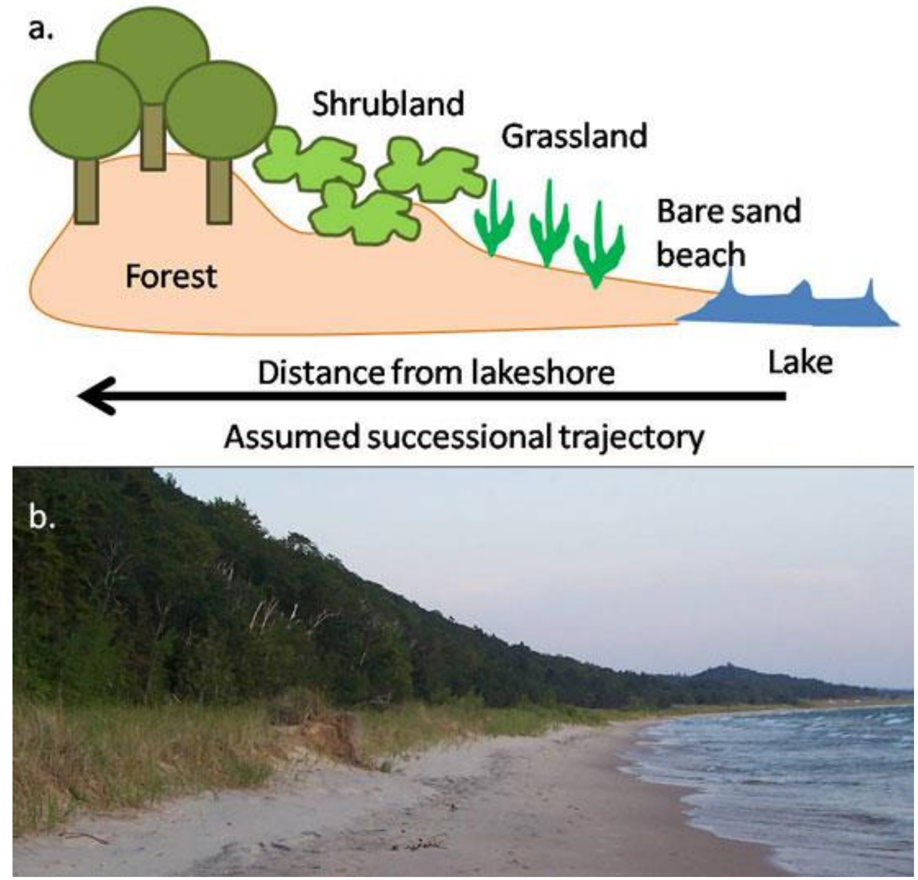
BIOL 410 Population and Community Ecology

Communities and disturbances

Succession

- Henry Cowles
  - 1899
  - Chronosequence of vegetation along sand dunes
  - Repeatable sequence of community changes

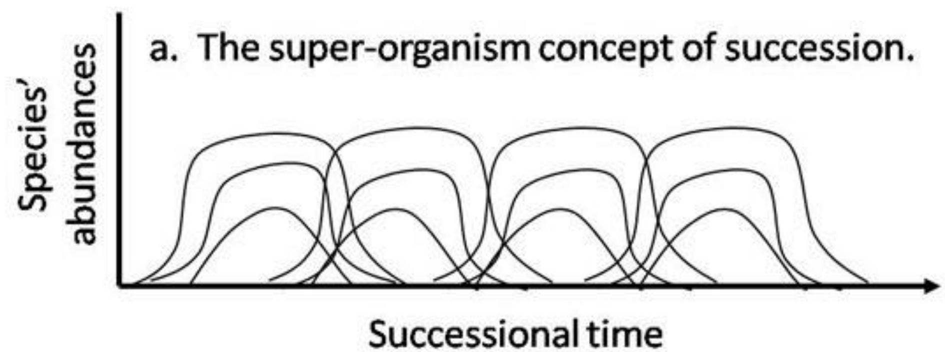


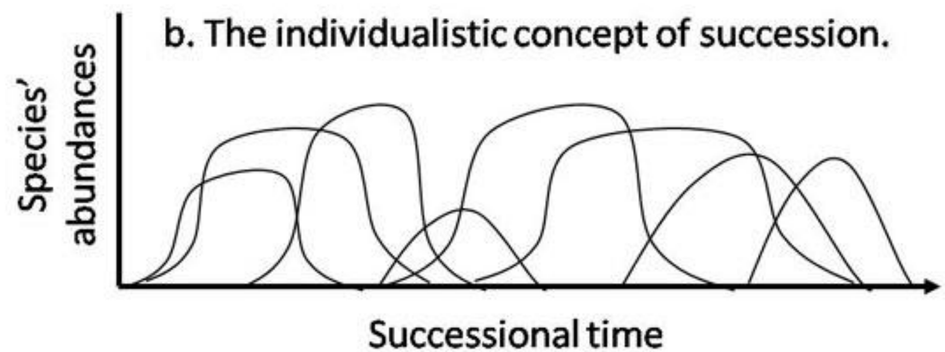
Sand dunes along shore of Lake Michigan

Succession

- Frederick Clements
  - 1900, 1920s
  - Groups of organisms tightly associated
  - Each environment characterized by a single “climax community”
  - Ecosystems could self-form, or self-renew
  - Very predictable successional change
  - “Super-organism” concept

