



**National Park Service
Fire Ecology Annual Report
Calendar Year 2007**

Summary

The Everglades National Park fire monitoring program continued to evolve in 2007 as the methods for reading the standard plots were refined to better meet the needs of South Florida ecosystems and park objectives. In the Pine Rocklands, monitoring of the host plants for rare butterflies continued and new insect diversity, shrub, and rare herbaceous plant monitoring studies were implemented in 2007. The crew archived several thousand photo-monitoring slides from previous years' reads. Our fire effects monitors continued to serve as advisors to the Pine Rockland Working Group, an international, multi-agency effort which has been effective at making recommendations and taking action to protect this imperiled ecosystem. In December, Fire Effects monitors organized the 7th annual 2007 Cape Sable Seaside Sparrow symposium (Fire Management Strategy of Occupied Cape Sable Seaside Sparrow Habitat).

The Fire Effects staff served on prescribed fires, wildland fires and out of park fire assignments. Collaboration between the Everglades Fire Effects team continued with the prescribed fire crew at Big Cypress. The Fire Effects staff along with one of the Prescribed Fire Technicians coordinated with the Exotics Coordinator and the Hole in the Donut Restoration Coordinator to develop prescribed fire objectives and combined monitoring efforts for the 2008 exotics areas burn plan.

Hillary Cooley, Maya Vaidya and Aerin Land (Lead Monitor, Fire Effects Monitors) represented Everglades National Park at the Archibold plant biologists meeting in April 2007. Aerin Land represented Everglades National Park at the Southern Forest Insect Work Conference in July 2007 and the Entomological Society of America conference in December 2007. Current data regarding fire effects on the candidate butterfly species for the federally endangered species and their host plants were presented at the meeting and conferences.

A new draft Fire Monitoring Plan including the adaptive management approach was written by Maya Vaidya (Assistant Lead Fire Effects Monitor) and Rick Anderson (Fire Ecologist). Aerin Land (Fire Effects Monitor) contributed to the writing of a NEPA compliance letter to the Fish and Wildlife Service regarding candidate butterfly species for the federally endangered species list living in Everglades National Park.

Table 1. Fire Effects Plot Workload 2007

Park	Monitoring Unit	Total plots installed to Date	Type of Plot (FMH, photo point, other)	Pre-burn	Immed. Post	Postburn (1-20 yrs)	Total Plots
Canaveral National Seashore	Pinus elliottii (Slash Pine Flatwoods)	10	FMH Forest plot	0	0	10	10
Everglades National Park	Pine Rockland	27	FMH Forest plot	0	7	10	17
	Short-hydroperiod Prairie	28	FMH Brush plot	0	5	8	13
	Long-hydroperiod Prairie	11	FMH Brush plot	1	1	1	3
	Coastal Prairie (Coastal Marsh)	18	FMH Brush plot	1	1	12	14
	1970's photo point relocation	225 (relocated 26)	Photo point	N/A	N/A	N/A	0
	Butterfly host plant	2	Host-plant monitoring	N/A	N/A	N/A	24
	Shrub monitoring (pilot)	6	Tagged individual shrub monitoring plot	7	1	N/A	8
	Insect monitoring (pilot)	6	Insect monitoring	N/A	N/A	N/A	36
	Phenology (pilot)	8	Phenology monitoring	N/A	N/A	N/A	13
Total		94		2	14	41	138

In 2007, the Everglades Fire Effects team conducted reads of 57 FMH plots, 47 reads in Everglades National Park and 10 reads in Canaveral National Seashore. Other monitoring included 24 butterfly host plant plot reads, 36 insect plots visits, 13 phenology plot reads and 8 shrub (Non-FMH) plot reads.

Table 2. Fire Ecology Staffing 2007

Monitor	Starting Date	Ending Date	# of Pay Periods	Training and Development
Rick Anderson	1/1/2007	11/10/2007	24	
Hillary Cooley	1/1/2007	8/4/2007	17	COR/COTR Contracting Officers Representative/Contracting Officers Technical Representative, S-131 Firefighter Type 1, S-133 Look Up, Look Down, Look Around, S-191 Introduction to Fire Signature Predictions, S-211 Portable Pumps, L-180 Human Factors on the Fireline, Intro to PMIS, NEPA Concepts Module 1&2, Endangered Species Act Counterpart Regulations for National Fire Plan Projects, Performance Management System, NPS Fundamentals IV, FEMA IS 00700 Oral presentations -Archibold Plant Biologists Meeting, Prairies workshop
Maya Vaidya	1/1/2007	12/31/2007	27	CPR/First Aid, Docushare Administrator Training, Hazardous Materials Training, S-234 Ignition Operations, FEMA IS 00700
Aerin Land	1/1/2007	12/31/2007	24	CPR/First Aid, Docushare Administrator Training, Hazardous Materials Training, S-234 Ignition Operations, FEMA IS 00700, S-271 Helicopter Crew Member, S-130/190 Introduction to Wildland Fire Behavior, I-100 Introduction to ICS, L-180 Human Factors on the Fireline, S-290 Intermediate Wildland Fire Behavior, Oral presentation -Archibold Plant Biologists Meeting, Poster Presentations - Southern Forest Insect Work Conference and Entomological Society of America
Katie Budzinski	10/28/2007	12/31/2007	4.5	
Colleen Hawks	12/9/2007	12/31/2007	1.5	
Dana Cohen	12/23/2007	12/31/2007	0.5	
SCA Interns			# of months	
Kelly McKean	1/1/2007	3/9/2007	2.25 months	S-271 Helicopter Crew Member,
Naomi Kibe	7/1/2007	12/31/2007	6 months	

Changes in the Fire Effects staff took place in 2007. Maya Vaidya was promoted to Assistant Lead Fire Effects Monitor in April 2007 and then to Lead Fire Effects Monitor in October 2007. Aerin Land was promoted to Assistant Lead in December 2007. Hillary Cooley left the program in August 2007 to work as the Exotics Coordinator for Everglades National Park - SFNRC. Katie Budzinski and Colleen Hawks were hired as the new Fire Effects Monitor GS 5 technicians in October and December of 2007. Two Student Conservation Association Interns worked with us in 2007 (Kelly McKean and Naomi Kibe). Naomi Kibe is an international volunteer from Japan. Rick Anderson was appointed Acting Fire Management Officer in November 2007. Dana Cohen was hired as Acting Fire Ecologist in December 2007.

Table 3. Management Objectives and Monitoring Results 2007

Monitoring Unit	Management Objective (Restoration)	Monitoring Results (% confidence interval)	Objective Achieved?
Slash Pine Savanna	<u>Canaveral-</u> Limit mortality of <i>Pinus elliottii</i> overstory trees to less than 30% as measured two years post burn.	Overstory pine mortality 22% 2 years post fire	Yes
	Induce top-kill of pole size hardwoods by 50-100% immediately post burn.	No longer monitoring hardwoods. (Resource objectives refined Nov. 2004)	N/A
	Promote 20% recruitment of seedling and pole sized PIEL >15cm in height five years post burn.	Have not completed 5 year post read.	N/A
	Reduce height of hardwoods and shrubs <6 feet immediately post burn.	No longer monitoring shrubs. (Resource objectives refined Nov. 2004)	N/A
	Increase cover of bare ground/open space to 25% bare ground / 75% litter cover 5 years post burn.	Have not completed 5 year post read.	Too soon to tell, will need to monitor additional years.
	<u>Everglades-</u> To maintain fire frequency return interval 1-5 yrs while maintaining up to 33% of the pinelands in a three year rough condition.	All Fire Effects plots have been treated with fire within the last 0-5 years. No plots are currently at a 3 year rough condition, 41% of plots are less than 3 year rough, 59% of the plots are greater than three year. *FMH plot burn history is not representative of entire pineland fire frequency and habitat rough condition	Yes Fire Frequency maintained at 1-5 yrs No-0% plots in a 3 yr rough condition **see * in column to left
Short Hydroperiod Prairie	Topkill >50% of encroaching woody species immediately post-burn	Did not complete belt transects Photomonitoring used to monitor woody species encroachment	No data * Photomonitoring data not analyzed
	Reduce fine fuels >70% immediately post-burn	Did not complete cover transects	No data * Photomonitoring data not analyzed
Coastal Prairie	Treat up to 100% of Old World climbing fern (<i>Lygodium microphyllum</i>) and/or Brazilian pepper (<i>Schinus terebinthifolius</i>) populations that have been identified by the Exotic Plant Management staff for fire treatment annually	No exotic plant populations were treated with fire	N/A
Long Hydroperiod Prairie	Topkill >50% of encroaching woody species immediately post-burn	Did not complete belt transects Photomonitoring used to monitor woody species encroachment	No data * Photomonitoring data not analyzed
	Reduce fine fuels >70% immediately post-burn	Did not complete cover transects	No data * Photomonitoring data not analyzed

Ecologist Accomplishments

Rick Anderson spent a substantial amount of time in 2007 working with Tom Ledbetter (Wildfire Suppression Specialist) to fill in for the Fire Management Officer (Bob Panko) when Bob was on leave or on assignment. Rick also continued to work on finalizing the Environmental Assessment for the Fire Management Plan. He continues to serve on the steering committee for Rx510 and taught the class at NAFRI in February-March. In November Rick taught a unit of RX-300 in Everglades National Park. He has been working with the S. Florida/Caribbean Inventory and Monitoring group to administer the contract with USGS to complete the park fire history map and subsequently create a Fire Return Interval Departure (FRID) map for EVER. He has continued a working relationship with Big Cypress fire effects staff as well as the Resource Management Specialist at Canaveral National Seashore. Times below are estimated.

Category	Percent Time	Accomplishments and/or areas of activities
Planning	35	EA for FMP, assist with Rx planning and recovery from 2007 Rx mishaps
Presentations	7	Teaching at Rx510 and Rx300
NPS Meetings/ task groups	13	Regular staff meetings at EVER, work with BICY and SFLC I&M
Interagency work	4	Participation on fire team and Rx510 steering committee
Fire Assignments	4	With Team
Research	5	Varied in support of strategic fire planning for EVER
Data entry	0	
Data Conversion	0	
Data analysis	4	Work with FIU researchers to analyze FE data, also to support EA
Supervision/Admin	28	Of FEM crew and of EVER Fire program in lieu of FMO
Training	0	
Miscellaneous		

Fire effects crew accomplishments and area of focus.

The fire effects crew monitored 57 FMH plots this year, 47 in Everglades National Park and 10 in Cape Canaveral National Seashore. The crew also monitored 2 Butterfly Host Plant plots on a monthly basis and installed Insect Sampling plots and Shrub Phenology and monitored every two months. Crew members and SCA Interns continued to scan and digitally store FMH slides. The 2007 Cape Sable Seaside Sparrow Symposium was organized by the fire effects crew. Crew members presented fire effects data at various venues, including the annual Plant Biologists of South Florida meeting, the Southern Forest Insect Work Conference, the annual Entomological Society of America conference, and the annual Everglades National Park Fire Management After Action Review.

Category	Percent Time	Notes
FMH plots	14%	Estimated amount of time spent collecting plot data; includes any preparation time.

WUI plots	N/A	NONE
CBI plots	N/A	NONE
Other plot work	17%	Butterfly host plant monitoring, insect collections, shrub phenology monitoring
Presentations	3%	Powerpoint presentations at Plant Biologists of South Florida meeting and the Everglades National Park Fire Management After Action Review; Poster presentations at the Southern Forest Insect Work Conference and the Entomological Society of America conference.
NPS Meetings/ task groups	3%	Annual AAR review, meetings with exotics control manager, daily briefing, Fire Management Plan meeting
Interagency work	10%	Cape Sable Seaside Sparrow meeting, Pine Rockland Working Group, Meetings with cooperators at Florida International University
Fire Assignments	8%	Big Cypress Complex, Sawmill Complex
Fuels Project work	N/A	NONE
Data entry	11%	Estimated amount of time spent entering data from paper to PC and filing field data sheets.
Data conversion	0%	Estimated amount of time to convert FMH data to FEAT; includes preparing species lists, error checking, learning conversion program, etc
Data analysis	11%	Time spent analysis data and developing sampling protocols for Canaveral and Everglades
Supervision/Admin	5%	Travel, payroll and purchasing, paperwork, etc. - Lead monitor-training new personnel, crediting plan, assisted Fire Ecologist in hiring of new crew members.
Training Training continued	12%	CPR/First Aid, Firefighter Refresher, S-271 Helicopter Crew Member, S-130/S-190 Introduction to Wildland Fire Behavior I-100 Introduction /L-180, Helicopter Crew Member Refresher, DocuShare Training, Hazardous Materials, S-290 Intermediate Wildland Fire Behavior, S-234 Ignitions Operations, COP/COTR (Contracting Officers Representative/Contracting Officers Technical Representative) Training, S-131 Firefighter Type 1, S-133 Look Up, Look Down, Look Around, S-191 Introduction to Fire Signature Predictions, S-211 Portable Pumps
Public outreach	2%	Gold Coast Railroad Museum Family Fun Day, 60 th Anniversary of Everglades National Park Celebration/Ceremony Day
Miscellaneous	11%	Local work on prescribed and wildland fires; Crew members and SCAs scanned FMH slides and stored digital photo monitoring images on archive DVDs; Assisted with burn boss training.

Sampling Design & Field Methods

Everglades National Park:

The FMH monitoring protocols employed in 2006 were continued in 2007 with some additions. In the forest plots: shrub cover and structure protocols were added and the cover point intercept line and observed species belt were added back into the protocols. In a subset of plots, the fuels transects were monitored to determine if there was a correlation between fuel biomass and shrub cover. In the Coastal Prairies a percent cover of *Lygodium* present was recorded, otherwise the brush plot monitoring protocols stayed the same.

The butterfly host plant monitoring continued for *Croton linearis* (host plant of the Florida leafwing and Bartram's hairstreak). Monitoring of *Zamia pumila* was ended due to the fact that the Atala butterfly is not currently in the park, nor are there any plans for release in the near future.

A pilot study was initiated to monitor effects of fire on individual shrub growth, resprouting, and phenology. Phenological plant response for all reproductive plants present was also recorded during the plot visit. Six plots were monitored, however only 1 plot burned.

Monitoring for this one plot only has continued (appendix B).

A pilot study to determine fire effects on the federally listed *Chamaesyce garberi* was initiated (appendix C).

A study was initiated in the Pinelands to monitor insect diversity and the effects of fire on the arthropod populations. The project proposal and methods can be found in appendix D.

An outline of Everglades monitoring protocols for the Pinelands can be found in appendix A.

Canaveral National Seashore:

Fire effects monitoring in the Slash Pine Flatwoods of Canaveral National Seashore continued.

Monitoring Results

Everglades National Park: The Everglades Fire Effects data was analyzed in 2006 by Jay Sah of Florida International University. A draft of the analysis report is attached (appendix E).

Research Projects/Collaboration

Collaboration with groups below has continued.

- Pine Rockland Working Group
- Annual Cape Sable Seaside Sparrow Symposium
- Florida International University on data-driven vegetation classification of south Florida plant communities
- University of Vermont on fire effects in the Pine Rocklands
- Fire Effects data analysis with Florida International University
- USGS/SFLC I&M to create FRID map for EVER

Adaptive Management

An adaptive management flowchart and outline were created for the fire effects monitoring program and inclusion in the Fire Monitoring Plan, appendix to the Fire Management Plan. The chart and outline can be found in appendix F. The Florida International University Sah report will be used to evaluate if the analyzed monitoring protocols are meeting the Fire Management objectives and the adaptive management approach applied in decision making regarding fire effects monitoring.

APPENDIX A

Everglades Pinelands Fire Effects Monitoring Protocols 2007

FMH (27 plots)
Croton (2 plots)
Shrubs (Non-FMH) (6 plots)
Insects (6 plots)
Phenology (6 plots)
Chamaesyce garberi (2 plots – 4 subplots / plot)

FMH Plots (27 Plots)

Schedule of Monitoring:

Pre Burn

Immediate Post Burn (within 2 weeks of fire being declared out)

1 year post

2 years post

5 years post

Pre Burn Monitoring:

All plots were monitored for a “pre burn” read after installation in 1999 – the pre burn data however does not take into account prior burn histories of the Pine Rockland blocks.

The methods used in 1999 have been modified – see supplemental methods sheets for pre burn methods employed (1999-2004)

Immediate Post Burn Monitoring:

Trees (>2.5cm DBH) measured for:

- Live / Dead
 - Measure of tree mortality
- Percent Crown Scorch
 - Estimate of % crown scorch – indicator of burn severity

Burn Severity

- Measure of severity of burn on substrate and vegetation

Habitat and vegetation

- Photo Monitoring
 - Assess changes in vegetation structure and habitat changes over time

1 Year / 2 Year / 5 Year Post Burn Monitoring

Trees (>2.5cm DBH) measured for:

- Live / Dead
- DBH
 - Diameter at breast height – % basal cover (Not Measured 1 Year Post)
- Crown position
 - An assessment of individual position in canopy – canopy structure (Overstory trees only >15cm DBH)

- Height
 - Used to determine structure and age class (Pole sized trees only 2.5-15cm DBH)
- Damage code
 - Any damage present and the extent to which it is adversely affecting the tree
- Density
 - Tag and measure every tree within the plot

Snags (> 8cm DBH)

- DBH
 - Diameter at breast height - (Not Measured 1 Year Post)
- Height
 - Used to estimate snag stand structure
- Condition code
 - Decay class of snag
- % Bark
- % Sapwood
- Cavity presence
 - Yes / No – is there a cavity large enough for a bird to enter
- Density
 - Tag and measure every >8cmDBH snag within the plot

Seedlings

- Height in class sizes
 - Population structure and age distribution
- Density
 - Changes in population densities and regeneration over time and in response to fire
- Live / Dead

Herbaceous and Woody Plants

- Point intercept method of plant measuring cover
 - Cover estimate of herbaceous and woody species
 - Structural component with height recorded for every spp
 - Frequency and diversity measure of species in the plot
 - Estimate of type and substrate presence
 - May be useful in determining connectivity of fuels on the ground
- Ocular observed spp
 - Check list of all plant species present in belt transect not already accounted for in previous monitoring – diversity and frequency of species in plots

Habitat and vegetation

- Photo Monitoring
 - Assess changes in vegetation structure and habitat changes over time

Croton Monitoring Plots (2 Plots)

Schedule of Monitoring

Monthly Monitoring

Croton (Tagged individuals)

- Live / Dead
- Height
 - Growth rates over time and in response to fire; size of individuals on which larva are found
- Crown area
 - Growth rates over time and in response to fire; size of individuals on which larva are found
- Post fire assessment
 - Burned or unburned recorded for individual plants
- Resprout
 - Resprouting response to fire
- Number of fruits/flowers/buds
 - Phenological response to fire and individual fecundity
- Herbivory
 - Signs of Leafwing and Batrtam's Hair Streak presence and herbivory
- Presence of Leafwing and Batrtam's Hair Streak Larva
 - Count of individual larva found; specific plant on which they were found; fire history of plot and of individual plant

Phenology

- Check list of all reproducing species in the plot and the phenological stage they are in
 - monitored every 2 months
 - Measure of seasonality of phenology and phenological response to fire

Individual Shrub Monitoring (6 plots)

Schedule of Monitoring

Pre Burn

Immediate Post Burn

Every 2 Months

Yearly

Pre Burn – Initial Monitoring

Shrubs (Tagged Individuals)

- Four species followed
 - *Guettarda scabra*, *Myrica cerifera*, *Myrsine floridana*, *Sideroxylon salicifolia*
- Tagged 20 individuals/species/plot
- Height
 - Growth rates – can be used to develop a regression equation to determine biomass in conjunction with crown area

- Crown dimensions (DBH if can't reach crown)
 - Growth rates – can be used to develop a regression equation to determine biomass in conjunction with height
- Damage
 - Assessment of insect damage, frost, etc.
- Frt/flw
 - Check if frt/flw at time of tagging

Every 2 Months Monitoring

Shrub Phenology / Fecundity

- Tally number of fruits/flowers/buds for individuals every 2 months
 - Measure of phenological response to fire and seasonal changes in reproduction
- Damage
 - Assessment of insect damage, frost, etc.
- Live / Dead

Immediate Post Burn Monitoring

- Burn Severity
 - Measure of burn severity of individual shrubs

Yearly Monitoring

- Live / Dead
- Height
 - Growth rates – can be used to develop a regression equation to determine biomass in conjunction with crown area
- Crown dimensions (DBH if can't reach crown)
 - Growth rates – can be used to develop a regression equation to determine biomass in conjunction with height
- Damage
 - Assessment of insect damage, frost, etc.
- Frt/flw
 - Check if frt/flw

Insect Monitoring (6 plots)

Schedule of Monitoring

Every 2 Months Monitoring

- Malaise Traps – set up every 2 months
 - Flight interception traps used to evaluate arthropod abundance, richness, evenness and diversity of flying insects – may be correlated with other data being measured in FMH plots
- Litter Samples- every 2 months

- Samples taken to evaluate arthropod abundance, richness, evenness and diversity of insects found in leaf litter – may be correlated with other data being measured in FMH plots

Phenology (6 plots)

Schedule of Monitoring

Every 2 Months Monitoring

- Check list of all reproducing species in the plot and the phenological stage they are in – monitored every 2 months
 - Measure of seasonality of phenology and phenological response to fire

Chamaesyce garberi (2 plots)

Schedule of Monitoring

Pre Burn

Yearly

Pre Burn – Initial Monitoring

- Tagged all Individuals in plot
 - Density
- Height
 - Growth rates
- Spread
 - Growth rates
- Damage
 - Assessment of insect damage, frost, etc.
- Frt/flw
 - Check if frt/flw

Yearly Monitoring

- Live / Dead
- Height
 - Growth rates
- Spread
 - Growth rates
- Damage
 - Assessment of insect damage, frost, etc.
- Frt/flw
 - Check if frt/flw

APPENDIX B
Individual Shrub Monitoring – Pilot Study – 2007

In 2007 it was decided by the Fire Ecologist that an investigation into fire effects on shrub growth and phenology was needed. Four shrub species were chosen either because they are common to the pinelands and/or are common hammock species. The species chosen to monitor were *Guettarda scabra*, *Myrica cerifera*, *Myrsine floridana*, and *Sideroxylon salicifolia*

Six existing FMH plots were randomly chosen in which to pilot this study. Plot 19 in block A, plot 4 in block E, plot 12 in block C, plot 14 in block J and plot 3 in block I2.

