Pieter Bruegel’s, “Hunters in the Snow”
Disturbance interacts with environmental gradients to influence the biota.

- It kills organisms, initiates succession, both disturbance and succession drive patch dynamics and influence the overall behavior of the landscape.
- The challenge is to understand the consequences of change and manage the change to accomplish management objectives.
Topics

- Disturbance Defined
- Ways to quantify disturbance
- Effects on landscape pattern
- Feedbacks from landscape pattern to disturbance
- Disturbance and succession
- Concepts in landscape ecology useful for restoring modern landscapes
  - Principles derived from pre-European settlement fire dynamics
  - Changes in forest ecosystems during fire exclusion period
  - Restoring fire to modern landscapes
Defining and Quantifying Disturbance

Disturbance – any relatively discrete event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability or the physical environment. (Pickett and White)
Defining and Quantifying Disturbance

Frequency - number of occurrences of the disturbance in a specified area per unit time.

Size - area over which the event occurs

Intensity - amount of energy involved in the event (e.g., fire temperature, wind speed).

Severity - degree to which the event influences the biota (e.g., percent of canopy trees killed)

Duration - length in time of each occurrence

Timing - time of year or phenological stage at which the event occurs.

Return interval – Time between disturbances.

Rotation period – Mean time needed to disturb and area equivalent to a defined study area.

A "disturbance regime" is the mean and variance in the above for a specified area over a specified time.
Defining and Quantifying Disturbance

Covariation in the elements of a disturbance regime: Fire in the PNW
Quantification of clearcutting and wildfire disturbances
Depicting disturbance regimes in three dimensions
Defining and Quantifying Disturbance

Wildfire and Logging (1, 2) disturbance regimes expressed in three dimensions.
Disturbance and Landscape Pattern

How does disturbance influence landscape pattern?
Disturbance and Landscape Pattern

How does disturbance influence landscape pattern?

• May alter abiotic factors in disturbance patch

• May reset community to early seral stage

• Over time, creates a mosaic of abiotic patches and seral stages across the landscape
How does disturbance influence landscape pattern?

- May alter abiotic factors in disturbance patch
- May reset community to early seral stage
- Over time, creates a mosaic of abiotic patches and seral stages across the landscape.
- Hence “patch dynamics”.
Landscape Position and Disturbance

Does susceptibility to disturbance vary with landscape position?

Fire in Northern Rockies?

- Frequency
- Severity
- Patch size
Landscape Position and Disturbance

Does susceptibility to disturbance vary with landscape position?

Fire in Northern Rockies?

Frequency
Severity
Patch size
Does susceptibility to disturbance vary with landscape position?

Fire in Northern Rockies?

1910 Fires
3 M acres
Dry fuels
80+ mph winds
Landscape Position and Disturbance

Does susceptibility to disturbance vary with landscape position?

Fire in Northern Rockies?

1910 Fires
Near complete tree mortality
Does susceptibility to disturbance vary with landscape position?
Yes, but very intense disturbance can override the landscape.
Does susceptibility to disturbance vary with landscape position?

Hurricane damage in New England?
Does susceptibility to disturbance vary with landscape position?

Hurricanes globally?
Landscape Pattern and Spread of Disturbance

How does vegetation pattern across the landscape influence spread of disturbance?

Franklin and Forman 1987
Succession - the non-seasonal, directional and continuous pattern of colonization and extinctions on a site by species populations.

Primary succession - succession following disturbance that removes all biotic material from the site.
Disturbance and Succession

Yellowstone Conifer Forests

Immediately after fire

5-15 yrs post fire
Disturbance and Succession

Yellowstone Conifer Forests

60-100 yrs post fire

120+ yrs post fire
Secondary succession - succession following a disturbance that leaves well-developed soil, seeds, and/or organisms on the site.

Biological legacy - organisms, propagules, and organic materials that survive disturbance.
Review how concepts in landscape ecology can help us restore modern landscapes

Topics

- Principles derived from pre-European settlement fire dynamics
- Changes in forest ecosystems during fire exclusion period
- Restoring fire to modern landscapes
Principles derived from pre-European settlement fire dynamics

- Landscape heterogeneity.
- Shifting steady state mosaic.
- Natural range of variation.
- Minimum dynamic area.
Natural Fire Concepts

Landscape Heterogeneity: Fire Frequency and Forest Dynamics

Vegetation

Old Growth Conifer
Aspen

Intense Fire

Year
Percent of Landscape

1610 1640 1670 1700 1730 1760 1790 1820 1850 1880 1910 1940 1970 2000
Natural Fire Concepts

Landscape Heterogeneity
Natural fire regime maintains the variety of seral stages and landscape patterns required by native species.
Natural Fire Concepts

**Shifting Steady-State Mosaic**

A landscape where the characteristics of individual patches are out of phase but the collective behavior of patches displays equilibrium.
If disturbance reoccurs often enough to be an agent of selection, the biota adjusts to it. e.g. tidal cycles, day/night cycles. Change would happen if these events ceased.

Incorporated disturbance - events necessary to maintain a biotic entity in its present state.