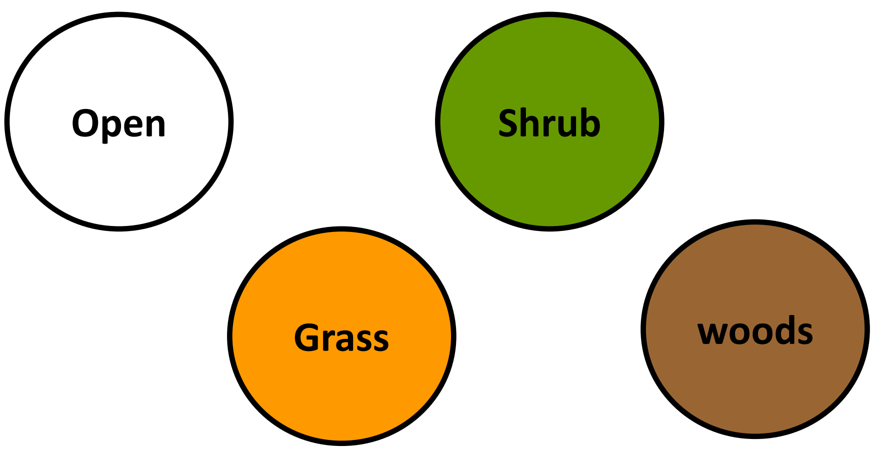
- Henry Gleason
  - Communities comprised of individual species
  - No climate state for ecosystems
  - Environment and movement impact species assemblages
  - Community change not as predictable as Clements proposed (chance events important: Neutral theory)





Stage examples

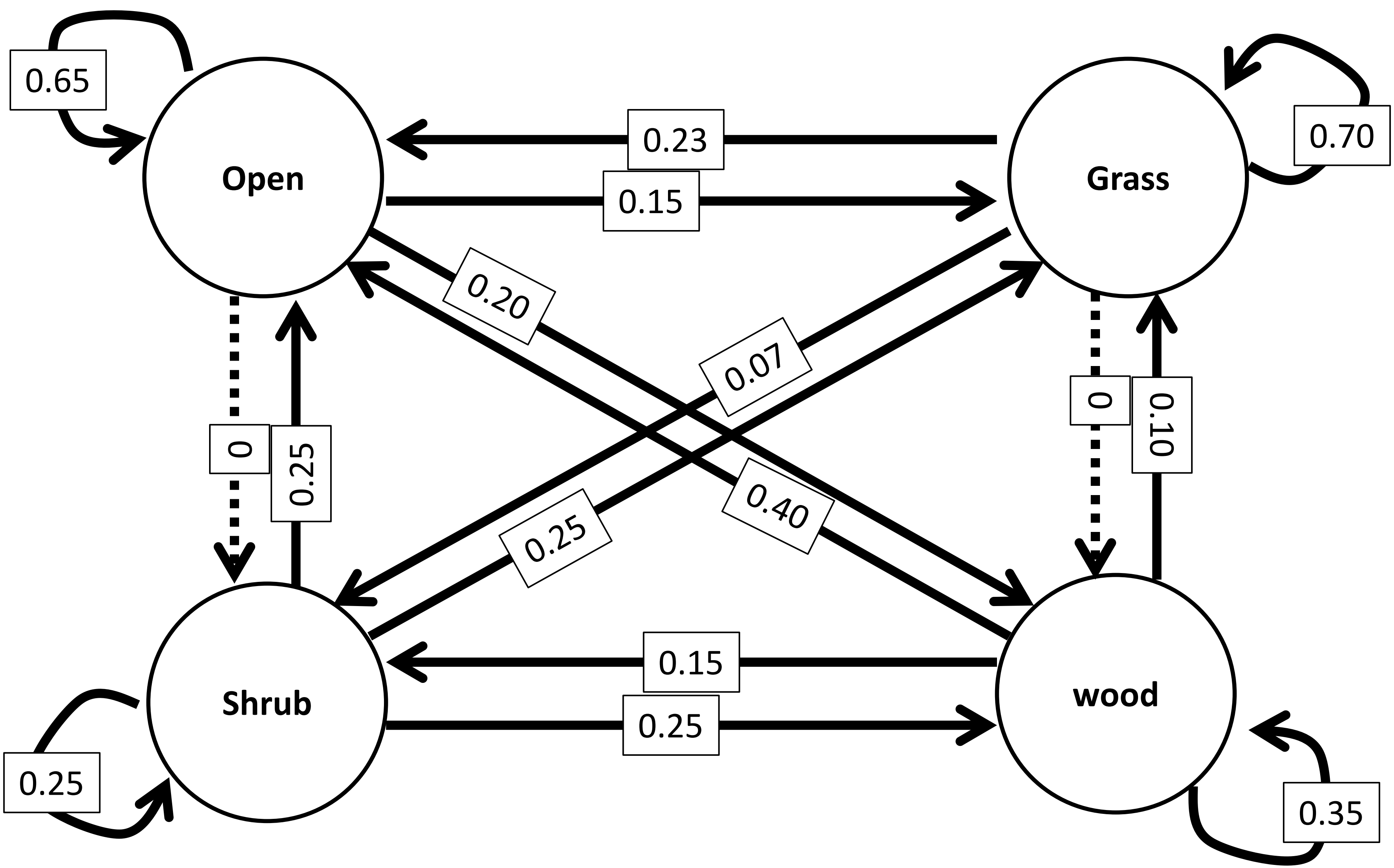
- Konza Prairie Nature area – Kansas



$$s(t) = [250, 100, 80, 70]$$

	Open	Grassland	Shrub	Woods
Open	0.65	0.23	0.25	0.40
Grassland	0.15	0.70	0.25	0.10
Shrub	0.00	0.07	0.25	0.15
Woods	0.20	0.00	0.25	0.35

Models – Loop Diagrams



Succession models

- Facilitation
- Inhibition
- Tolerance

Vol. 111, No. 982 The American Naturalist November–December 1977

MECHANISMS OF SUCCESSION IN NATURAL COMMUNITIES AND THEIR ROLE IN COMMUNITY STABILITY AND ORGANIZATION

Joseph H. Connell and Ralph O. Slatyer

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It is in changing that things find repose. [Heraclitus]

