RUTGERS

The State University of New Jersey

Prescribed fire and soil disturbance effects on above ground and belowground processes in the NJ Pinelands.

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http://marine.rutgers.edu/pinelands/station.htm

Pinelands Herb Layer Plant Communities

Alternate stable states

Ericaceous herb layer

graminoid herb layer

Lichen & moss herb layer

Disturbance has been postulated as the mechanism that causes shifts between Alternate Stable States

Plant communities

Microbial communities

Nutrient dynamics

Sandy soils

Background

Liebig's law of the minimum

- Growth is limited by the availability of the single necessary factor in least supply relative to demand (light, water, nutrients)

- Over time depletion of the necessary factor leads to reduced productivity and vegetation tolerant of impoverished conditions

Liebig's law of the minimum

- Macro nutrients & Micro nutrients

- Nitrogen is considered to be the element most limiting to temperate and boreal forests
  - Primary production fixes atmospheric nitrogen in organic compounds
  - Primary producers require larger quantities of nitrogen than of other nutrients
    - nitrogen is energetically expensive to obtain

Liebig's law of the minimum

- Phosphorus is the one major element that must be supplied by the parent material
  - low atmospheric returns
  - Sandy soils have small phosphorus reserves
  - Phosphorus acquisition is moderately expensive energetically

- Vegetation tolerant of impoverished conditions tightly cycle elemental nutrients in low supply

- Successful species in a community retain & efficiently use limiting nutrients

Effects of Disturbance

- **Hypotheses:**
  - **Soil Disturbance will mobilize nutrients**
    - **Damaged plants leak → mineralization**
  - **Fire will mobilize nutrients**
    - **volatilization (C & N) & mineralization**
  - **Mineralized nutrients may be incorporated into plant and microbial biomass**
    - **fertilizer effect**

Effects of Disturbance

- **Hypotheses:**
  - **Retention of mineralized nutrients is limited**
    - **sandy soils**
  - **Mineralized nutrients not incorporated into biomass are leached**
    - **stream eutrophication**
  - **Significant disturbance →community change**

Fire

- **High speed decomposition**
- **Volatilization loss**

  of Carbon & Nitrogen
- **Non-biological mineralization**
  - **Fertilization effect**
  - **increased pH**
  - **Leaching loss of nutrients**

Soil Disturbance

- **Above ground**

  &

  Belowground mortality

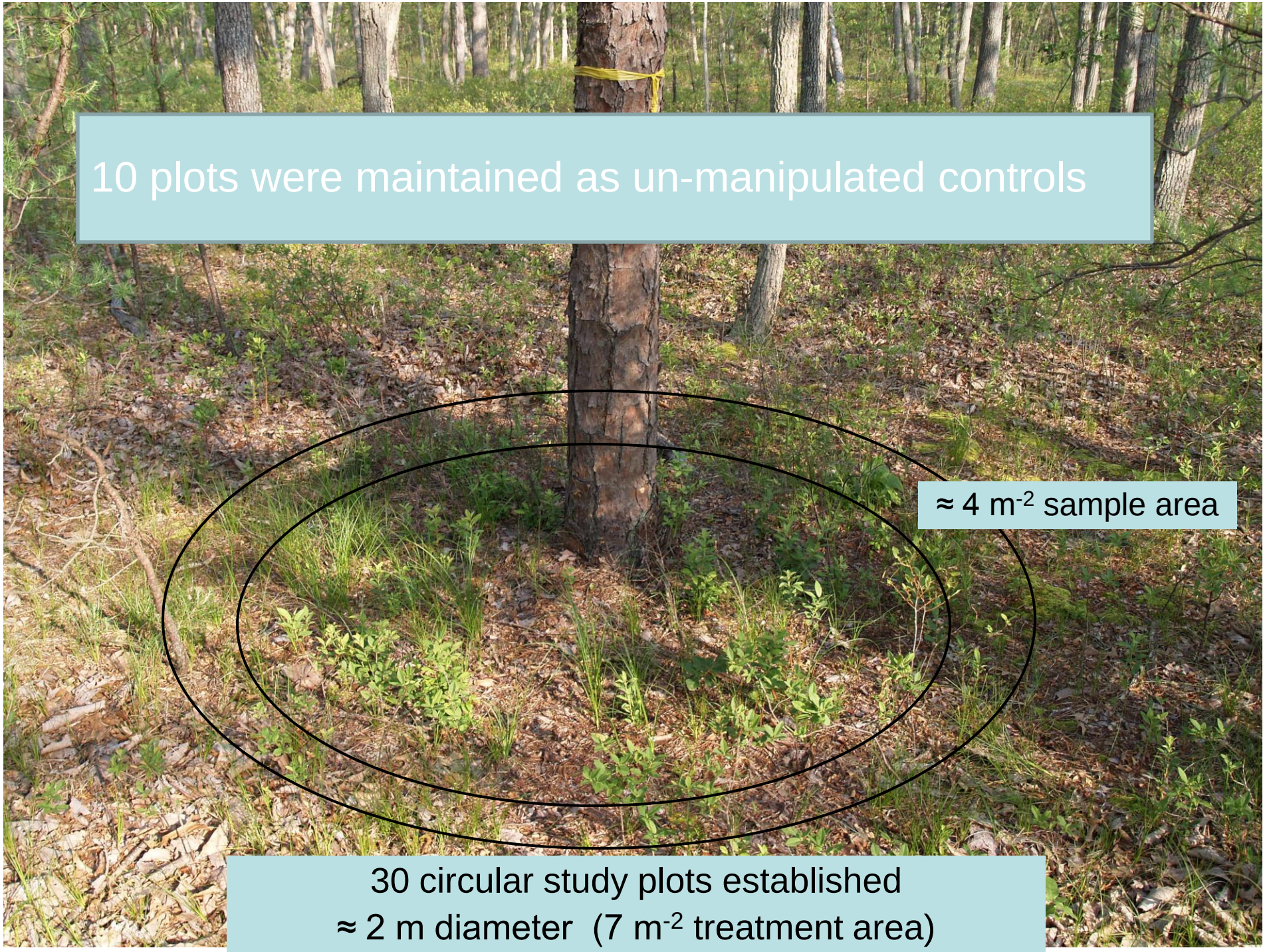
- **biological mineralization**
  - **Fertilization effect**
  - **increased pH**
  - **Leaching loss of nutrients**