What is disturbance at one level of a nested hierarchy may be incorporated disturbance at the level above.
Natural Fire Concepts

Natural Range of Variation

Vegetation

Old Growth Conifer

Aspen

Intense Fire

Natural Range of Variation (NRV)

Percent of Landscape

Year

Old Growth Conifer

Aspen

Intense Fire

Natural Fire Concepts
Minimum Dynamic Area

Minimum Dynamic Area – Smallest landscape where a collective behavior of individual patches displays equilibrium.
Minimum Dynamic Area

Nature reserve

Minimum Dynamic Area – Smallest landscape where a collective behavior of individual patches displays equilibrium.
Natural Fire Concepts

Fire Varies with Biophysical Setting

- Grassland: 10-15 years
- P. flexilis
- P. menziesii
- Study Area
- P. conora
- P. engelmannii
- A. lasiocarpa
- Pseudotsuga menziesii
- Pinus albicaulis
- Abies lasiocarpa
- timberline ecotone
- Alpine Tundra

Fire Frequency

- 10-15 years
- 20-30 years
- 200-250 years
Natural Fire Concepts

Fire Varies with Biophysical Setting

Historical Natural Fire Regime
- Fire Regime I, 0-35 year freq, low severity
- Fire Regime II, 0-35 year freq, stand replacement
- Fire Regime III, 35-100+ year freq, mixed severity
- Fire Regime IV, 35-100+ year freq, stand replacement
- Fire Regime V, 200+ year freq, stand replacement
Summary

- Many pre-European landscapes were in some equilibrium as maintained by natural disturbance.
- Principles derived from this "natural condition" have been used to guide modern management.

Littell 2001

Romme and Despain 1989
Fire Exclusion Era

Vegetation Change

Stand Type

- Conifer forests
- Very open conifer forests
- Scattered clumps of conifers
- Conifer/aspen forests
- Aspen/conifer forests
- Aspen forests
- Willow
- Non-forest
- Unknown cover type
Fire Exclusion Era

Vegetation Change: Conifer Expansion

1871

1981
Fire Exclusion Era

Vegetation Change: Conifer Expansion

Powell et al. in prep. Monitoring Forest Response to Past and Future Global Change in Greater Yellowstone
Fire Exclusion Era

Vegetation Change: Conifer Expansion:
Change from Reference Data

1971-1999: All Elevations

Mean = 3.68
Stderr = 0.49
N = 817
T value = 7.54
P < .0001
Vegetation Change: Conifer Expansion: Change from Reference Data

1971-99 by Elevation Class

Change in Percent Conifer (mean +/- stderr)

- Low
- Mid
- High

Fire Exclusion Era
Fire Exclusion Era

Vegetation Change: Conifer Expansion: Change from Reference Data

1971-1999 By Aspect

For low elevation class: SE=9.5%
Fire Exclusion Era

Vegetation Change: Conifer Expansion: Change from Satellite Data

1985-1999

- conifer increase
- conifer decrease

10 0 10 20 Kilometers
Fire has been largely excluded from lower elevation forests since the late 1800s.

Conifer has expanded over aspen, grassland, and sagebrush and later seral stages have replaced earlier seral stages.

Rates of change vary with biophysical setting and are especially fast at lower treeline.

Even with the large fires in 1988, conifer expansion has offset conifer decrease since 1985.
Mast, Veblen, and Hodgson (1997) - found that a mean of 35% of four study sites changed from grassland to Ponderosa Pine forest between 1937 and 1988 along the Colorado front range.

Covington and Moore (1994) - simulated changes in Ponderosa pine basal area at 8 northern Arizona sites and found a mean increase from 17 ft$^2$/ac in 1867 to 306 ft$^2$/ac in 2027.

Dando and Hansen (1990) - quantified a 35% increase in area of Douglas-fir and Rocky Mountain Juniper forest between 1954-1979 near Butte, Montana.
Population has increased 55% 1975-95

Rural homes increased 108% 1975-99

Gude et al. 2006
Consequences: Fundamental Rescaling of Disturbance and Landscape Dynamics?
Consequences: Natural Range of Variation?

Vegetation

Old Growth Conifer

Aspen

Intense Fire

Fire Exclusion Era

New Trajectory?

NRV

Consequences: Natural Range of Variation?

Vegetation

Old Growth Conifer

Aspen

Intense Fire

Fire Exclusion Era

New Trajectory?

NRV
Decline of fire-dependent communities and species.

Fire Exclusion Era
Consequences: Loss of Dynamic Steady State?
Fire Exclusion Era

Consequences: Loss of Dynamic Steady State, Especially in Biodiversity Hotspots?

Deviation from Natural Fire Regime (USFS).

Hot Spots for Bird, Tree, and Shrub Species Richness (Hansen et al. 2003).
Fire Exclusion Era

Consequences: Rescaling of Fire Regimes to Less Frequent but More Severe?
Fire Exclusion Era

Consequences: Increased Risk to Homes?

Legend
- National Park Service
- Other federal lands
- Greater Yellowstone
- USFS recent fires

Home density
- Low ← High
Fire Exclusion Era

Consequences: Increased Risk to Homes?
Fire Exclusion Era

Consequences: Loss of Minimum Dynamic Area?

GYE from Space: 1972

1988 Yellowstone Fires
Restoring Landscape Patterns

Traditional Logging does not Adequately Mimic Wildfire: More Innovative Silviculture is Needed

Wilmer 2000
Restoring Landscape Patterns

Crown Fire is Needed: Prescribed Surface fire is Not Enough

Beaverhead Deerlodge NF
Henderson 1998
Restoring Landscape Patterns

Restoration is Best Tailored to Biophysical Setting
Restoring Landscape Patterns

Landscape-Level “Zoning” is Needed

- Heavy-handed fuel control
- Prescribed fire
- “Let-Burn” policy
- Zoning against new subdivision
Guiding Principles

- Natural range of variation is not likely an option in many settings due to ecological rescaling and social acceptance.

- Active management is required to restore many ecosystems

- Manage at appropriate space and time scales to achieve ecological objectives.

- Use a combination natural fire, prescribed fire, silviculture, and land use planning.

- Integrate management across public and private lands.
Discussion

Text Fig 7.16