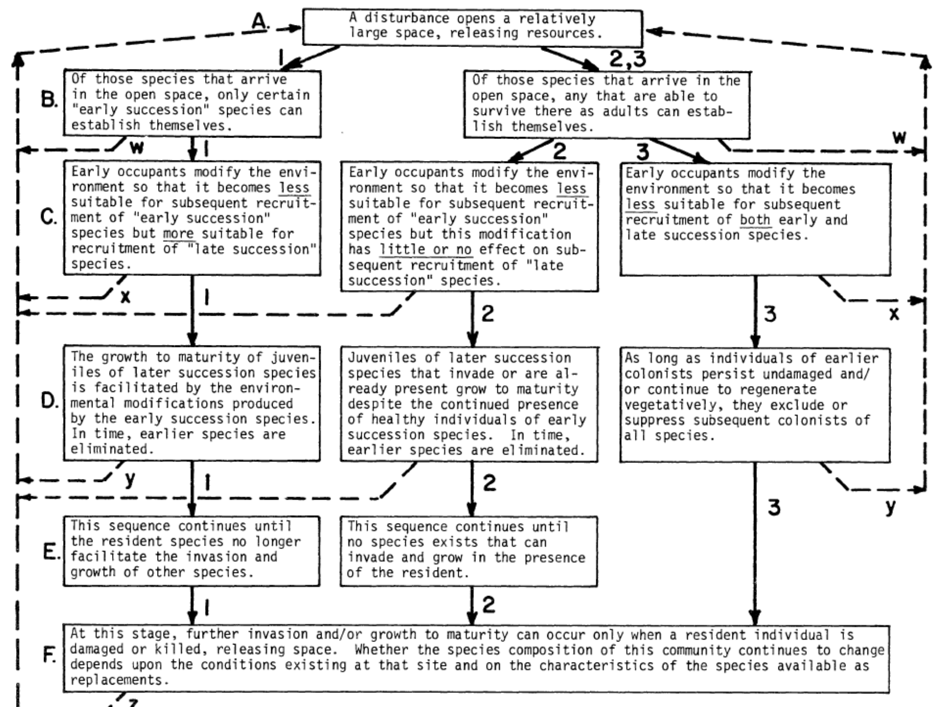


Fig. 1.—Three models of the mechanisms producing the sequence of species in succession. The dashed lines represent interruptions of the process, in decreasing frequency in the order w, x, y, and z.

Succession models

- Facilitation
  - Disturbance
  - Open space, resources released (some)
  - Only “early succession” species can establish
  - Early occupants
    - Modify environment to make it less suitable for subsequent colonization of “early” species
    - Make it more suitable for recruitment of “late” succession species
  - Growth (resource use) of “late” succession species eventually excludes “early” species
  - Continues until resident species no longer facilitates invasion of new species
  - Climax community

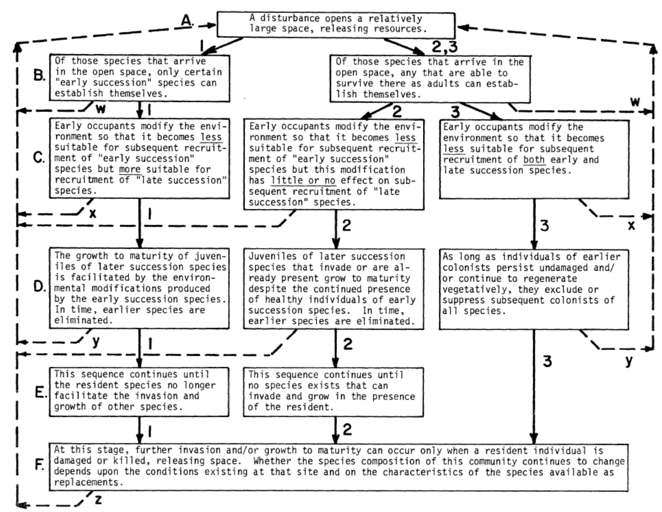
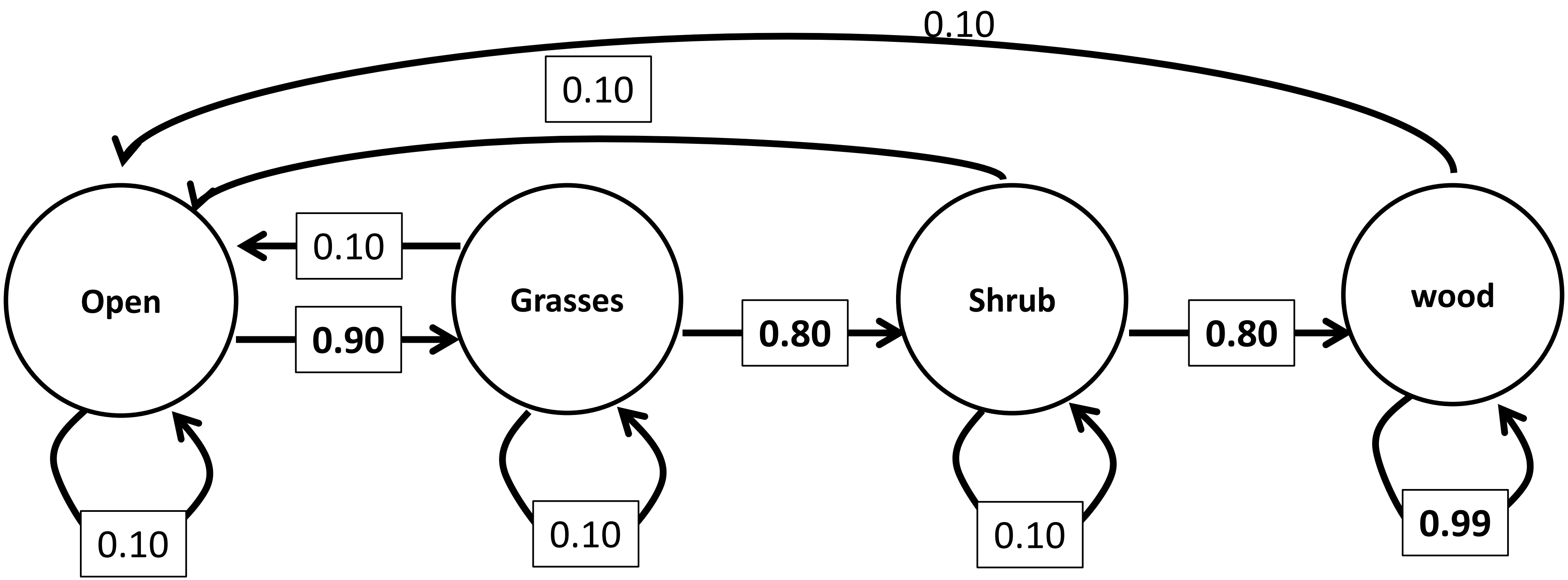


Fig. 1.—Three models of the mechanisms producing the sequence of species in succession. The dashed lines represent interruptions of the process, in decreasing frequency in the order w, x, y, and z.