Tagging occurred in April/May 2007. A total of 20 individuals per species per plot were tagged. In plots with less than 20 individuals per species, all individuals of the species were tagged. To distribute shrubs tagged, 5 individuals per species per quarter were chosen when possible. A range of size classes were chosen subjectively by the monitors tagging individual shrubs. Individuals were tagged with numbered brass tags and wire around the base of the plant.

Initial data collected included height and crown length and width (cm) (or height and DBH (cm) for shrubs of sufficient height), location within the plot, and presence of fruits/flowers. Post burn data collected included burn severity on the individual shrubs immediately post and presence of resprouts up to 6 months post.

Phenology data is collected for each shrub every two months and began in July 2007. Number of fruits, flowers and buds are recorded as an exact count for up to 25 and estimated in classes beyond 25.

The classes are:

0-25 – exact number recorded

25-50

50-100

100-200

200-500

500-1000

>1000

By September 2007, only one plot had burned (plot 14 block J). This is the only plot on which post burn data was collected and currently is the only plot still being monitored.

APPENDIX C
Chamaesyce garberi monitoring

In April 2007, *Chamaesyce garberi* monitoring plots were installed in 2 pine plots (PIEL 4 and PIEL 8). Four 1m radius circular plots were installed along the 0P-50P FMH center plot line. Plots were installed every ten meters around already installed rebar. All *Chamaesyce garberi* individuals within the plot were measured and tagged with a numbered brass tag.

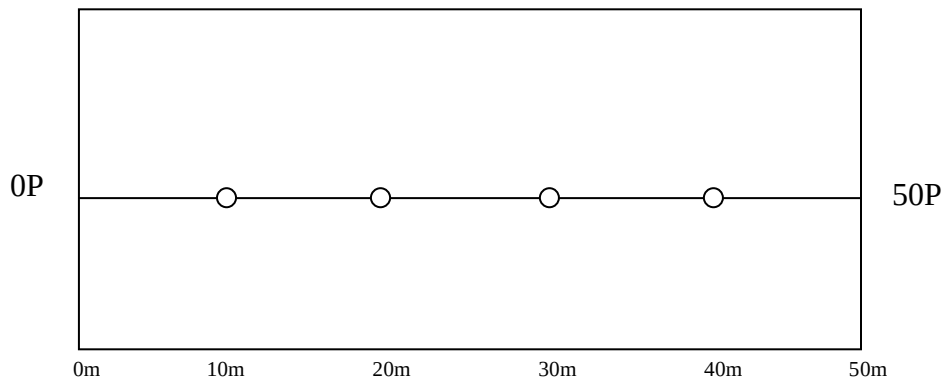
Measurements recorded:

Height (cm) – measure from the tallest green to the ground at a 90° angle

Spread (cm) – a measurement of length from the center of the plant to the farthest green

Fruit/flower – a presence/absence record of fruits and flowers on each individual

FMH Plot: ○ *Chamaesyce garberi* plots (center marked with rebar)



APPENDIX D

Proposal to Monitor Insect Diversity in the Pinerocklands

Monitoring arthropod abundance, diversity, richness and evenness within the pine rocklands of the Everglades National Park

Introduction

The pine rockland habitat in south Florida supports the most diverse plant community in the state and is home to many endangered plant species, some of which occur nowhere else in the world (Hammer 2002). This rare and imperiled habitat consists of an open Slash pine (*Pinus ellioti densa*) canopy with an understory of shrubs, palms and herbaceous plants. The forest floor contains sparse soil and leaf litter covering a limestone surface.

Wildland fires maintain this unique ecosystem by recycling nutrients, promoting seed germination, and reducing hardwood competition (Whelan 1995). In the absence of fire, hardwood succession ensues. As a result, the open pine canopy becomes a dense hardwood “hammock” and a thick, moist layer of soil and leaf litter accumulates. Habitat fragmentation caused by urban and agricultural developments has reduced the frequency of natural fire ignition and created the need for prescription burning. Research is ongoing to determine the ideal season, frequency, and severity of fire that is necessary to maintain the diverse pine rockland habitats (Snyder 1986; Slocum et al. 2003; Snyder et al. 2006).

The diversity of organisms within a habitat can be a strong indicator of its stability, productivity, and complexity (Tilman et al. 1996). One group of organisms that has not been quantified in the pine rocklands are in the phylum arthropoda. Insects outnumber all other animals on the planet (Triplehorn and Johnson 2005) and play vastly important roles in the ecological processes of a habitat, including pollination, nutrient recycling, and providing a prey base for many animals. The richness and diversity of terrestrial arthropods is often correlated with plant species diversity (Siemen et al. 1998), habitat structure (Uetz 1975) and leaf litter structure and depth (Coleman and Rieske 2006). It is possible that the pine rocklands support an arthropod community as diverse and rare as its plants.

Currently, invertebrates are the most understudied organisms within the Everglades (Brown et al. 2006), with most research focusing on exotic, invasive flora (Clouse 1999; Costello et al. 2003) and fauna (Koptur 1992; Ferster and Prusak 1994) or high profile butterfly species (Saarinen and Daniels 2006). There has been little investigation into native arthropod communities (Pascarella et al. 2001) and no study has addressed the impact of fire management on arthropod populations within the pine rocklands of the Everglades.

Changes in plant composition and structure due to different fire management practices can be highly influential on arthropod abundance and diversity. For instance, some plants experience increased fruiting and flowering following a fire (Gunderson et al 1983; Negron-Ortiz and Gorchoy 2000), which provides an abundant food source for many vertebrates and invertebrates. Some experience reduced fecundity and fruiting and flowering does not return to full capacity for two years (Gunderson et al 1983). In areas with frequent (<2 yr) fires, these plants may be unsuitable as a food source for pollinators. Highly mobile, generalist insects can immigrate or emigrate from areas as habitat suitability fluxuates, while specialists with low mobility would not be as adaptable.

In 2007 a study was initiated to examine the arthropod community of the pine rocklands in the Everglades National Park and how it relates to fire. Objectives for this study include:

1. Evaluate arthropod abundance, richness, evenness and diversity using malaise traps and litter sampling in pine rockland during wet and dry seasons,
2. Samples will be collected in conjuncture with FMH and shrub monitoring to determine if there is a correlation between habitat characteristics (structure of woody shrubs, shrub species composition, shrub phenology, litter cover and depth) and arthropod abundance, richness, evenness and diversity
3. Collect arthropod samples from plots with varying fire histories to examine fire effects on arthropod communities over time.
4. Using available keys all adult arthropods will be identified to order and family and immature arthropods will be identified to order.

Materials and Methods (Feb. 2007)

This study will be conducted in the pine rocklands of the Everglades National Park (Homestead, FL USA). A total of six FMH plots will be monitored for arthropod abundance, richness, evenness and diversity. Three plots with different fire histories will be monitored from areas scheduled to burn in 2007 and three additional plots with differing fire histories will be monitored in areas not scheduled to burn in 2007. Arthropod sampling will occur 6 times a year, during the early (June), mid (August) and late (October) wet season and the early (December), mid (February) and late (April) dry season. Two methods of arthropod sampling, malaise traps and leaf litter collections, will be used in each of the 6 plots, for a total 12 arthropod samples collected per sampling month.

Malaise traps are tent-like flight interception traps that utilize insects' tendency to fly up when an obstacle is encountered. A collection jar is located at the top of the trap and contains a 6.5 cm² portion of Vapona® (dichlorvos) pest strip that kills all arthropods and prevents destruction of small or delicate specimens. One malaise trap will be opened for 48 hours in each of the 6 plots every sampling period, for a total of 36 malaise samples collected each year. The traps will be placed in the most open area of the plot and trap location coordinates will be recorded using GPS and will be the same for each recurrent sampling. An area within the plot will be considered open if all palms and woody shrubs within at least 2 m radius are below 1 m in height. When possible, the traps will be established in Q4, however, if not suitable open space can be located the traps will be placed in Q1. Specimens will be stored in a freezer until identification.

Leaf litter sample sites will be a 0.5 m² area and are randomly selected within Q4 of each plot. Within each sample site, percent litter cover will be visually assessed and litter depth will be measured from the center of the site. Within the sample site dead, unattached organic matter will be collected to fill quart sized plastic bag. Arthropods will be extracted from the litter samples with Burlese funnels for 48 hours and stored in 70% ethanol until identification.

This project will require approximately 3 full days of field work every two months. At least two people will be needed for the field work and occasional assistance with insect identification may be needed. At one year we will re-examine our methods to determine if our objectives are being met. Sampling frequency and techniques will be adjusted as needed.

Materials and Methods (Updated Aug 2007)

This study is being conducted in the pine rocklands of the Everglades National Park (Homestead, FL USA). A total of six FMH plots are monitored for arthropod abundance, richness, evenness and diversity. Three plots with different fire histories were chosen from blocks scheduled to burn in 2007, but only one plot burned during the 2007 fire season. Three additional plots with differing fire histories were chosen from areas not scheduled to burn in 2007. Arthropod sampling occurs 6 times a year, during the early (June), mid (August) and late (October) wet season and the early (December), mid (February) and late (April) dry season. Two methods of arthropod sampling, malaise traps and leaf litter collections, are used in each of the 6 plots, for a total 12 arthropod samples collected per sampling month.

Malaise traps (1 per plot) were placed in the most open area of Quarter 4 of the plot and trap location coordinates were recorded using GPS and will be the same for each recurrent sampling. An area within the plot was considered open if all palms and woody shrubs within at least a 2 m radius are below 1 m in height. Traps are aligned so that the collection jar faces north and opened for 48 hours during the February and April. This sampling interval yielded small amounts of arthropods. In order to collect more specimens, the traps were left open for 96 hours, beginning in June. Specimens are stored in a freezer until identification.

Leaf litter sample sites are 0.5 m² areas randomly selected within Q4 of each plot. Within each sample site, percent litter cover is visually assessed and litter depth is measured from the center of the site. All dead, unattached organic matter is collected from the sample site and placed in a plastic bag. Arthropods are extracted from the litter samples with Burlese funnels for 48 hours and stored in 70% ethanol until identification.

This project requires approximately 3 full days of field work every two months. At least two people are needed for the field work and occasional assistance with insect identification may be needed. At one year we will re-examine our methods.

Literature Cited

Brown, M.T., M.J. Cohen, E. Bardi and W.W. Ingwersen. 2006. Species diversity in the Florida Everglades, USA: a systems approach to calculating biodiversity. *Aquatic Sciences* 68:254-277.

Clouse, R. 1999. Leaf-litter inhabitants of a Brazilian pepper stand in Everglades National Park. *Florida Entomologist* 82:388-403.

Coleman, T.W. and L.K. Rieske. 2006. Arthropod response to prescription burning at the soil-litter interface in oak-pine forests. *Forest Ecology and Management* 233:52-60.

Costello, S.L., P.D. Pratt, M.B. Rayamajhi and T.D. Center. 2003. Arthropods associated with above-ground portions of the invasive tree, *Melaleuca quinquenervia*, in south Florida, USA. *Florida Entomologist* 86:300-322.

Emlen, J.T. 1970. Habitat Selection by Birds Following a Forest Fire. *Ecology* 51:343-345.

- Ferster, B. and Z. Prusak. 1994. A preliminary checklist of the ants (Hymenoptera: Formicidae) of Everglades National Park. *Florida Entomologist* 77:508-512.
- Gunderson, L., D. Taylor and J. Craig. 1983. Fire effects on flowering and fruiting patterns of understory plants in pinlands of Everglades National Park. Report SFRC-83/04, National Park Service, South Florida Research Center.
- Hammer, R.L. 2002. *Everglades Wildflowers*. Globe Pequot Press, Guilford CT.
- Jacobsen, R.E. and S.A. Perry. 2007. *Polypedilum nubifer*, a chironomid midge (Diptera: Chironomidae) new to Florida that has nuisance potential.
- Koptur, S. 1992. Plants with extrafloral nectaries and ants in Everglades habitats. *Florida Entomologist* 75:38-50.
- Negrón-Ortiz, V. and D.L. Gorchov. 2000. Effects of fire season and postfire herbivory on the cycad *Zamia pumila* (Zamiaceae) in slash pine savanna, Everglades National Park, Florida. *International Journal of Plant Sciences* 161:659-669.
- Pascarella, J.B., K.D. Waddington and P.R. Neal. 2001. Non-apoid flower-visiting fauna of Everglades National Park, Florida. *Biodiversity and Conservation* 10:551-566.
- Peck, S.B. 1989. A survey of insects of the Florida Keys: Post-Pleistocene land-bridge islands: Introduction. *Florida Entomologist* 72:603-612.
- Saarinén, E.V. and J.C. Daniels. 2006. Miami Blue butterfly larvae (Lepidoptera: Lycaenidae) and ants (Hymenoptera: Formicidae): new information on the symbionts of an endangered taxon. *Florida Entomologist* 89:69-74.
- Sah, J.P., M.S. Ross, J.R. Snyder, S. Koptur and H.C. Cooley. 2006. Fuel loads, fire regimes, and post-fire fuel dynamics in Florida Keys pine forests. *International Journal of Wildland Fire* 15:463-478.
- Sah, J.P., M.S. Ross, S. Koptur and J.R. Snyder. 2004. Estimating aboveground biomass of broadleaved woody plants in the understory of Florida Keys pine forests. *Forest Ecology and Management* 203:319-329.
- Slocum, M.G., W.J. Platt and H.C. Cooley. 2003. Effects of differences in prescribed fire regimes on patchiness and intensity of fires in subtropical savannas of Everglades National Park, Florida. *Restoration Ecology* 11:91-102.
- Snyder, J.R. 1986. The impact of wet season and dry season fires on Miami Rock Ridge Pineland, Everglades National Park, South Florida. Report SERC 86/06.
- Snyder, J.R., M.S. Ross, S. Koptur and J. Sah. 2006. [Developing Ecological Criteria for Prescribed Fire in South Florida Pine Rockland Ecosystems](#). Report SERC 2006-1062.

Triplehorn, C.A. and N.F. Johnson. 2005. Borror and DeLong's Introduction to the Study of Insects, 7th ed. Belmont, CA, USA.

Whelan, R.J. 1995. The Ecology of Fire. Cambridge University Press. New York, NY, USA.

**Effects of prescribed fires in reducing the fuels and suppressing the
hardwood growth in pinelands and short-hydroperiod prairies**



Jay P Sah and Michael S. Ross
Southeast Environmental Research Center
Florida International University, Miami, FL 33199

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1 Introduction

In South Florida ecosystems, many plant communities require occasional burnings (Egler 1952; Robertson 1953; Wade et al. 1980; Snyder 1991; Beckage et al. 2004). In the Everglades also, researchers have recognized the role of fire in maintaining the health of plant communities, such as pine forests and prairies (Snyder et al. 1990; Lockwood et al. 2003). Long term exclusion of fire from these communities usually results in a change in species composition and community structure, leading to the decline in habitat quality. In recent decades, human-induced changes in hydrologic and fire regimes in the Everglades have affected the way communities in this system were burned historically. Thus, management strategies for Everglades ecosystems, particularly, pine forests, wet prairies and coastal prairies, need to accommodate manipulations of fuels and fires, including the implementation of prescribed burnings, so that current fire events mimic the historical fire regimes.

Everglades National Park initiated a Fire Monitoring Program in 1999 in Slash Pine Savannas in Long Pine Key with distinct management goals. In the following years, the program was extended to other habitat, such as Marl Prairies, Sawgrass Prairie, Coastal Prairie, and *Melaleuca* (Exotic) stands. A number of plots have been established in these habitats to collect data before and after fire (**Figure 1.1**). Many of these plots received burning (single or multiple treatments), while some of them were not burnt for several reasons. In the plots stratified sampling was used to collect data for herb, shrub, and tree (only pinelands) strata, and fuel loads. To collect data in different strata, various sampling units, plot-quarter, belt and line transect were used, following the methods described in Fire Monitoring Handbook (FMH). Most of those data are analyzed and results are presented in subsequent sections in this document.

The major goals of analyzing the available data collected in fire monitoring plots between 1999 and 2004 were to evaluate the efficiency of the sampling methods in assessing vegetation response to fire and to recommend necessary improvements. The analytical methods applied to these data varied among habitat types and sampling procedures. Results of data analysis are summarized below, arranged in section and sub-sections by community types. Section 2 describes the fire history of monitoring plots, based on fire data available for 1949 to 1998. Sections 3, 4 and 5 describe in detail the Pine forests, freshwater wet prairies and coastal prairies, respectively. In each of these three sections, results of pre-burn data are first summarized, followed by fire behavior and fuel consumption, and then by effects of fire on community structure and composition. Section 6 includes the conclusions and recommendations, in which major findings from data analysis are summarized and improvements in sampling protocols are suggested.

2. Fire monitoring plots and their fire history

2.1 Pine forest plots

In the pine forests of the Long Pine Key, 28 50m x 20m plots were established to monitor the effects of prescribed fires on tree mortality, pine regeneration and understory vegetation. Out of 28 plots, Plot 2 was never burned and therefore it was not monitored. The remaining 27 plots had different fire history, varying in fire frequency, calculated over 50 years (1949 to 1998). Time elapsed between the last burn and first prescribed burn also varied among plots. Most of the plots were burned 6-9 times over the period of 50 years (**Figure 2.1**), and 80% of plots were burned within 2 to 4 years before the first prescribed burn initiated in 1999 (**Figure 2.2**).

2.2 Freshwater Prairies

Fire plays an important role in suppressing woody plant encroachment in wet prairies in Everglades. However, how frequent those areas should burn to get desired response is not well understood. To examine the effects of fire frequency on woody plants in both long and short hydroperiod prairies, fire monitoring plots were established in sawgrass (*Cladium jamaicense*) prairie and muhly (*Muhlenbergia capillaris* sub sp. *filipes*) prairie, which are similar to *Cladium* and *Muhlenbergia* wet prairies described by Ross et al. (2006). Though the term Marl Prairie is used in Fire Monitoring Database, the nomenclature, will follow Ross et al. (2006), since marl prairie not necessarily includes only short-hydroperiod muhly-grass dominated communities. Instead, the term ‘marl prairie’ is used for both long- and short-hydroperiod graminoid vegetation which are present on marl substrates.

To monitor the effects of fire, 11 and 28 plots were established in the *Cladium* and *Muhlenbergia* wet prairies, respectively. Like pine forest plots, these brush plots also had different fire history. Over 50 years, from 1949 to 1998, mean fire frequency was 0.08 fire/year. The number of fires per plot ranged between 0 and 10, and muhly plots burned more frequently than sawgrass plots (**Figure 2.2A**). In wet prairies, time elapsed between the last burn and the first prescribed experimental burn also varied. Two sawgrass plots in which prescribed burn was done in 2001, time since last burn was 6 and 11 years. In muhly plots, it ranged between 2 and 15 years (**Figure 2.2B**).

2.3 Coastal Prairies

In the Everglades National Park, coastal prairies are located between the tidal mud flats of Florida Bay and dry land. The vegetation in this region is dominated by *Cladium jamaicense*, *Juncus roemerianus* and *Spartina bakerii*. In recent years, encroachment by mangroves has threatened the existence of coastal prairies. To monitor effects of fire on vegetation, 18 plots were established in south western and western part of Everglades National Park. Prescribed burns were conducted in 16 of them. Before the start of prescribed burn, 11 plots were never burned over 50 years, 1948-1999. Even in the rest five plots, the fire frequency was very low, 0.02 to 0.06 burns/years, less than in forest and freshwater prairies, and the time elapsed between last burn and the first prescribed burn ranged between 3 and 17 years (**Figure 2.3**).

3. Pine forests

Twenty seven pine forest plots were burned over 7 years, from 1999 to 2005. Fuel load, fire behavior and vegetation data were collected before and after each burn following the protocols described in Fire Monitoring Handbook (FMH). Although prescribed burning started in 1999, not all 27 plots were burned in the same year and in the same season within a particular year. The plots were burned mostly from March to August. However, few burnings took place in other months, between November and February. Among 27 plots, 14 plots were burned only once in 7 years, while others were burned either 2, 3 or 4 times. In the first burning, Plots 3 and 20 did not burn, and in the second burning a very small portion of Plot 20 burned, where as Plot 3 did not burn at all. That resulted in irregular sampling in these two plots. In assessing the effects of fire on community structure and tree mortality in post burn years, these two plots were excluded from the analysis.

3.1 Pre-burn status

3.1.1 Fuel loads

In a fire-prone plant community, higher fuel loads usually generate more severe fires (Rothermel 1972; Brown and Davis 1973), which can be detrimental to ecosystem function. Thus, fuel reduction has been recognized as one rationale for employing prescribed fire in different ecosystems, including South Florida pine forests. To assess the effects of prescribed fire on fuel loads, fuel measurements were taken along four randomly selected 50 feet transects (termed as Brown's Transects). Litter and duff depths were recorded every 5' along the transects. Downed woody materials, that included 1, 10, 100 and 1000 hour fuels, were also recorded along the same transects.