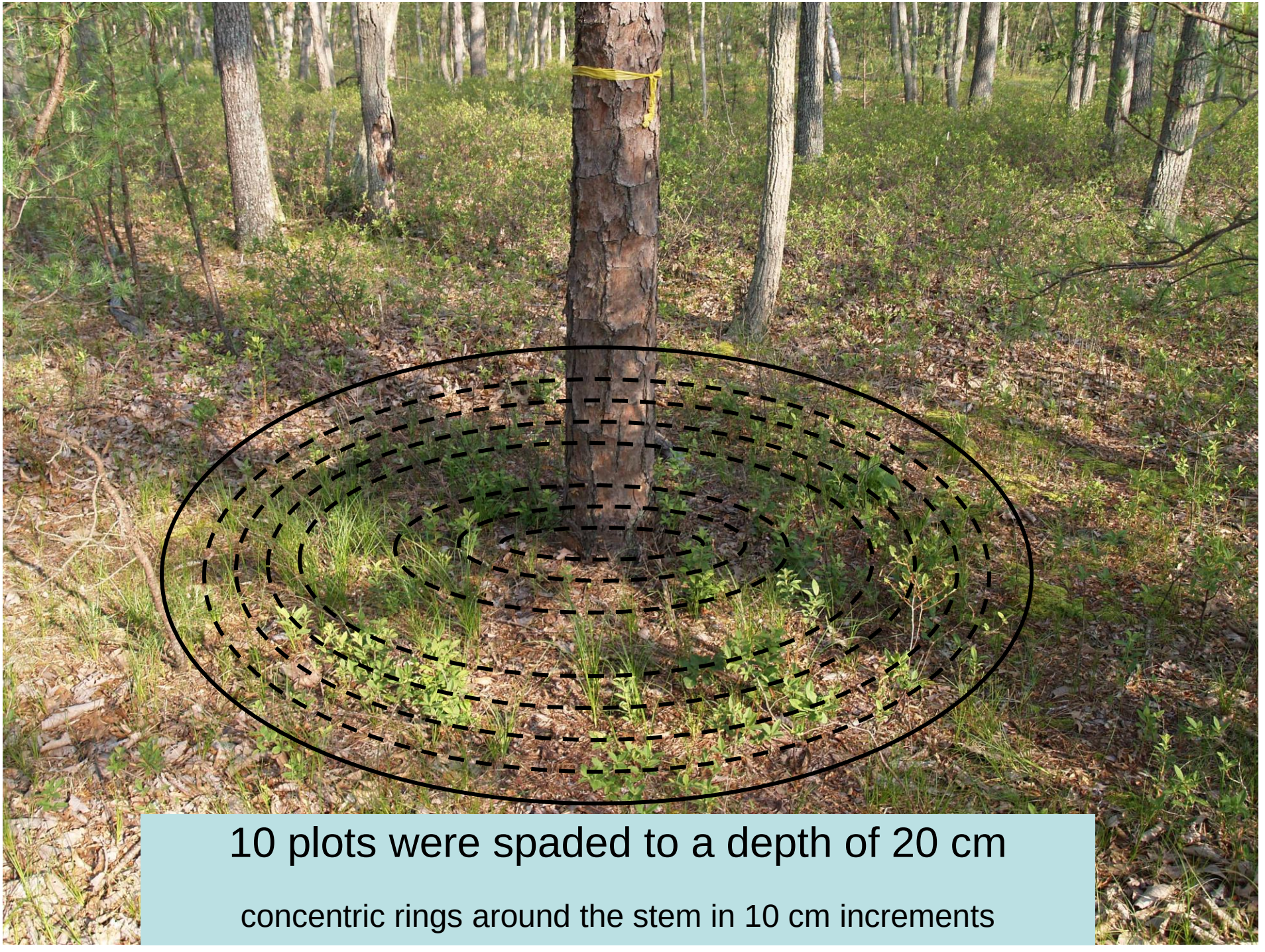
Experiment

- replicated chronic, low intensity disturbance

  fire vs soil disturbance

- to determine:
  - if canopy tree growth is affected
  - if herbaceous layer plant community changes
  - how soil nutrient availability is affected


10 plots were maintained as un-manipulated controls
≈ 4 m-2 sample area
30 circular study plots established
≈ 2 m diameter (7 m-2 treatment area)



10 plots were spaded to a depth of 20 cm

concentric rings around the stem in 10 cm increments


10 plots were burned

Treatment Methods

- 10 burned plots

- Fire severity was low (propane torch)
  - ericaceous stems killed by heat scorch
  - standing dead carex biomass burned
  - ≈ 50% of the litter layer consumed.

Treatment Methods

- 1 burn treatment tree & 1 spade treatment tree lost due to wind-throw
- Total of 28 samples

spading and prescribed fire treatments applied late Feb – early March 2007,2008, 2009, 2010 & 2011

Vegetation Analysis Methods

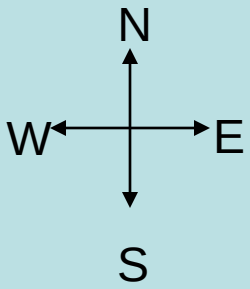
- Ground cover analysis

  late summer, 2006 – 2011

  – Graminoid ramet and plant stem count, by species litter depth and % cover lichen + moss

- Summer 2011, following % cover, stem and ramet count the vegetation was clipped at the ground surface
  – leaf, stem and ramet mass determined
- Canopy tree growth performance was determined by annual DBH measures
- March 2012 canopy cover of 7 spade, fire & control treatment trees was determined by upward facing LIDAR acquisition

LIDAR acquisition



Horizontal cover
4 transects, returns / meter

Vertical cover
Standard deviation of return height

Soil Analysis Methods

- Soil samples from 0-20 cm depth were obtained
  - 3 months post fire (May 2007)
  - 3 months post fire (May 2011)
  - Early October 2007- 2010
    - at the onset of senescence
    - ≈ 7 months post fire treatment

Soil Analysis Methods

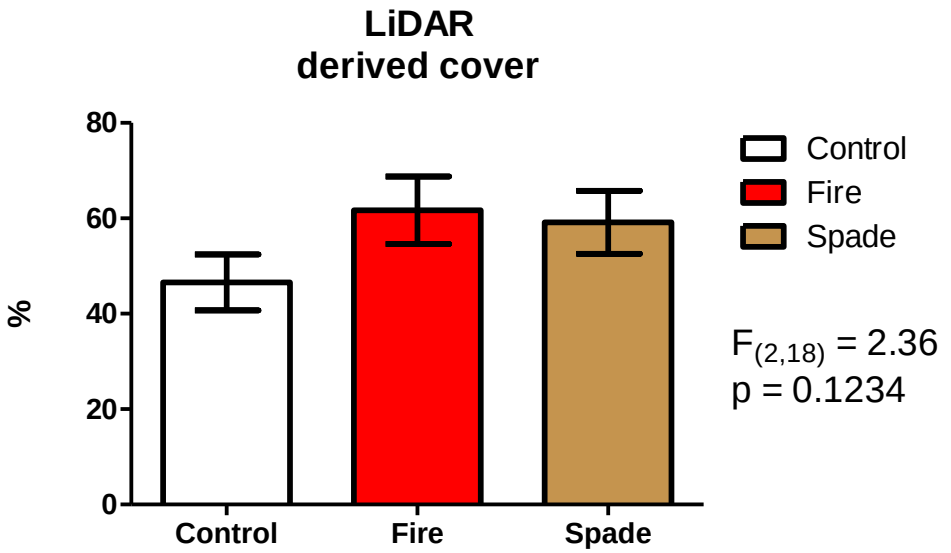
- Litter depth, soil bulk density
- Soil Nutrient analysis:
- extractable inorganic nitrogen (NH_4 & NO_3)
- extractable inorganic phosphate (PO_4)
- Microbial Biomass Nitrogen (MBN).

Canopy Layer response

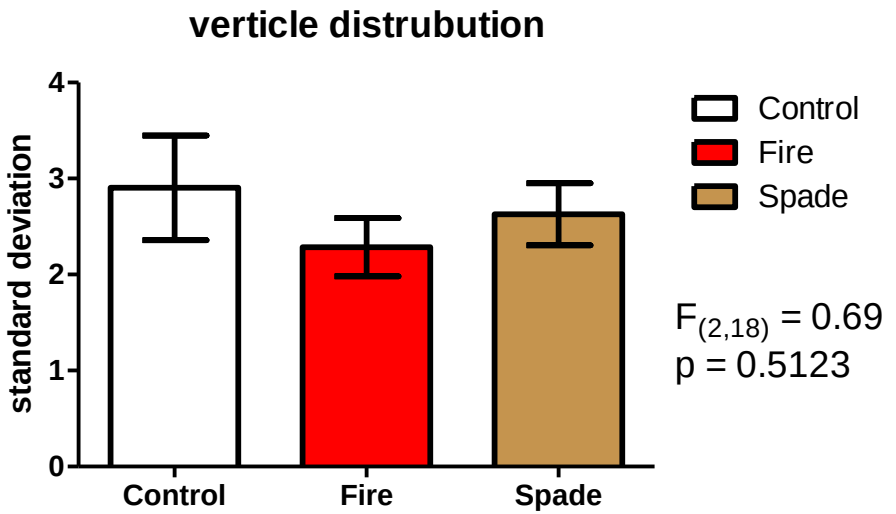
gypsy moth, *Lymantria dispar*

Gypsy moth larvae consumed the deciduous tree canopy in May 2007
Approximately 15 % of the oaks in the study area died as a result

