Using vulnerability profiles to quantify forest health: proof of concept

John J. Battles
University of California, Berkeley
May 15, 2014

Hyink et al. 2007
outline

1) theory: density-dependence and forest health
2) evidence: density-dependence and forest health
3) link tree vitality to forest health
4) application
Reinke Reference Curve (1933)

\[ N_{den} = kD_{QM}^{-1.605} \]

Stand mortality rate (1998)

\[ u_k = aD_k^{-2/3} \]

Reinke (1933) J. Agricultural Research 46: 627-638
Self-thinning rule

\[ \log N = -\frac{3}{2} \log M + k \]

- Infertile site or different species: Magnitude changes BUT same functional relationship

**Theory**

- \( \log_{10} \text{Number of survivors} \)
- \( \log_{10} \text{mean Mass per plant} \)
- \( \log_{2} \text{TIME} \)
PERFECTING A STAND-DENSITY INDEX FOR EVEN-AGED FORESTS

By L. H. Reineke

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INTRODUCTION

An adequate expression for density of stocking in even-aged forests has long been sought by foresters. Comparison of total basal area of the stand with yield-table values of basal area for the same age and site quality has been the usual method of evaluating stand density. Other methods have been proposed, but none has given results good enough to warrant general adoption or displacement of the basal-area method. It is the purpose of this paper to present a stand-density index which does not require a yield table and which is not affected by possible errors in shape of the total basal area-age curve. This stand-density index, based on the relationship between number of trees per acre and their average diameter, is premised on the characteristic distribution of tree sizes in even-aged stands.

It is a well-established fact that in any given stand a curve showing the relative (percentile) frequency of occurrence of the various tree sizes (diameters) has a characteristic form, often approximating that of the "normal frequency curve" or "normal curve of error" (1, 2, 3, 4, 6, 7).

\[
\log N = -1.605 \log (D + k)
\]
Metabolic Scaling Theory of Biology
21st Century

(Metabolic scaling theory of plant growth)

Price et al. 2010. New Phytologist
Allometry: a fundamental biological principle

\[ Y = Y_0 r^\Phi \]

- \( Y \) is a functional characteristic (e.g., growth)
- \( Y_0 \) is the normalization constant
- \( \Phi \) is the allometric exponent
- \( r \) is measure of tree size (e.g., tree mass)

THEORY ("the forest is the tree")

West et al. 2009. PNAS: 7040-7045

Enquist et al. 2009. PNAS: 7046-7051
evidence

Tree Growth and Competition

Tree Death and Growth
Evidence

$SDI_{\text{max}}$

Shaw 2005; Shaw and Long 2007
Self-thinning rule

\[
\log QMD = \frac{3}{2} \log TPA + k
\]
Evidence

$\text{SDI}_{\text{max}}$ and MSB
Lower growth in crowded forest (density dependence)

Evidence

van Doorn (2014) Eitzel et al. 2013
Evidence from Sierra Nevada:
Slower growing trees more likely to die
Trees as foundation species

Vulnerability profiles
Key question: Do treatments designed to modify fire behavior improve forest health?
Trees as foundation species

Ellison et al. 2005

“Vitality” of the trees is a necessary but not sufficient condition for a healthy forest.
A VITALITY-BASED MODEL RELATING STRESSORS AND ENVIRONMENTAL PROPERTIES TO ORGANISM SURVIVAL

JAMES J. ANDERSON

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Vitality and bark beetle resistance of fertilized Norway spruce

Maarit Kytö *, Pekka Niemelä ¹, Erkki Annila

Finnish Forest Research Institute, Vantaa Research Centre, P.O. Box 18, FIN-01301 Vantaa, Finland
Quantify probability of survival for trees using long-term growth rates.
Example: sugar pine and blister rust
Model survival as a function of growth
Vulnerability profiles

Entire population

Trees with blister rust removed

less healthy

healthy

Difference

Battles et al. 2008
application

Blodgett Forest, CA

Last Chance, CA
Last Chance Forest Health

Tree cores collected and processed
Lead: John Sanders

Vulnerability models developed
Lead: Adrian Das

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<th>Analyzed (rings read)</th>
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To be collected in 2018?
Application

Blodgett FFS

Mechanical only

Fire hazard: low
Forest re-growth: high

Mechanical + fire

Fire hazard: very low
Forest re-growth: unchanged

Fire only

Fire hazard: very low
Forest re-growth: unchanged

Application

![Graph showing vulnerability index for different species and conditions](image)

- **Abies concolor**
- **Calocedrus decurrens**
- **Pinus lambertiana**
- **P. ponderosa**
- **Psuedotsuga menziesii**

Vulnerability index categories:
- Control
- Fire
- Mech
- Mech+fire

Collins et al. In prep
Do treatments designed to modify fire behavior improve forest health?

**MECH at Blodgett**
forest health response surprisingly both in magnitude and longevity

**MECHFIRE at Blodgett**
lowest vitality predicted

Basic scaling question for SPLATs
Is there a fireshed wide benefit?

Applied question for SPLATS
Do these responses hold in an adaptive management context