is not possible to test for the significance of any differences.

Thirdly, we estimated the frequency distribution around the mean by determining the period between successive fires in each block. To do this, we divided each block into 10 equal sub-blocks, and randomly assigned sub-blocks as burnt or not in each year based on the percentage burnt (i.e., if 20% of a block had burnt, two randomly selected sub-blocks were designated as having burnt). A key assumption in doing this was that each subdivision of a block had an equal chance of burning; this assumption was the only way to deal with the data, as the exact location of each fire within blocks with incomplete burns was not known. These data were used to determine the distribution of periods between successive fires in each block. To determine the distribution for the whole area being examined, we totalled the periods for all blocks, weighted by area.

We used maps of the land systems[11] and of rainfall to examine patterns of fire frequency. The rainfall distribution was derived from a national database that models rainfall from existing recording stations and topographical factors at a resolution of one minute by one minute.[16] We also divided the data into different periods in order to determine the effects of climatic periods, and periods of differing management policies, on fire frequency.

Seasonality of fires

Seasonality of fires was examined monthly. The area burnt in each month was totalled for the area, time period, and cause. We used these data to establish whether seasonal differences in the proportion of area burnt varied between the land systems in the park, and between wet or dry periods. We also examined whether fires of different origin (particularly those started by lightning) differed in their seasonal occurrence.

Size of fires and extent of area burnt

The extent of fires was calculated from the area of the management blocks, and the estimates of the percentage of the block that burnt. These were then totalled for different landscapes, rainfall zones or time periods of interest (such as wet and dry climatic cycles, and periods of differing management policy). The estimation of the size of fires was constrained by the fact that fire records were kept for individual management blocks and not for individual fires. Thus, if a fire burnt over more than one block, this was not recorded. However, occurrences of the same fire burning in more than one block prior to 1992 were rare, as fires were almost always confined to a single block by effective backburning from the boundaries. For the fires that occurred after 1992, accurate maps of individual fires were available. We were able, in these cases, to estimate the areas of individual fires from these maps, using the areas of management blocks as a basis.

Fire climate

Climate and weather are important in determining the opportunities for fires to occur and spread, and together with fuel properties will affect their size and intensity. We obtained daily weather data from two representative weather stations in the park (Skukuza and Letaba, see Fig. 1) for the period 1981 to 1997, and used the U.S. National Fire Danger Rating System[17] to calculate daily indices of fire danger. The data used included daily maximum and minimum temperature and relative humidity, cloud cover, rainfall duration and wind speed, and an estimate of the fuel composition and structure (we used fuel model L). Results are expressed in terms of a 'burning index', which can be related to the spread and intensity of a fire under prevailing conditions.

Effect of fuel load on the occurrence of fire

Grass biomass (fuel) estimates were defined from one to four points per management block for approximately two-thirds of the blocks in the park from 1989 onwards. These points were distributed across the whole park and all land systems, and were taken to be representative of fuel loads throughout the block. The single point (or in the case of blocks with multiple sampling points, the mean) biomass per block was determined for each year from 1989 to 1996. The annual occurrence of fire (other than in firebreak burns) in blocks was recorded as a binary variable — burnt or not burnt. The probability of a fire of any size occurring in a block in a given year was then estimated as a function of biomass using logistic regression.[18]

Results

Fire frequency

The mean fire return period for the entire dataset was 4.5 years. However, the distribution around the mean was not symmetrical (Fig. 6), and the median fire interval was 3.1 years. This indicates a skewed distribution in the data, with many short-interval fires, but a few areas experiencing relatively long intervals between fires, thus increasing the mean interval between them. Fires that burnt within one year of a previous fire accounted for 16% of the area burnt over the past 56 years; a further 17% of the area burnt within 2 years of a previous fire, and another 16% within 3 years (Fig. 6). Thus, for more than half a century, about half the area burnt within 3 years of the previous fire. About 80% of the area burnt within 7 years of the previous fire, and a small proportion (about 10%) burnt 10 years or more after the previous fire. As can be expected in a large and diverse area, the spatial distribution of mean fire return periods varied spatially (Fig. 7).

Mean and median fire return periods ranged from 2.7 to 7.1, and 1.8 and 4.6 years, respectively, in the 11 major land systems of the park (Table 2) between 1941 and 1996. The range of intervals between fires for the different land systems was from 1 to between 30 and 40 years. Most land systems had mean fire return periods of between 4 and 5.8 years, and two (the Klipkoppies and Phalaborwa systems) had mean fire return periods of 6 years or more. The median fire return period was generally shorter than the mean, and was much less for the Malelane system (1.8 as opposed to 5.3 years). Few areas (less than 1% of the Malelane land system to 10% of the Klipkoppies land system) managed to escape fire for more than 15 years (Fig. 8).

