

Managing for Complexity

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Themes in Talk

- ◆ Historical focus of silviculture is changing
 - societal view of the role and importance of forests
 - biodiversity and disappearance of primary forest
 - increased understanding of ecosystem functions and processes
- ◆ Silviculture needs
 - a new conceptual approach on which to base our scientific understanding of forest ecosystems
 - to develop a new management framework
- ◆ Complex systems science and viewing forests as complex adaptive systems can provide silviculture a new conceptual framework
- ◆ Managing for complexity involves thinking carefully about types of interactive processes that occur within forests and how they enable forests to resist stress and self-organize with minimal intervention after disturbance

Acknowledgements and self-promotion



Christian

Klaus

Dave



Sybille Haeussler, UNBC,
helped with many ideas

CRITIQUE *of* SILVICULTURE

Managing for Complexity



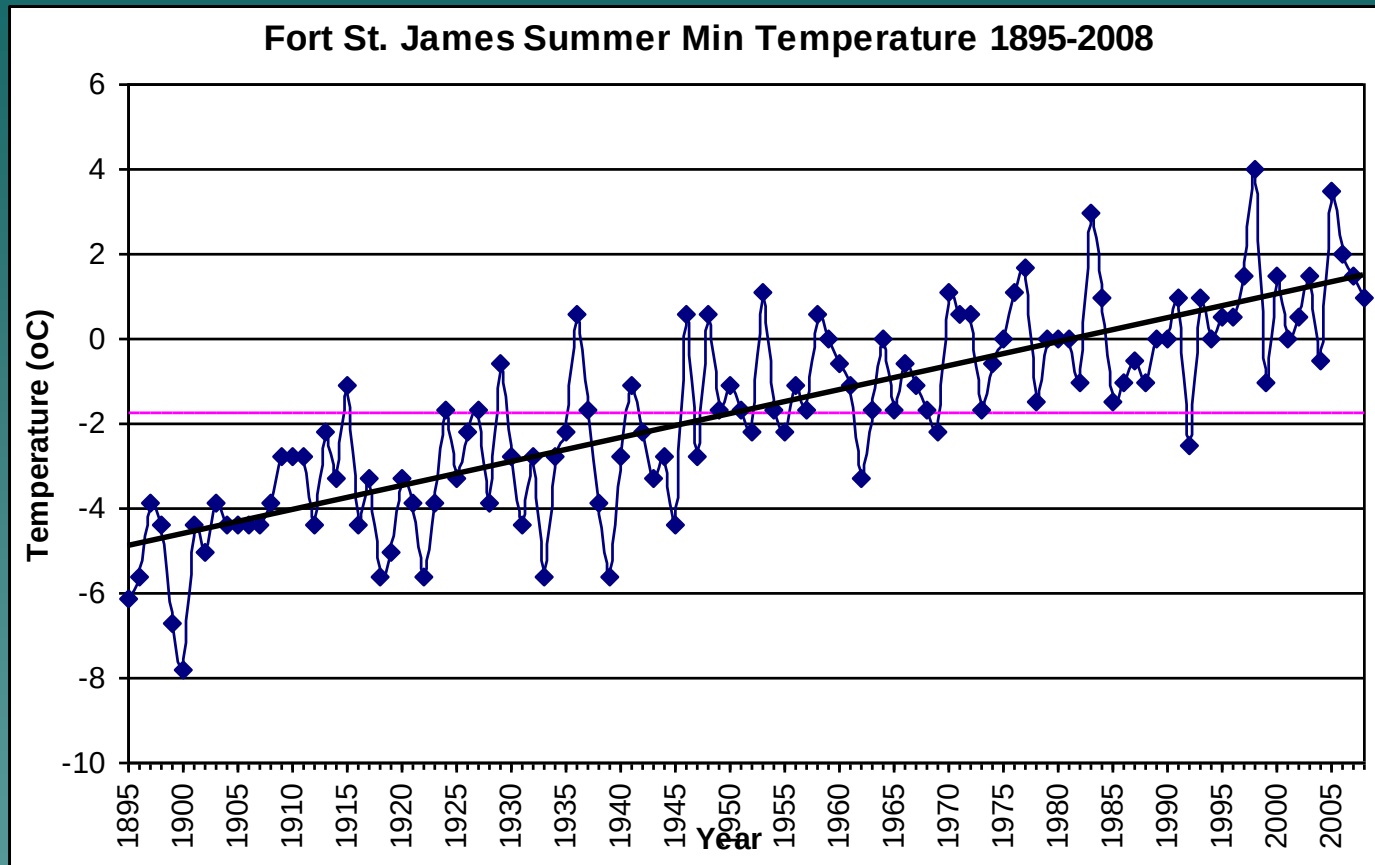
*Klaus J. Puettmann,
K. David Coates, and Christian Messier*