Cover

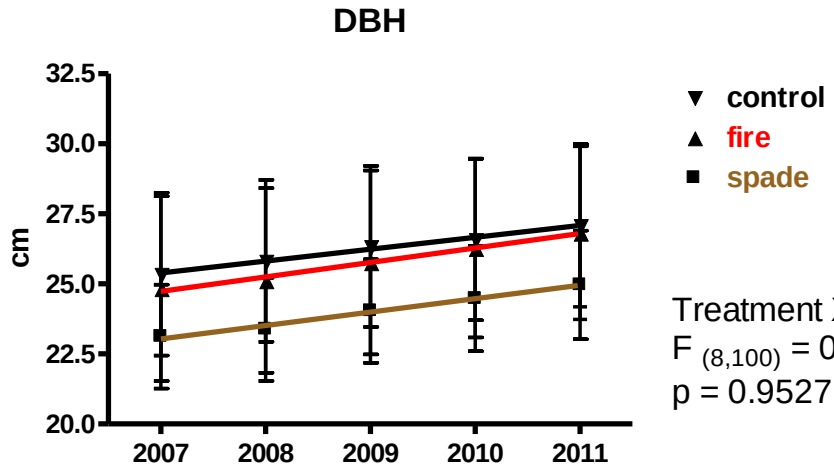


$F_{(2,18)} = 2.36$
$p = 0.1234$



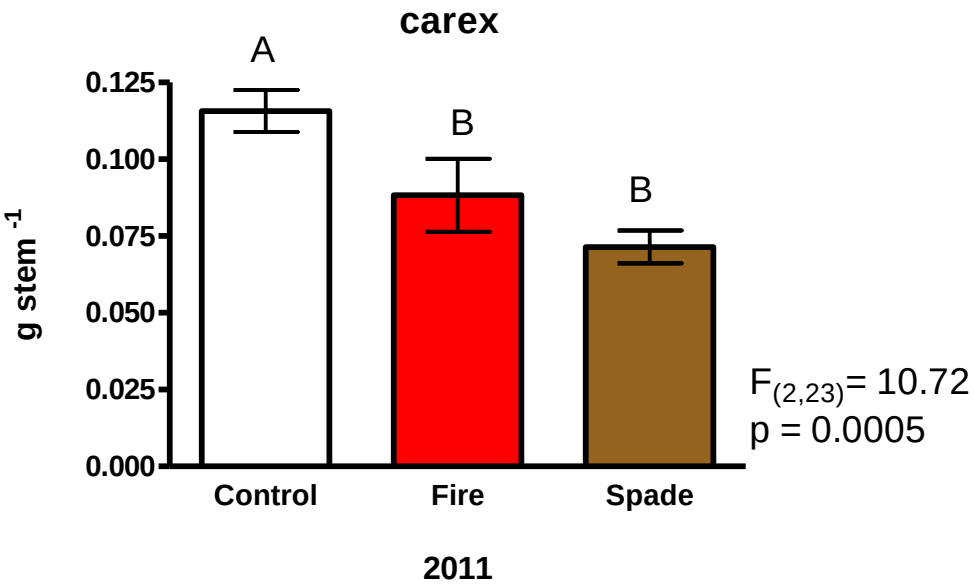
$F_{(2,18)} = 0.69$
$p = 0.5123$

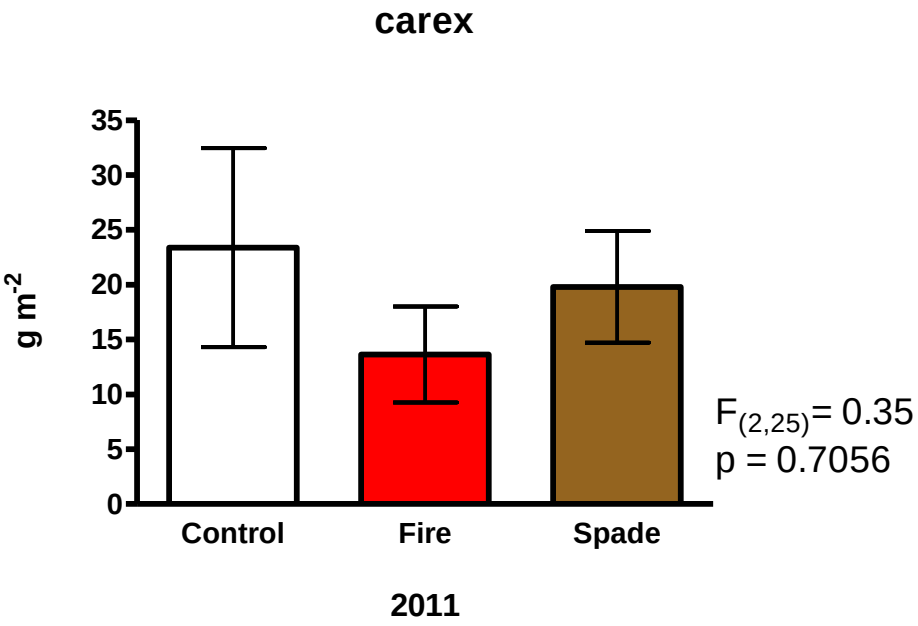
Stem growth over time



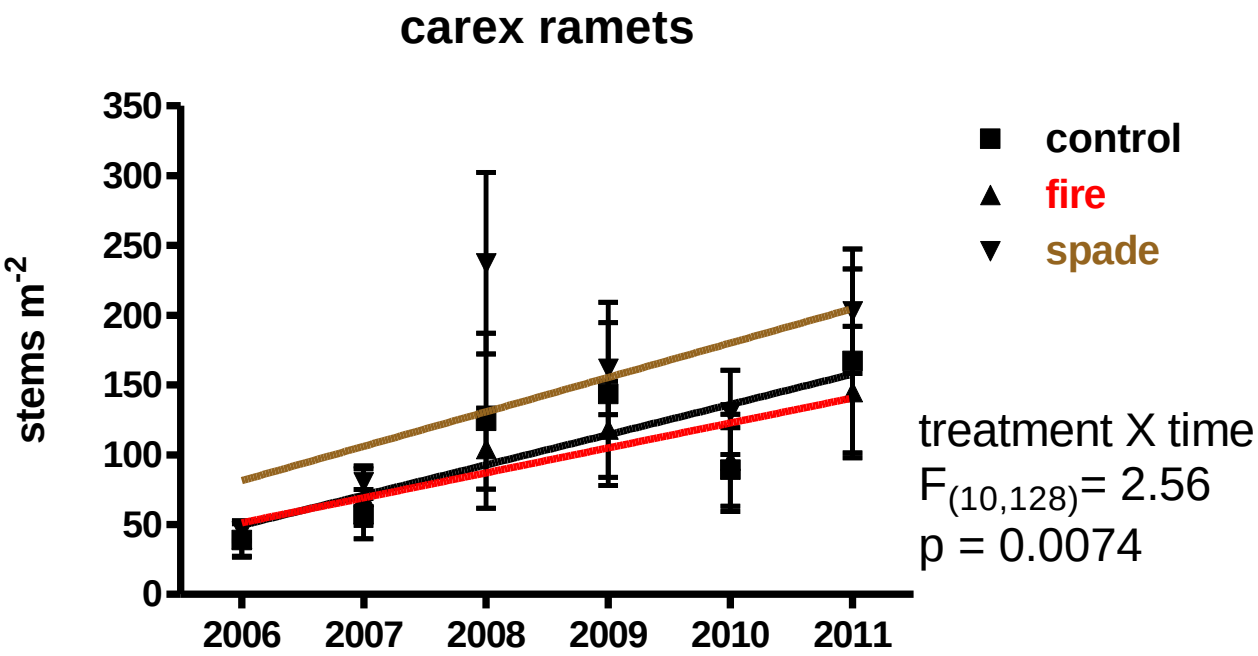
Treatment X Time
$F_{(8,100)} = 0.33$
$p = 0.9527$

Herbaceous Layer response

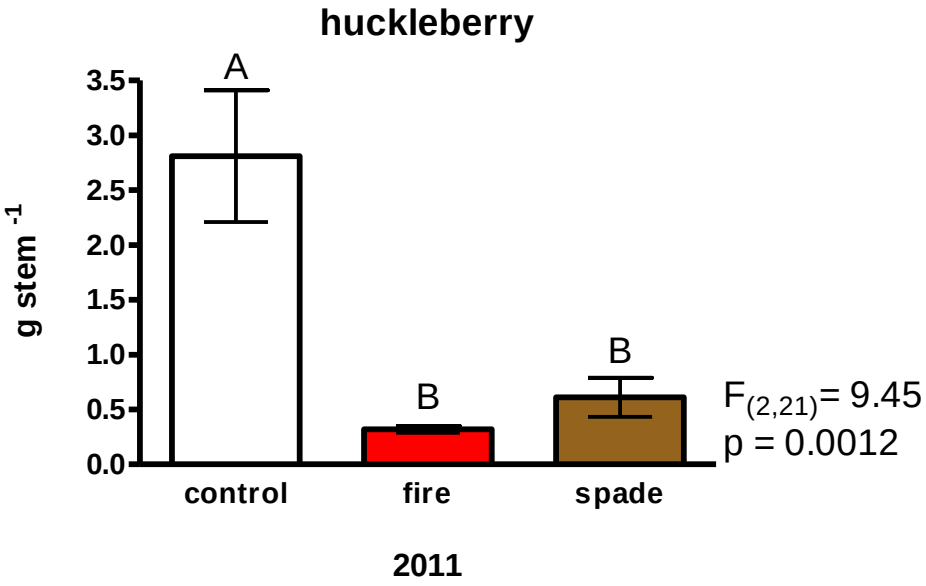




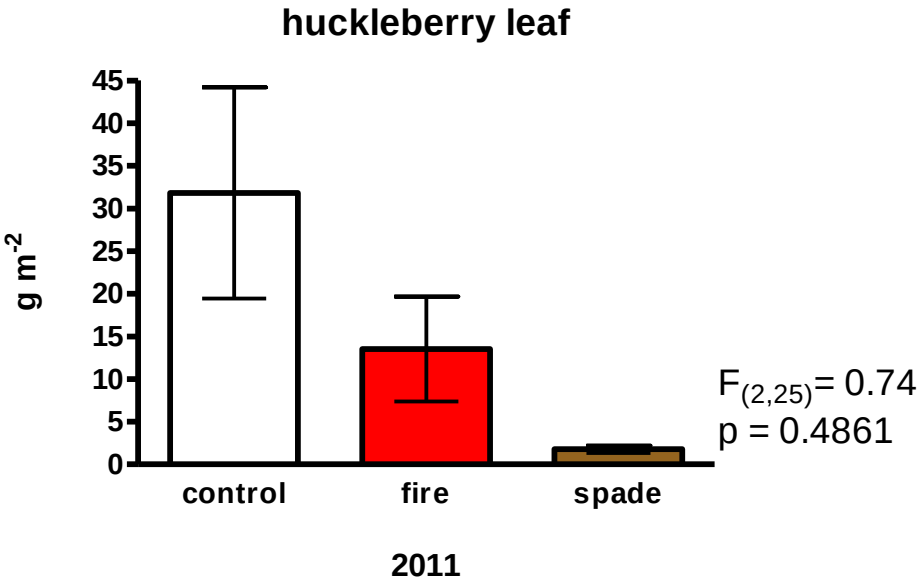
Control has more robust ramets but disturbance treatments have more ramets



