Monitoring Ecosystem Diversity for Sustainable Forest Management
Outline

- Context
- What are ecosystems and landscapes?
- Why monitor ecosystem diversity?
- What causes ecosystem diversity?
- Ecosystem diversity research
- Monitoring ecosystem diversity
Canadian Council of Forest Ministers

"Biological diversity" (biodiversity) refers to the variability among living organisms and the ecological complexes (ecosystems) of which they are a part.
3 Elements are useful, but arbitrary

- “… variability among living organisms and the ecological complexes (ecosystems) of which they are a part.”
- biodiversity is a concept rather than a measurable entity
- everything doesn’t correspond to one group of elements
- “ecological complexes” imply relationships
- relationships involve processes
  - ecological processes do not fit neatly into one of three “scales”
  - e.g. interaction between disturbance regime and the flow of genes among fire-disturbed patches in the landscape
Ecosystem diversity

- Easiest of 3 biodiversity elements to monitor
  - relatively small number of elements to measure and monitor (assuming we can properly identify them in the first place)
  - possible (in many cases) to measure or estimate historical ecosystem diversity for use as baseline or range of natural variability
  - foresters have been doing it since Time Began
  - Geographic Information Systems make it fun
Definitions

- **Ecosystem**
  - “a relatively homogeneous area of organisms interacting with their environment” (Forman 1995)

- **Landscape**
  - “a mosaic where a cluster of local ecosystems is repeated in similar form over a kilometers-wide area” (Forman 1995)
4 Indicators of Ecosystem Diversity:

1. Percentage and extent, in area, of forest types relative to historical condition and to total forest area
2. Percentage and extent of area by forest type and age class
3. Area, percentage and representativeness of forest types in protected areas
4. Level of fragmentation and connectedness of forest ecosystem components
Two key aspects of ecosystem diversity

1. Disturbance history of vegetation patches
   - Composition
     - e.g. disturbance history class X ELC class
   - Spatial aspects
     - of ELC X disturbance history class patches
     - size distribution, shape distribution
     - spatial arrangement (fragmentation, edge relationships)

2. Linear developments
   - Composition
     - e.g. road density by type
   - Spatial aspects
     - e.g. average distances to road
Why monitor ecosystem diversity?

- Because.
- CCFM says so.
- It’s important.
- Species respond to ecosystem diversity:
  - habitat supply
  - metapopulation dynamics
  - edge effects
  - fragmentation
Causes of ecosystem diversity

Landform diversity + Disturbance history = Ecosystem diversity
Ecosystem diversity research

Comparative studies in forested ecosystems

1. Same place, different times
   - Use historical estimates of disturbance history to generate maps for different times in the past
   - Use 2 or more distinct mapped vegetation data sets
     - Reed et al. 1995, Ripple et al. 1991

2. Different places, same time
   - Mladenoff et al. 1993

3. Linear developments
   - McLellan 1990, Sawyer 1998
Measurements

1. Disturbance history of vegetation patches
   - changes in age class distribution
   - patch size, shape, edge density
   - spatial arrangement of patches

2. Linear developments
   - km of roads / km of land
Research results

1. Same place, different times
   - demonstrate trends caused by natural and human-caused disturbance
     - patch density, patch size, patch perimeter, contrast, etc.

2. Different places, same time
   - demonstrate differences in ecosystem diversity among lands with different disturbance histories
     - amount of old forest, patch size distribution, interior habitat

3. Linear developments
   - demonstrate magnitude through time
Edge density, Oregon

Lookout Creek

Wallin et al. 1997
Fig. 2. Clearcuts/undisturbed matrix map set. The five maps depict the cumulative area, by decade, of clearcutting for the period 1950–1993.
Fig. 4. Landscape structure measurements for the vegetation/habitat structure map set: (a) number of patches, (b) mean patch size, (c) mean patch perimeter, (d) total perimeter, (e) mean patch shape, (f) fractal dimension.
Changes in area & patch size in FMF

### Total Area

- **1950**: Young forest: [chart value], Old forest: [chart value]
- **1995**: Young forest: [chart value], Old forest: [chart value]

### Mean Patch Size

- **1950**: Young forest: [chart value], Old forest: [chart value]
- **1995**: Young forest: [chart value], Old forest: [chart value]
Fig. 1. Maps of 2 wheel drive access road development in the Kootenay Region of British Columbia between 1952 and 1986. Dead-end roads entering cutting units are not included.

Figure E: From McLellan (1990)
Linear developments, SW Alberta

Sawyer et al. 1998
Monitoring ecosystem diversity

1. Data requirements
2. Synthesis & analysis
3. Reporting
1. Data requirements

- Mapped disturbance patches (GIS)
  - harvested, by type (clearcut, partial cut…)
  - “natural”, by type (fire, insects, disease, wind…)
  - only mappable patches need apply

- Mapped ecological land classification
  - including computer-assisted
    - e.g. ELDAR
  - existing coarse ELC’s are available

- Mapped linear developments
  - roads, seismic lines, trails (by type)
  - traditional land records or remote sensing
Landsat TM
Port Renfrew, BC

1984

1991
Landsat TM
Port Renfrew, BC
2. Synthesis and analysis

- Intersection of disturbance patches and ELC
  - age class distribution by ELC class
    - proportion of each age class by ELC class
  - patch size distribution by ELC class
  - other measures by ELC class

- Landscape pattern metrics
  - many indices, choose some easy ones
  - Fragstats and other GIS add-ons

- Linear developments
  - intersected with land cover strata
Patch size in FMF

Lower Foothills

Upper Foothills

Subalpine

Area (%)

Patch size (ha)

(20-yr classes)
3. Reporting

- Link to existing programs where appropriate
  - National Forest Inventory (CFS)
  - Earth Observation for Sustainable Development

- Easy access to monitoring data improves effectiveness for managers
  - Internet is an excellent tool

- Distinction between natural and human-caused disturbance is critical to report
Figure 1: Road density in forested ecozones.

Total forest area in Canada, Pacific Maritime, Montane Cordillera, Boreal Shield, Atlantic Maritime, and Atlantic Maritime, showing the percentage of productive forest area and the percentage of forest area in timber-productive forest.

Figure 5: Age-class distribution of timber-productive forest.

Figure 10: Protected forest area in the four main forested ecozones.

Pacific Maritime:
- % of forest area protected:
  - Strictly protected
  - Other protected

Montane Cordillera:
- % of forest area protected:
  - Strictly protected
  - Other protected

Boreal Shield:
- % of forest area protected:
  - Strictly protected
  - Other protected

Atlantic Maritime:
- % of forest area protected:
  - Strictly protected
  - Other protected

*Strictly protected areas are equivalent to IUCN categories 1-3, and exclude industrial activities such as forestry, mining, and agriculture. Other protected areas are equivalent to IUCN categories 4-6.*
National Forest Inventory

- A network of sampling points across the country
- Estimation of some attributes from remote sensing sources
- Estimation of species diversity, wood volumes and other detailed data from ground-based sub-sample
- Estimation of change from repeated measurements