Facilitation Model

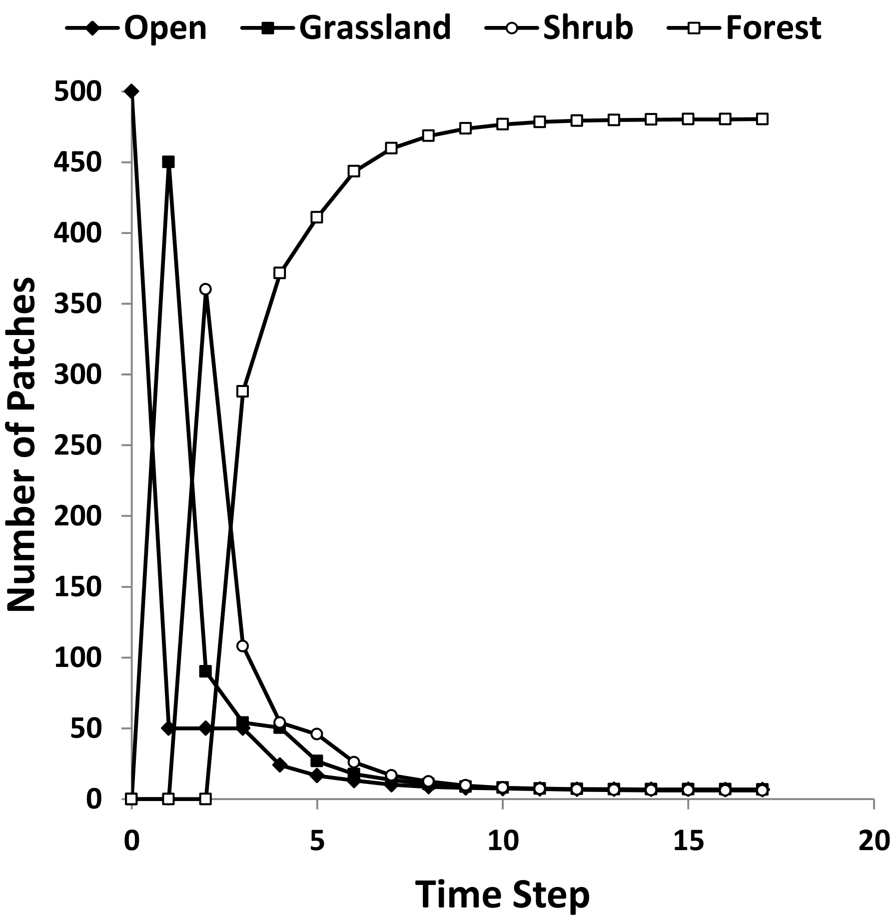
- Directional pattern to succession



Facilitation Model

	Open	Grassland	Shrub	Woods
Open	0.10	0.10	0.10	0.01
Grassland	***0.90***	0.10	0.00	0.00
Shrub	0.00	***0.80***	0.10	0.00
Woods	0.00	0.00	***0.80***	***0.99***

$$s(t) = [500, 0, 0, 0]$$



Succession models

- Inhibition
  - Disturbance
  - Open space, resources released (some)
  - Any species that arrive can establish themselves
  - Early occupants
    - Modify environment to make it less suitable for subsequent recruitment of both "early" and "late" succession species
  - As long as "early" species exist they inhibit recruitment
  - When "early" species is displaced (damaged, killed), recruitment of other species occurs (condition dependent)
  - Continues until climax community reached