In pre-burn pine forest plots, mean ($\pm$ SE) litter and duff depth were 0.95 ± 0.17 cm (0.37 ± 0.07 "") and 1.18 ± 0.13 cm (0.46 ± 0.07 ""), respectively. Plot 12 had the highest amount of duff whereas Plot-26 shared the rank with that plot in litter depth (**Figure 3.1**). Depth of both duff and litter were not significantly related to fire frequency over 50 years. However, amount of litter showed increasing trend with time since last fire ($r = 0.315$), though the relationship was not statistically significant ($p = 0.11$). Duff and litter depth were significantly related to standing pine trees, and were higher in the plots with high tree basal area (**Figure 3.2**)

(More to be added XXX)

3.1.2 Pine density and basal area

In the Long Pine Key pine forests, mean pre-burn density of pine trees was 344 trees/ha. The density of pine trees in LPK forest was much lower than in the Lower Keys (570 trees/ha), but it was higher than in the Raccoon Point (231 trees/ha) in the Big Cypress National Preserve. The size frequency distribution of trees varied among fire monitoring plots (**Figure 3.3**).

Table 3.1: Slash pine tree density in Long Pine Key pine forest and other pine forests in Florida Keys and Everglades

Pineland	Density (trees/ha)	BA (m ² /ha)
LPK	300	7.89
Pine Island (pre)	399	19.35
Pine Island (post)	154	6.96
BPK	570	8.57
Raccoon Pt	231	5.84
Lostman's Pines	477	10.91

For monitoring purpose, trees were categorized into two different strata, understory (termed as 'pole' (dbh <15 cm), and overstory (>15cm). Size structure in these two strata was different (**Figure 3.4**)

Pre-burn tree density in monitoring plots was not significantly related to elevation, though the basal area showed increasing trend with elevation ($r = 0.267$), but the relationship was not statistically significant ($p > 0.05$).

Fire frequency and size distribution of trees

Total pre-burn tree density in the pine forest did not show significant relationship with fire frequency over 50 years or time since last fire. However, repeated burnings in the past seem to have reduced the number of small sized tree, as both density and basal area of large-sized (>15 cm dbh) tree in the plots increased ($r = 0.35$ and $r = 0.41$, respectively) with fire frequency (**Figure 3.5**). In contrast, both density and basal area showed decreasing trend ($r = -0.18$ and $r = 0.29$, respectively) with time since last fire, though the relationship was not statistically significant ($p > 0.05$).

3.1.3 Shrub density

Prescribed fires in the Everglades National Park were aimed at reducing the cover of hard wood shrubs in the understory of pine forests by 50-100% immediately after the fire and 0-50% after one year post burn. To monitor the changes in woody plant cover before and after burn, woody plant density was measured within a narrow belt of 30 m x 0.5 in pine forest. Although shrub cover might not be fully represented in the density, the later was considered as a proxy of the woody plant cover.

Prior to prescribed burn, the mean shrub density in the pine forests was 68,865 stems/ha (**Figure 3.6**). However, only about a third (31.5%) of them was mature. More than half (57.8%) of hard wood shrubs were immature, and a small percentage of total woody stems were re-sprouts (10.6%).

3.1.4 Understory vegetation

Under story vegetation structure and composition was monitored using point intercept method along a 30 m line transect within a 10m x 30m quadrat in each monitoring plot. Along the transect, 100 points were sampled using a 0.6 mm diameter rod. All vascular plants touching the rod were identified to species, and the tallest height and substrate was recorded. Other than periphyton, nonvascular plants were not identified. Species observed but not intersected along the transect were recorded within 5 m on either side of the line, i.e. in a 10m x 30m area.

Species cover

Vegetation sampling along the transect was meant to monitor effect of fire on cover of both herbaceous and woody species in the understory of pine forest plots. Since 100 points were sampled along the transect, percentage cover of each species was calculated as the number of times that a species was hit along the transect.

In the pre-burn pine forest plots, understory vegetation was dense. In these plots, cover of 145 species were recorded along transect. Out of them, forbs, shrubs, and grasses were 37.5%, 29.2% and 16.7%, respectively. *Pinus elliotii* var. *densa* was only tree species, cover of which was recorded in the height category ranging from 0.02 to 2.00 m. Almost all species were native except Jute (*Corchorus siliquosus*), a shrub. Another exotic species, Brazilian pepper (*Schinus terebinthifolius*), which was recorded in only one plot (Plot 13) one year after fire was absent in the pine plots before prescribed burn.

Mean cover of species ranged between 0.04% and 20.04%, and 31 species had >1% mean cover (**Figure 3.7**). Sawgrass (*Cladium jamaicense*) had the highest cover (20.0%), followed by *Muhlenbergia filipes* (16.0%), *Schizachyrium rhizomatum* (12.4%) and *Andropogon cabanisii* (10.6%). These grasses are also dominant in prairies adjacent to pine forests in Long Pine Key. Among woody species, two palms, saw palmetto (*Serenoa repens*) and sabal palmetto (*Sabal palmetto*) had the highest cover. Other dominant woody species were wax myrtle (*Myrica cerifera*), locustberry (*Byrsonima lucida*), coco-plum (*Chrysobalanus icaco*) and myrsine (*Myrsine floridana*).

One of major objectives of prescribed fire in Long Pine Key pine forests was to increase the cover of endemic species (Appendix 3.1). Out of 22 species that were considered for “Increase” objective, 8 species were found in pre-burn plots. Those were *Chamaesyce pinetorum*, *Chamaesyce porteriana* var. *porteirana*, *Chamaesyce* sp. (not identified to species), twin flower (*Dyschoriste angusta*), Scale-stem (*Elytraria caroliniensis* var. *angustifolia*), Pineland morning glory (*Jacquemontia curtissii*), Florida Gamagrass (*Tripsacum floridanum*) and Pineland noseburn (*Tragia saxicola*). Among them, Pineland morning glory only had the mean cover >1%, whereas rest had mean cover between 0.04% and 0.89%.

3.2 Fire behavior and fuel composition

3.2.1 Fire intensity and severity

Various measures of fire intensity and burn severity were recorded just after the fire. Burn severity was recorded on 0-5 scale along fuel transects. Char height, which is considered as a surrogate of fire intensity was measured on all trees. Crown scorch percentage was also recorded.

Fire severity index

Fire severity index was recorded on 0 to 5 scale, where the increasing numbers represented less severity. The part of a transect that did not burn was assigned the value 5. For convenience in representing fire severity, scale was switched in analysis so that higher number would indicate high severity.

In pine plots which were burned first time since plots were established in 1999 for monitoring, mean severity index ranged between 0 and 2.2 (**Figure 3.8A**). Plots 3, 17 and 19 had burn severity 0, as the Plot 3 did not burn while Plots 17 and 19 partly burned, but not at the transect where severity was recorded. Plot 26 had the highest burn severity. Burn severity showed increasing trend with the amount of ground fuel present in duff and litter layer, but the relationship was not significant at plot level. The variability within plot might have been masked by plot level average. Similarly, plot level burn severity was not significantly correlated with fire frequency calculated over 50 years prior to the first prescribed burns (**Figure 3.9**).

Char height, Scorch height and Scorch percent

Both char height and crown scorch height are considered as surrogates of fire intensity (Waldrop and Brose 1999; Menges and Deyrup 2001), while crown scorch percent is an indicator of burn severity (Jain 2004). After the first burn in the pine plots, mean ($\pm$ SD) char height and scorch height were 2.11 m ($\pm$ 1.52) and 1.55 m ($\pm$ 3.90). Scorch percent ranged from 0 to 97%. High variability (CV >100%) in scorch height and scorch percent was probably due to wide range in height of trees. Out of 25 burned plots, 10 plots did not have any tree showing the sign of scorch. Among the all burned plots, Plot 26 had the most intense fire during the first prescribed burn (**Figure 3.8B, C**).

Neither char height nor crown scorch height or scorch percent, was significantly correlated with 50yr fire frequency. However, it was surprising that char height tended to be higher ($r = 0.33$) in the plots which were burned more frequently over 50 years prior to the prescribed burn (**Figure 3.10**). In general, char height, which is an indicator of fire intensity, was expected to be lower in frequently burned plots than in least frequent burned plots, as frequent burning in plots would result in low density of hard woods, and therefore low fuel loads.

Plot level measures of both fire intensity (char height and scorch height) and burn severity (scorch percent) were non-linearly related to fire severity index, recorded along the fuel

transects (**Figure 38 B, C, D**). Mean values of char height, crown scorch height and scorch percent exponentially increased with an increase in severity index. Severity index was better predictor of char height ($R^2 = 0.74$), and thus fire intensity, than of crown scorch measurements ($R^2 = 0.34$ & 0.48 for scorch height and scorch percent, respectively).

3.2.3 Fuel consumption

In most of plot 5 to 90% of litter and 20 to 80% of duff layer were consumed by fire. However, an increase in litter and duff depth was recorded in some plots. Amount of duff increased in Plots 4, 8, 10, 11, and 23, whereas litter depth increased in Plots 11, 19 and 21. In Plot 11, litter depth increased more than twice and duff depth increased more than 32 times.

(More to be added XX)

3.3. Effect of fire

3.3.1 Pine tree mortality

Mean pine tree mortality one year after first burn was 7.62%, and pole mortality (10.92%) was significantly higher than overstory tree mortality (6.09%) (**Figure 3.11**). Mean pole mortality increased in one year, from 6.64% just after fire to 10.92% one year after fire. Overstory tree mortality was within the lower quartile of the range that was targeted for prescribed burn. Pine tree mortality varied among plots; 48% of plots had no tree mortality at all. Variation among fire-induced pine tree mortality could be due to various reasons, including fire history of the plots, size distribution of the trees, differences in fire behavior, and others. Since data on behavior of previous fires for the sampling plots were not available, it was hard to assess only the effects of stand age i.e. time since last fire on the fire behavior and on tree mortality. Relatively young trees were more likely to die due to fire (**Figure 3.12**). The over all tree mortality was strongly, but non-linearly correlated ($R^2 = 0.436$) with the burn severity index (**Figure 3.13**), suggesting that pine tree mortality increased exponentially when the fire intensity increased above certain threshold. Fire intensity in the prescribed burns was not directly measured. Instead, char height, crown scorch height and crown scorch percent were measured within one month of fire. Tree mortality was strongly correlated with all these measures of fire intensity or fire severity.

3.3.2 Pine seedling mortality

Seedling mortality increased asymptotically. Seedling mortality of hundred percent reached at the mean burn severity index of 1.8 (**Figure 3.14**).

(More to be added XX)

3.3.3 Hardwood shrub reduction

For the monitoring purpose, plots were first time burned in different seasons over four years, between 1999 and 2003, resulting in fires varying greatly in their characteristics among and within plots. After the first burn in 25 plots (two plots did not burn), the mean shrub density was reduced by 44.3% to 39,000 stems/ha immediately after fire. Fire killed majority of immature and mature shrubs, though many of them had already re-sprouted at the time of measurements, usually taken within one month after fire. The number of re-sprouts had increased by 137%, from 7,933 to 18,733 stems/ha. Therefore, the net reduction in mean density of immature and mature shrubs was 61.4 and 71.8%, respectively, showing that fires were effective in reducing the shrub density in pine forests. However, within one year after the first burn, the seedling density increased by five folds, and the density was almost same as it was before burning (**Figure 3.15**). Density of mature shrubs increased slightly 1 yr after the post burn, however it was still 60% less than what was prior to burning. In two years after burn, mature shrub density further increases by 40%, but a sharp decrease in re-sprouted shrubs and increase in seedling density indicated that most of re-sprouts of year-1 were categorized as seedlings in Year-2. This suggests that the distinction between immature and re-sprout shrubs was not sharp, and observers could easily mix-up these two categories, as the fire marks faded up in course of time.

Out of 27 plots, 10 plots were burned second time two years after first burn. In those plots, the density of immature and mature shrubs was reduced by more than 70%, however not all of them were killed by the fire. Many of them re-sprouted within one month after fire. There was about 10 times increase in re-sprouts, many of which were probably categorized as immature in one and two years after fire, adding to the number of immature shrubs. Mature shrub density slightly increased in subsequent years after second burn, however it was much lower than the density before the first and second burn. The mature shrub density was only xx and xx% of what it was prior to 2nd burn, and xx and xx% of the density present before the first burn.

Two plots were burned third time. Among those two plots, one plot was burned after two years and the other was burned after one year of second fire. On average, immature and mature shrubs were reduced by 89% & 75%, respectively immediately after post burn, however, many of them re-sprouted within one month, and net reduction was 45%. After one year, the density of immature shrubs increased, mostly due to recording of re-sprouted ones as immature shrubs. The net reduction in shrub density after one year was only 34%.

3.3.4 Herb layer vegetation (rare and endemic plants)

The effect of prescribed fire on cover of endemic species showed mixed results. In Pine forests, thirteen endemic species were recorded in either one or more survey, before and after fire. Out of 8 species that were recorded in pre-burn plots, two species were not again found after fire. *Chamaesyce* sp.2 and *Tragia saxicola* were recorded in pre-burn Plot 8 and Plot 14, respectively, but had very low cover. They were not present in any plot after fire. In contrast, five species (*Chamaesyce* sp.1, *Digitaria pauciflora*, Florida privet *Forestiera segregeta* var. *pinetorum*, Pineland Poinsettia *Poinsettia pinetorum*, and Coontie *Zamia integrifolia*)

appeared first time in survey 6 month or 1 year after first burn. However, four of them had very low cover, and three were found in only one plot. Fire had positive impact on Pineland Poinsettia *Poinsettia pinetorum*, which appeared only after prescribed burn, had >1% mean cover 6 months after second burn.

Two endemic species which responded positively to the prescribed fires were *Chamaesyce porteriana* var. *porteirana* and twin flower (*Dyschoriste angusta*). Their cover significantly increased. Mean cover of *C. porteriana* was significantly (paired 't'-test, $p < 0.05$) higher in 1 and 2 years after both 1st and 2nd burns. Cover of twin flower was higher in survey 6 months and 1 year after fire than in 2 year after fire, showing that this species may grow well in the area that burns annually. Cover of Pineland morning glory (*Jacquemontia curtissii*) decreased just after fire, but again increased 2 years after 2nd burn. Monitoring for longer period will be needed to conclude definitely about its responses to fire frequency. Prescribed fires seem to have negative impact on *Chamaesyce pinetorum*, as its mean cover was significantly lower in post-burn than in pre-burn surveys. Two species, Scale-stem (*Elytraria caroliniensis* var. *angustifolia*) and Florida Gamagrass (*Tripsacum floridanum*) did not show any significant change in cover 1-2 years after fire.

4. Freshwater prairies

Fire monitoring plots were established in two different types of prairies, long and short hydroperiod wet prairies. In *Cladium*-dominated long hydroperiod prairies, there were 8 monitoring plots. Since these plots were established in 1999, pre-burn data were collected in all eight plots in between 2000-2003. However, only two plots (Plot # 6 and Plot 8) were burned till 2005. Even among these two plots, Plot 8 was not entirely considered as a *Cladium* prairie plot (See Analysis Considerations), and the records of Plot 6 revealed no woody plants. Hence, only pre-burn data from *Cladium* prairie plots were analyzed. However, despite some differences in composition of Plot 8 from other *Cladium* plots, it was grouped with them for analytical purpose. It would not significantly impact the results, as the results were only descriptive, and effect of fire was not assessed in these plots.

Out of 28 *Muhlenbergia* prairie plots, 21 plots were burned over 5 years, 2000-2004. In 16 burned plots, data were collected through 1 year after first burn, whereas in four plots through 2 years after fire. Only two plots were burned second time before 2005.

4.1 Pre-burn status

4.1.1 Shrub density

Major objective of fire management in both *Cladium* and *Muhlenbergia* prairies was to reduce cover of woody species, including exotic shrubs and trees. In wet prairie, 35 woody species were recorded. Among them two species, Brazilian pepper (*Schinus terebinthifolius*) and *Melaleuca quinquenervia* were exotic species. Most common shrubs were *Angadenia berterii*, *Randia aculeata*, *Sideroxylon reclinatum*, *Solanum donianum*, and *Myrsine floridana*.

To monitor the effects of prescribed burn on woody species in wet prairies, shrub density was recorded within 5 m wide and 30 m long belt transect. However, the different belt width was used in four *Muhlenbergia* plots (Plot # 7, 8, 9 & 10) to collect pre-burn shrub data, and in Plot # 10 to collect post-burn data. In order to be consistent in comparison between pre- and post-burn shrub densities, these four plots were not included in analyzing shrub density data.

Cladium prairie

Shrub density in *Cladium* prairies was relatively sparse (139 stems/ha), and more than 90% of shrub stems were immature (**Figure 4.1**). Total shrub density was negatively correlated with fire frequency, though the relationship was not significant. Similarly, time since last fire had not significant effect on shrub density. In *Cladium* prairies, there were eight species of shrubs. However, only Brazilian pepper (*S. terenthifolius*) had the density of greater than 50 stems/ha, and it also had the highest frequency among all species (**Figure 4.2**).

Muhlebergia prairie

Mean shrub density in *Muhlenbergia* prairie was 20 times higher than in *Cladium* prairie, even though former was more frequently burned than the later over 50 years prior to present sampling, suggesting that factors other than fire also plays important role in growth of shrubs in prairies. In *Muhlenbergia* prairie, mean shrub density was 2,850 stems/ha (**Figure 4.3**), two thirds of which were still immature stems. Shrub density showed decreasing trend ($r = -0.301$) with an increase in fire frequency. However, the correlation was not significant ($p > 0.05$) (**Figure 4.4**). Surprisingly, the shrub density was negatively correlated ($r = -0.36$; $p = 0.08$) also with time since last fire, indicating that recent fires were not intense enough to kill the shrubs and many of them resprouted after fire. Immature shrubs were much higher in those plots than mature shrubs.

Prior to prescribed burns, 26 shrub species were recorded in *Muhlenbergia* prairie (**Figure 4.5A**). Twenty four of them were native and two species, *Melaleuca* (*Melaleuca quinquenervia*) and Brazilian pepper (*S. terebinthefolius*) were exotic. Among them, seven species had mean density of >100 stems/ha. Those were *Angadenia barterii*, *Solanum donianum*, *Phyla stoechadifolia*, *Myrsine floridana*, *Sideroxylon reclinatum*, *Conocarpus erectum* and *Schinus terebinthefolius*. These species had different proportions of immature and mature stems. For instance, most of *Phyla stoechadifolia* and *Solanum donianum* stems were matured, where as more than 75% stems of other species, including exotic Brazilian pepper, were immature. Not all shrub species were uniformly distributed in the prairie. *Angadenia barterii* was the most widely distributed species followed by wax myrtle, and about half of 26 shrub species were recorded in only one *Muhlenbergia* prairie plot (**Figure 4.5B**).

4.2 Fire behavior

(To be added later XX)

4.3 Effects of prescribed fire

4.3.1 Shrub density reduction

4.3.2 Vegetation cover and species richness

(To be added later XX)

5. Coastal prairie

5.1 Pre-burn status

5.1.1 Shrub density

The objective of fire management in coastal prairies was to reduce exotic species, though the coastal prairie in general may be invaded by native woody species, such as wax myrtle (*Myrica cerifera*), white mangrove (*Laguncularia racemosa*), button wood (*Conocarpus erectus*), and sabal palm (*Sabal palmetto*), as well as exotic species, such as Brazilian pepper (*Schinus terebinthefolius*) and climbing fern (*Lygodium microphyllum*). To monitor the effect of prescribed burn on woody species, shrub density was recorded before and after fire. Like in Brush plots, shrub density was recorded within a 5 m wide and 30 m long belt transect in all but one coastal prairie plot. In Plot-6, shrub stems were counted in 1 m wide transect, and therefore it was excluded from analysis. The number of shrub stems was recorded in three categories; mature, immature and re-sprout. Although both dead and live shrub densities were recorded, the analysis was performed only on live shrubs.

Before experimental burn started, coastal prairie plots had more mature than immature shrubs. Mean pre-burn shrub density was 5,270 stems/ha (**Figure 5.1**), of which 55.8% were mature shrubs. Re-sprouts were virtually absent (only 0.15%). Shrub density in coastal prairie plots varied greatly, but the density was neither related to fire frequency nor time since plots were burned last. Only four plots were burned 1-3 times over 50 years, 1949-1998. Mean shrub density in these plots was not significantly different from that in the unburned plots, indicating that woody invasion in the coastal prairie plots was not solely caused by the absence of fire or the frequency of fire even in the burned plots was not enough to have significant impact on the woody invasion. The four burned plots had not burned since 10 years.

Prior to prescribed burns, 14 shrub species were recorded in coastal prairies. Thirteen of them were native and the one, Brazilian pepper (*S. terebinthefolius*) was exotic (**Figure 5.2**). Among them, the seven species that had mean density of >200 stems/ha were wax myrtle (*M. cerifera*), Brazilian pepper (*S. terebinthefolius*), myrsine (*Myrsine floridana*), and button wood (*C. erectus*), Carolina wolfberry (*Lycium carolinianum*), red bay (*Persea borbonia*) and (*Baccharis* sp.). These species had different proportions of immature and mature stems. Most of wax myrtle and Carolina wolfberry stems were matured, where as more than 90% of exotic Brazilian pepper stems were immature, indicating recent invasion in the prairies. However, not all shrub species were uniformly distributed in coastal prairies. Wax myrtle was the most widely distributed followed by Brazilian pepper, saltwater false willow (*Baccharis angustifolia*), red bay and myrsine (**Table XX**). Four shrub species were found in only one coastal prairie plot.