Island Press 2009

New Realities for Silviculture

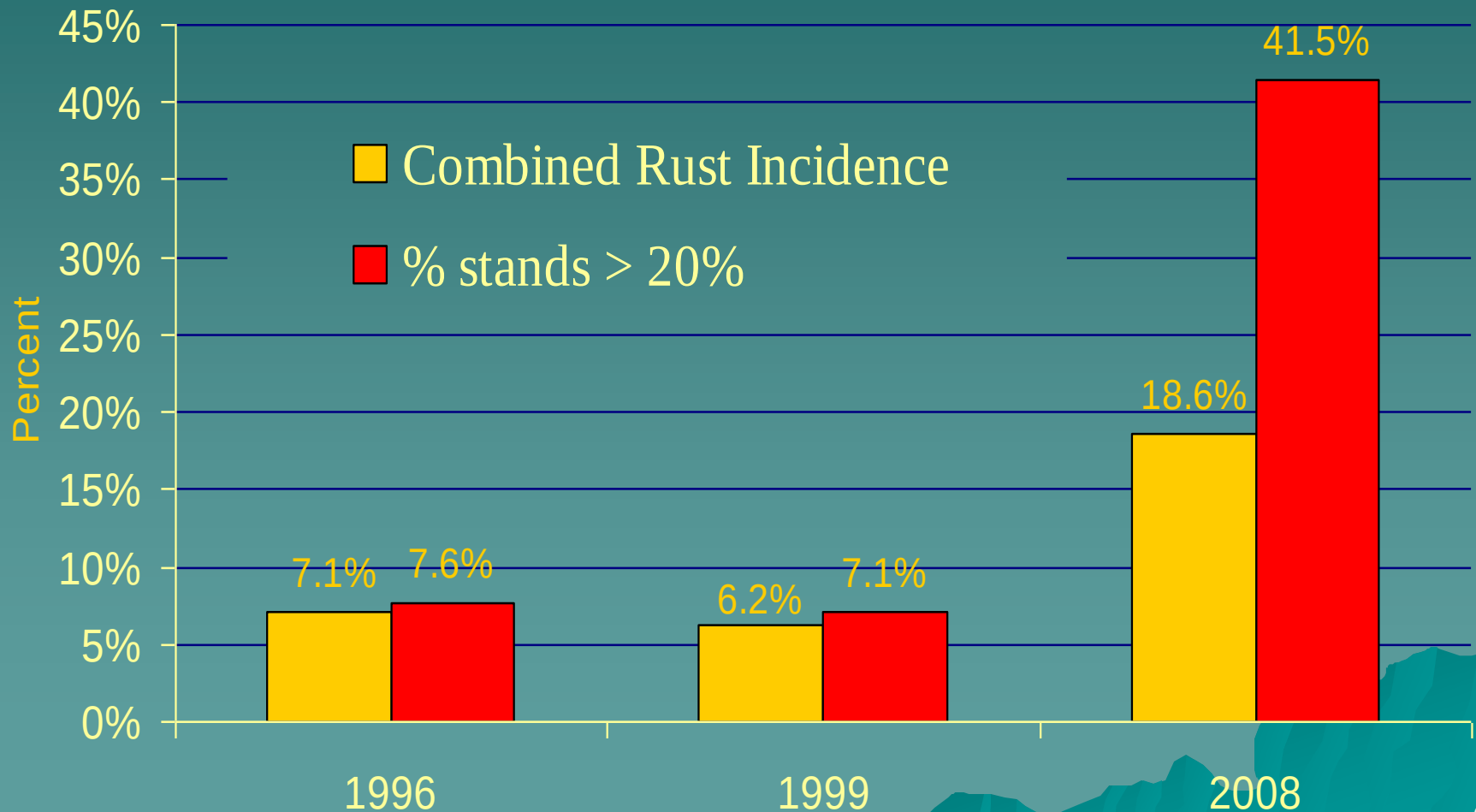
- ◆ An era of new climates
- ◆ Changing abiotic conditions
- ◆ Invasive species
- ◆ Unexpected disturbances
- ◆ Economic and social change
- ◆ Generation of novel ecosystems