Rainfall has a marked effect on the production of grass fuels, and therefore on fire return periods. This was evident for areas that receive a mean annual rainfall of over 700 mm (Table 3). Here, the mean return period was 3.5 years, compared with around 5.2 years for areas with annual rainfall between 400 and 700 mm. Fire returns were longer in dry periods (where grass productivity, and hence fuel loads, would have been low) than in wet (Table 4). For the 10 years between 1971 and 1980 (a wet cycle, see Table 1), the mean return period was 4.3 years over the whole of the park. Over a similar period between 1983 and 1992 (a dry cycle), the corresponding period was 9.1 years. Mean fire return periods were similar between 1941 and 1956, prior to prescribed burning, and between 1957 and 1992, when prescribed burning was actively practised (5.9 and 6.2 years, respectively, Table 4). It would appear, therefore, that attempts at protection from fire did little to reduce fire frequencies. With the adoption of a policy of lightning fire, indications are that the

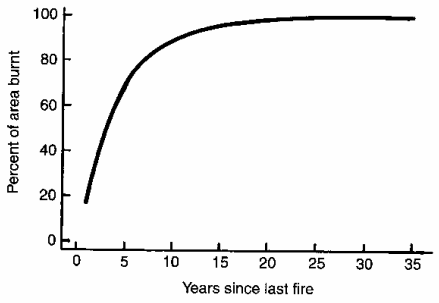


Fig. 6. The cumulative probability of fire in the Kruger National Park, calculated from fire records between 1941 and 1996.

mean fire return periods have become longer. Because this policy has only operated for 5 years, we compared the mean fire return periods between 1992 and 1996 (where prescribed burning was not carried out, and lightning fires were allowed to burn) with a period of equal length and similar rainfall (1981–85). The mean return period under the lightning fire policy was 13.3 years, more than double that in the prescribed burning era (6 years, Table 4). This indicates that, for dry periods at least, the new policy could lead to longer intervals between fires.

Fire season

Fires occurred in all months of the year for the period of analysis (1957 to 1996), but most of the area (80%) burnt in the months from June to November (Fig. 9). September, October and November had the largest proportions of area burnt (23, 21 and 15%, respectively). Firebreak burns were conducted earlier in the year, with most (70% of the area) being carried out between May and July. Prescribed burns, which accounted for 43.7% of the total area burnt (see below), were concentrated late in the dry season, with 66.5% of the prescription-burnt area being burnt in the months of September, October and November. Lightning fires tended to be later in the year, with 84.7% of the area attributed to this cause burning between September and January. Other fires (most of which were of human origin) followed the same seasonal pattern as prescribed burns (80% of the area burning from July to November).

The seasonal distribution of fires was examined for the period when the lightning fire policy was in operation (1992–96). Here, a total of 712 031 ha was burnt in 5 years (Table 4). These fires were

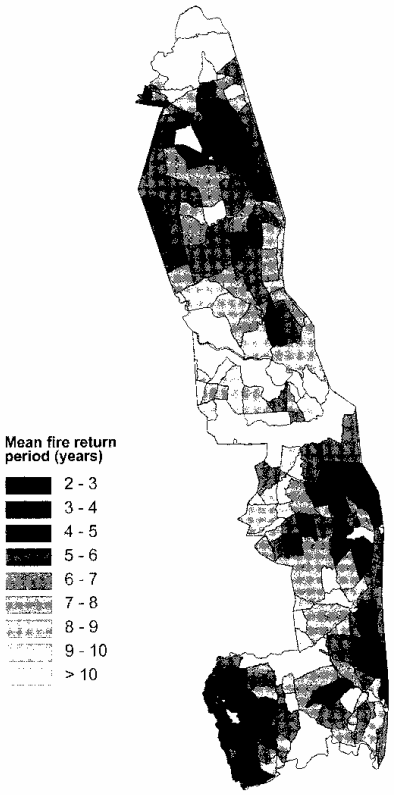


Fig. 7. Map of the Kruger National Park showing mean fire return periods calculated from fire records between 1957 and 1996. See Fig. 1 for scale.

Table 2. Fire return periods in 11 land systems (after Venter[11]) in the Kruger National Park, South Africa, between 1941 and 1996. Means with the same superscript letter do not differ significantly at $P < 0.0005$.