Lantana: flowering shrub

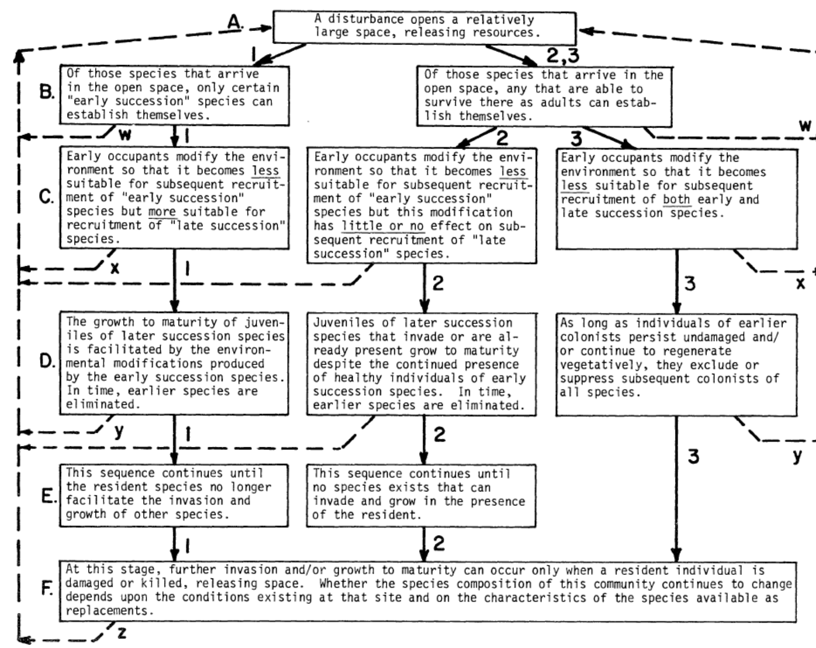
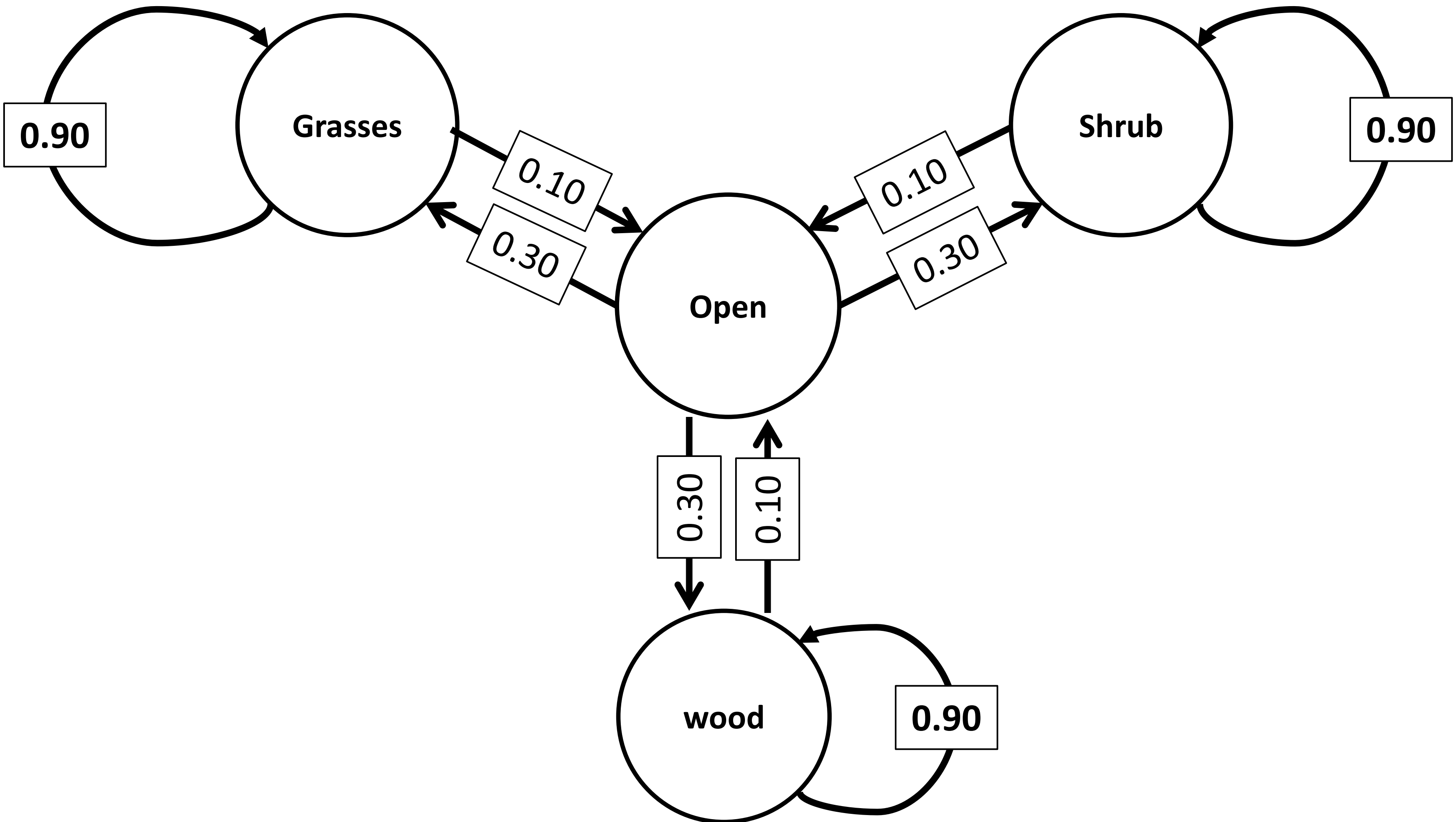


FIG. 1.—Three models of the mechanisms producing the sequence of species in succession. The dashed lines represent interruptions of the process, in decreasing frequency in the order w, x, y, and z.

Inhibition Model

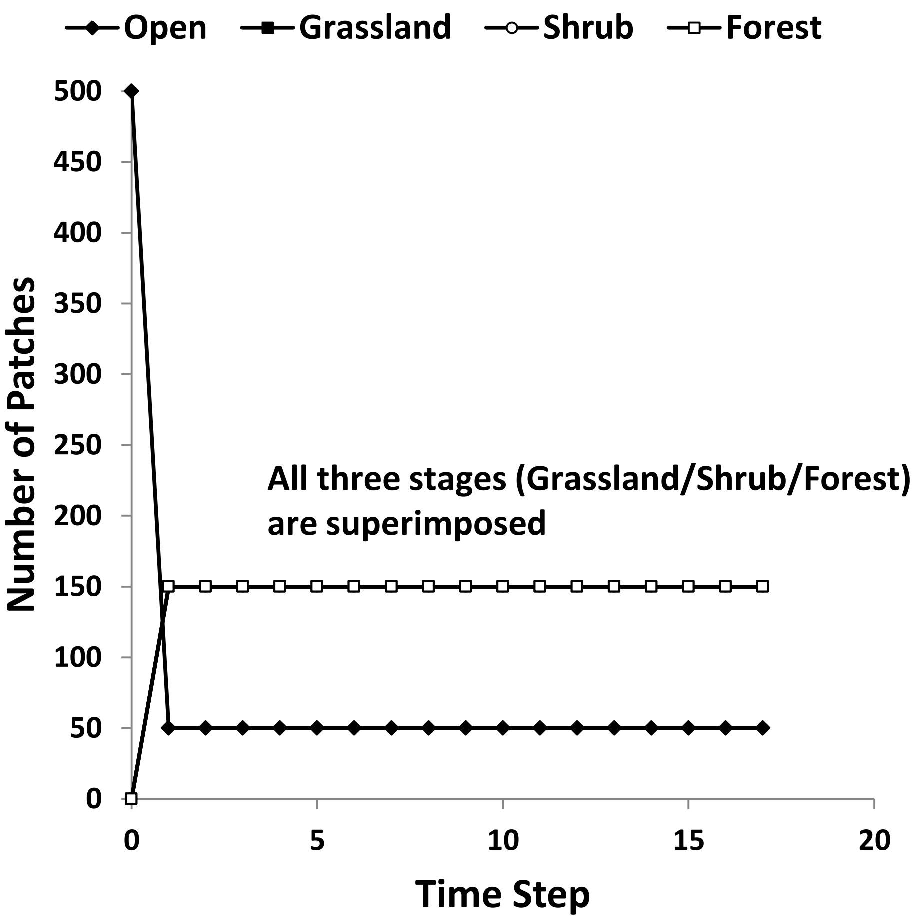
- Stage replacement occurs only following additional disturbance