5.2 Fire behavior

(To be added XXX)

5.3 Effect of prescribed fire

5.3.1 Shrub density reduction

The response of shrub density to prescribed burnings was assessed in all those plots which were burned between 2000 and 2004. Fire consumed most of woody shrubs, both mature and immature stems. In the burned plots, post-burn mean ($\pm$ SE) density of live shrub stems was only 385 ($\pm$ 212) stems/ha, i.e. 92% reduction in total number of shrub stems. However, after one year of prescribed burn, the shrub density again increased. It was two and half times higher than what it was before burn, mostly due to an increase in re-sprout. The shrub density remained high also in two years after fire, but less than that in the first post-burn year. The most noticeable effect of prescribed burn, however, was the reduction in mature stems. In the first post-burn year, the mature stems represented only 1.6% of total shrubs, though its proportion increased to 15% by the next year, indicating that the effect of fire was temporary, and in absence of another fire, shrubs will continue to grow. Only one plot was burned second time within 3 years, and the results from this plot can not be generalized.

Native and exotic shrub species differed in their response to prescribed burns. Immediately after fire, mortality of Brazilian pepper was higher than wax myrtle and myrsine, which were most dominant native species in coastal prairies. However, Brazilian pepper re-sprouted much more vigorously than other species within one year, and its density was much higher even at the end of second post-burn year. In the post burn period, increase in density of *B. angustifolia* and white mangrove (*Laguncularia racemosa*) was also noticeable.

5.3.2 Vegetation cover and species richness

(To be added later XX)

Conclusions and Recommendations

(To be added XXX)

Monitoring shrub cover in pine forest and brush plots

Reduction in shrub cover

One of the major objectives of prescribed fires in the Everglades National Park is to reduce the cover of hardwood shrubs in the understory of pine forests and of any woody species in marshes and prairies (termed as ‘brush plots’) by 50-100% immediately after the fire and 0-50% within the first post burn year. To monitor the changes in woody plant cover before and after 1999-2005 burns, woody plant density (number of stems) was recorded in both pine forest and brush plots. Although shrub density might not fully represent cover, as called for in the objective, it was considered as a proxy of woody plant cover. Furthermore, to capture the structural aspects of the woody plant guild, the number of shrub stems was recorded in three categories; mature, immature and re-sprout, with the assumption that these categories represent not only the developmental stage of woody species, but also reflect their vertical structure. In this respect, the desirable outcome of prescribed fire is a significant reduction in mature woody stems, so that the probability of encroachment and establishment of hardwood species in pinelands and of any woody species in prairies can be minimized.

Shrub density vs cover

Despite several advantages of using density as a variable to monitor shrub dynamics in pine forests and grasslands, the major limitations of density measurements are difficulties in identifying individuals of several shrub species and in differentiating the ecological importance of large and small shrubs. Shrub density measurement fails to include information on the size of individuals, which are important in estimating standing biomass (fuel), and ultimately in predicting fire behavior. Cover measurement has the advantage over density, particularly for shrubs for which identification of individuals (as opposed to ramets of the same individual) is a major problem in the field. Moreover, shrub cover, which is expressed as the percentage of ground covered by the vegetation when viewed from above, is considered an effective measure of plant abundance and distribution, and often is considered to be of greater ecological significance than density (Mueller-Dombois and Ellenberg 2002).

Ecological significance of cover:

- Cover provides a better estimate of plant biomass than the number of individuals. Plant biomass, as an indication of organic material accumulated in the ecosystem, is also a measure of fuel loads, which are closely related to fire behavior.
- Cover influences the understory/ground environment by modifying light and temperature, and thus affects ground vegetation composition, a primary interest in prescribed fire aimed at influencing the population dynamics of endemic and threatened species.

- Cover also influences soil water dynamics through interception of rainfall and transpiration, thus affecting fuel moisture content

Besides its greater significance, the measure of cover also has some limitations. For instance, cover is more sensitive to seasonality, its measurements usually favor the species with larger and horizontally spread leaves, and it poorly reflects the mortality and recruitment which are important measures for monitoring population dynamics of species. However, when measured with height (a measure of vertical depth), shrub cover is a better indicator of community structure --- an emergent character that determines fuel loads and their connectivity, both important for fire behavior --- but also is of major interest in terms of community development.

Methods used to measure shrub cover

The most commonly used method of measuring plant cover in different strata is the ocular estimation of species cover within plots that vary in shape and size. While the method is not very time consuming, it is subjective and prone to observer bias. Various techniques supplement the method to make the estimates more objective and accurate, allowing monitoring of species cover to be meaningful in assessing successional trends and plant responses to experimental manipulations (Mueller-Dombois and Ellenberg 2002). Alternatively, a line transect is frequently used to measure plant cover. In this method, cover is estimated from the portion of meters intercepted along a transect usually delineated by a measuring tape, or as the percentage of regular or randomly spaced points along the transect that are intersected by the species of interest.

Line intercept vs Point intercept

Both line intercept and point intercept transects are used to estimate plant cover within plots. A line intercept transect is a kind of belt transect reduced from two dimensions, length and width, to the single dimension, length. It also can be viewed as a cluster of point intercepts, because each section of a line represents an infinite number of points.

Theoretically, any of these two, line intercept or point intercept transect, can be used to estimate plant cover within the fire monitoring plots. However, the line intercept method is most commonly used to estimate shrub cover (> 1m tall), whereas the point intercept is often used for ground vegetation cover (< 1 m tall).

Height: Whether a line or point intercept transect is used, the structural development of woody plants in both forest and brush plots can be more accurately assessed when shrub cover is measured in conjunction with plant height. To incorporate height in shrub cover measurements, the canopy cover intercepted by the line or point can be recorded by pre-determined height classes or the average height of each canopy may be estimated. For monitoring change in cover, the use of height classes will satisfy the requirement. The following size classes are suggested:

1. <0.15 m
2. 0.15 – 0.5 m
3. 0.5 – 1.0 m
4. 1.0 – 1.5 m
5. 1.5 – 2.0 m
6. 2.0 – 2.5 m
7. > 2.5 m

In brush plots, where shrubs are very sparse, classes 3 and 4, and classes 5 and 6 can be merged together. While measurement of cover in height classes will be used to monitor structural changes, for biomass estimation done on the basis of percentage cover at the plot level (see next sub-section), height estimation of each canopy intercepted along the transect will be needed.

Use of line intercept transect

- Within a monitoring plot, multiple transects should be used to capture within-plot variation. Use of a single transect, as currently used in ENP, will not suffice to represent the 0.1 ha plot.
- The length and number of transects can differ in pine forest plots and brush plots. Since brush plots usually have low shrub cover, the line transect used in brush plots should be longer than in forest plots.
- In the FIREMON document, five 20 m transects are recommended for a monitoring plot of 0.04 ha (20m x 20m). An ENP fire monitoring plot (50m x 20m), which has 4 quadrants and nine markers (Figure 1), can easily accommodate 20m, 25m or longer transects without extra effort required to establish additional markers. Use of at least three 25-50 m transects is suggested.
- While recording the shrub cover intercepted by the line transect, canopy overlap among individuals of the same species is usually not differentiated, but if canopy of different species overlap, they are recorded separately.
- Canopy intercepted by the line usually has gaps of different sizes. The canopy is considered to be closed if the gap is smaller than a pre-determined gap size (usually 5 cm).

Use of point intercept transect

Theoretically, line and point intercept methods can be used as alternatives. However, the point intercept method is not considered ideal for the shrubs greater than 1m. Still, if the use of point intercept transect is desired for any reasons, such as to achieve high precision per point, to reduce the time spent in taking measurements, etc., the point intercept method should be calibrated against the line intercept method. In the calibration process, measurements should be taken using both line and point intercept methods along a

number of transects from several plots representing different stages of post burn development. Moreover, there is also a need for caution, as the density of points per transect will severely affect the relationships. To get statistically valid results from calibration, different densities of points along the point intercept transect need to be tested, or the minimum density of points required in point intercept method should be first determined across several plots, and then that level of sampling intensity should be used in calibration process.

Shrub cover and estimation of understory fuels

Repeated measures of shrub cover (%) by line and/or point intercept transect will help to monitor a change in understory woody composition in the pine forest and woody encroachment in brush plots. However, it can not be directly used to estimate standing shrub layer fuel loads, unless a plot-based model for defining the relationship between structural parameters (cover and height) and biomass is developed. While plot-based models using crown cover (%) are readily available for herb layer vegetation, or will require a limited effort to develop, only a few studies have developed plot-based models for shrubs using their percent cover as a predictor (Ohmann et al. 1981; Halpern et al. 1996), and none have been attempted for shrubs in South Florida pine forests or prairies. Theoretically, development of a plot-based shrub biomass model is not impossible, but will require much effort, as several replicates of plots representing different stages of development would be required to capture the variability across the spatial and structural development (successional) gradients. Nevertheless, to estimate shrub biomass, models have been developed utilizing the relationship between crown dimensions (with or without height) and biomass for a number of shrub species (Peek 1970; Ludwig et al. 1975; Martin et al. 1981). These models are based on measurements taken on individual shrubs representing a range of size classes rather than community level parameters. In order to use such models, for example the models developed for Florida Keys pine forests (Sah et al. 2004), measurement of crown dimensions and height of shrub individuals in a number of sampling units within the plots will be required. Since fuel load is always expressed in per unit area basis, it is important that the sampling units used to estimate biomass represent an area, which could be a number of belt transects divided into sections representing contiguous or randomly selected plots of uniform shape and size. Plots may even be systematically selected if re-sampling is desired. For this purpose, a minimum of 10-20% of the area of each monitoring plot should be sampled.

REFERENCES

- Beckage B, Platt WJ, Slocum MG, and Panko B. 2003. Influence of the El Niño–Southern Oscillation on fire regimes in the Florida Everglades. *Ecology* 84: 3124–3130.
- Egler FE. 1952. Southeast saline Everglades vegetation, Florida, and its management. *Vegetatio* 3: 213–65.
- Halpern, C.B., Miller, E.A. and Geyer, M.A. 1996. Equations for predicting aboveground biomass of plant species in early successional forests of the western Cascade Range, Oregon. *Northwest Science* 70, 306–320.
- Jain, T.B. 2004. Tongue-tied. *Wildfire* 92. Available at <http://wildfiremag.com/ar/tonguetied/index.htm> [Verified 21 April 2006]
- Lockwood, J. L., Ross M. S. and Sah, J. P. 2003. Smoke on the water: The interplay of fire and water flow on Everglades restoration. *Frontiers in Ecology and the Environment* 1 (9): 462–468.
- Ludwig, J.A., Reynolds, J.F. and Whitson, P.D. 1975. Size-biomass relationships of several Chihuahuan desert shrubs. *American Midland Naturalist* 94, 451–461.
- Martin, W.L., Sharik, T.L., Oderwald, R.G. and Smith, D.W. 1981. Equations for estimating above ground phytomass in the understory of Appalachian oak forests. School of Forestry and Wildlife Resources. Virginia Polytechnic Institute and State University, Blacksburg, VA, USA.
- Menges, E.S. and Deyrup, M.A. 2001. Postfire survival in south Florida slash pine: interacting effects of fire intensity, fire season, vegetation, burn size, and bark beetles. *International Journal of Wildland Fire* 10, 53–63.
- Mueller-Dombois, D. and Ellenberg, H. 2002. Aims and Methods in Vegetation Ecology. The Blackburn Press, Caldwell, NJ, USA.
- Ohmann, L.F., Grigal, D.F and Rogers, L.L. 1981. Estimating plant biomass for undergrowth species of northeastern Minnesota forest communities. General Technical Report NC-61. USDA Forest Service, North Central Forest Experimental Station, St. Paul, MN, USA, 10 pp.
- Peek, J.M. 1970. Relation of canopy area and volume to production of three woody species. *Ecology* 51, 1098–1101
- Robertson WB Jr. 1953. A survey of the effects of fires in Everglades National Park. National Park Service Report. Homestead, FL: Everglades National Park.

- Sah, J P., Ross, M .S., Koptur, S. and Snyder, J.R. 2004. Estimating aboveground biomass of broadleaved woody plants in the understory of Florida Keys pine forests. *Forest Ecology & Management*. 203:319-329.
- Snyder, J.R. 1991. Fire regimes in subtropical South Florida. In 'Proceedings of the Tall Timbers Fire Ecology Conference No. 17 – High intensity fire in wildlands: management challenges and options. 18–21 May 1989'. pp. 303–319. (Tall Timbers Research Station: Tallahassee, FL)
- Snyder JR, Herndon A, and Robertson WB Jr. 1990. South Florida rocklands. In: RL Myers and Ewel JJ (Eds.) *Ecosystems of Florida*. Orlando FL: University of Central Florida Press. pp. 230–77.
- Wade D, Ewel J, and Hofstetter R. 1980. Fire in South Florida ecosystems. US Forest Service General Technical Report SE–17. Asheville, NC: Southeast Forest Experiment Station.
- Waldrop T.A, Brose P.H. 1999. A comparison of fire intensity levels for stand replacement of table mountain pine (*Pinus pungens* Lamb.). *Forest Ecology and Management* **113**, 155–166.

Appendix 3.1: List of species to be considered for “Increase” Objective

Amorpha crenulata
Argythamnia blodgettii
Chamaesyce conferta
Chamaesyce deltoidea
Chamaesyce garberi
Chamaesyce pinetorum
Chamaesyce porteriana var. *porteriana*
Croton arenicola
Digitaria pauceflora
Dyschoriste angusta
Elytraria caroliniensis var. *angustifolia*
Forestiera segregata
Galactia pinetorum
Jacquemontia curtisii
Lantana depressa
Linum carteri var. *smallii*
Phyllanthus pentaphyllus var. *floridanus*
Poinsettia pinetorum
Ruellia succulenta
Tragia saxicola
Tripsacum floridanum
Zamia integrifolia

Some comments

- To calculate tree mortality at plot level, plot size seems small. To have meaning full analysis of tree mortality plot size should be of 1 ha.
- Fuel moisture data needs to be collected.
- Over the prescribed burn period, using fire frequency as a predictor (for prescribed burn period) was not possible, as plot numbers are not constant, and the plot number was very few for later burns

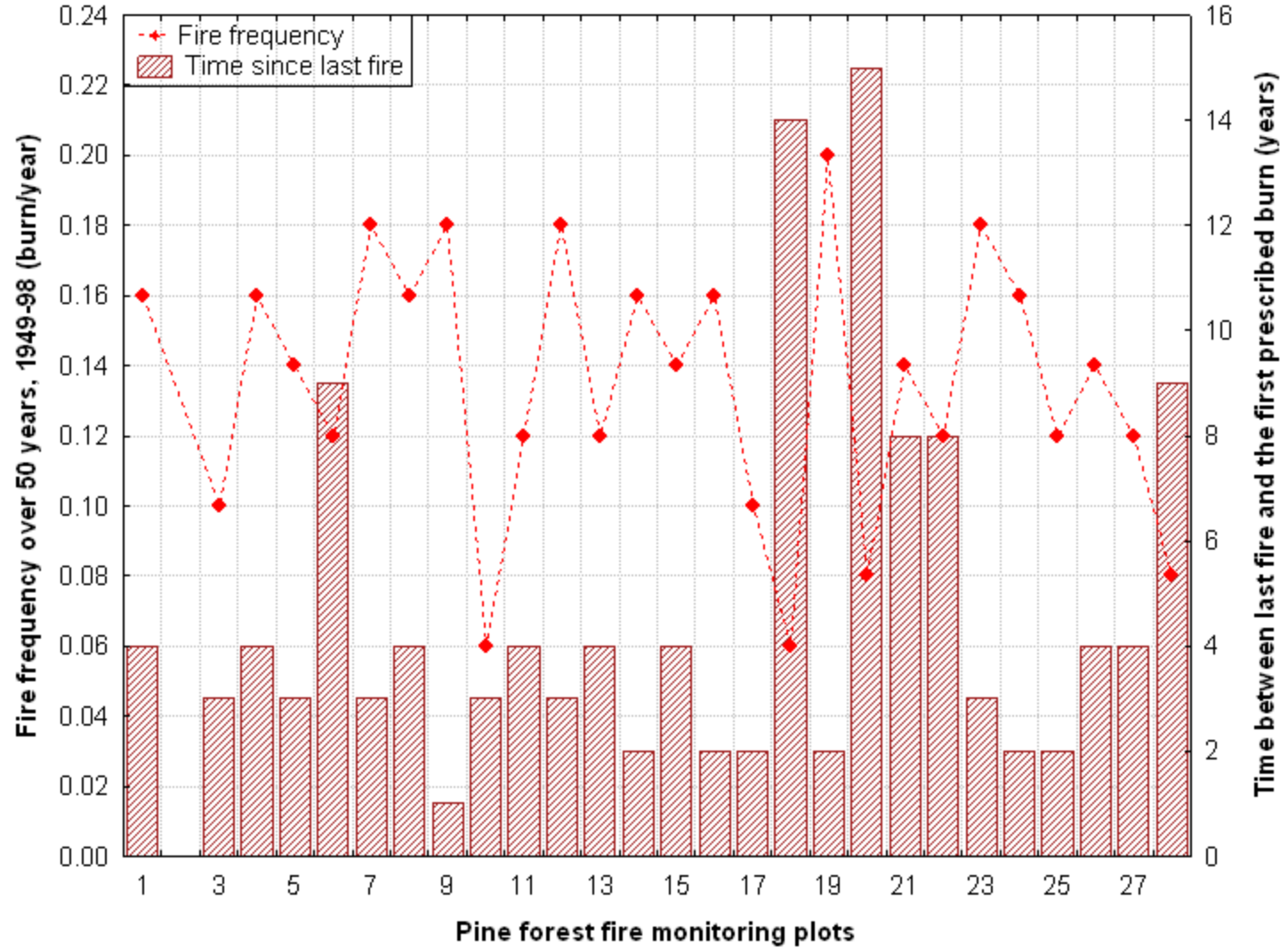


Figure 2.1: Fire frequency over 50 years, 1949-98, and time between last fire and the first prescribed burn in the Pine forest fire monitoring plots.

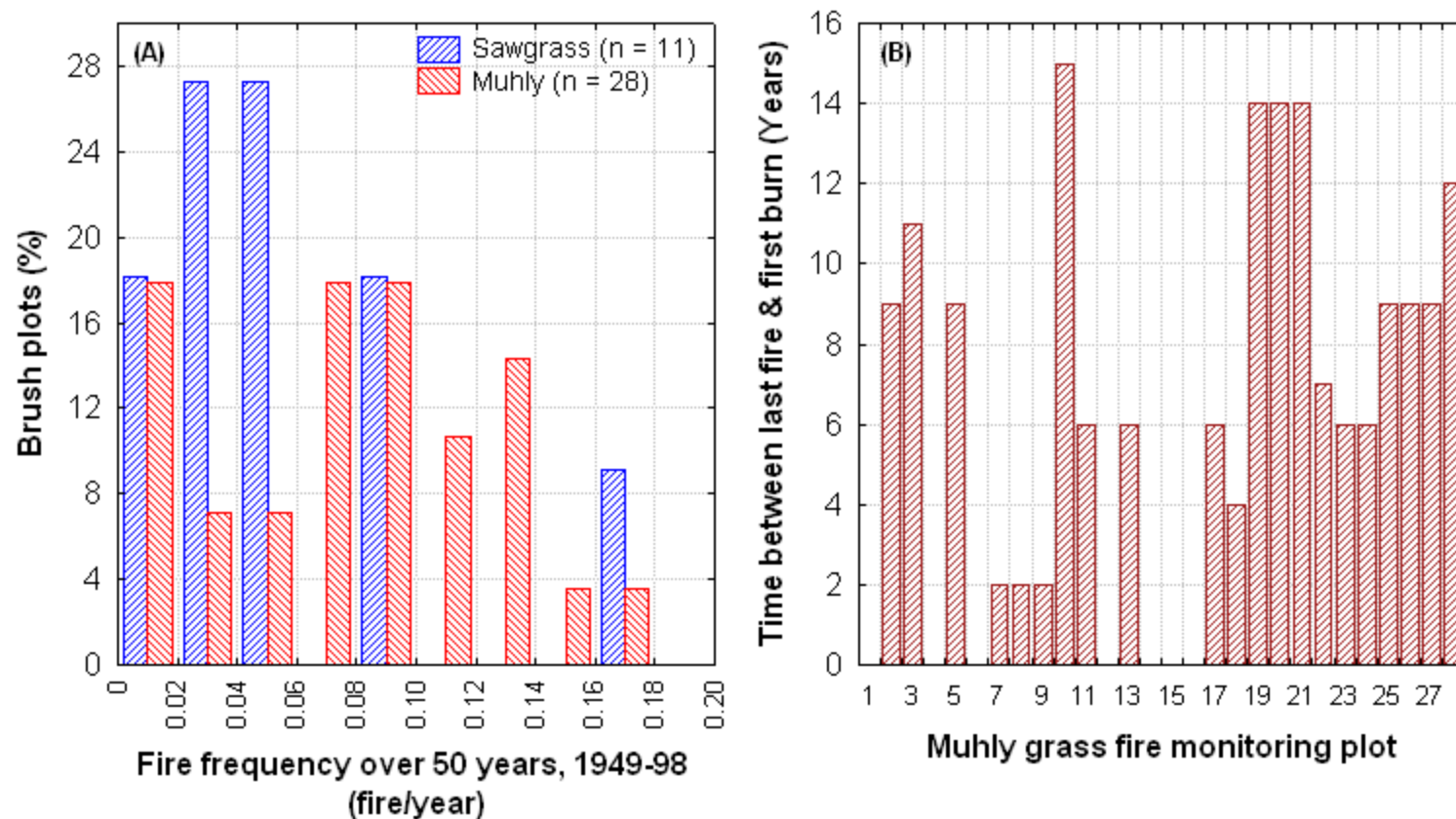


Figure 2.2: Fire frequency over 50 years, 1949-98, and time between last fire and the first prescribed burn in the marsh and prairie fire monitoring plots. (A) Percentage of Cladium and Muhly plots with different fire frequency, (B) Time between last fire and the first prescribed burn in those Muhly plots in prescribed burn was done for monitoring.