New Reality



Climate variability - change in average, variation, and/or extreme values

Morice TSA, combined mean rust incidence by stand
and percent of stands with >20% incidence in
1996 (n=66), 1999 (n=98) and 2008 (n=82)



Thanks to Alex Woods

New Reality

- ◆ **Ability to manage will be enhanced/constrained by:**
 - **Changing Economic/Social Conditions**

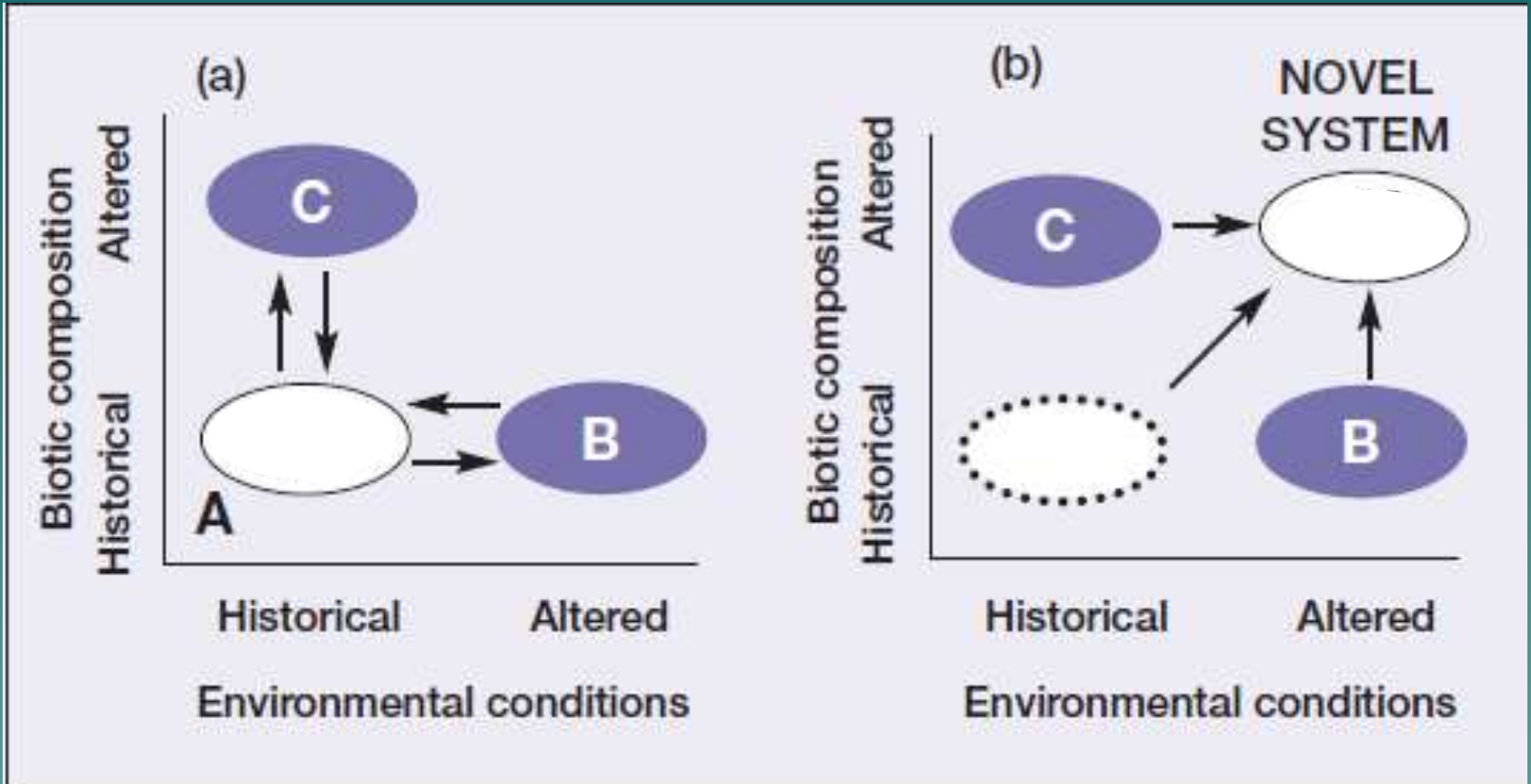
Minister Bell's
carbon credit
silviculture

