Formulating an Expanding-Gap Regeneration System for *Quercus* Dominated Stands

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Presentation Outline

• What is an irregular shelterwood system?

• Rational for applying an irregular shelterwood system in Quercus stands

• “Proof of concept” study and future exploration
Historical Context
The Irregular Shelterwood System: Review, Classification, and Potential Application to Forests Affected by Partial Disturbances

Patricia Raymond, Steve Bédard, Vincent Roy, Catherine Larouche, and Stéphane Tremblay

ABSTRACT

The irregular shelterwood system is an integral part of forest management in northeastern North America. The maintenance or restoration of irregular shelterwood stands can be achieved, especially in areas under ecosystem-based management. The objectives of this system are to assemble existing knowledge about the system, clarify the terminology in use, and discuss its place in silviculture in northeastern North America. Irregular shelterwood is compared with other regeneration methods and we propose a classification based on three variants. This silvicultural system is compatible with ecosystem-based management in forest types driven by partial stand mortality and gap dynamics and provides opportunities for maintaining oldgrowth forest attributes. However, it presents important challenges, especially with regard to planning, growth and yield predictions, and operational application.

Keywords: ecosystem-based management, irregular uneven-aged silviculture, multiple stand, irregular shelterwood systems, regeneration methods

In many North America jurisdictions, the management of public forests has gradually shifted from timber production to ecosystems-based management, with a focus on late-successional habitat (Rohm and Franklin 1997). In a managed ecosystem, applying principles of ecosystem-based management is a way of achieving sustainable forest management objectives (Galindo-Leal and Rasmussen 1995). This implies that silvicultural practices must emulate ecological processes and interactions of composition, structure, and ecosystem function to be maintained within their limits of natural variability (Kaufmann et al. 1994, Szymon et al. 2002, Gauthier et al. 2008) at multiple spatial and temporal scales (Galindo-Leal and Rasmussen 1995). At the stand scale, the growing interest in ecosystem-based management brings into question current silvicultural practices and how they can contribute to maintaining ecological values (Guldin 1996, Puettmann and Ammer 2007).

This article focuses on the silviculture of irregular stands. In American forestry textbooks, uneven-aged stands are clearly distinguished from even-aged stands (Smith et al. 1997, Nyland 2002). Even-aged stands are composed of trees in the same age class, with the oldest and youngest trees differing...
Irregular Shelterwood System Defined

Three general classifications:
• Expanding-gap irregular shelterwood
• Continuous cover irregular shelterwood
• Extended irregular shelterwood

Expanding-gap irregular shelterwood -

“Aims to regenerate new cohorts in groups that are gradually enlarged until the stand is totally removed”

Continuous cover irregular shelterwood –

“Sequence of cuttings is applied more freely in space and time, which permits maintenance of a multicohort structure and a continuous forest cover”

Irregular Shelterwood System Defined

Extended Irregular Shelterwood –
“Aims to regenerate the whole stand while ... two cohorts are maintained for at least 20% of the rotation length”

## Expanding-gap irregular shelterwood

<table>
<thead>
<tr>
<th>Variant</th>
<th>Expanding-gap irregular shelterwood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other names</td>
<td>Bayerischer Femelschlag</td>
</tr>
<tr>
<td></td>
<td>Acadian Femelschlag</td>
</tr>
<tr>
<td></td>
<td>Irregular group shelterwood</td>
</tr>
<tr>
<td></td>
<td>Bavarian shelterwood</td>
</tr>
<tr>
<td></td>
<td>Coupe progressive irrégulières par trouées agrandies</td>
</tr>
<tr>
<td>Period of regeneration</td>
<td>&gt;20% rotation length</td>
</tr>
<tr>
<td>Harvesting pattern</td>
<td>Group gradually expanded</td>
</tr>
<tr>
<td>Final removal</td>
<td>Optional</td>
</tr>
<tr>
<td>Arrangement of cohorts</td>
<td>Juxtaposed cohorts</td>
</tr>
<tr>
<td></td>
<td>New cohort established besides the previous one</td>
</tr>
<tr>
<td>Vertical structure</td>
<td>Regular at small scale</td>
</tr>
<tr>
<td></td>
<td>Single layer</td>
</tr>
<tr>
<td>Horizontal structure</td>
<td>Irregular</td>
</tr>
<tr>
<td></td>
<td>Mosaic of cohorts</td>
</tr>
</tbody>
</table>
Irregular Shelterwoods and *Quercus* Forests

- *Femelschlag* systems are used throughout Europe

- While interest is gaining, no examples of expanding-gap irregular shelterwoods exist in North American oak forests