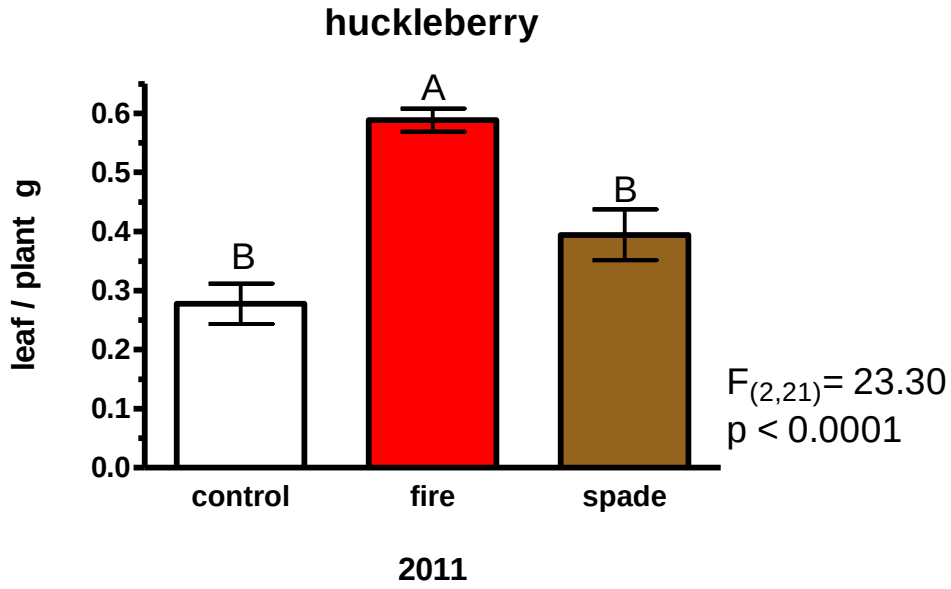
Spade and fire treatment
carex ramet count slopes are positive
Control treatment slope flat