Western
Forest
Products
Stock
Quote



2008

New Reality



Seastedt et al. 2008, *Frontiers in Ecology*, 547-553

Novel ecosystems will be increasingly common

Silviculture

- ◆ Silviculture is the management and study of forests to produce desired attributes and products. Silviculture has strong traditions that have been developed, articulated, and refined over several centuries – this can be a strength and a limitation
- ◆ Silvicultural practices, regardless of management objective, aim to control the establishment, composition, structure, growth and **role** of trees within managed forests

Foundations of Silviculture

- ◆ Developed from long-term observation, experience, local trials and research
- ◆ Strong influenced by European silviculture developed in 18th century
- ◆ Silvicultural systems are the defining characteristic of the discipline

Core Principles of Silvicultural Practice

- ◆ **Dominant focus on trees**
 - often to the exclusion of other plants, animals, and ecosystem processes
- ◆ **Stands as uniform entities**
 - tree-based stand descriptors averaged over whole area
- ◆ **Agricultural approach to research**
 - searching for best treatments
 - emphasis on uniform tree species composition and structure
- ◆ **Scale independent view of practices**
 - linear scaling, variability averaged
- ◆ **Focus on predictability**
 - orderly and predictable forest development
 - growth and yield models that predict one species
 - idealized conditions

New Silvicultural Challenges

- ◆ Manage forests to provide a variety of desired ecosystem goods and services at an acceptable cost
- ◆ Ensure ability of managed forests to adapt to diverse and unexpected future conditions
- ◆ Prescribe and promote novel ecosystems
- ◆ **Increase ecosystem resilience and adaptability, and promote desirable outcomes**

What is a forest?



Resilience/Adaptability



Dothistroma damaged lodgepole pine plantation

Resilience/Adaptability



MPB damaged lodgepole pine stand

Silviculture for Resilient and Adaptable Forests

- ◆ Manage forests as complex systems
 - requires major shift in philosophical and research approaches
 - new management tools
 - new conceptual framework to organize thinking

A Complex System

- Has many parts (components)
- The parts **interact**
- Interaction among the parts causes the behaviour of the whole to be more than the sum of its parts.

Traditional Science: reductionist, disciplinary, linear

Complex Systems Science: holistic, interdisciplinary
(both are quantitative & evidence-based)

Convergence of Soft & Hard Science

Soft Science

Holistic

Descriptive

Fuzzy

Conceptual

Models

Hard Science

Reductionist

Quantitative

Precise

Predictive

Models

“Clementsian” paradigm

Classification

“Gleasonian” paradigm

Prediction, Theory-

building

Complex Systems Theory allows these two views to be reconciled

What is Complexity?

Scientific definitions:

- ◆ Phenomena that arise due to interactions among the parts of a complex system (emergence and self-organization)
- ◆ The hidden order that lies between order and randomness
- ◆ The amount of information needed to fully describe or recreate the system

Science of Complexity

- ◆ **Varied history in multiple disciplines**
- ◆ **Set of theoretical frameworks that apply to systems in natural and social sciences**
- ◆ **Forest ecosystems are the poster child of complexity because:**
 - they are composed of many parts (trees, insects, soil) and processes (nutrient cycling, seed dispersion, tree mortality)
 - the parts and process interact with each other and the environment over multiple spatial and temporal scales
 - these interactions can give rise to heterogeneous structures and nonlinear relationships
 - these relationships represent a combination of randomness and order
 - they contain negative and positive feedbacks
 - the system is open to outside world
 - they are sensitive to initial conditions

The MOST important idea from Complex Systems Science:

Much of the order/pattern we see in the world comes, not from top down control, but from local-level (bottom-up) interactions among system components.