Land system	Salient features	Area (km^2)	Extent of fires between 1941 and 1996 (km^2)	Fire return periods (years)		
				Mean	Median	Range
Malelane	*Combretum apiculatum* bush savanna on granite. Rainfall 600–700 mm/yr	400.3	5415	5.3[ac]	1.8	1–34
Skukuza	*Combretum apiculatum/Terminalia sericea* bush savanna on granite. Rainfall 500–750 mm/yr	3742.6	35 496	4.2[bd]	3.3	1–40
Satara	*Acacia nigrescens/Sclerocarya birrea* tree savanna on basalt and gabbro. Rainfall 500–650 mm/yr	2599.7	27 766	5.0[c]	2.9	1–35
Vutome	*Acacia welwitschii/Euclea divinorum* tree savanna on Karoo sedimentary rocks. Rainfall 500–650 mm/yr	746.6	5767	5.8[c]	3.8	1–39
Sabiepoort	*Combretum apiculatum/Pterocarpus rotundifolius* bush savanna on rhyolite. Rainfall 500–650 mm/yr	855.0	9362	4.1[bd]	2.6	1–34
Phalaborwa	*Colophospermum mopane/Combretum apiculatum* bush savanna on granite. Rainfall 450–600 mm/yr	4981.9	40 521	7.1[e]	3.4	1–32
Letaba	*Colophospermum mopane* bush savanna on basalt and gabbro. Rainfall 450–500 mm/yr	3418.2	29 884	4.4[ad]	2.9	1–33
Bulweni	*Terminalia sericea/Combretum zeyheri* bush savanna on deep recent sands. Rainfall 450–500 mm/yr	395.3	2459	3.7[bdf]	3.3	1–30
Klipkoppies	*Colophospermum mopane/Combretum apiculatum* tree and bush savanna on rhyolite. Rainfall 450–500 mm/yr	482.4	3457	6.1[ce]	4.6	1–32
Nwambiya	*Baphia massaiensis* bush savanna on recent sands. Rainfall < 400 mm/yr	508.1	3884	3.6[bf]	3.4	1–35
Pafuri	*Colophospermum mopane/Burkea africana* tree and bush savanna on volcanic rocks and floodplains. Rainfall 400–650 mm/yr	861.7	3935	2.7[f]	4.5	1–35
Total		18 991.8	167 947	4.5	3.1	1–40

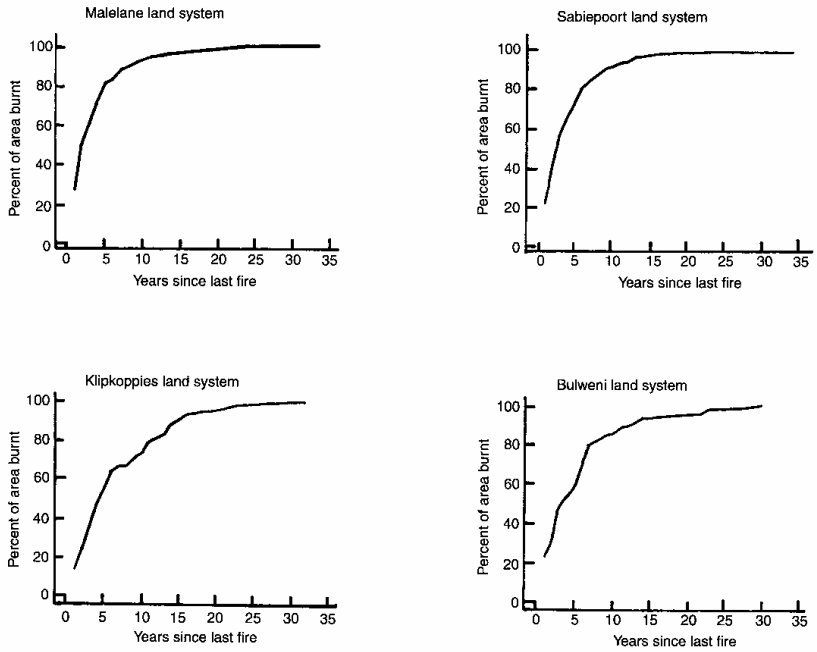


Fig. 8. The cumulative probability of fire in four land systems (see Table 2) in the Kruger National Park, calculated from fire records between 1941 and 1996.

concentrated in the three months from September to November, when 83% of the area was burnt (Fig. 10). We also examined a period of equal duration and similar rainfall (1981–85), when the policy of prescribed burning was in operation. Here, a much greater area was burnt (1.57 million ha), with 82% of the burns occurring over either an earlier or longer period (six months from June to November). The adoption of a lightning fire policy has therefore led to a discernible shift in fire season.

Size of fires and extent of area burnt

Fires covering 16.79 million ha occurred during the 56 years between 1941 and 1996 in the park. Of this area, 5.15 million ha burnt from 1941 to 1956, for which the records are not detailed enough to provide more than an annual total for each year. During the era of prescribed burning, 2213 prescribed burns were carried out, and these affected about 5.1 million ha (46.3% of the 10.92 million ha burnt during that period). There were also

Table 3. Fire return periods for zones of mean annual rainfall in the Kruger National Park. Means with the same superscript letter do not differ significantly at $P < 0.0005$.