- Potential benefits of expanding-gap systems include:
  1. Structural complexity and continuous forest cover
  2. Multiple income flows over rotation
  3. Regeneration of diverse species groups, from shade intolerants in gap centers to intermediates and shade tolerants along gap edges
Our long-term goal is to develop an expanding-gap based silvicultural practices that address the oak regeneration problem present within the Central Hardwood Forest Region (CHFR)
Research Needed for System Development

Source: Troup 1928
Research Needed for System Development

Developing a expanding-gap regeneration system requires understanding of how the following factors influence spatial variation in resource gradients and regeneration dynamics:

• Gap size
• Edge effects
• Canopy structure in the forest matrix
Developing a expanding-gap regeneration system requires understanding of how the following factors influence spatial variation in resource gradients and regeneration dynamics:

- Gap size
- Edge effects
- Canopy structure in the forest matrix

This presentation integrates results from complementary research studies that together support the basis for applying expanding-gap regeneration systems in oak dominated stands.
**Gap Size**

Lhotka (In Press) tested the effect of three gap sizes on oak recruitment 48 years following treatment.

**Edge Effects**

Lhotka and Stringer (In Review) characterized the relationship between distance from anthropogenically created edge and the height and density of oak reproduction.

**Midstory Removal**

Parrott et al. (In Press) evaluated the effect of midstory removal on understory light availability and oak seedling survival and growth after 7 growing seasons.
Robinson Forest Gap Size Study

- Established 1960
- Three gap sizes: 50, 150, 250 ft
- 27 experimental plots
Robinson Forest Gap Size Study

USDA Forest Service: 1991

Lhotka: 2008
*Thanks to Matt Strong

Plot 10: 150 ft Opening
Age 23 (1983)

Plot 10: 150 ft Opening
Age 48 (2008)
### Stand Structure after 48 Years

<table>
<thead>
<tr>
<th>Opening Size</th>
<th>BA (m² ha⁻¹)</th>
<th>Trees (ha⁻¹)</th>
<th>QMD (cm)</th>
<th>Top Height (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>12.2ᵃ*</td>
<td>1008.2ᵃ</td>
<td>12.2ᵃ</td>
<td>19.8ᵃ</td>
</tr>
<tr>
<td>150</td>
<td>21.1ᵇ</td>
<td>953.7ᵃ</td>
<td>17.0ᵇ</td>
<td>26.6ᵇ</td>
</tr>
<tr>
<td>250</td>
<td>21.6ᵇ</td>
<td>719.1ᵃ</td>
<td>19.7ᶜ</td>
<td>28.6ᵇ</td>
</tr>
</tbody>
</table>

*Means with similar letters are not statistically different (α = 0.05)*
## Robinson Forest Gap Size Study - Results

### Overstory Trees ha\(^{-1}\) by Treatment following 48 Years

<table>
<thead>
<tr>
<th>Species Group</th>
<th>Opening Size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50 ft</td>
</tr>
<tr>
<td>Oak</td>
<td>27.4(^a)*</td>
</tr>
<tr>
<td>Maple</td>
<td>82.2(^a)</td>
</tr>
<tr>
<td>Yellow-poplar</td>
<td>0(^a)</td>
</tr>
<tr>
<td>Hickory</td>
<td>12.1(^a)</td>
</tr>
<tr>
<td>Other Commercial</td>
<td>6.1(^a)</td>
</tr>
<tr>
<td>Other</td>
<td>9.1(^a)</td>
</tr>
</tbody>
</table>

*Means within a species group that have similar letters are not statistically different (\(\alpha = 0.05\))
<table>
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<th>Species Group</th>
<th>Opening Size</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50 ft</td>
<td>150 ft</td>
<td>250 ft</td>
</tr>
<tr>
<td>Oak</td>
<td>27.4a*</td>
<td>89.3b</td>
<td>49.5b</td>
</tr>
<tr>
<td>Maple</td>
<td>82.2a</td>
<td>51.4a</td>
<td>52.4a</td>
</tr>
<tr>
<td>Yellow-poplar</td>
<td>0a</td>
<td>39.3b</td>
<td>50.4b</td>
</tr>
<tr>
<td>Hickory</td>
<td>12.1a</td>
<td>4.7a</td>
<td>2.9a</td>
</tr>
<tr>
<td>Other Commercial</td>
<td>6.1a</td>
<td>2.7a</td>
<td>4.9a</td>
</tr>
<tr>
<td>Other</td>
<td>9.1a</td>
<td>5.4a</td>
<td>3.4a</td>
</tr>
</tbody>
</table>

*Means within a species group that have similar letters are not statistically different (α = 0.05)
Size of opening influenced structure and composition and apparent trends suggest:

- 50 ft opening favored maple
- Dominant and codominant oak density was “maximized” in 150 ft opening
- Yellow-poplar increased with larger opening sizes
Gap Size Study: Role of Light in Species Trends

Berea Forest Edge Effects Study

• Initiated by Lhotka and Stringer in 2011

• Goal was to further understanding of how forest edge influences the development of advance reproduction along the gradient extending from a regeneration opening into adjacent, intact forest areas

• 48 m transects surround to 9-year-old clearcuts on Berea College Forest
Berea Forest Edge Effects Study – Seedling Heights

![Graph showing seedling heights near clearcut edges. The x-axis represents distance from the clearcut edge in meters, and the y-axis represents oak reproduction height in centimeters. The data points show a decrease in height as the distance from the clearcut edge increases.]
Berea Forest Edge Effects Study – Seedling Density

The graph shows the relationship between oak reproduction density (stems ha\(^{-2}\)) and distance from the edge (m). As the distance from the edge increases, the oak reproduction density decreases significantly. The data points with error bars represent the variability in the reproduction density at different distances from the edge.
Edge Environment: Seedling Radial Growth

Distance from Edge Interval
- 8 to 0 m
- 0 to 10 m
- 11 to 20 m
- 21 to 30 m
- 31 to 40 m

Mean Ring Increment (mm)

Year

Lhotka and Stringer (2013)
Data indicate that environments associated with forest edges can increase the size and density of oak reproduction and that the edge influence may extend up to 20 m.
Berea Midstory Removal Study

- Initiated by Dillaway and Stinger (2004)
- 4 sites, Berea College Forest
- Midstory removal treatment (20% basal area reduction)
- Natural advance reproduction and underplanted seedlings
- Monitored 7 years
- Understory microclimate characterized
Berea Midstory Removal Study - Results

- Midstory removal increased understory light availability
  - Removal 10.3% full sunlight
  - Control 1.5% full sunlight
Seven-year natural and underplanted seedling responses to midstory removal (Parrott et al. In Press)

<table>
<thead>
<tr>
<th></th>
<th>Natural Reproduction</th>
<th>Underplanted</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Black Oak</td>
<td>White Oak</td>
</tr>
<tr>
<td><strong>Survival (%)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>---</td>
<td>70.4*</td>
</tr>
<tr>
<td>Midstory Treatment</td>
<td>---</td>
<td>85.9*</td>
</tr>
<tr>
<td><strong>Mean height (cm)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>52.3</td>
<td>28.9*</td>
</tr>
<tr>
<td>Midstory removal</td>
<td>77.1</td>
<td>45.3*</td>
</tr>
<tr>
<td><strong>Mean GLD (mm)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>8.5</td>
<td>4.7*</td>
</tr>
<tr>
<td>Midstory removal</td>
<td>13.0</td>
<td>7.8*</td>
</tr>
</tbody>
</table>
Developing a expanding-gap regeneration system

Understanding factors that influence spatial variation in resource gradients and regeneration dynamics:

• Gap size
• Edge effects
• Canopy structure in the forest matrix
An Expanding-Gap Approach for Oak

What about gap size?
An Expanding-Gap Approach for Oak

What about gap size?

Research indicates that silvicultural gaps 1.5 to 2.5 times the dominant tree height can:

1. Improve oak recruitment within gaps
2. Create edge environments that may increase density and height of oak reproduction in the adjacent forest matrix
What about edge effects and forest structure in matrix?

Environmental effects of forest edges on oak may extend up to 20 m from opening.
What about edge effects and forest structure in matrix?

Altering vertical profile of matrix through midstory removal may further the extent of the edge influence.

Estimated to be 30 m
What about edge effects and forest structure in matrix?

Removal of midstory canopies around silvicultural gaps may:

1. Improve oak survival and growth in areas to be released during subsequent gap expansions
2. Extend the enhancement effect of the edge environment on oak reproduction further in the forest matrix
An expanding-gap irregular shelterwood that uses intermediate gap sizes and midstory removal as a preparatory treatment around gaps may represent a novel silvicultural practice for increasing oak regeneration potential within the CHFR.
Expanding-Gap Irregular Shelterwood for Oak

Initial Gaps: 1.5 to 2.5 tree heights
Expanding-Gap Irregular Shelterwood for Oak

Midstory removal as preparatory cut around gaps
Expanding-Gap Irregular Shelterwood for Oak

Subsequent gap expansion into midstory removal areas based upon oak reproduction development
Midstory removal following gap expansions
• Expanding-gap Study
  – Lhotka, Stringer, Patterson
  – 12 replicated gaps
  – Two treatments

• Research foci:
  – Establishment and growth dynamics
  – Light transmittance modeling
Future Extensions