(self-organization)

Examples: 'hearts & minds' ant colonies, global recession, viral marketing, civil society



Complex Adaptive Systems

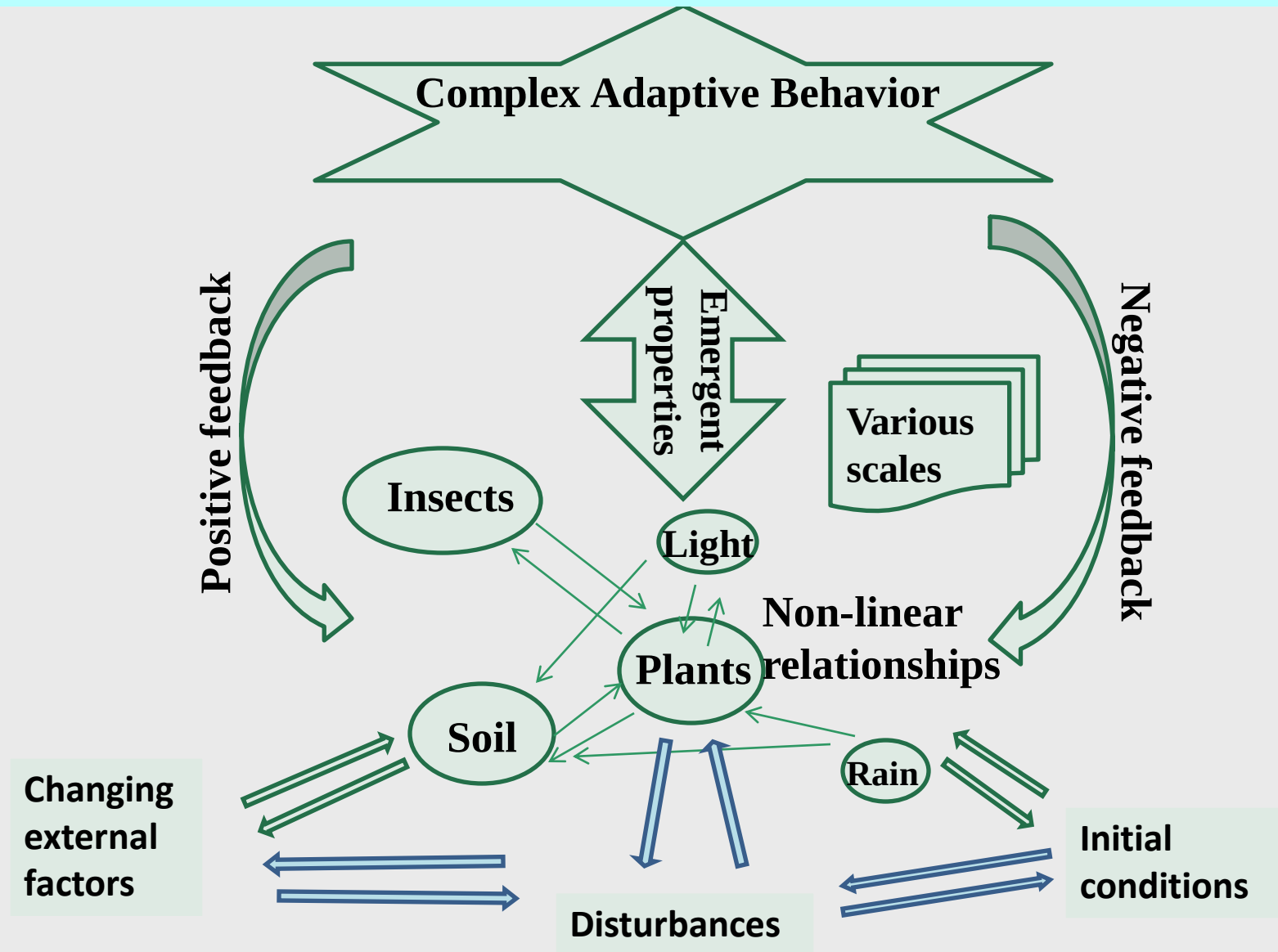
"Complex systems in which the individual components are constantly reacting to one another, thus continually modifying the system and allowing it to adapt to altered conditions"

Levin 1998

Forests as Complex Adaptive Systems

- ◆ Uncertain future conditions
 - Implies allowing forest development to follow a variety of possible paths
- ◆ Ill-defined boundaries
 - Outside influences inherent characteristic of forest ecosystem dynamics
- ◆ Never at equilibrium
 - Adopt view that ecosystem structures and process are continually changing and this change is important
- ◆ Self-regulated
 - Occurs through positive and negative feedback loops
 - Requires new multi-scale research approaches
- ◆ Develop unexpected properties
 - Important factor in ecosystem resilience – ‘creativity’
- ◆ Affected by initial conditions or previous states
 - Remember previous states, e.g. coppice systems, present day structural retention