Mean annual rainfall zone (mm)	Area (km^2)	Area burnt between 1957 and 1996 (km^2)	Mean fire return period (years)
400–500	6251	37 852	5.0^a
500–600	8663	54 919	5.3^b
600–700	2745	16 976	5.2^{ab}
700–800	314.6	1665	3.5^c
800–900	69.5	1238	3.5^c

Table 4. Mean fire return periods for wet and dry climatic periods, and for periods of varying management policies in the Kruger National Park (18 991.8 km^2).

Period of analysis	Extent of fires (km^2)	Mean fire return period (years)
Wet climatic cycle (1971–1980)	44 149	4.3
Dry climatic cycle (1983–1992)	20 834	9.1
Limited prescribed burning and active fire protection (1941–1956)	51 541	5.9
Active prescribed burning (1957–1992)	109 750	6.2
Active prescribed burning (1981–1985)*	15 733	6.0
Lightning fire policy (1992–1996)	7120	13.3

*This period was chosen for a similar rainfall pattern to the period under which the lightning fire policy had been operative, for comparative purposes.

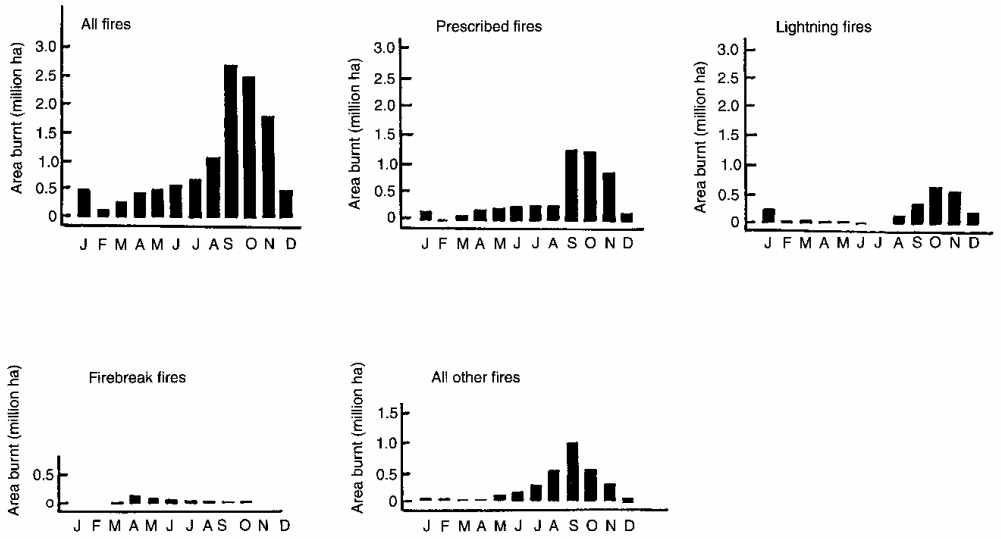


Fig. 9. Monthly distribution of total area burnt by different sources of ignition in the Kruger National Park between 1957 and 1996.

742 firebreak burns during this period, which affected an estimated total of 577 140 ha (see methods). Thus, formal management accounted for only 52% of the area burnt during this period. Lightning fires accounted for 2.5 million ha, or 21.6% of the area burnt between 1957 and 1991. Because these fires tended to occur later in the season, it can be assumed that their extent would have been greater if prescribed burning, which removed fuels that could have burnt in lightning fires, had not taken place. The balance of fires was caused mainly by poachers and refugees or were escape fires from burning operations.

Between 1957 and 1991, most fires were between 2000 and 4000 ha in size (Fig. 11A). Those more extensive than 10 000 ha burnt only 6% of the total area; the largest fire on record for this period was 18 110 ha. The period between 1992 and 1996 was characterized by 102 small fires of <10 000ha, and twelve really large ones (Fig. 11B). The large fires (>10 000 ha) accounted for 73% of the area burnt; four of these fires were greater than 30 000 ha in size (52 811, 75 396, 75 831 and 204 172 ha, respectively). These four fires all occurred in 1996, and were the largest fires recorded in the park's history.

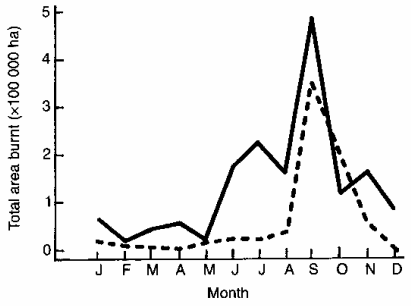


Fig. 10. Monthly distribution of area burnt in all fires under two fire management policies (lightning fires, dashed line, and prescribed burns, solid line) for two periods with similar rainfall (1981–85 for prescribed burning, and 1992–96 for lightning fires).