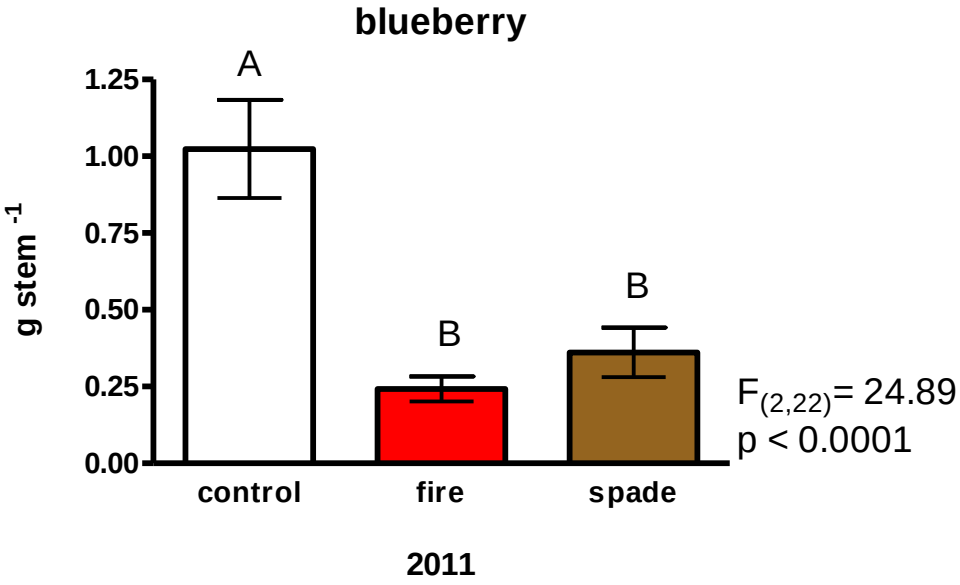
Control stems are more robust

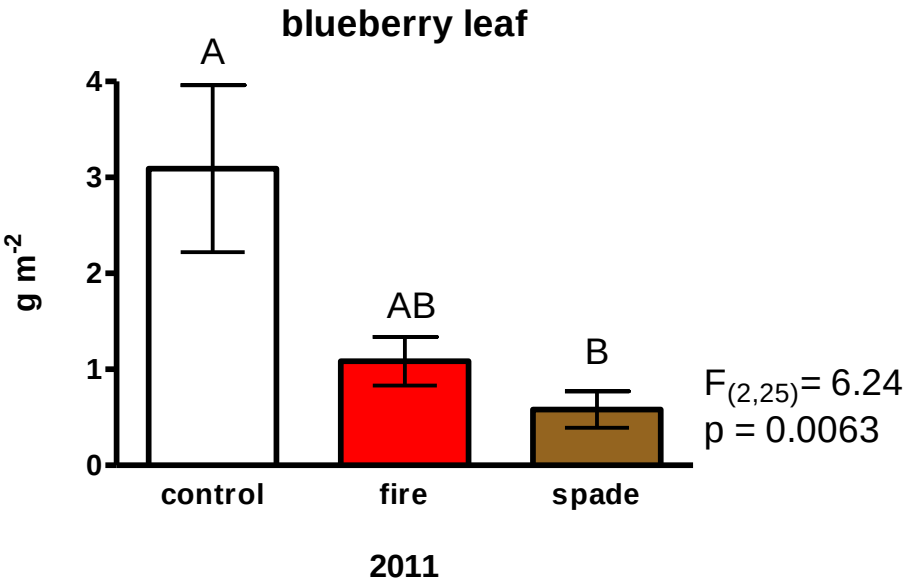


new stem produces more leaf / stem

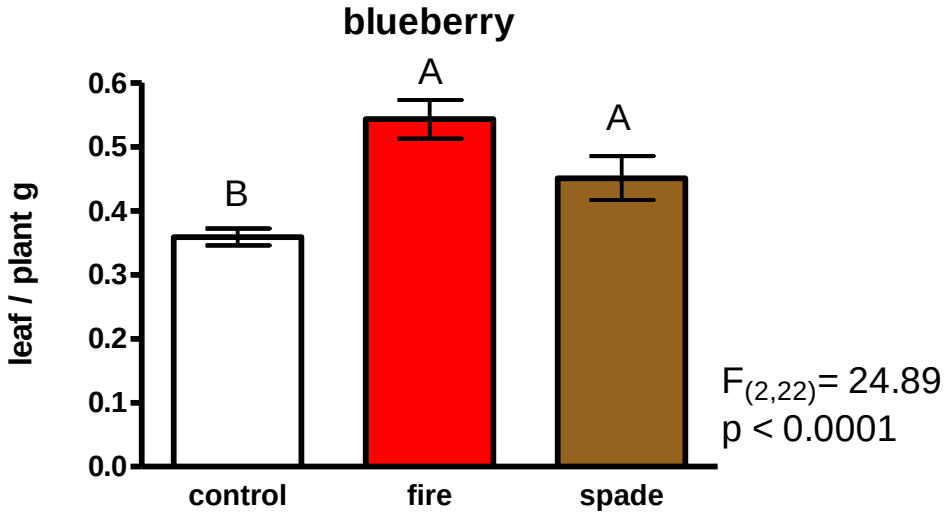


Fire treated plots produce more leaf / stem

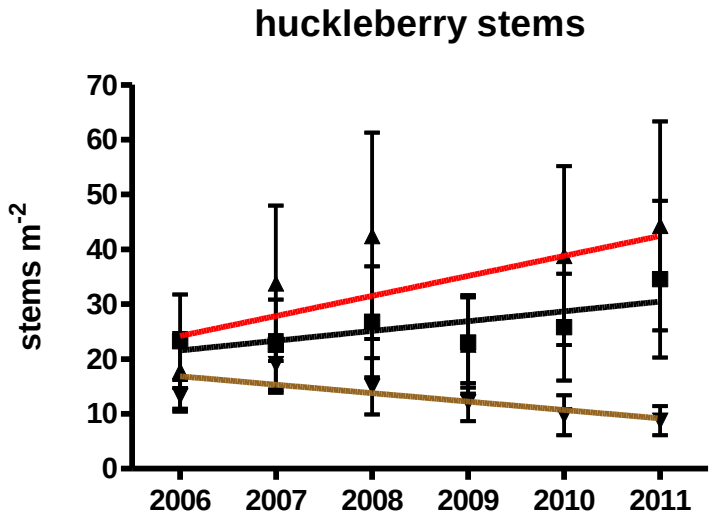




Control stems are more robust

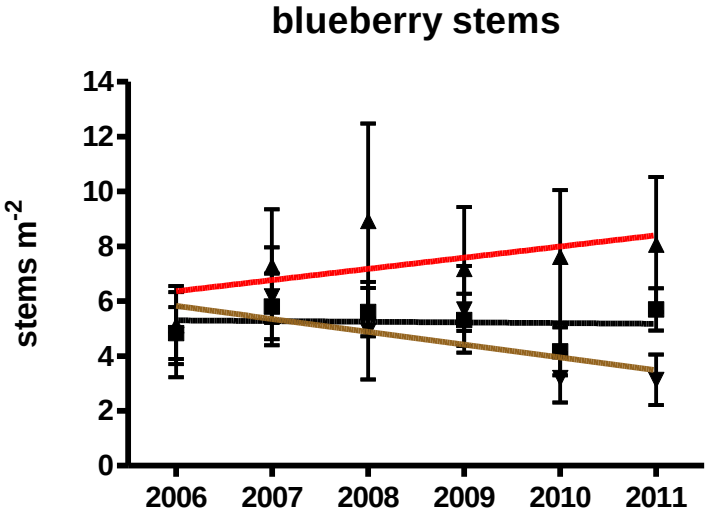


Disturbance treated plots produce more leaf / stem



treatment X time
$F_{(10,128)}$= 5.59
p < 0.0001

Spade treatment huckleberry stem count decreased over time

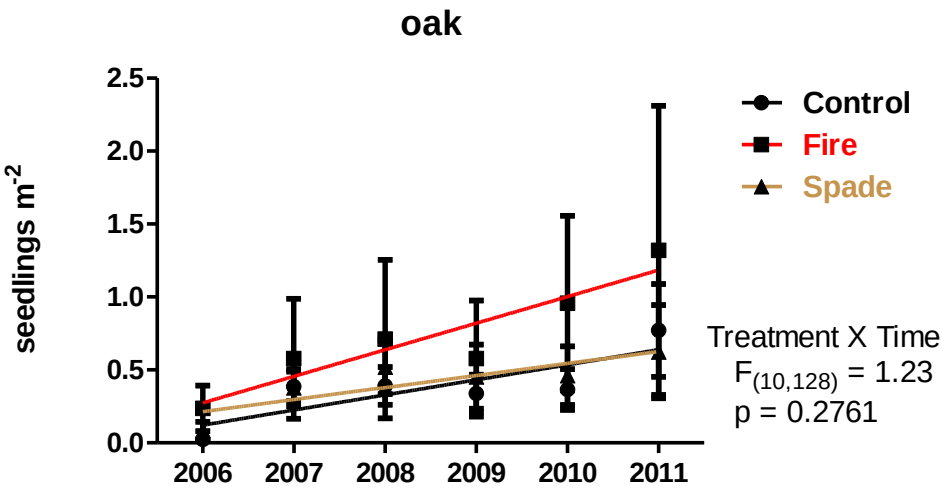


treatment X time
$F_{(10,128)}$= 1.73
p = 0.0811

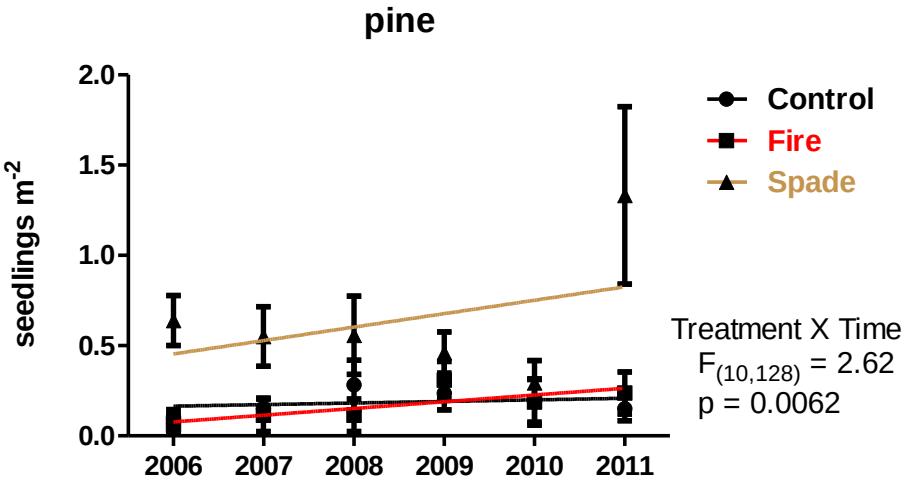
Spade treatment blueberry stem count decreased over time

Stem count
% change 2006 - 2011

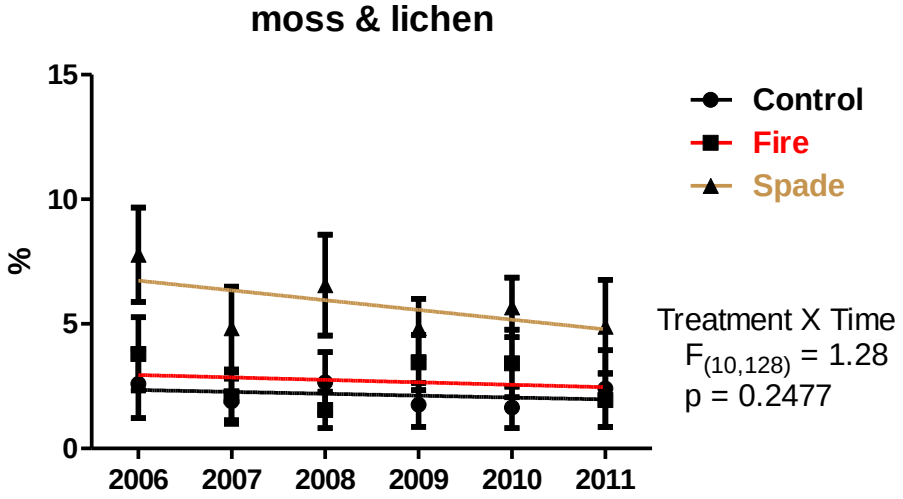
	Carex	Huckleberry	Blueberry
Control	77	35	16
Fire	70	56	29
Spade	78	-49	-50



No difference in oak regeneration



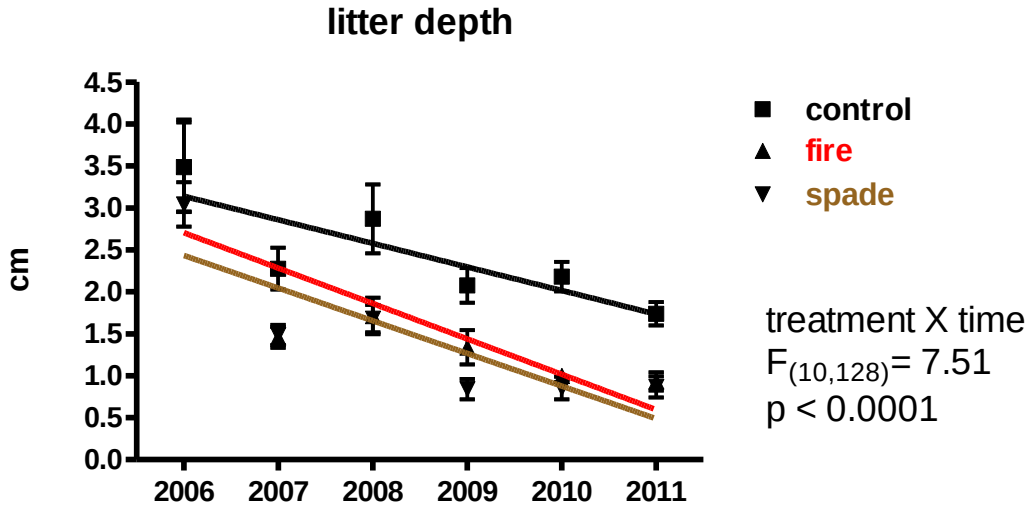
Pine regeneration greatest in Spade plots