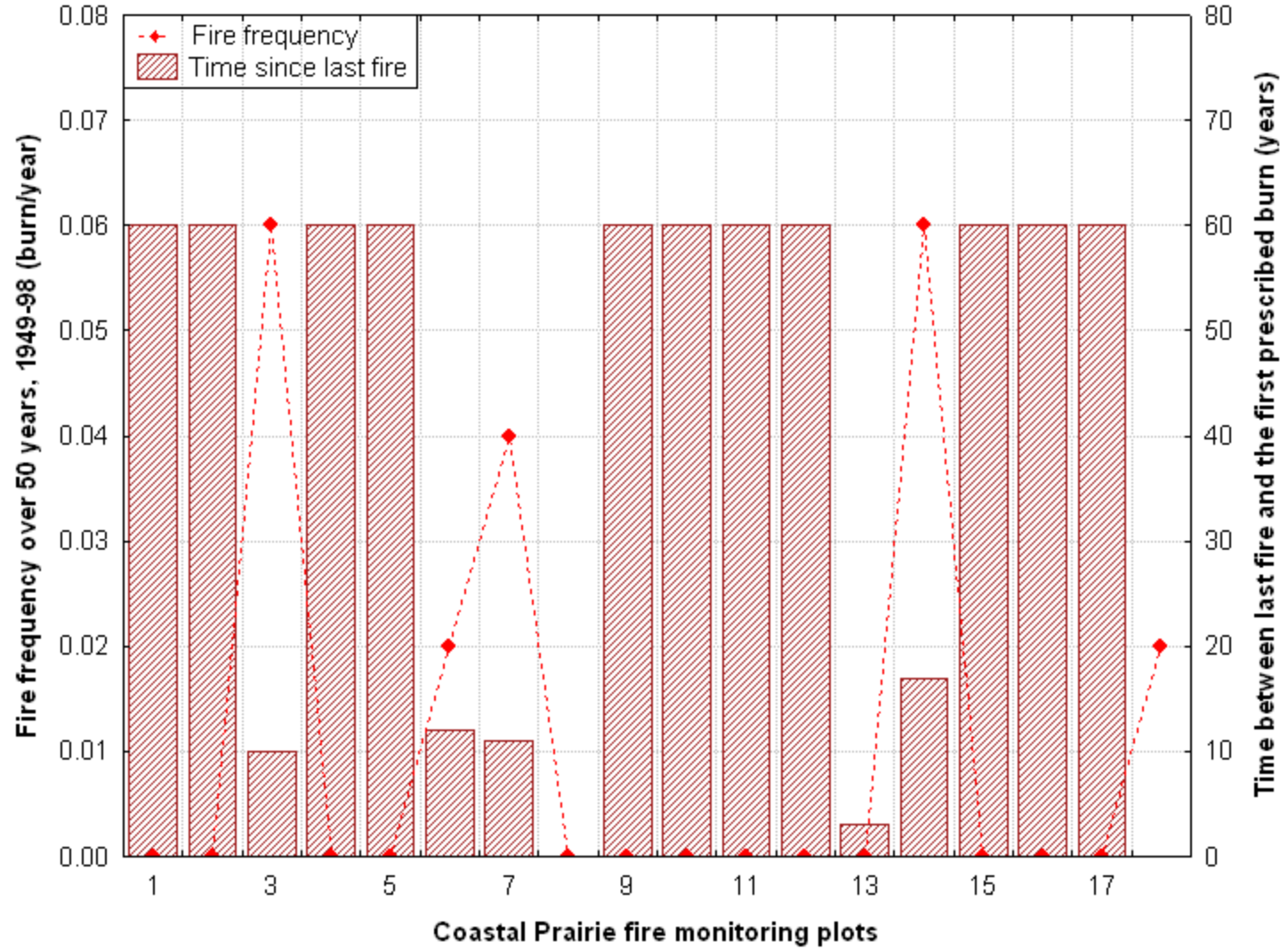


Figure 2.3: Fire frequency over 50 years, 1949-98, and time between last fire and the first prescribed burn in Coastal Prairie fire monitoring plots.

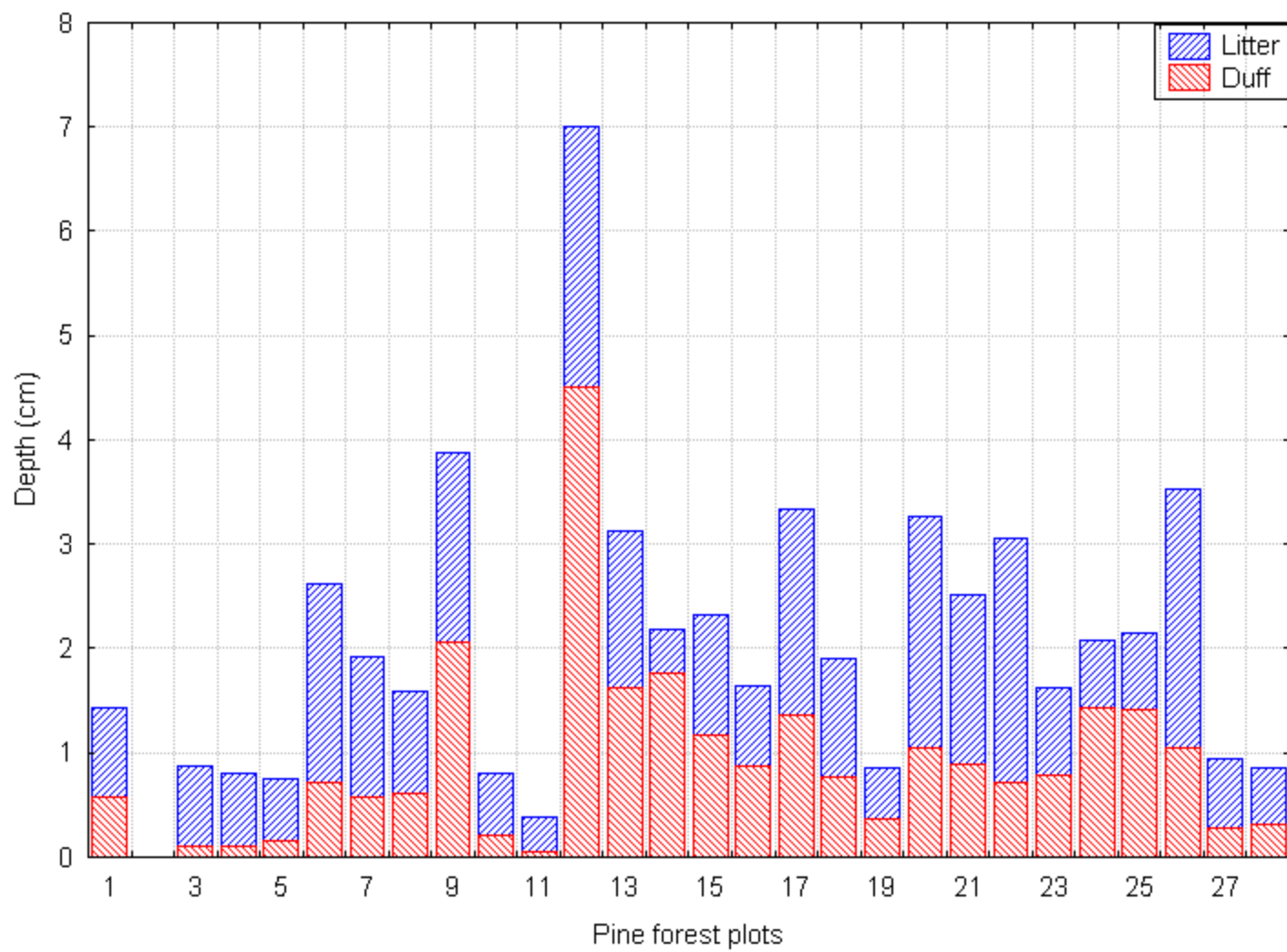


Figure 3.1: Duff and litter depth in pine forest fire monitoring plots.

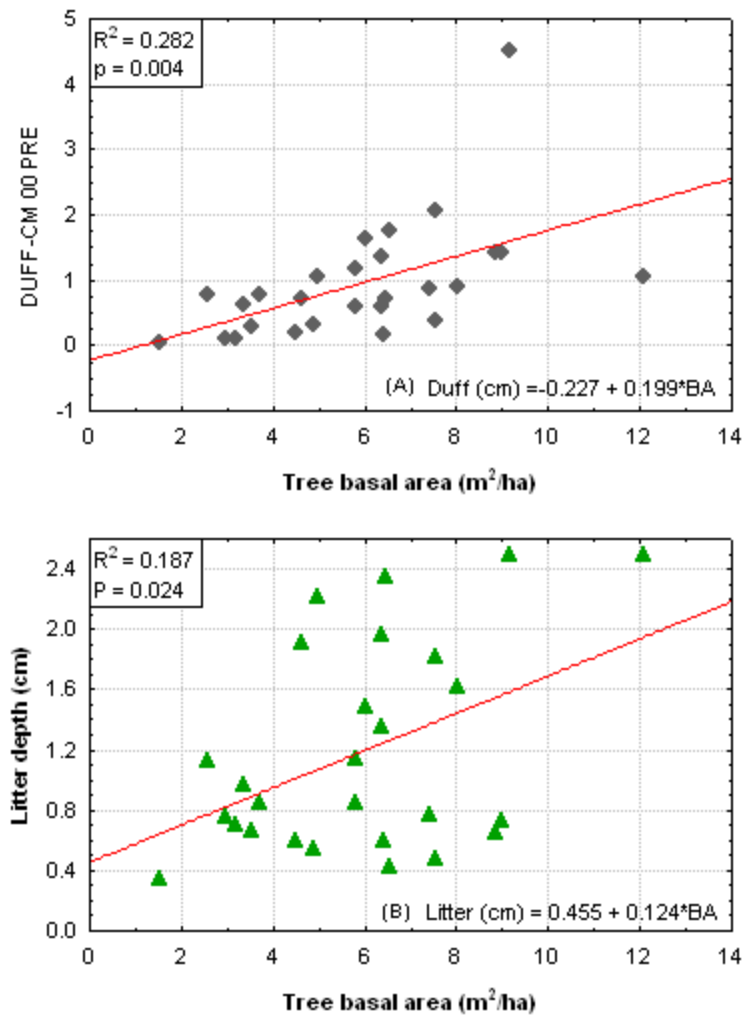


Figure 3.2: Duff and litter depth in relation to pine tree basal area in pine forest fire monitoring plots

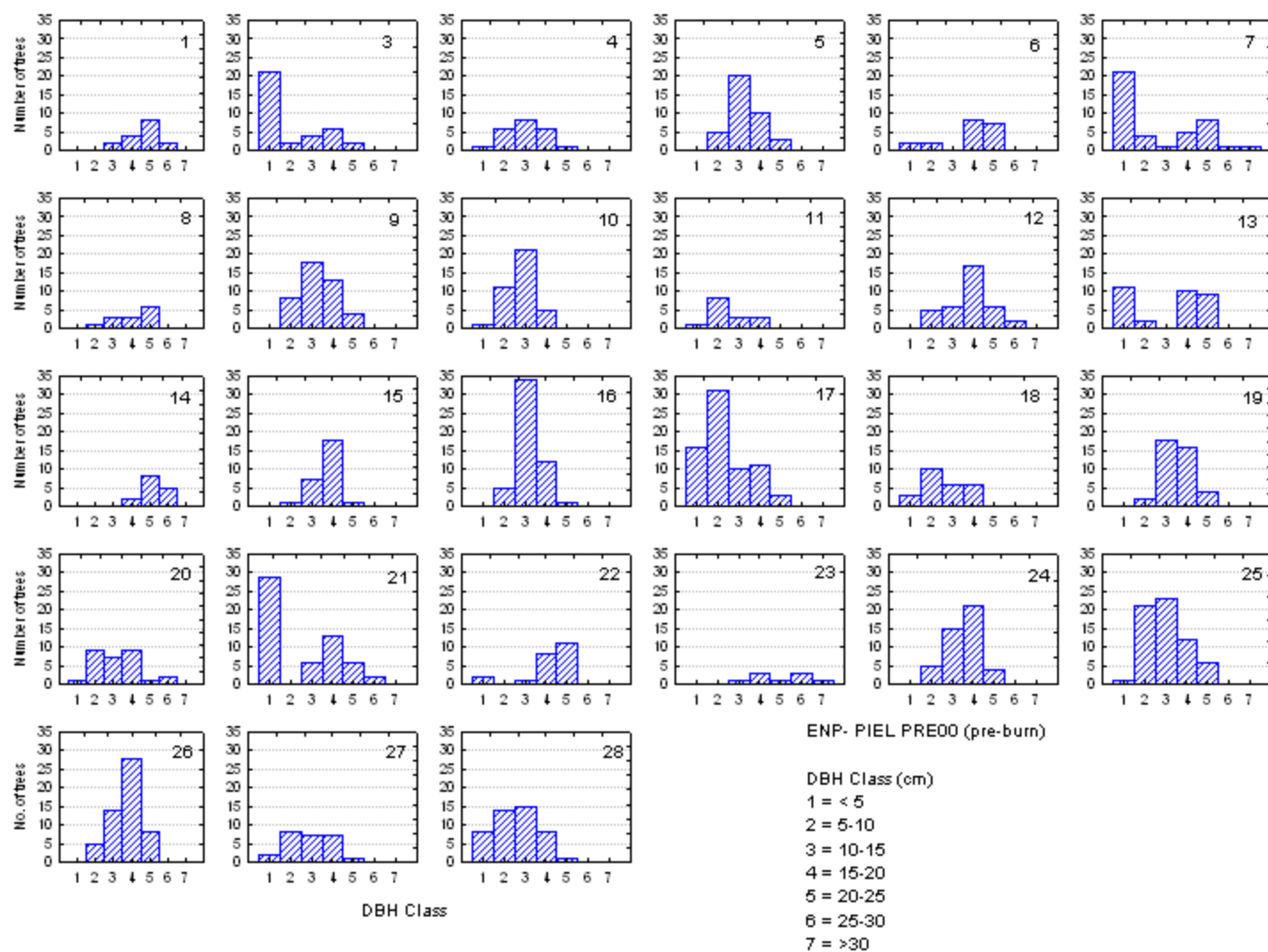


Figure 3.3: Pre-burn tree size distribution in pine forest plots

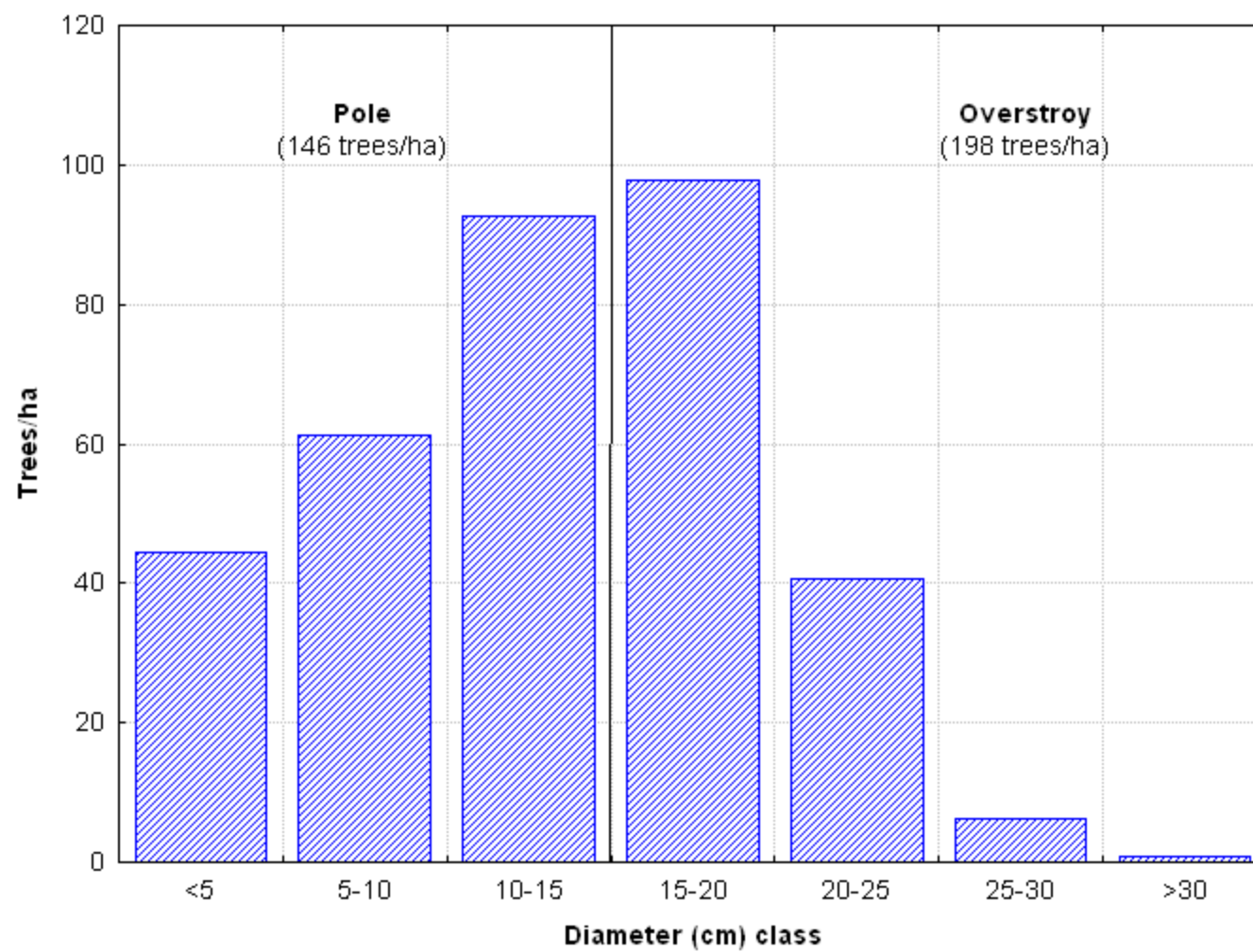


Figure 3.4: Tree size distribution in two strata, under (<15cm) and overstory (>15cm) in pine forest plots

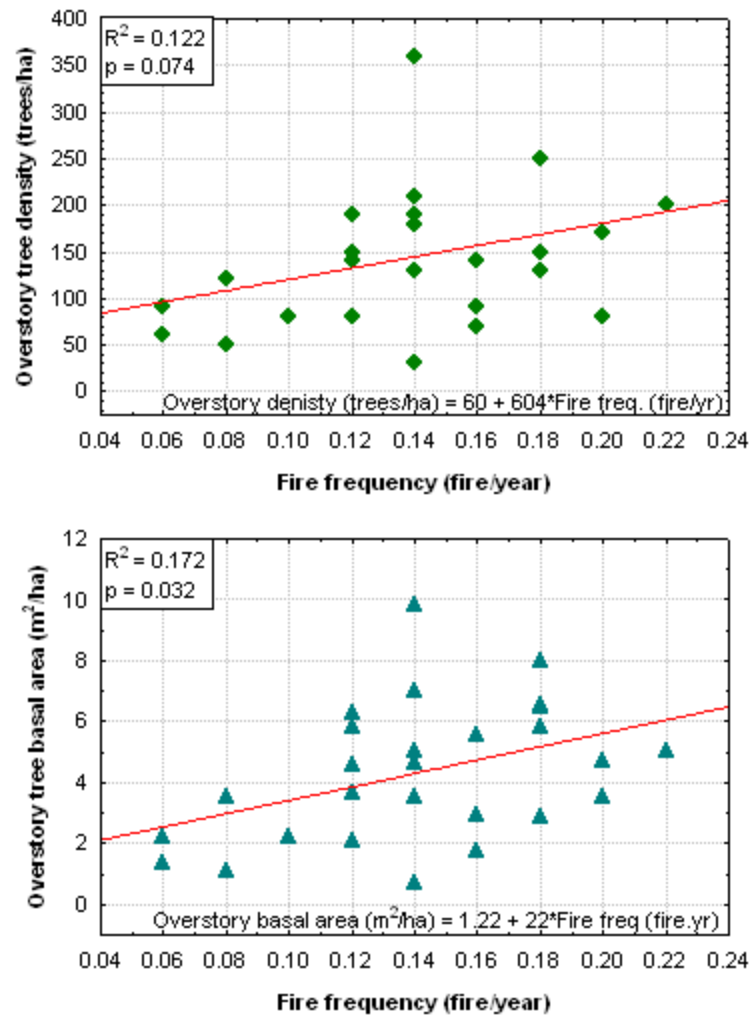


Figure 3.5: Pre-burn overstory pine tree (>15 cm dbh) density and basal area in relation to fire frequency over 50 years, 1949-1998 in pine forest fire monitoring plots.