Fire climate

The mean burning index for each month at both of the stations analysed (Fig. 12) shows that conditions conducive to fires were highest during July, August and September, and lowest from December to March. Skukuza has higher mean burning indices as it experiences higher mean windspeeds than Letaba. Because the burning indices are mean (monthly) conditions, it is more useful to determine when extreme conditions occur, as are the times when large fires can be expected. Daily burning indices of greater than 50 (at Skukuza) and 39 (at Letaba) are in the top 5% of all values recorded at these stations. The occurrence of these conditions shows a far greater seasonal trend (Fig. 12). Such conditions occur frequently from June to October, and hardly ever between December and April (Letaba had higher occurrences in these months, as it is much drier than Skukuza, see Fig. 2).

The conditions that prevailed during the large fires of 1996 are of particular interest. These fires, in the south of the park, burnt between September 25 and October 5 of 1996. On these days, the burning index was always above 27, and exceeded 50 on three of the days. The park's managers contended that these conditions were unusual, and not likely to occur frequently. We determined that these conditions occurred at least once in 7 of the 16 years between 1981 and 1996 (Fig. 13). However, in at least 3 of these years (1989, 1992 and 1994), mean fuel loads (as determined in routine pre-fire surveys) were low (<2500 kg ha^{-1}, ranging from 1132 to 2128 kg ha^{-1}). Higher fuel loads were present in 1990 and 1991 (2740 and 2686 kg h^{-1}, respectively), while in 1996 the mean fuel load was 3653 kg ha^{-1}. Estimates of fuel load were not available for the only other year in the period analysed that had extended periods of severe fire weather (1986, Fig. 13). While this analysis covers only a short period, it appears that conditions of severe fire weather that coincide with fuel loads in excess of 3500 kg ha^{-1} are necessary for extensive (>30 000 ha) fires. The frequency of occurrence of such conditions over the long term is not known, but may be rare.

Effect of fuel load on the occurrence of fire

There was a significant relationship between grass biomass

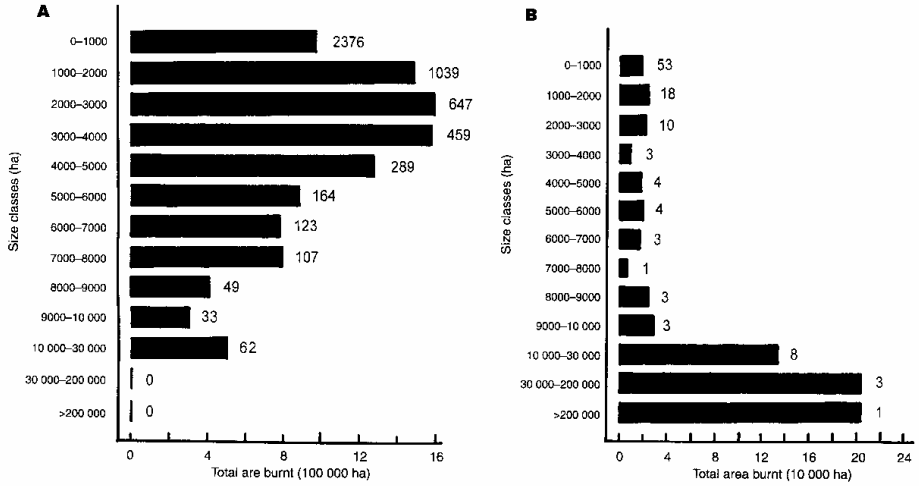
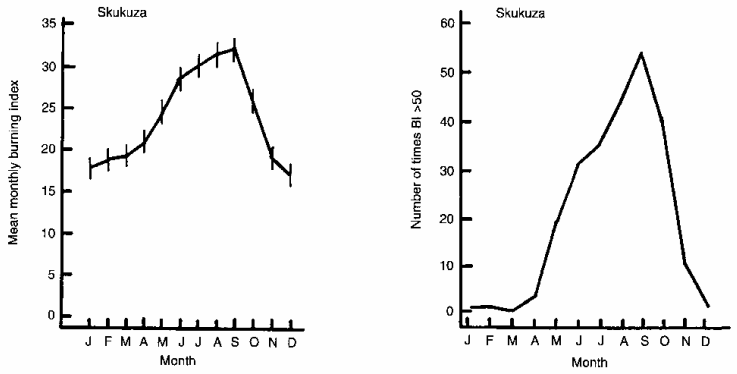


Fig. 11. Distribution of area burnt in fires of different size classes in the Kruger National Park. **A**, fires burnt between 1957 and 1991, when prescribed burning on fixed blocks was conducted; and **B**, fires burnt between 1992 and 1996, under a policy of lightning fires. The number of fires is shown next to the bars. Note the changes of scale for fires >10 000ha.

(fuel), and the probability of a fire occurring in any given block, and this relationship varied between years (Fig. 14, Table 5). The probability of a fire of any size occurring depends on grass biomass. The reason for the relationship differing between years may be due to the severity of fire weather, with the probability of fire increasing in those years where severe fire weather coincides with higher fuel loads. This is indicated in Fig. 14, where the probability of fire was higher in 1996 (a year with severe fire weather) than in 1995 (a year without such weather).