Inhibition Model

	Open	Grassland	Shrub	Woods
Open	0.10	0.10	0.10	0.01
Grassland	0.30	*0.90*	0.00	0.00
Shrub	0.30	0.00	*0.90*	0.00
Woods	0.30	0.00	0.00	*0.90*

$$s(t) = [500, 0, 0, 0]$$



Succession models

- Tolerance
  - Disturbance
  - Open space, resources released (some)
  - Any species that arrive can establish themselves
  - Early occupants
    - Modify environment to make it less suitable for the “early succession” species, but has little effect on recruitment of “late” succession species
    - “Late” species are simply those that arrive later or grow slowly (i.e. sequence only determined by life-history-characteristics)
  - Later successional species (that invade or already present) grow to maturity, while over time early species are eliminated
  - *Continues until climax community reached*

Shade tolerant trees

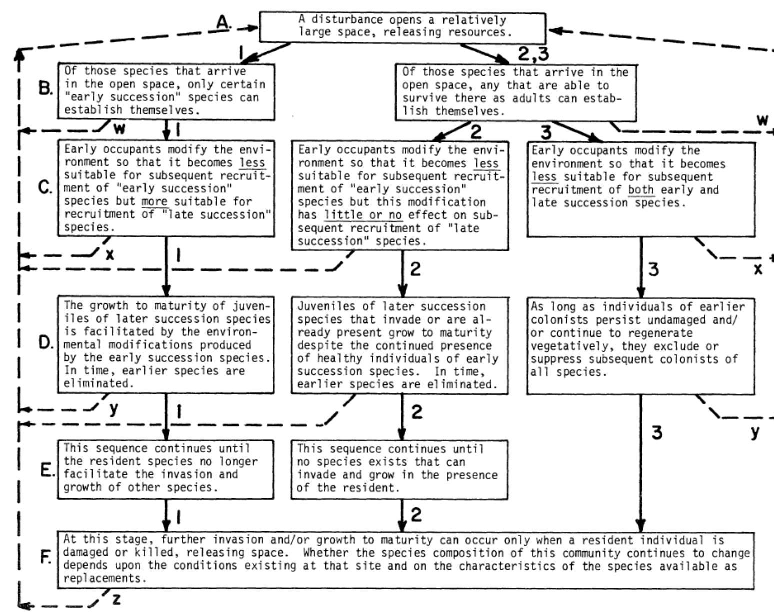
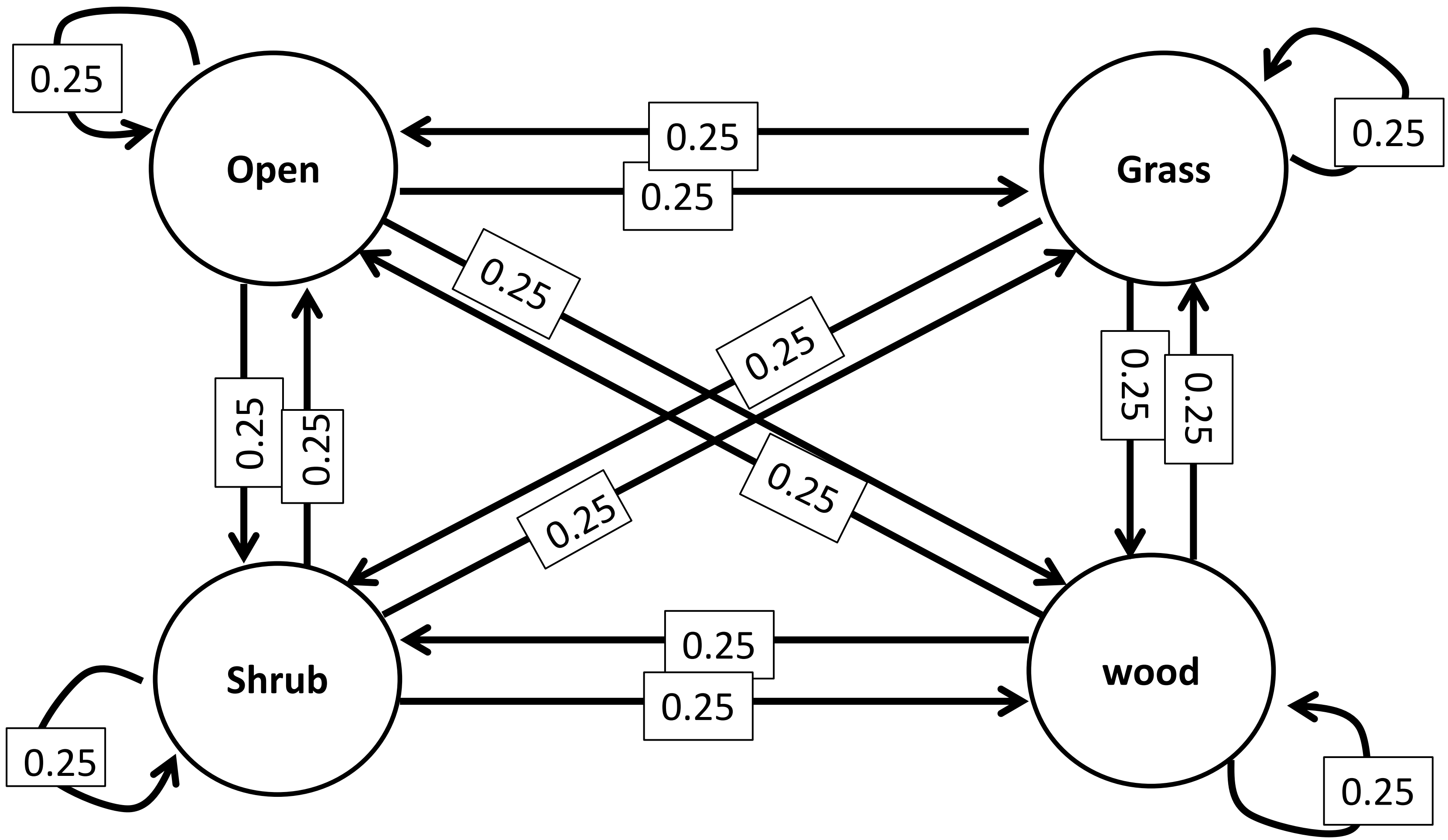