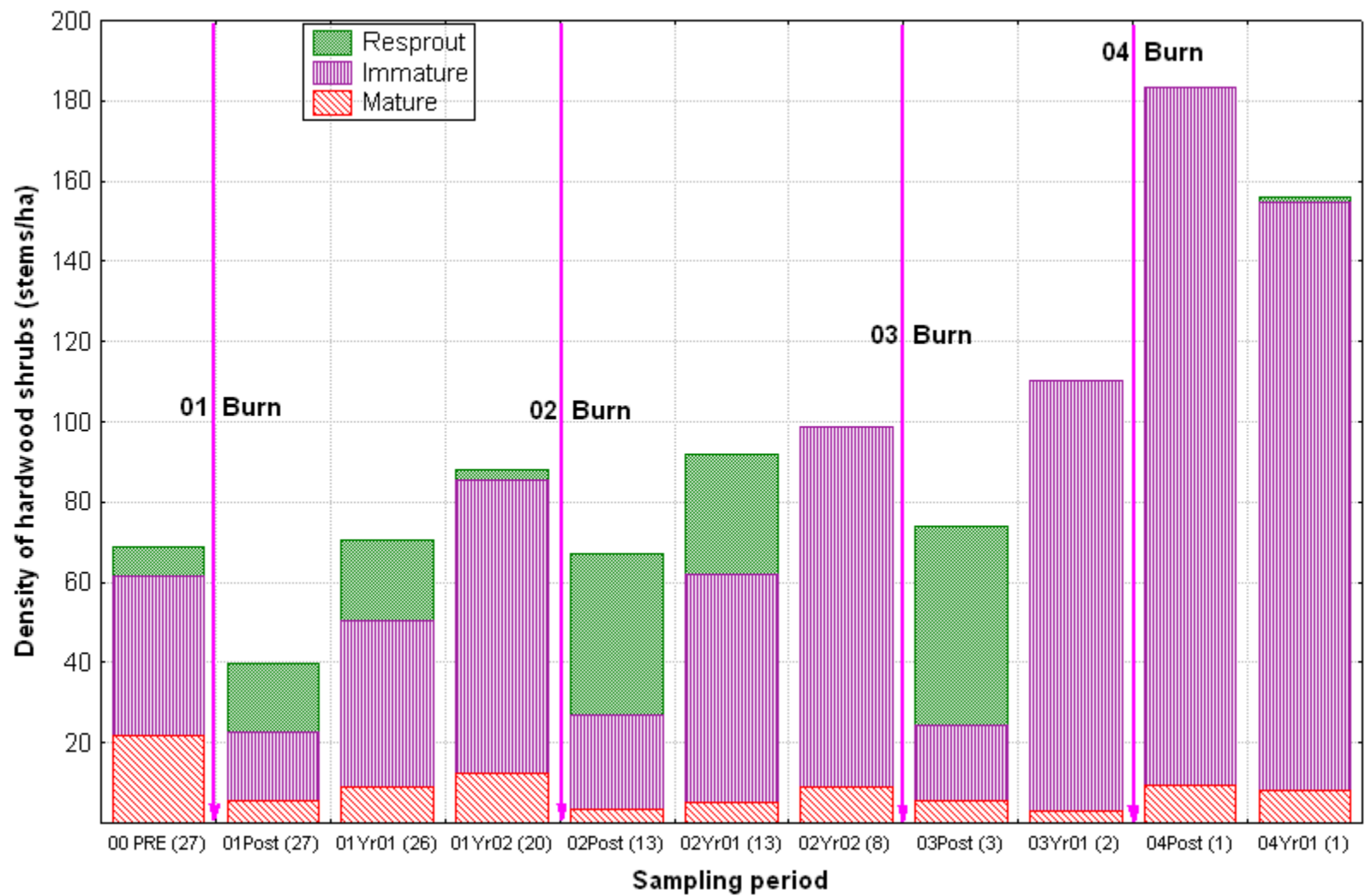


Figure 3.6: Mean density of hardwood stems of three different growth stages (mature, immature and re-sprout) in pine monitoring plots

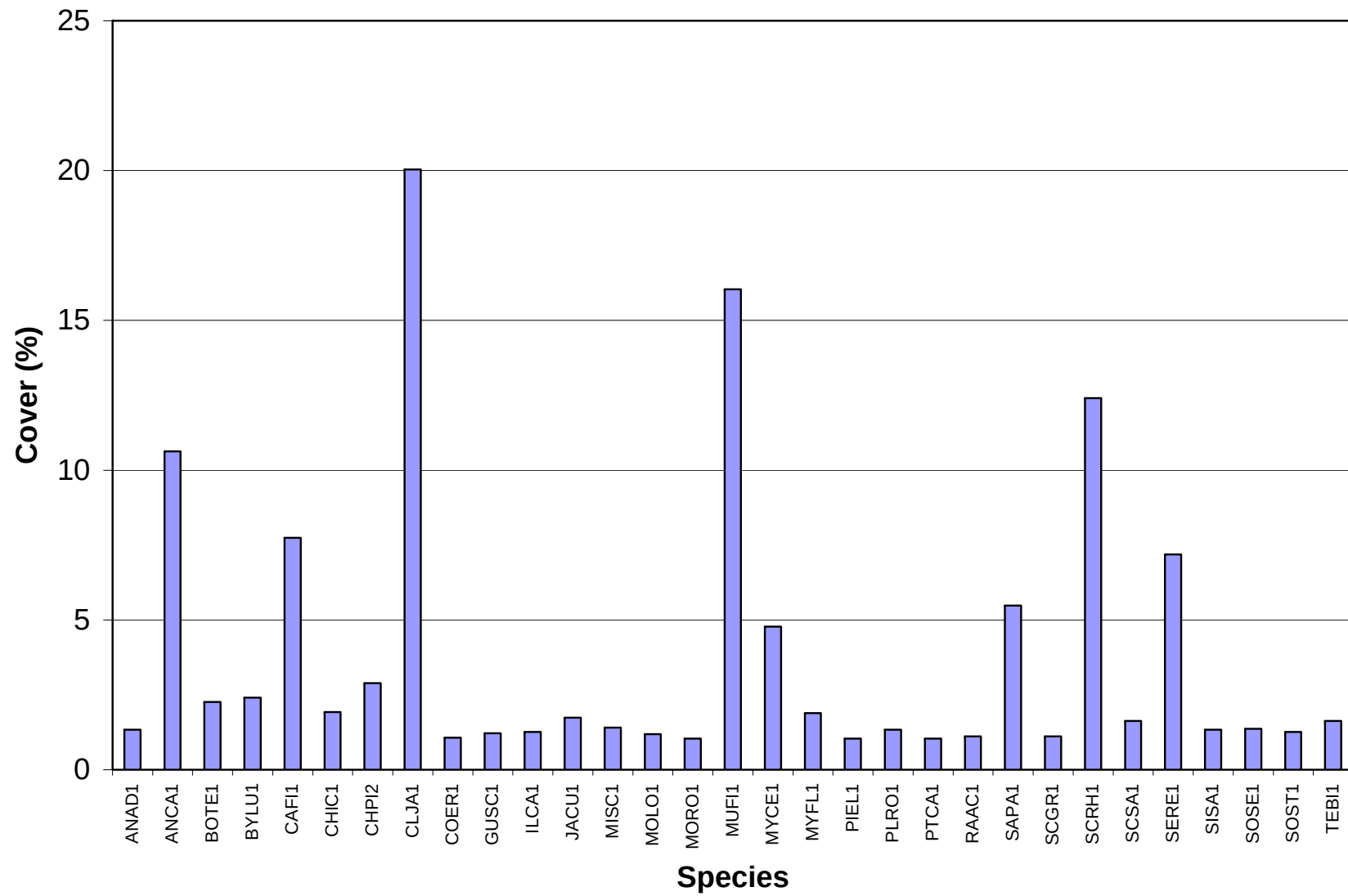


Figure 3.7: Plant species with mean cover >1% in the understory of pine forests

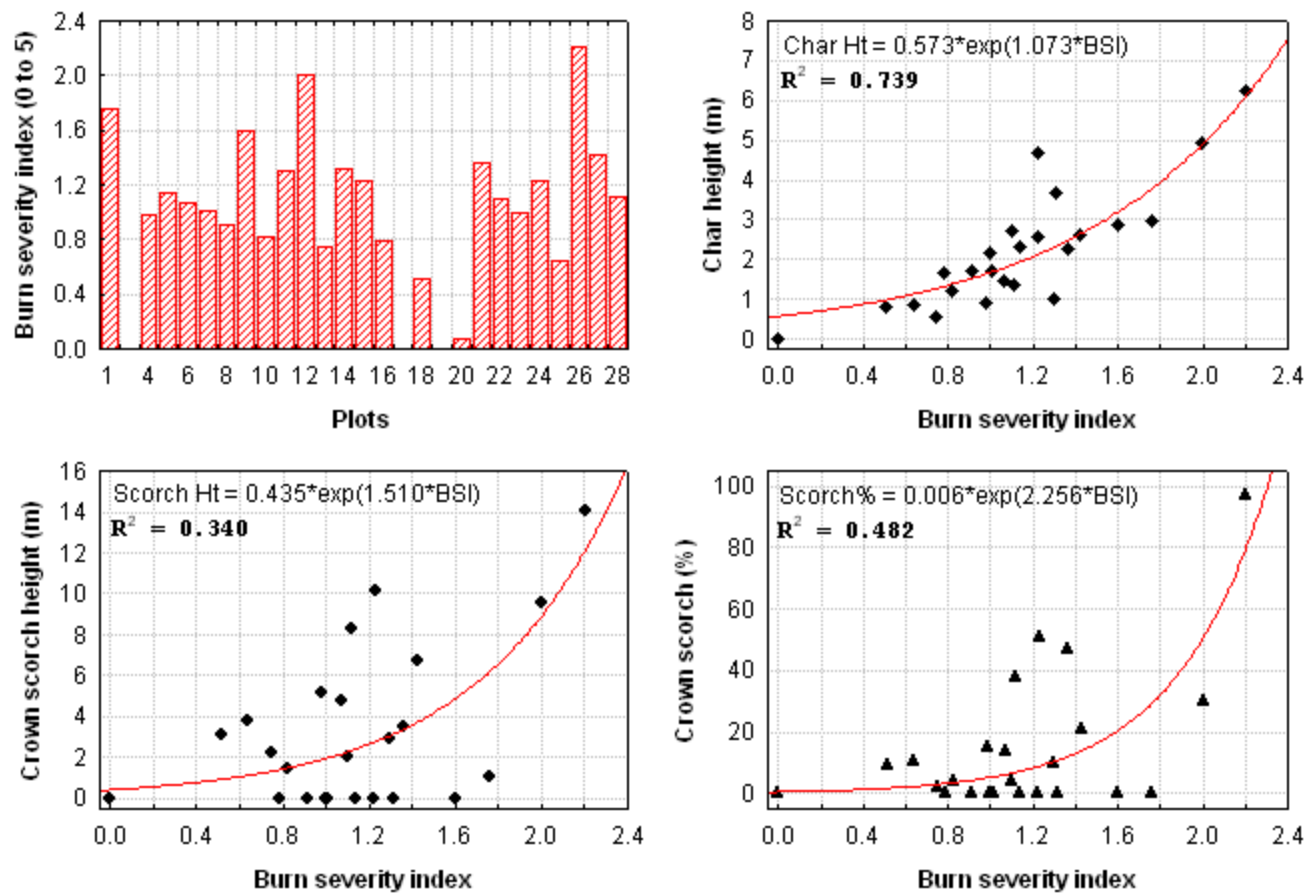


Figure 3.8: Fire severity index, and its relationship with char height, crown scorch height and crown scorch percent in pine forest plots

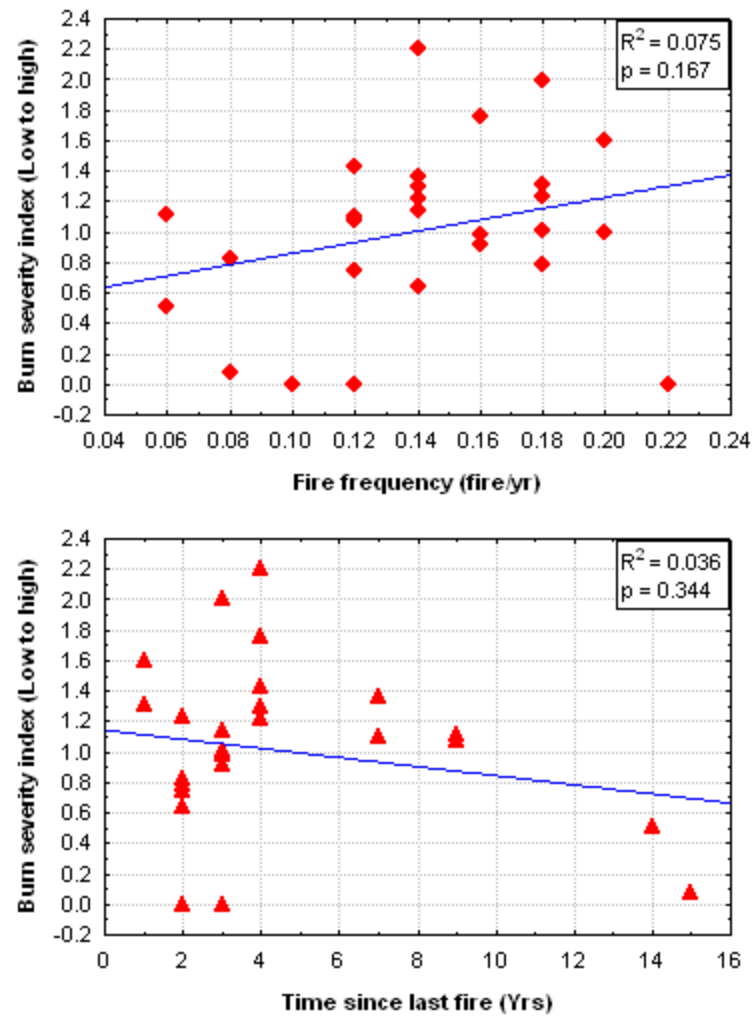


Figure 3.9: Burn severity recorded after first burn and its relationship with fire frequency over 50 years before burn and time since last fire.

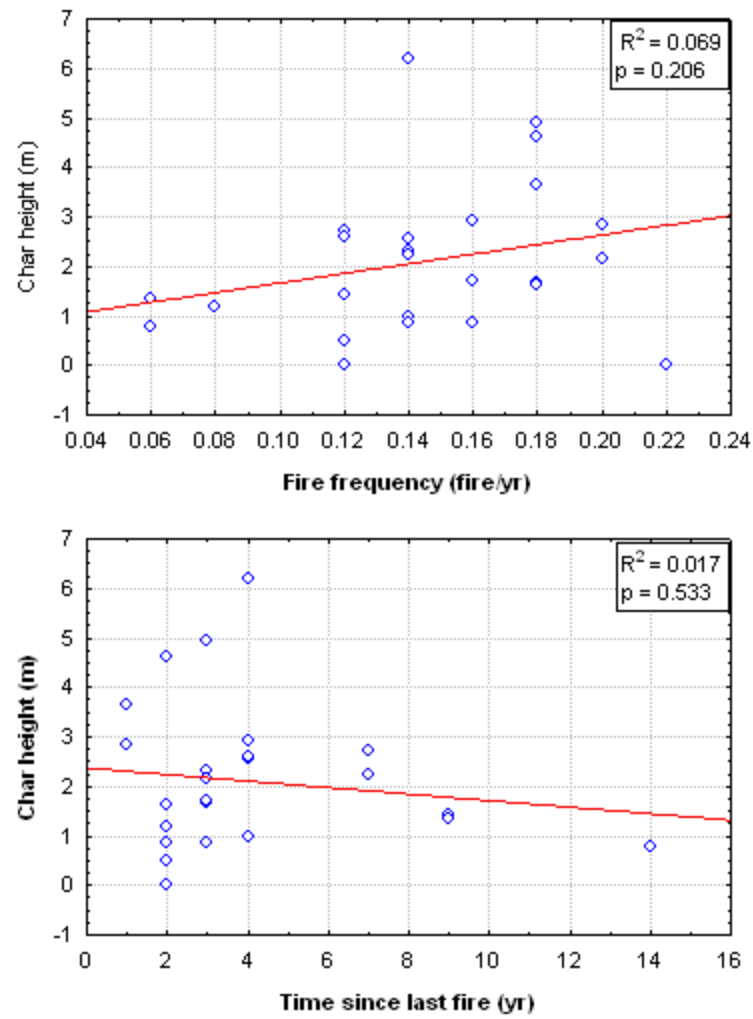


Figure 3.10: Char after measured after first burn and its relationship with fire frequency over 50 years before burn and time since last fire.

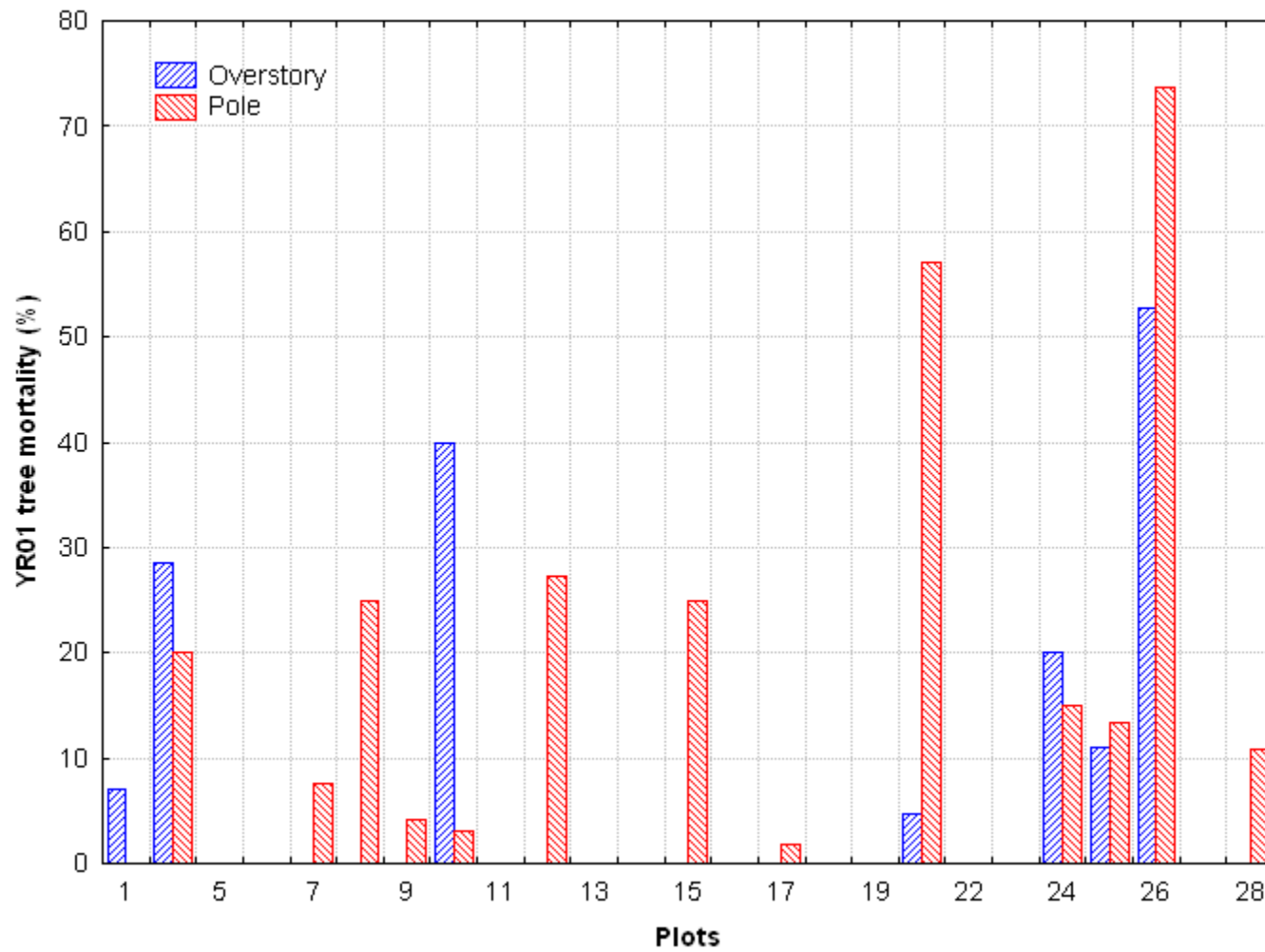


Figure 3.11: Overstory and Pole tree mortality after first burn in pine forest fire monitoring plots