No difference in moss / lichen cover

Soil Nutrient / Microbial Biomass Response

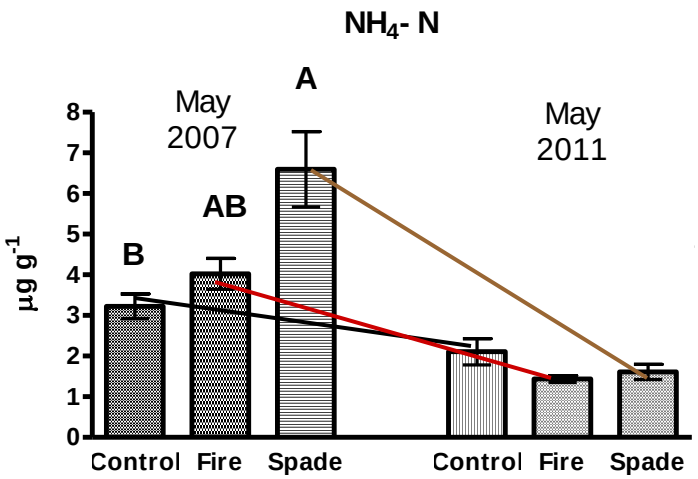
Soil Surface



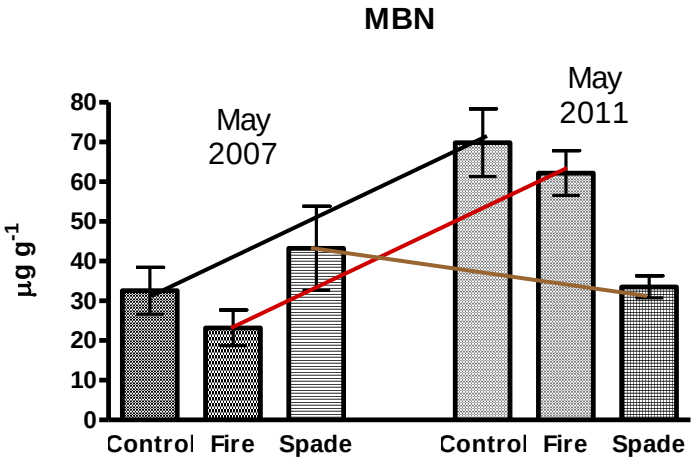
Litter depth decreased in all treatments over time

Litter depth decrease was greater in the disturbance plots

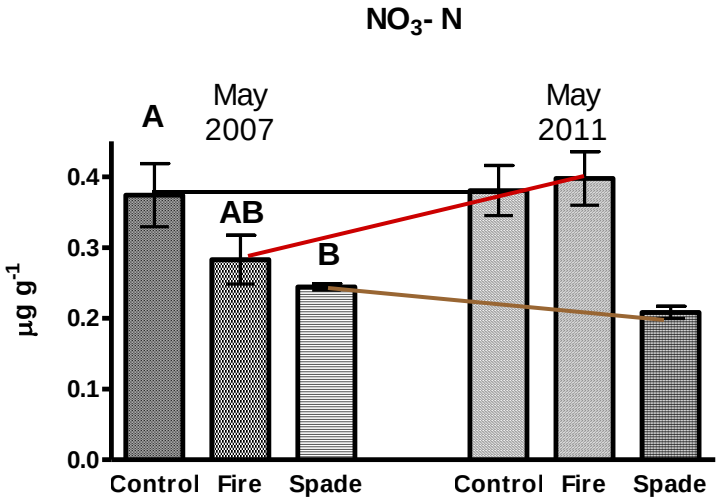
Reduced stem mass resulted in reduced litter retention in disturbance plots



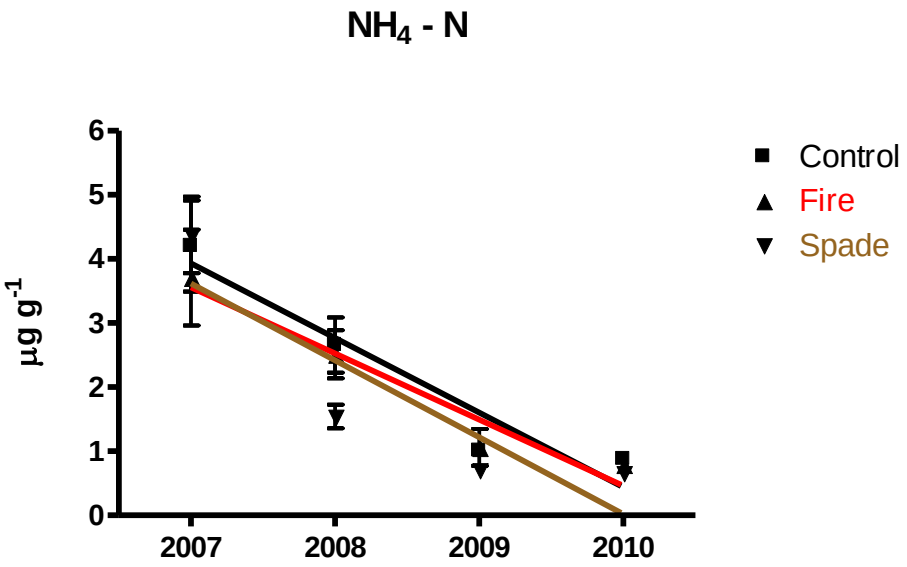
F (2,26) = 6.90
p = 0.0040



F (2,22) = 1.01
p = 0.3800



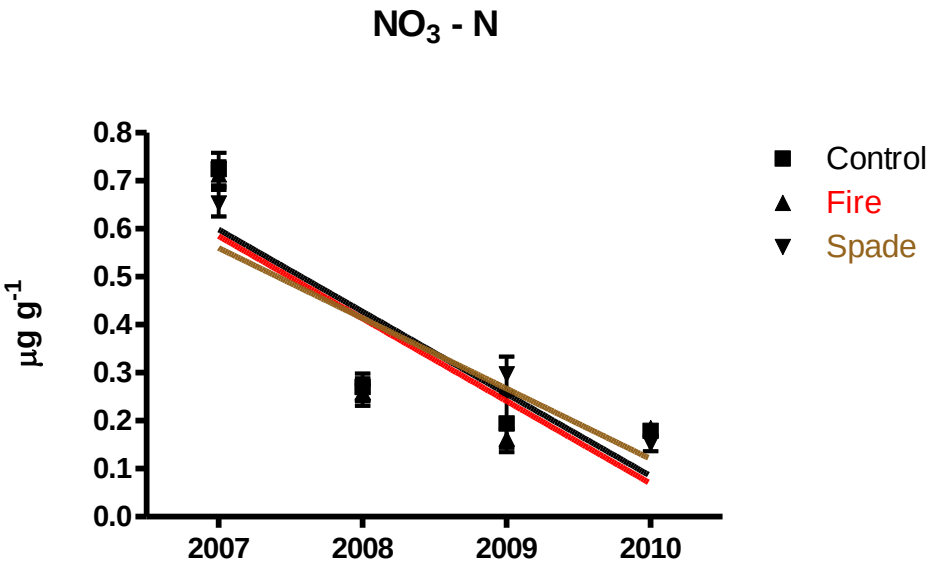
F (2,26) = 3.970
p = 0.0314



Heavy oak gypsy moth defoliation of oaks in 2007

Canopy opening from oak mortality & increase shrub layer growth

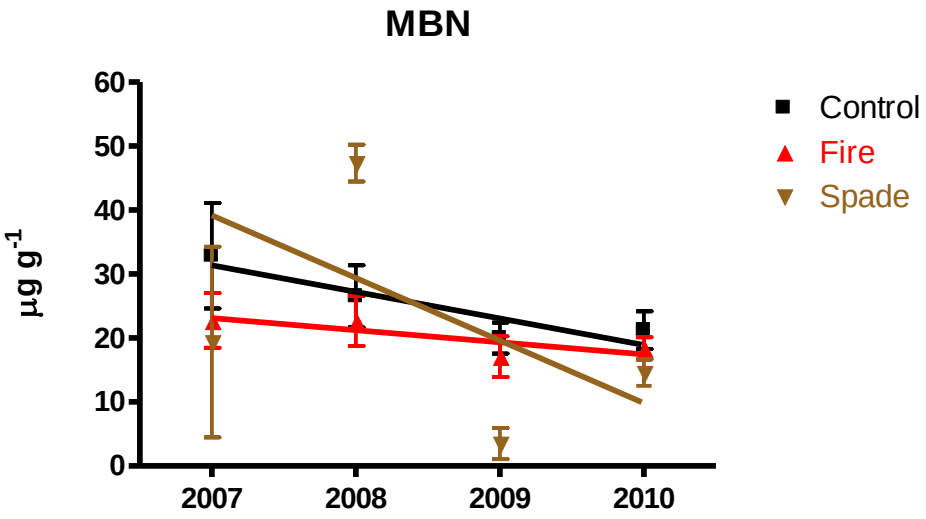
Increased nitrogen demand from increased shrub species