Complexity: Concept and theory



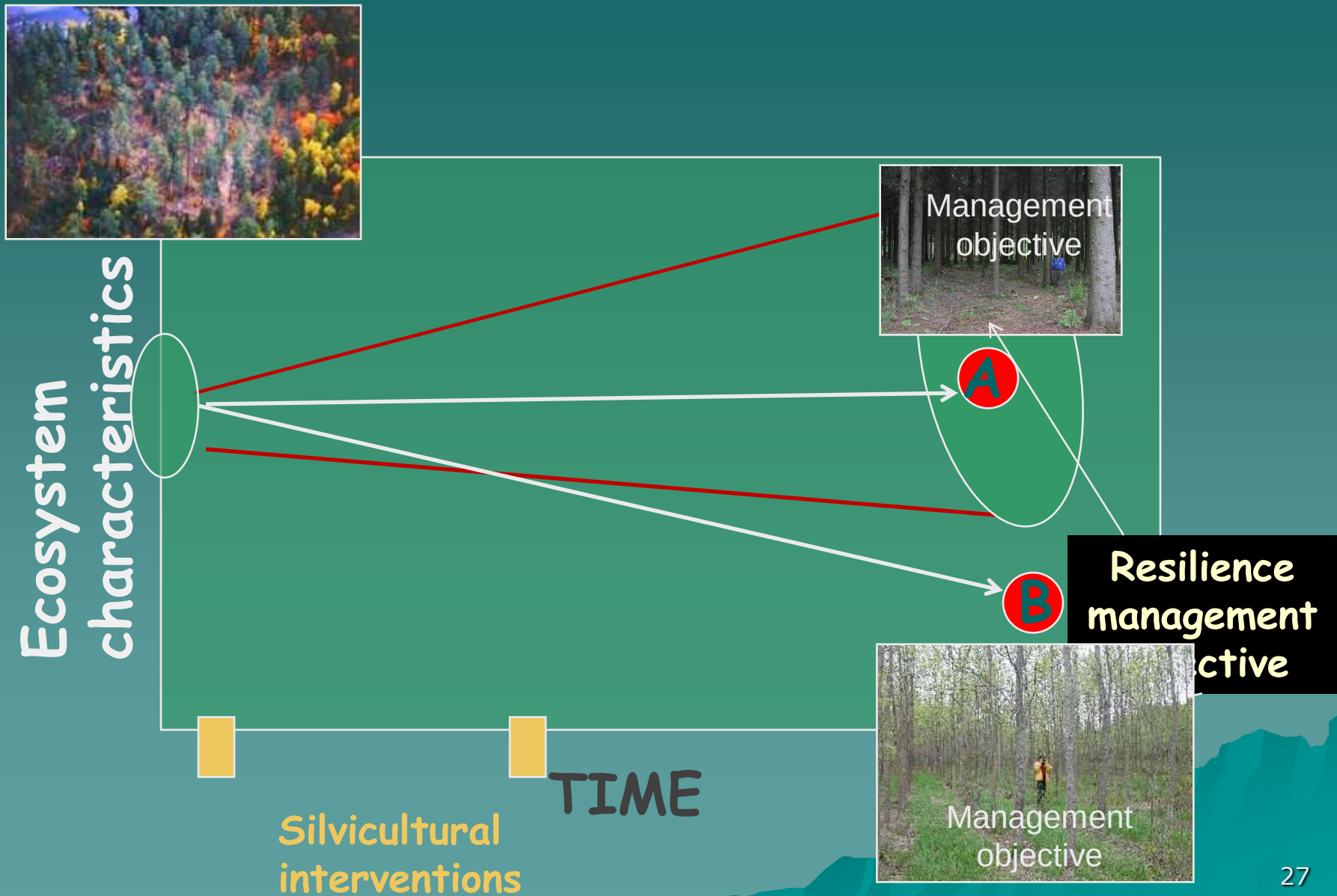
Strength and Weaknesses of “Old” Silviculture