FIG. 1.—Three models of the mechanisms producing the sequence of species in succession. The dashed lines represent interruptions of the process, in decreasing frequency in the order w, x, y, and z.

Tolerance Model

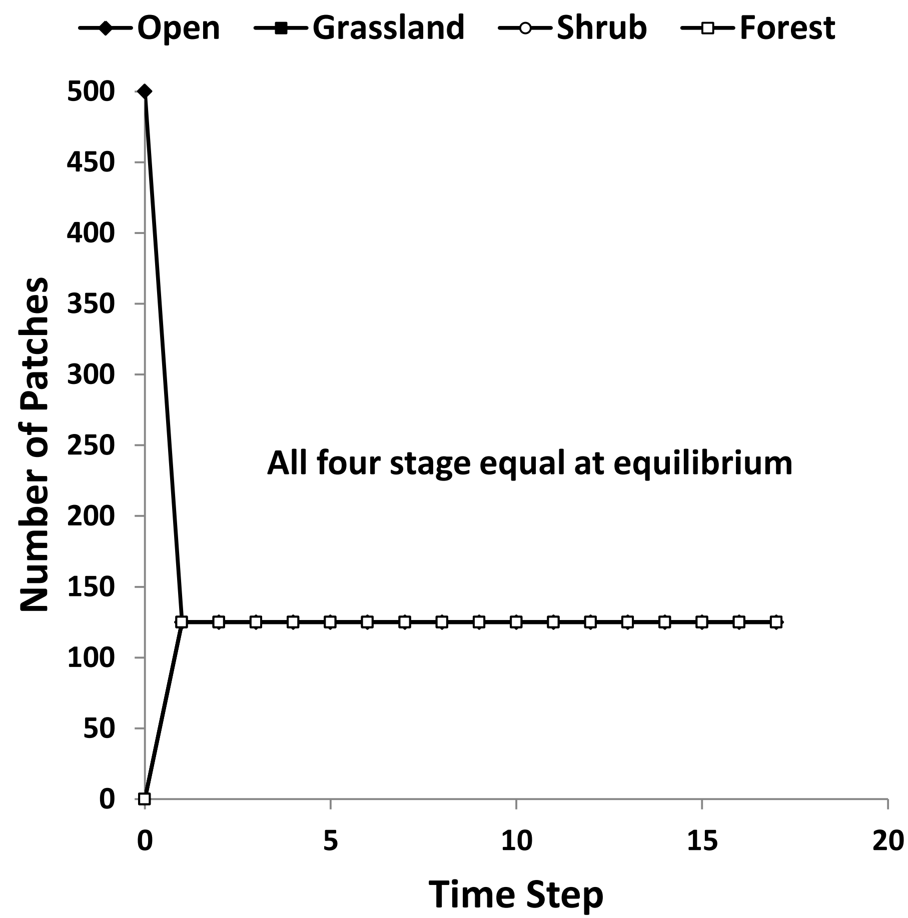
- All transition equally likely



Tolerance Model

	Open	Grassland	Shrub	Woods
Open	0.25	0.25	0.25	0.25
Grassland	0.25	0.25	0.25	0.25
Shrub	0.25	0.25	0.25	0.25
Woods	0.25	0.25	0.25	0.25

$$s(t) = [500, 0, 0, 0]$$



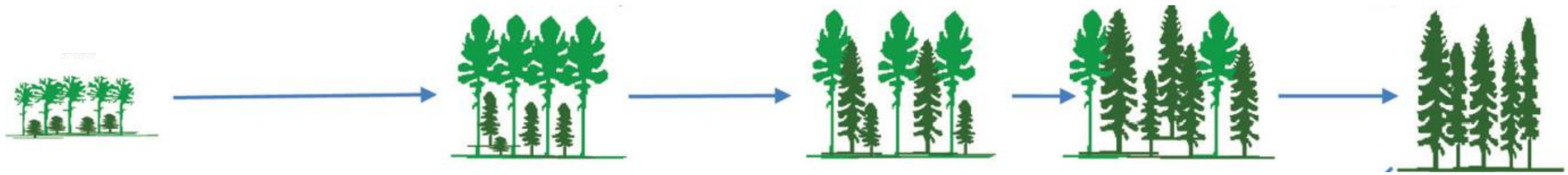
Forest succession

Forest succession

- Aspen
  - Vegetative regeneration
    - Suckering
  - Fast regeneration following fire
  - Shade intolerant