Spade treatment slope less steep

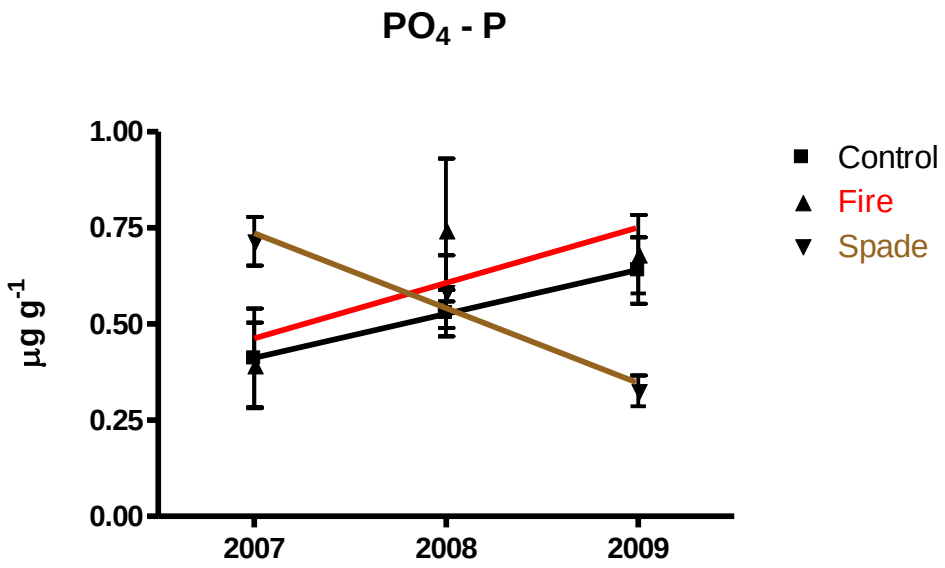
Spade treatment reduced nitrogen demand from the herb layer

Increased nitrification of ammonium by soil bacteria in spade plots



Microbial biomass does not decline in control or fire treatment plots

Only Spade treatment slope significantly negative



Only Spade treatment slope significantly negative

Spade treatment damages plant roots
phosphate lost from dying roots leached from the soil

Conclusions

Canopy Layer:

- Canopy trees did not benefit or suffer as a consequence of fire or soil disturbance
  - Fire mineralized nutrients did not lead to increased tree biomass
  - Root disruption did not lead to reduced rates of biomass growth or canopy cover after 5 years of disturbance

Conclusions

Herb Layer: (After 5 years of treatment)

- Carex ramet count increased
  in disturbance treatments
- Disturbance treatments decreased mass / ramet
- Fire increased huckleberry leaf mass
- both disturbance treatments increase blueberry leaf mass
- Huckleberry & Blueberry stem count decreased due to spade treatment

Conclusions

- Litter inputs reduced due to disturbance
  - fewer & smaller stems retain less litterfall
    - Litter dam effect
- Reduced litter inputs ultimately result in reduced nutrient inputs

Conclusions

Soil Nutrients / Microbial Biomass:

- Ammonium declined across all treatments
  - Herb layer response to gypsy moth defoliation ?
- Nitrate also declined, although less steeply for spade treatment
  - Reduced ammonium demand and greater nitrification ?
- MBN declined over time in spade treatment
  - coupled with reduced herb layer indicates nitrogen leaching from spade treatment plots
- Phosphate steeply declines in spade treatment

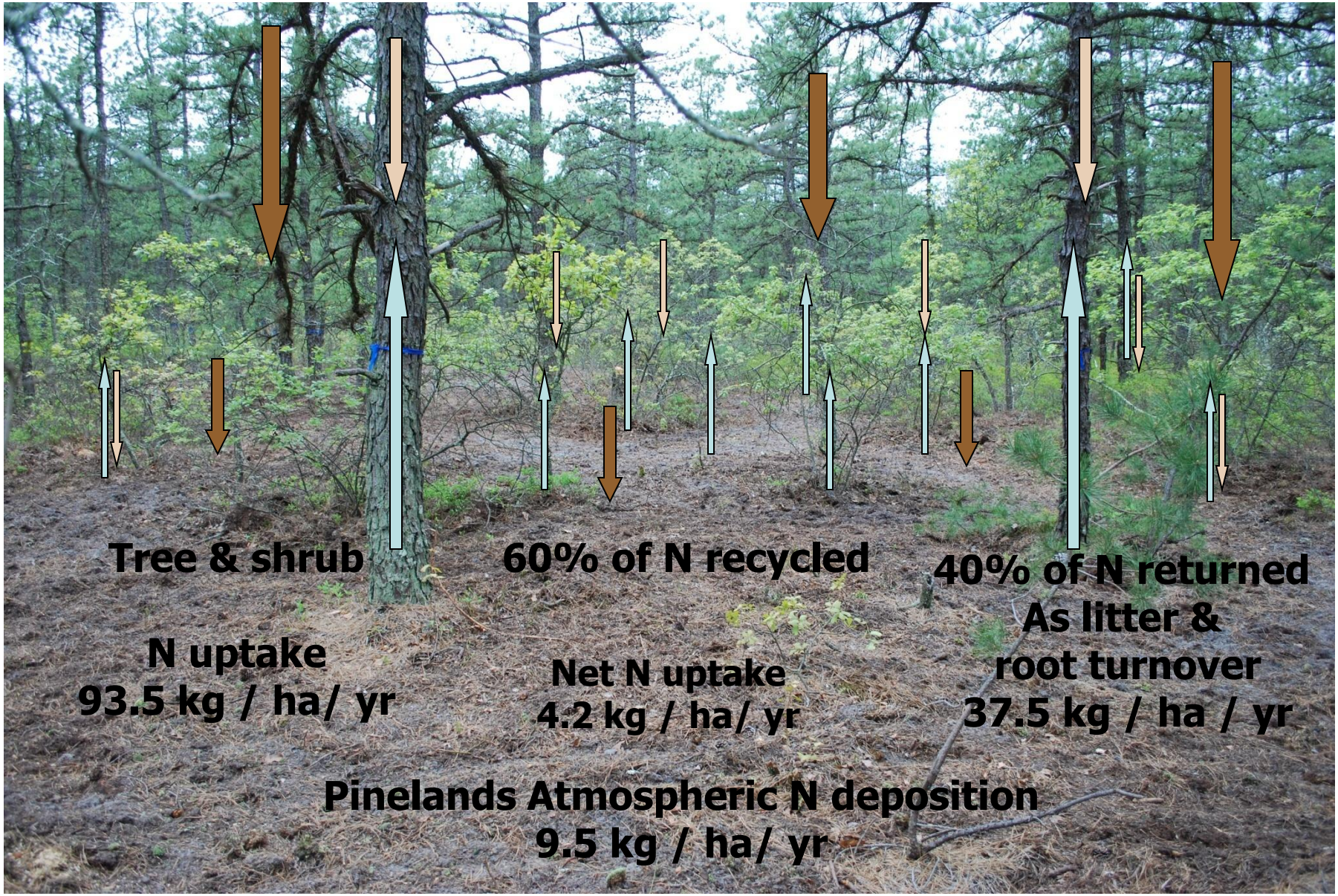
Discussion

- Growth is limited by the availability of a single necessary factor in least supply relative to demand (light, water, nutrients)
  - Oak mortality due to gypsy moth defoliation increased sunlight and reduced competition for water & nutrients
  - Soil inorganic nitrogen stores declined irrespective of treatment

- Nitrogen is considered to be the element most limiting to temperate and boreal forests
- In the pine barrens → Yes & No