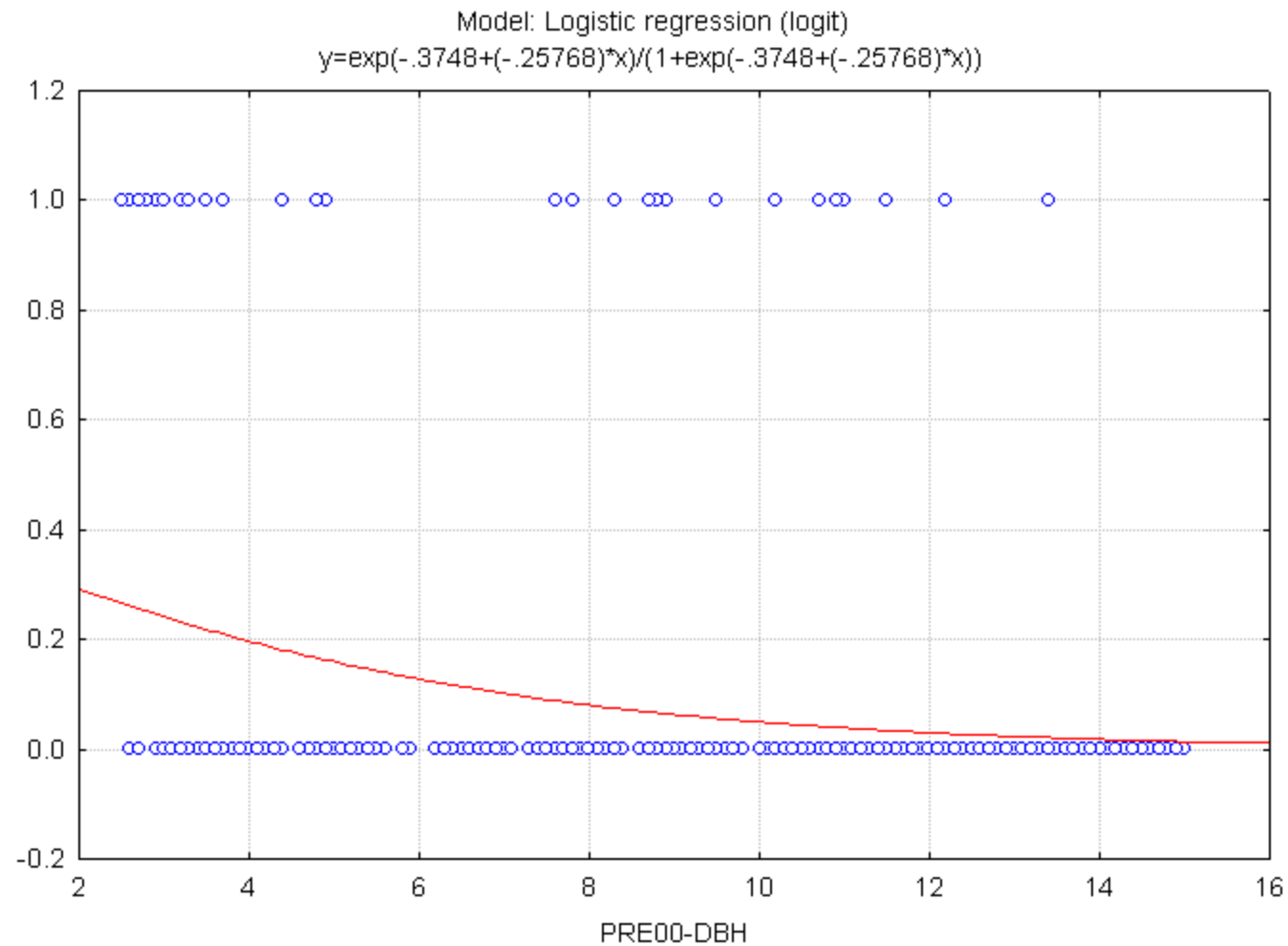


Figure 3.12: Logistic regression showing the relationship between pine tree mortality and diameter at breast height (DBH)

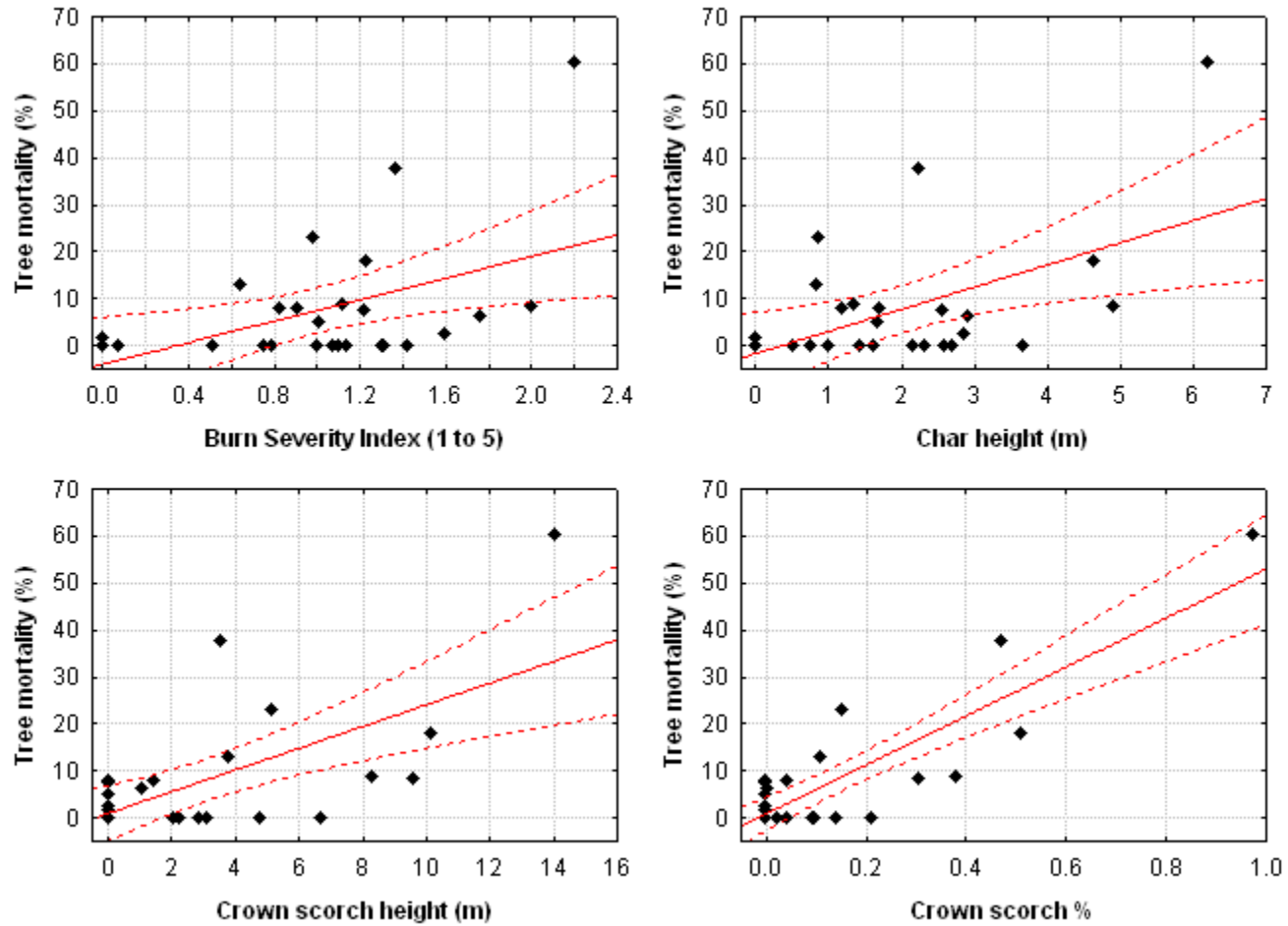


Figure 3.13: Tree mortality in relation to burn severity and intensity index

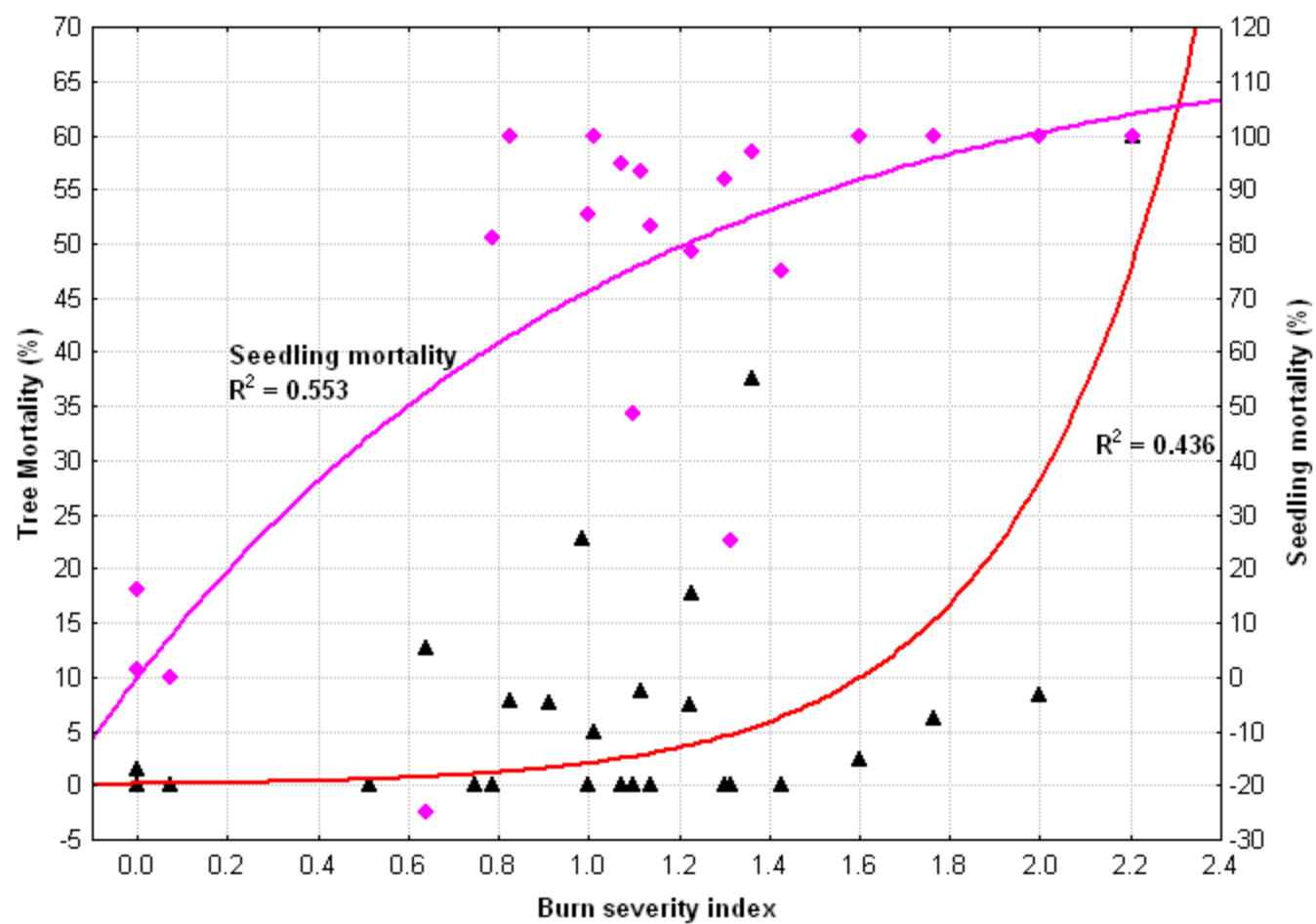


Figure 3.14: Pine tree and seedling mortality in relation to Burn Severity Index

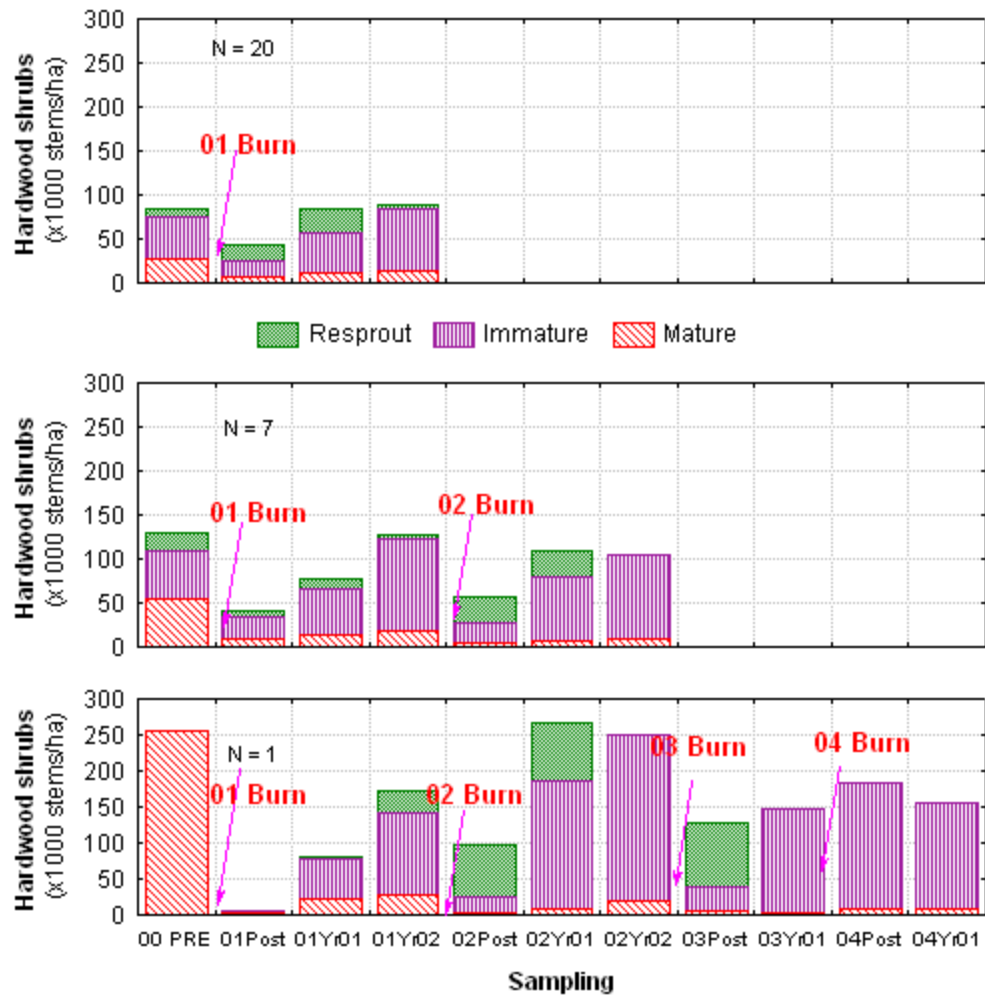


Fig 3.15: Before and after fire density of hardwood shrubs of three growth stages, mature, immature and re-sprout in pine forest fire monitoring plots

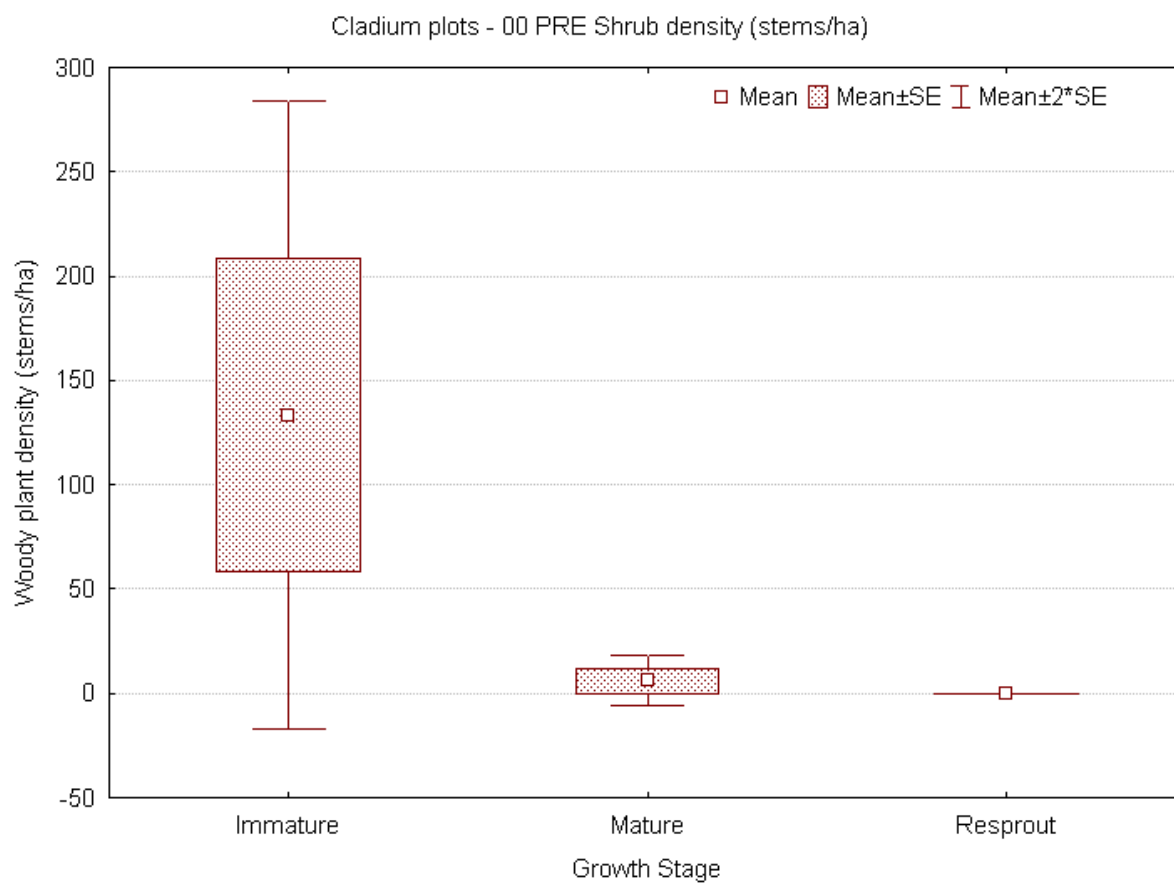


Figure 4.1: Mean density of woody plants of three growth stages (mature, immature and re-sprout) in *Cladium* prairie plots.

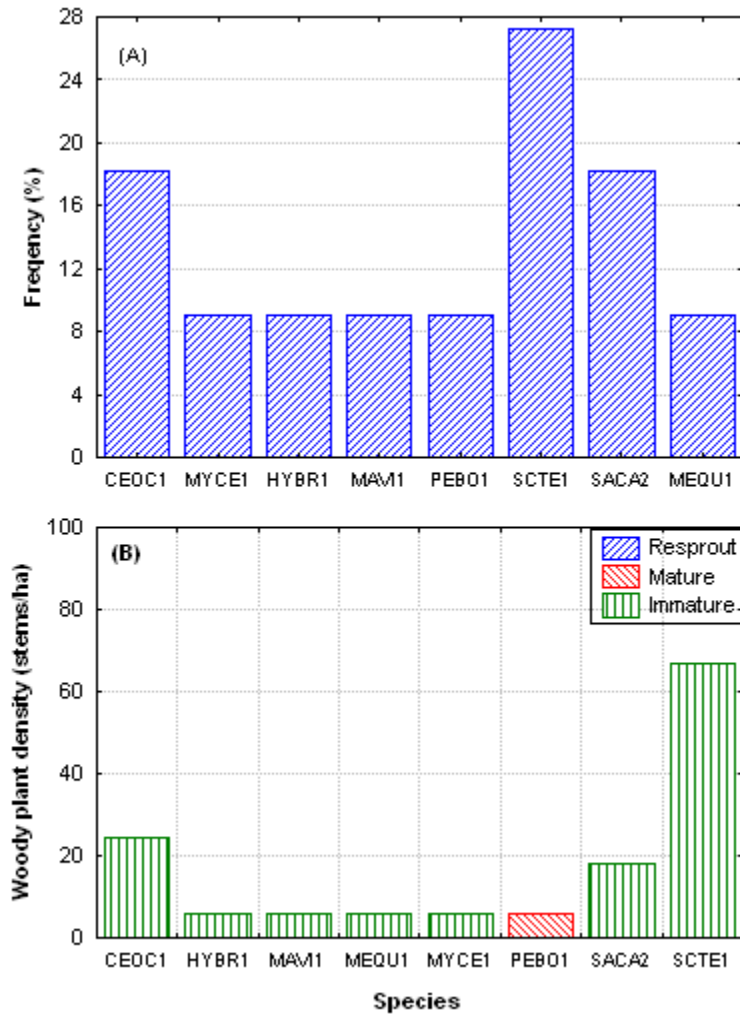


Figure 4.2: Frequency of occurrence and density of woody species in *Cladium* prairie plots.

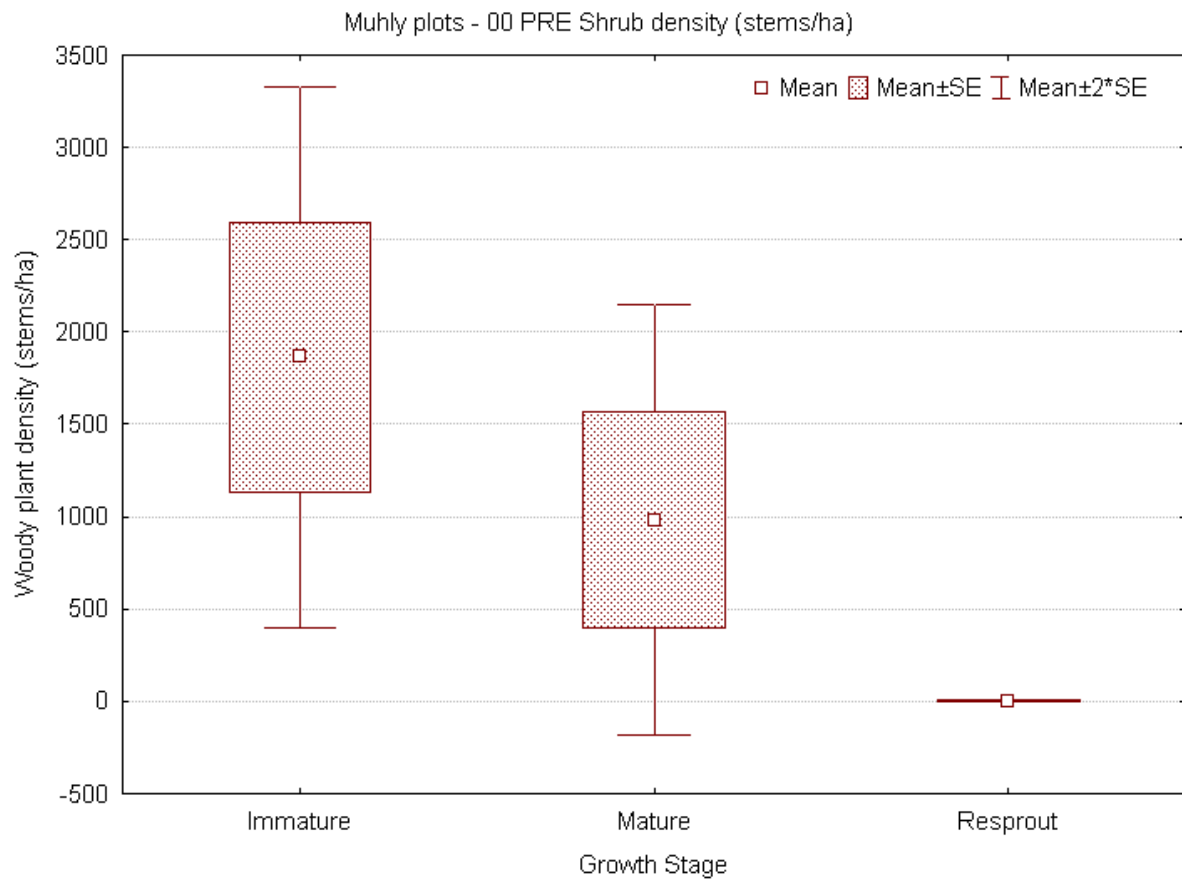


Figure 4.3: Mean density of woody plants of three growth stages (mature, immature and re-sprout) in *Muhlenbergia* prairie plots.