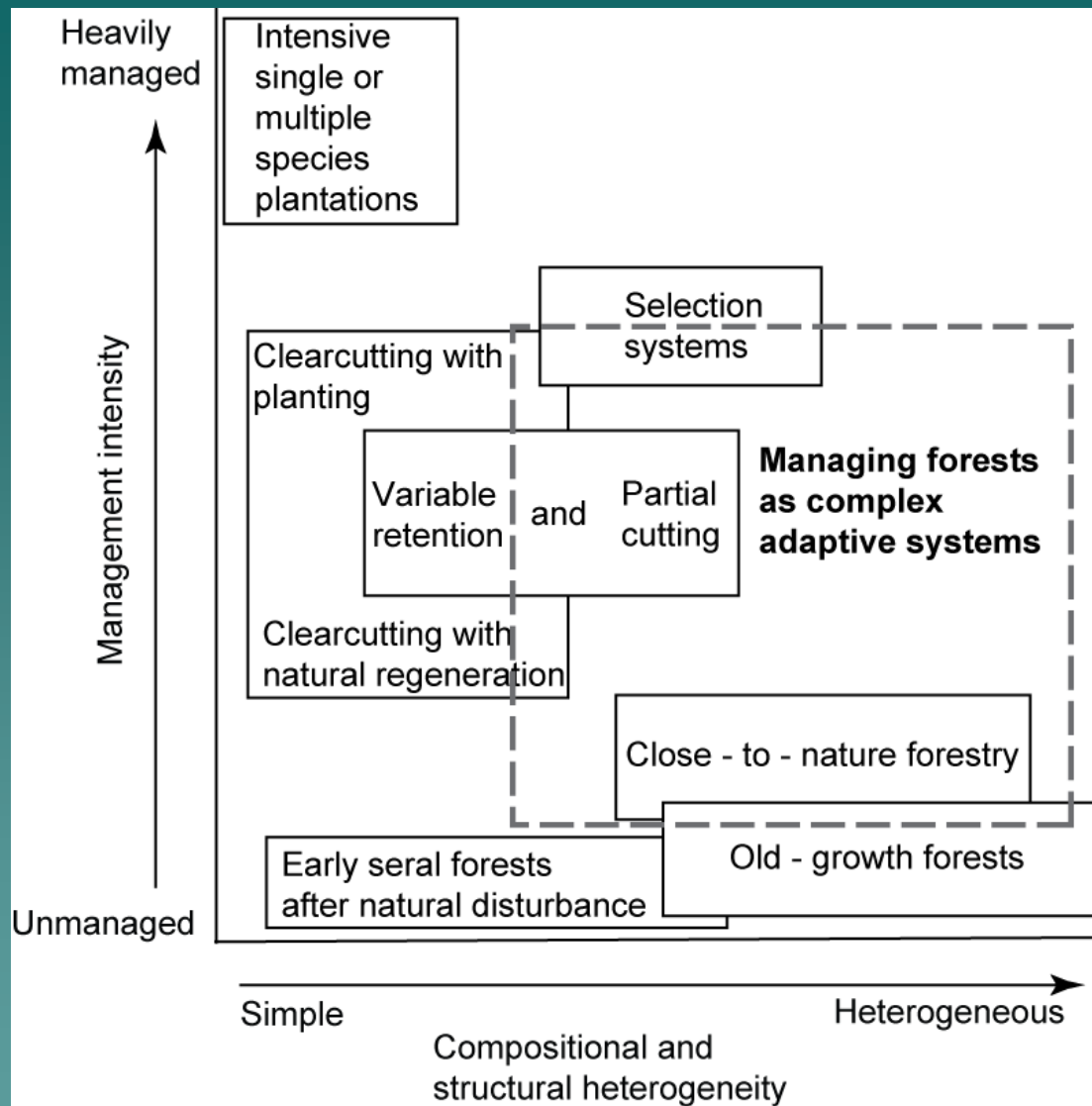
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Management Criteria

- ◆ **Traditional Silviculture**
 - emphasis on control to achieve optimal productivity
 - presumption of predictability
 - assessed at stand scale
 - based on mean response
- ◆ **Silviculture: Managing for Complexity**
 - emphasis on resilience and adaptability
 - promote flexibility and variability
 - assessed at systems scale
- ◆ Focus shifts from predictability & control to exploring alternatives and adapting to uncertainty

“Complexity” management approach





Managing for Complexity



More than a heterogeneous stands
More than an uneven-aged silviculture
More than diversity