Discussion

The fire history in the Kruger National Park

There are many difficulties associated with constructing a fire history in ecosystems where long-lived trees that bear fire scars and annual rings are absent. As a result, detailed analyses of fire frequencies in such ecosystems tend to be rare. The lack of detailed analyses can lead to erroneous interpretations of fire frequency. This was the case in the Kruger National Park, where perceptions among managers were influenced by the mean fire return periods of around 7 years, based on analysis of data for 1980–1992.[7] Because mean return intervals are normally calculated without considering the shape of the frequency distribution about the

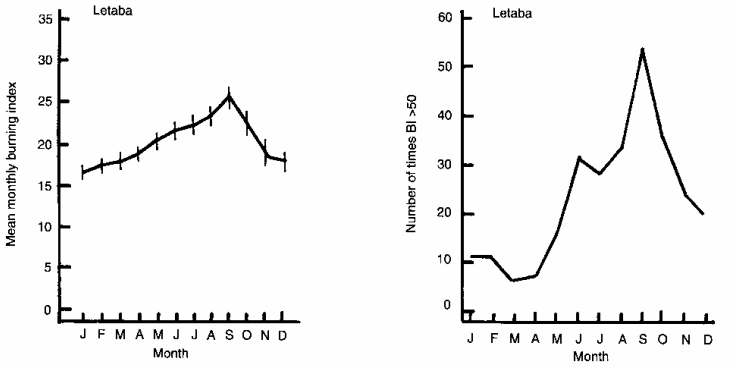


Fig. 12. Annual cycle of mean monthly burning index, and the number of days in each month that the burning index (BI) was in the top 5% of all values recorded, at two stations in the Kruger National Park. Data are for the period 1981–97; bars represent 95% confidence intervals of the mean.

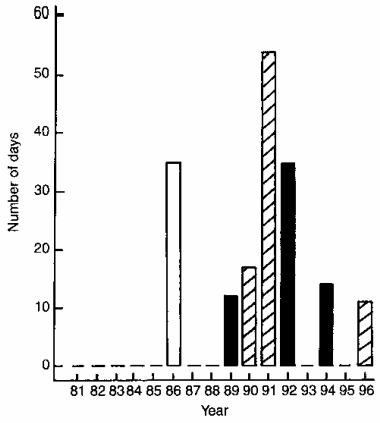


Fig. 13. The occurrence of extended periods (>10 days) of high fire danger (burning index >27 on each day, with at least three days >50) at Skukuza between 1981 and 1996. Shaded bars show years where conditions occurred together with high (> 2500 kg ha^{-1}) fuel loads. Solid bars indicate years when fuel loads were below 2500 kg ha^{-1} (fuel estimates were not available for 1986).

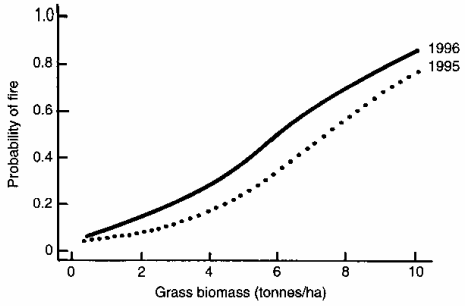


Fig. 14. The relationship between grass biomass (fuel) and the probability of fire in two individual years in the Kruger National Park. Severe fire weather conditions occurred in 1996, but not in 1995. The regression equations were $P(f) = e^Z/(1 + e^Z)$, where $P(f)$ = the probability of fire, e = the base of natural logarithms, and $Z = -3.47 + 0.00047b$ for 1995, and $-2.47 + 0.00051b$ for 1996 (b = grass biomass in kg ha^{-1}).

mean,[19] it was assumed that periods between fires were acceptably long. This study has shown that the return period between fires is much shorter than originally believed, as the median value for fire return period was well below the mean for most land systems. Concerns have recently been raised that the park has been burnt too frequently,[5] resulting in deterioration of the grass sward and in relatively high mortality of trees. Our data support the notion that the park has been burnt frequently. Large areas of the park have been subjected to annual and biennial burns, and this could have important implications for the conservation of vegetation structure and biodiversity.

Fire season is another element of the fire regime that can have important biological effects. This analysis has shown that most fires take place in relatively rain-free winter months, when grasses are dormant and dry. However, there appears to be an important difference in seasonality between fires caused by lightning and other fires. Lightning fires tend to occur later in the year, and even in the period after the start of summer rains. Proponents of a policy of lightning fires (where lightning-ignited fires dominate) argue that the shift in fire season brought about by prescribed burning differs significantly from the regime under which the ecosystem evolved, and that this shift could have undesirable consequences. The effects of changes in fire season on grass species is relatively well understood,[20,21] but the impacts on the balance between grass and woody species is less well understood and may be significant. This is one area where savanna ecologists could profit from an improved understanding of the physiology, reproductive biology and life history characteristics of the most important woody species. The lack of such knowledge has been identified as a conspicuous deficiency in the understanding of savanna dynamics,[22] and will be needed to interpret the response of woody species to shifts in fire season.