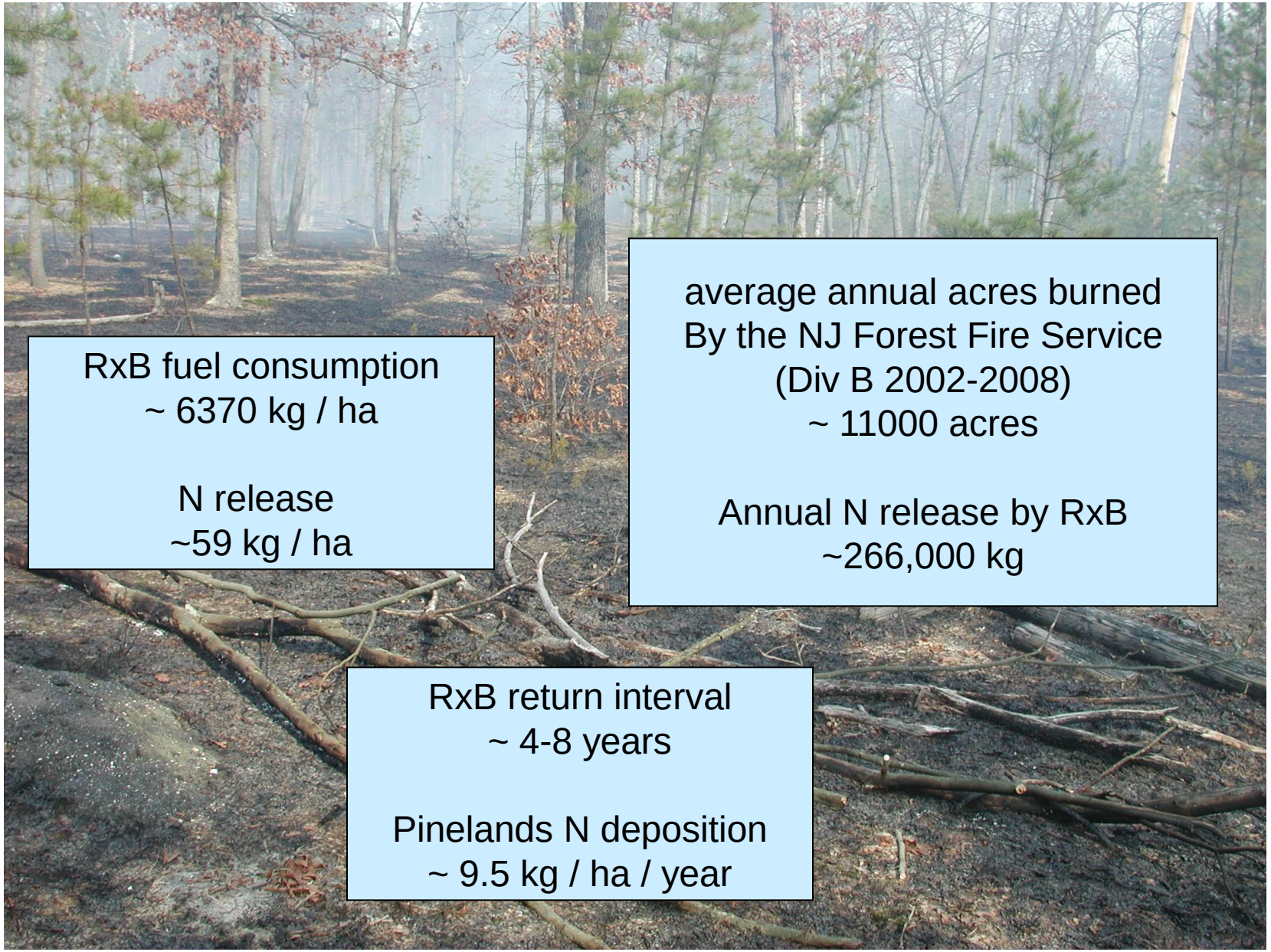
Pineland Upland Forest

Leaky Ecosystem



Uptake values USFS

Fire in the Pines



RxB fuel consumption
~ 6370 kg / ha

N release
~59 kg / ha

average annual acres burned
By the NJ Forest Fire Service
(Div B 2002-2008)
~ 11000 acres

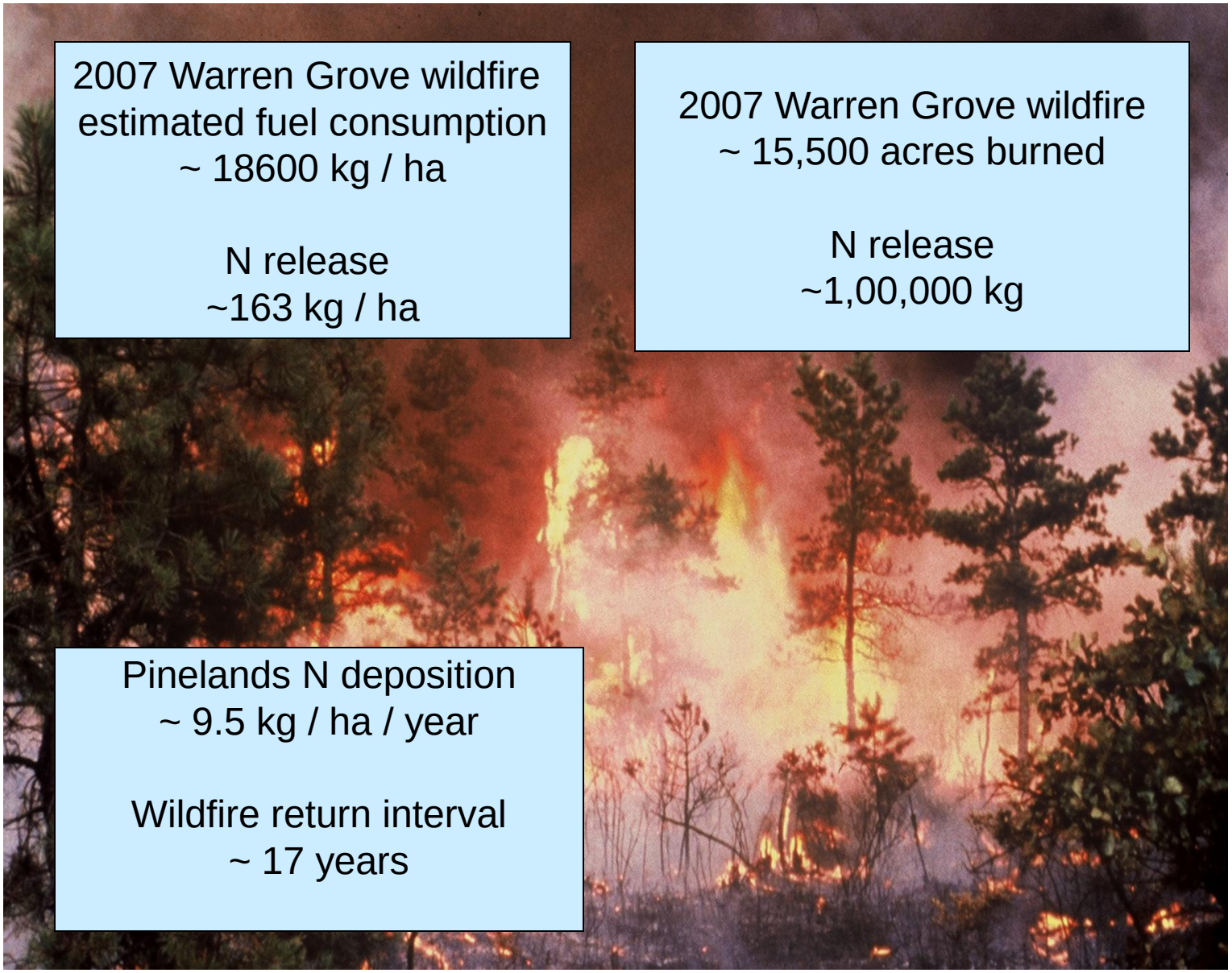
Annual N release by RxB
~266,000 kg

RxB return interval
~ 4-8 years

Pinelands N deposition
~ 9.5 kg / ha / year

Fuel consumption values USFS

Wildfire in the Pines



2007 Warren Grove wildfire
estimated fuel consumption
~ 18600 kg / ha

N release
~163 kg / ha

2007 Warren Grove wildfire
~ 15,500 acres burned

N release
~1,00,000 kg

Pinelands N deposition
~ 9.5 kg / ha / year

Wildfire return interval
~ 17 years

Fuel consumption values USFS

Conclusion

- Soil disturbance by spading yielded:
  - Increased carex, decreased huckleberry & blueberry
  - Reduced microbial biomass
    - Indicating reduced C, N & P immobilization
    - increased N leaching
  - Reduced soil phosphorus
    - C & N immobilization ceases at the point of P limitation
      - Disturbance reduces P retention
      - Extent of P retention in soils is unknown

- High intensity disturbance can significantly impact
  - Ecosystem productivity
  - Water quality down gradient

- Pinelands plant communities are essential for nutrient retention & forest productivity


Thank You
Pinelands Research Series,
April 17, 2012
Pinelands Commission, Richard J. Sullivan Center
15 Springfield Road, New Lisbon, NJ