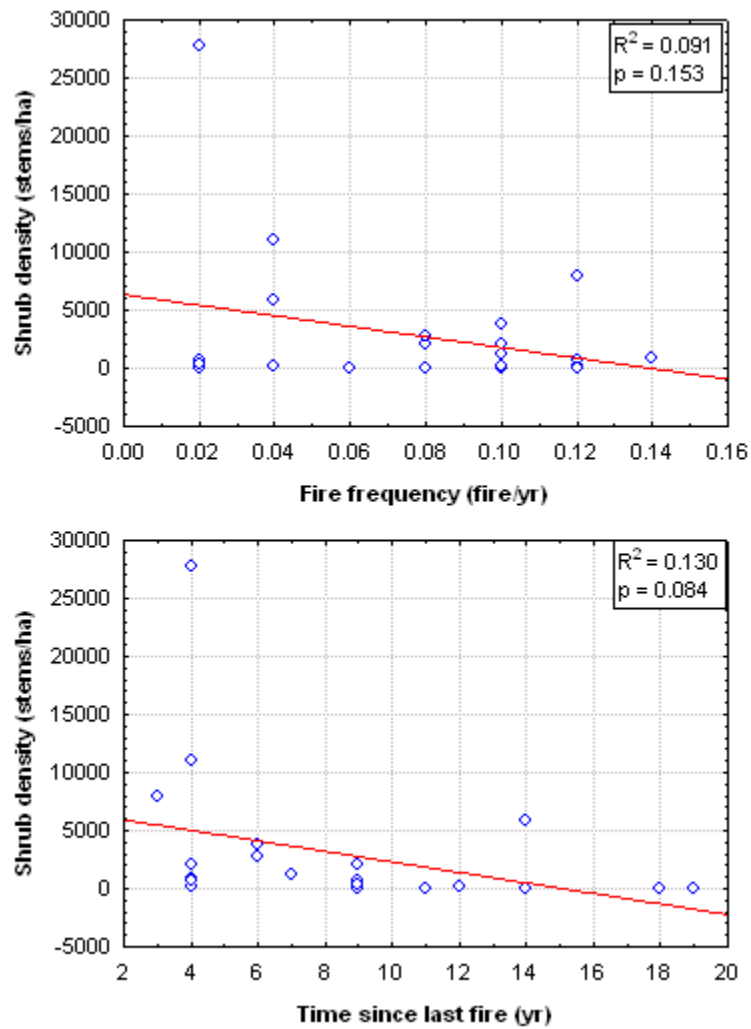


Figure 4.4: Linear regressions showing the relationship of Shrub density in *Muhlenbergia* prairie with fire frequency over 50 years prior to the sampling and time since last fire.

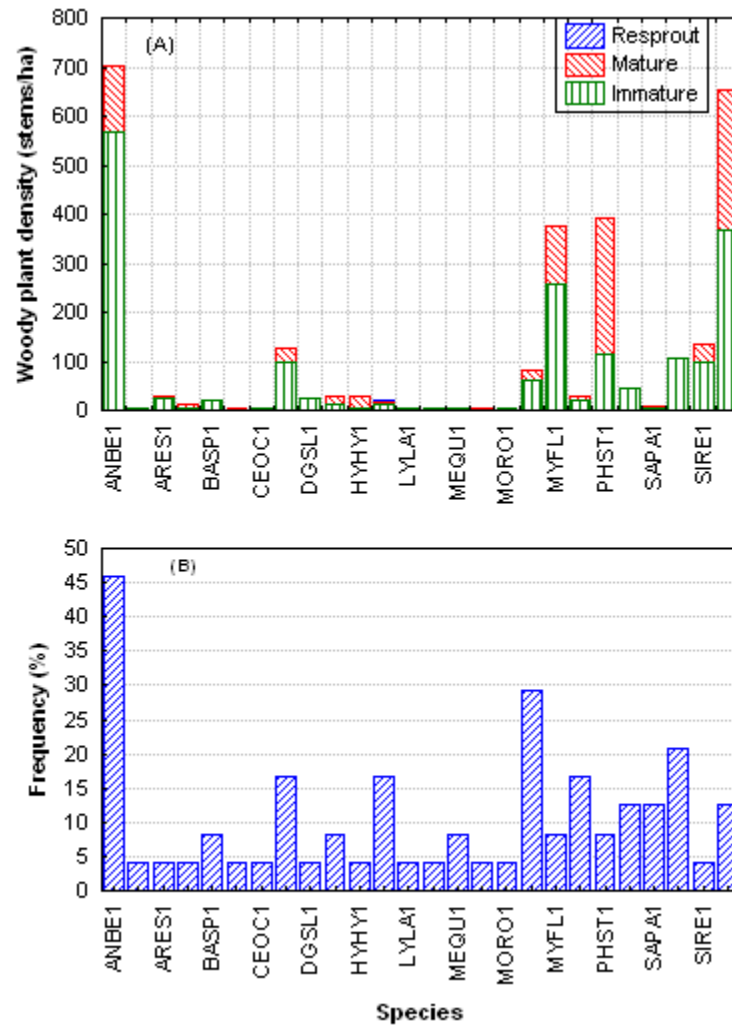


Figure 4.5: Frequency of occurrence and density of woody species in *Muhlenbergia* prairie plots.

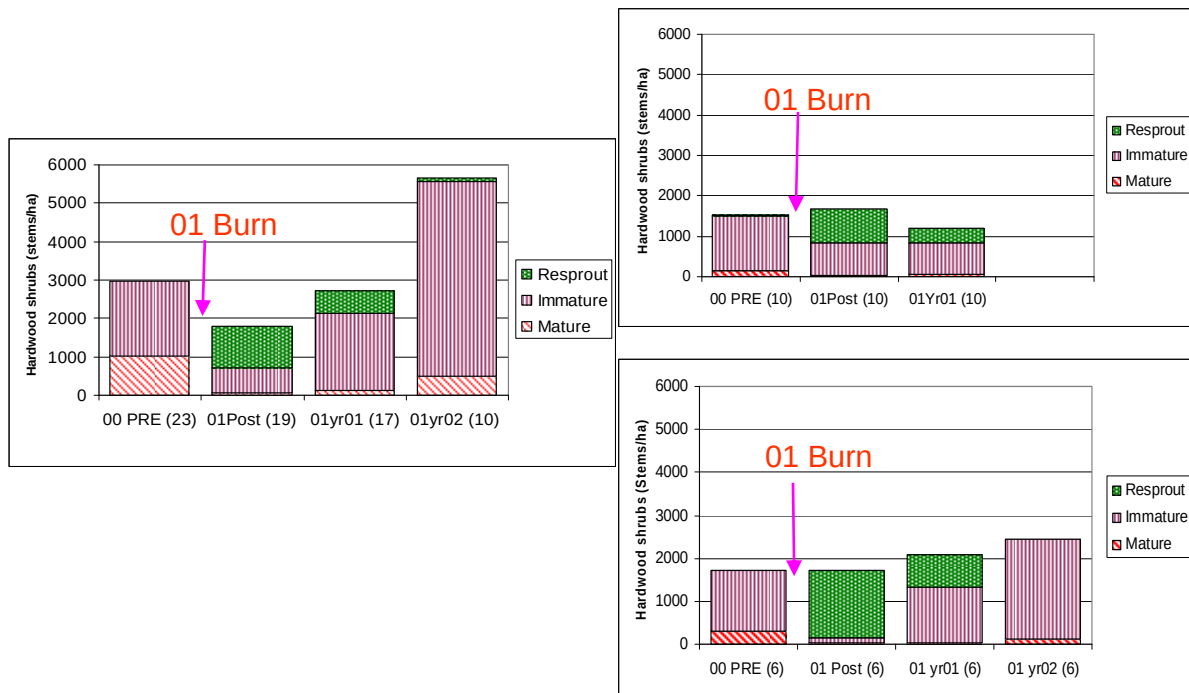


Figure 4.6: Mean density of mature, immature and re-sprout stems of woody species before and after prescribed burn in *Muhlenbergia* prairie.

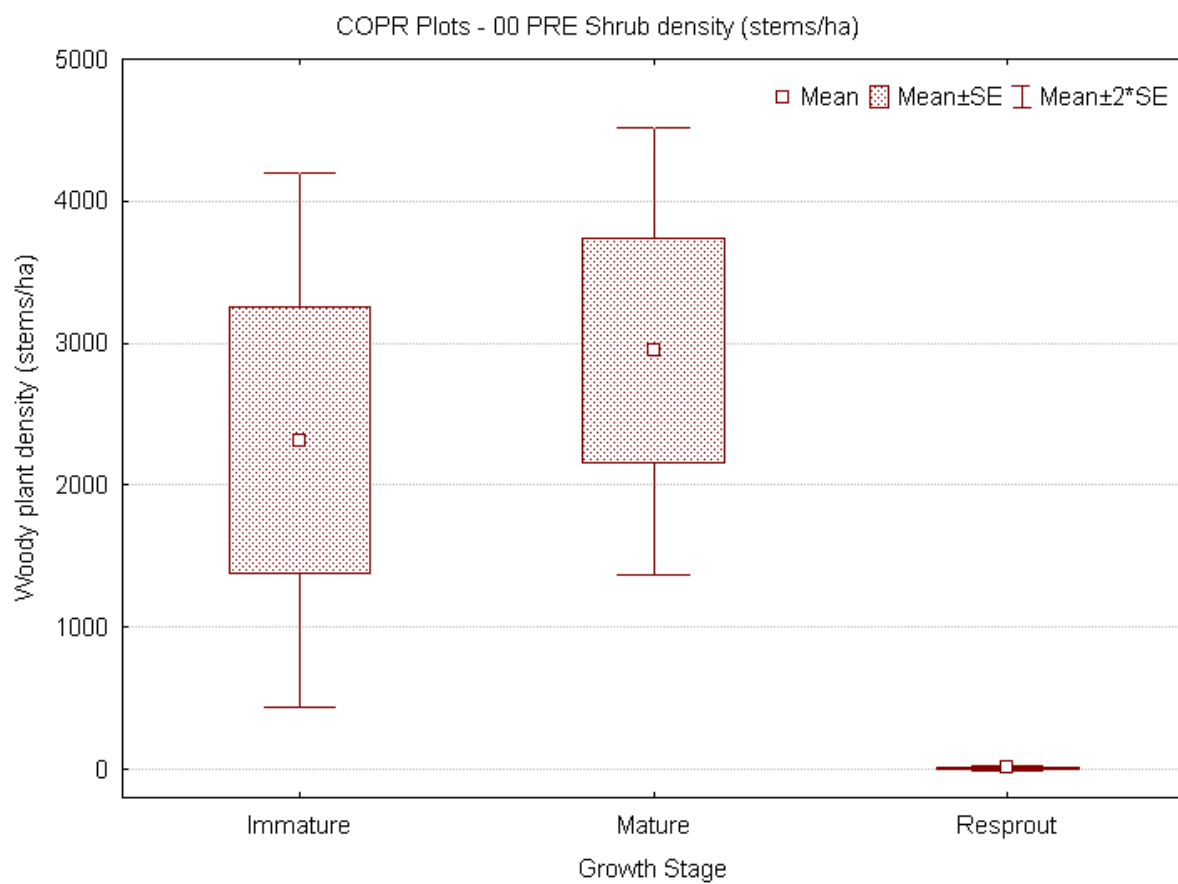


Figure 5.1: Mean density of woody plants of three growth stages (mature, immature and re-sprout) in Coastal prairie plots.

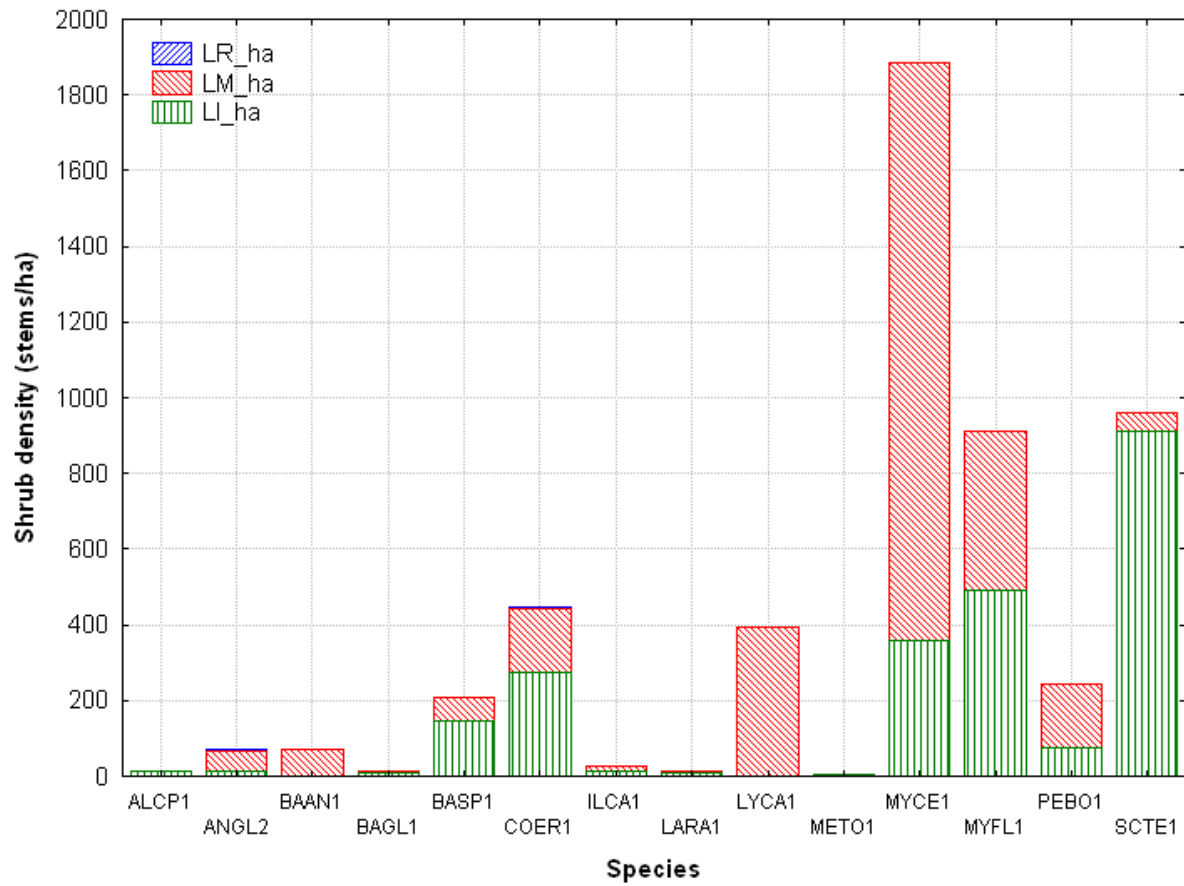
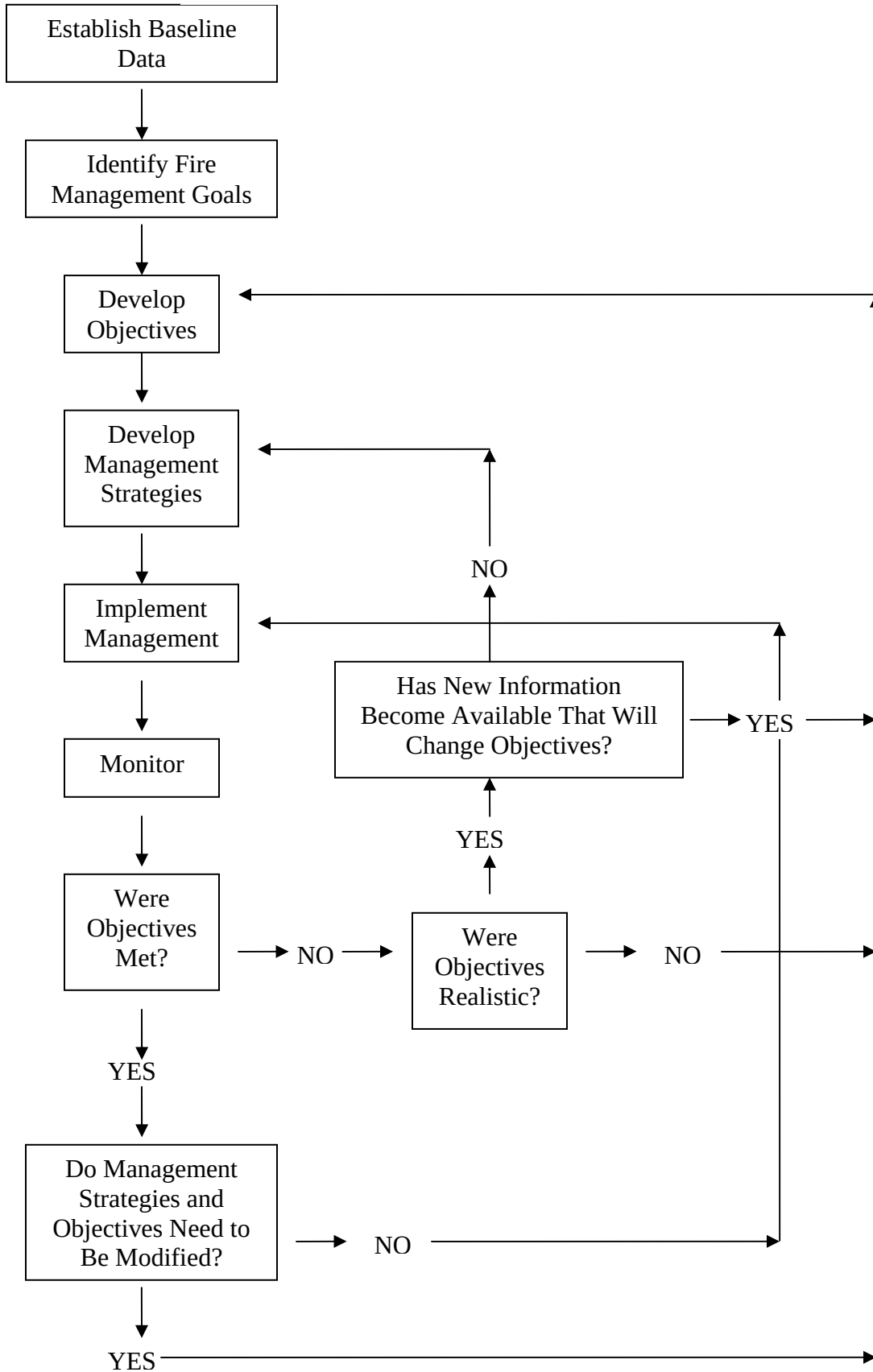


Figure 5.2: Pre-burn density of mature, immature and re-sprout stems of woody species in Coastal prairie plots.

APPENDIX F

Adaptive Management Flow Chart



The following steps will be followed when applying adaptive management.

Applying Adaptive Management Approach

1. Monitor baseline data.
2. Identify quantifiable targets illustrating desired state of ecosystem.
3. Develop objectives.
4. Develop strategies to meet objectives.
5. Implement Appropriate Management Response.
6. Monitor variables to capture system response.
7. Assess if objectives have been met.
8. Evaluate objectives.
9. Evaluate the burn prescription and management strategies.
10. New information as well as research and monitoring results will be assessed annually by South Florida Natural Resource Center and Everglades Fire Management to determine if objectives are appropriate. If needed, new objectives will be created and prescriptions and strategies developed to achieve desired objectives.

Literature Cited

Elzinga, C., Salzer, D. and Willoughby, J. 1998. Measuring and Monitoring Plant Populations. BLM Technical Reference 1730-1.

National Park Service. 2006. South Florida and Caribbean Parks Exotic Plant Management Plan and Environmental Impact Statement. Volume 1.

USDI National Park Service. 2001 Fire Monitoring Handbook. Boise (ID): National Interagency Fire Center. 274p.

Williams, B.K., Szaro, R.C., Shapiro, C.D. 2007. Adaptive Management: The U.S. Department of the Interior Technical Guide. Adaptive Management Working Group, U.S. Department of the Interior, Washington, DC.

Other Literature related to topic

Bowman, R and G.E. Woolfenden. 2002. Nest Site Selection by Florida Scrub_Jays in Natural and Human-Modified Habitats. Wilson Bulletin 114(1):128-135.

Breining, D.R. and P.A. Schmalzer. 1990. Effects of Fire and Disturbance on Plant and Birds in a Florida Oak/Palmetto Scrub Community. American Midland Naturalist 123(1):64-74.

Breinger, D.R., M.A. Burgman, B.M. Stith.. 1999. influence of habitat quality, catastrophes, and population size on extinction risk of the Florida scrub-jay. Wildlife Society Bulletin 27(3):810-822.

Hawkes, C.V. and E.S. Menges. 1996. The Relationship between Open Space and Fire for Species in a Xeric Florida Shrubland. Bulletin of the Torrey Botanical Club 123(2):81-92.