Variation between and within land systems

The range of fire return periods varied almost threefold, from 2.7 to 7.1 years. The reasons for this variation are complex and related to the dynamics of the fuel layer and to sources of ignition. Fuel loads in savanna ecosystems are largely dominated by the grass layer; the grass biomass is a function of rainfall, soil fertility and herbivory.[23] Some examples of these interactions are discussed below.

The Malelane land system had the shortest median return period (1.8 years, Table 2). Here, relatively high rainfall and low fertility combine to produce a high biomass of grass. These grasses are seasonally unpalatable, and such areas are known locally as sourveld. Herbivory levels in sourveld are lower, and fire frequencies are consequently higher.[20] The true sourveld areas make up a smaller proportion of the Malelane and Skukuza land systems; these are described by Gertenbach[10] as two landscapes that make up 846 km^2. Median fire return periods for both areas were 1.9 years. In addition to higher fuel loads, the areas are also on the boundary of the park, where additional sources of ignition and firebreak burning affect fire frequency.

The Satara land system has lower rainfall than the Malelane, but is characterized by relatively nutrient-rich, basalt-derived soils. Grasses in this area tend to be palatable throughout the year (a condition known locally as sweetveld), and herbivory levels are high. Despite lower rainfall and higher levels of herbivory, the mean fire return period does not differ significantly from that of the Malelane system. We attribute this to the ability of the fertile soils to produce good crops of grass in years of relatively high rainfall, which in turn support a similar number of fires to the Malelane system.

Table 5. Diagnostics of two logistic regressions giving the relationship between grass biomass and the probability of fire in the Kruger National Park in 1995 and 1996 (see Fig. 14).

Year	Estimates	Standard error of estimates	% deviance explained	Significance (P)
1995	Constant (–3.7)	0.4504	7.006	0.0004
	Biomass coefficient (0.00047)	0.000134		
1996	Constant (–2.47)	0.3539	13.358	<0.0005
	Biomass coefficient (0.00051)	0.000080		

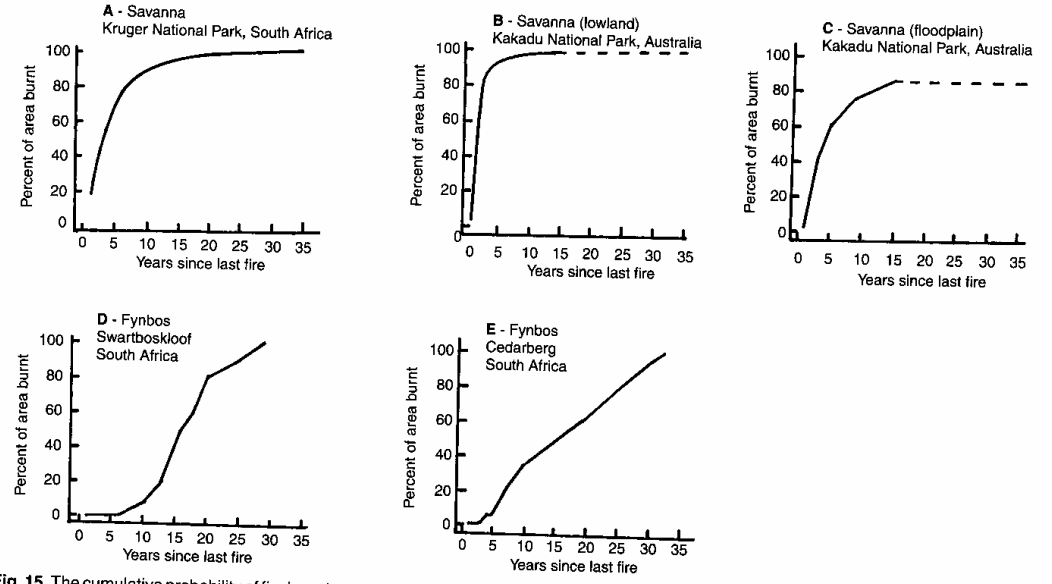


Fig. 15. The cumulative probability of fire in various ecosystems for which detailed fire histories are available. **A**, savannas in the Kruger National Park (this study); **B** and **C**, savannas in the Kakadu National Park, Australia;[25] **D**, fynbos shrublands at Swartboskloof;[27] and **E**, fynbos shrublands in the Cedarberg mountains.[26] Dashed lines indicate extrapolations beyond the available data.