Differences between:

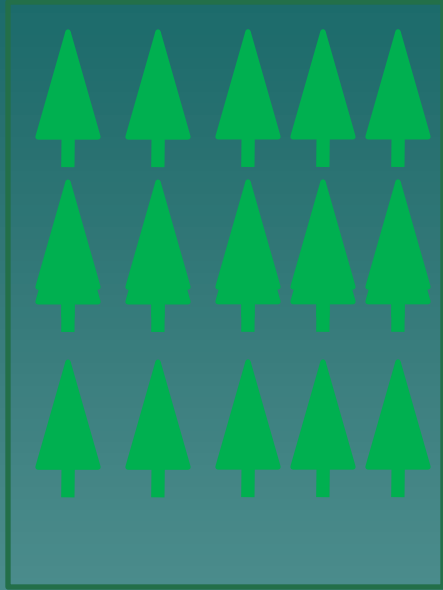
- ◆ Complexity
- ◆ Diversity
- ◆ Resilience

Just because System A is more diverse than System B doesn't necessarily mean System A is more complex (it's all about the interactions & the feedbacks)

Complexity doesn't necessarily give rise to resilience (e.g., positive feedbacks can be destabilizing; critical dependencies can make a system vulnerable)

Diversity often (but not always) gives rise to stability or resilience

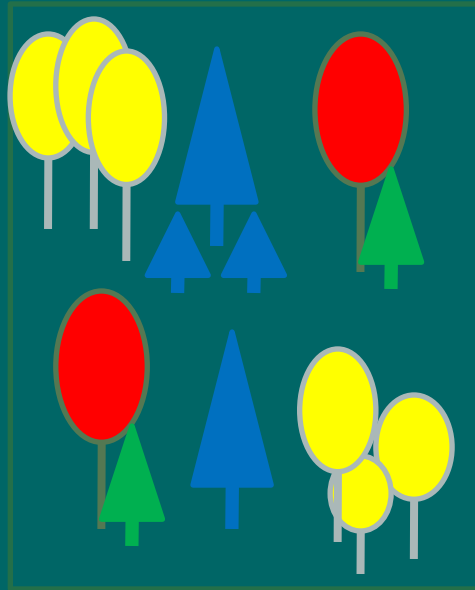
Order



Pine plantation

Diverse?
Complex?
Resilient?

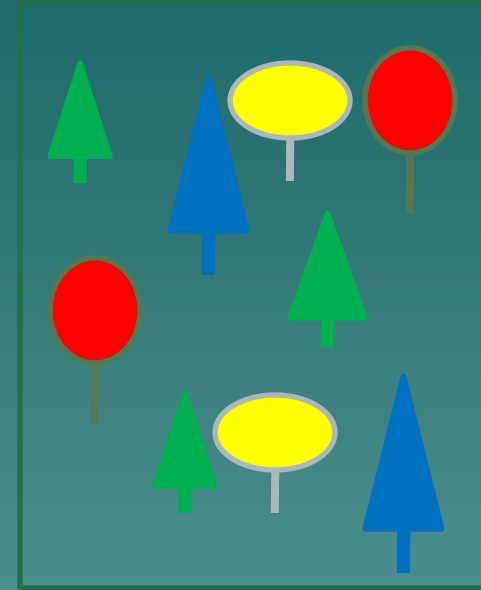
Managing for Complexity



Mixed species plantation

Diverse?
Complex?
Resilient?

Random



Mixed species plantation

Diverse?
Complex?
Resilient?

“Complexity” management approach

- ◆ **Focus on bottom-up approach with elements having direct and indirect influence on system scale**
- ◆ **Focus on interactions of subsystems and components**
- ◆ **Focus on whole system, rather than components**

“Complexity” management approach

- ◆ **Assumption of predictability is replaced by assumption of incomplete knowledge**
- ◆ **Decision criteria: flexibility**
- ◆ **Higher importance of potential future conditions in decision process**
- ◆ **Ensure continued ability of ecosystem to adapt to new conditions**

Current Species Selection and Stocking Standards

◆ Species choice

- strong management focus on one or two species

◆ Density/stocking

- based on stand averages
- uniform within and among stands; desire for sample plots to be similar



Pine Plantation - Burns Lake, BC

“Complexity” management approach