The Phalaborwa (on granite) and Letaba (on basalt) land systems, north of the Olifants River, are dominated by mopane trees and shrubs. This species dominates on both granite and basalt, because of shallow soils underlain by impervious bedrock.[24] On basalts, grass biomass (and thus fuel) is presumably higher after good rains on the relatively fertile soils, which could explain the difference in mean fire return periods (4.4 and 7.1 years) despite similar rainfall.

Variation in mean fire return periods can be as great within land systems as between them. This can be seen in the mosaic of different return periods in adjacent areas (Fig. 7). The fact that these periods vary substantially between blocks with the same underlying geology and vegetation type, and the same climate and weather is probably due to differences in the dynamics of the fuel layer. This is probably a function of differential rates of herbivory. For example, Russell-Smith and co-workers[25] attributed a marked increase in fire frequency to increased herbaceous fuel loads associated with the removal of feral water buffalo in Kakadu National Park in Australia. Herbivory in turn is possibly related to the distribution of artificial water points. There are 611 boreholes and 129 dams in the park, and these have a strong influence on the spatial distribution of grazing pressure. The relationships between the artificial provision of water, herbivory, fire and feedback effects on vegetation dynamics are topics that need to be researched to be able to assess the consequences of ecosystem management in the area.

Comparison with other ecosystems

Detailed accounts of the fire history of savanna ecosystems are rare, but Russell-Smith and his co-workers[25] assembled a 15-year fire history for savanna vegetation types in the Kakadu National Park, northern Australia, from LANDSAT MSS imagery (Fig. 15). Here, fire frequencies were very high in lowland vegetation, with a median return period of less than 2 years. The floodplains at Kakadu, on the other hand, were characterized by less frequent fires, and a median return period of around 4 years. It would appear, therefore, that fire frequencies in the Australian park were similar to those in the Kruger National Park. The Kakadu data were also analysed with respect to fire size; while the median fire size was <300 ha, some very large, late dry season fires (>400 000 ha) did occur. These are typical of uncontrolled, late dry season fires in the vast unpopulated expanses of northern Australia.[25] Such fires have not, until recently, been a feature of the Kruger National Park, as fires were confined to management blocks.

Fire histories are also available for several fynbos (shrubland) ecosystems from the mediterranean-climate areas of the Western Cape, South Africa.[26,27] Here, fire return periods are longer (in the order of 15 years). A further feature of these ecosystems is that the distribution of fire return periods tends to be symmetrical around the mean (Fig. 15), so that median and mean values for fire return periods are similar. This indicates a normal distribution of return periods around the mean, as opposed the savanna systems which have skewed distribution. Fire return periods are also longer than for savanna, probably as a result of the coarser nature of fynbos fuels, coupled with slower build-up rates and less frequent occurrences of weather conditions conducive to large fires. The approach for depicting the distribution of fire return periods provides a useful descriptor of the fire regime in grasslands, savannas, and shrublands such as chaparral, fynbos, or heathlands. This is because fires in these ecosystems tend always to be surface fires burning in grass layers (for savannas and grasslands) or shrub canopies (in shrublands). In coniferous and boreal forests, on the other hand, the approach is less informative. In these ecosystems, fires can burn as low-intensity surface fires, or high-intensity crown fires, and these fires will have fundamentally different effects with the same frequency and return periods.

The management of fire regimes

The current fire management policy in the Kruger National Park allows 'natural' fires to burn freely. Prescribed burning is

not carried out, and fires of human origin are extinguished. However, anthropogenic fires have been a feature of the last 35 000 years or more. Because lightning alone may not ignite sufficient fires to simulate the park in historical times, some consideration must also be given to allowing additional fires to burn. These would make up for fires that would have been started by man in the past, or those that would have entered the park from outside but are not now able to do so. Managers are required to contain fires that are not started by lightning, and it is assumed that the area burnt by non-lightning fires will be sufficient to make up for the additional fires that would have occurred in the past. Because of the uncertainty about the nature of the historical fire regime, managers will have to monitor the occurrence of fires, and base the need to intervene on the patterns of fire that establish themselves. The application of these principles is discussed in another paper.[28] The present analysis provides a benchmark around which rules can be developed to test whether an acceptable fire regime does eventuate. The indications to date are that some significant shifts have already taken place. The overall area that has burnt under the lightning fire policy is smaller, and the fires have been in the form of a few very large conflagrations, and relatively fewer small ones. Mean return periods between fires has increased, and there has been a shift in the occurrence of fire to later in the season. The degree to which these shifts can be accommodated will depend on their actual or predicted impacts. We suggest that managers draw up hypothetical thresholds to the distribution curves for fire frequency and season that can be taken as indicators of potential concern.[28] Fire records can be updated annually, using computer technology,[29,30] and tested against these thresholds. In addition, managers can monitor trends in the plant and animal communities in the park. Any changes in the structure or composition of these populations or communities can be interpreted in terms of the fire regime and its history.

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