- Spruce
  - Regeneration from seed
  - Shade tolerant

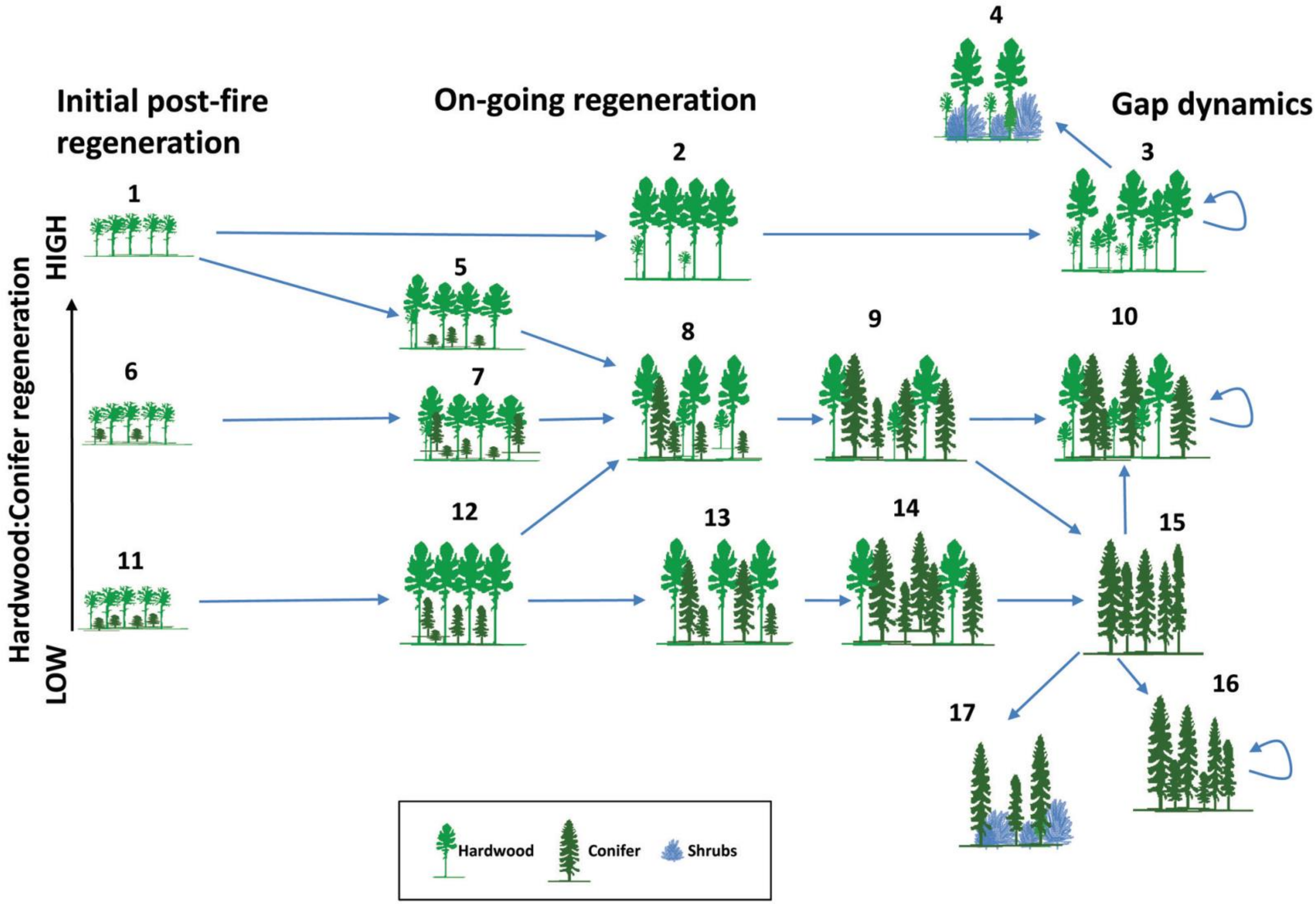
Forest succession



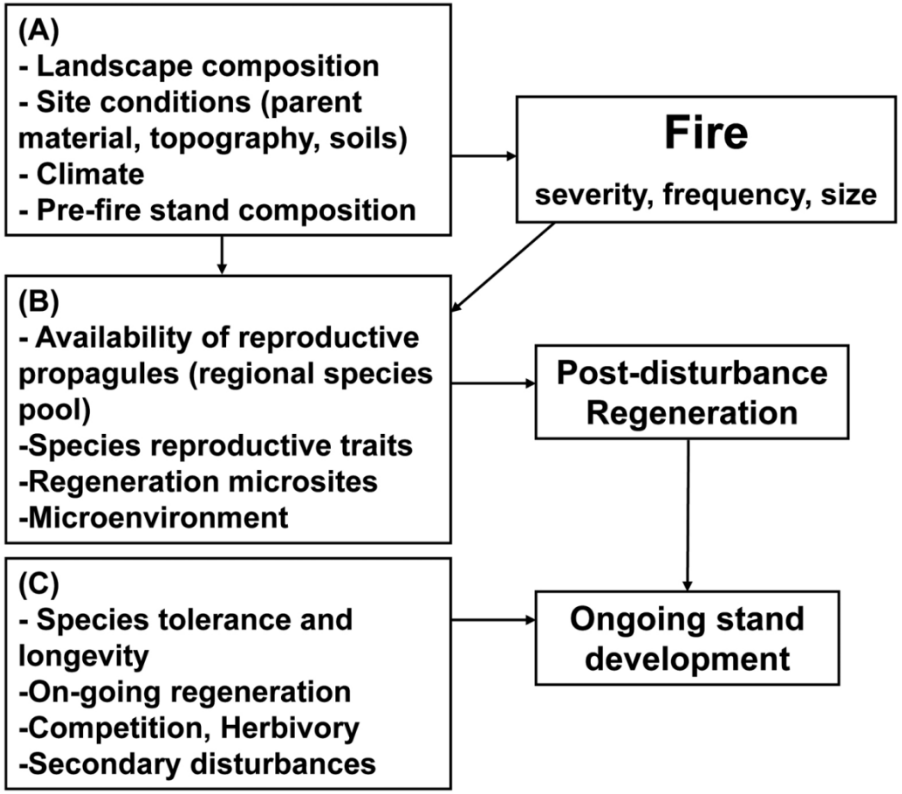
Boreal mixedwood stand dynamics: Ecological processes underlying multiple pathways[1]

by Yves Bergeron[1,6,7], Han Y.H. Chen[2], Norman C. Kenkel[3], Albanie L. Leduc[4] and S. Ellen Macdonald[5]

Forest succession



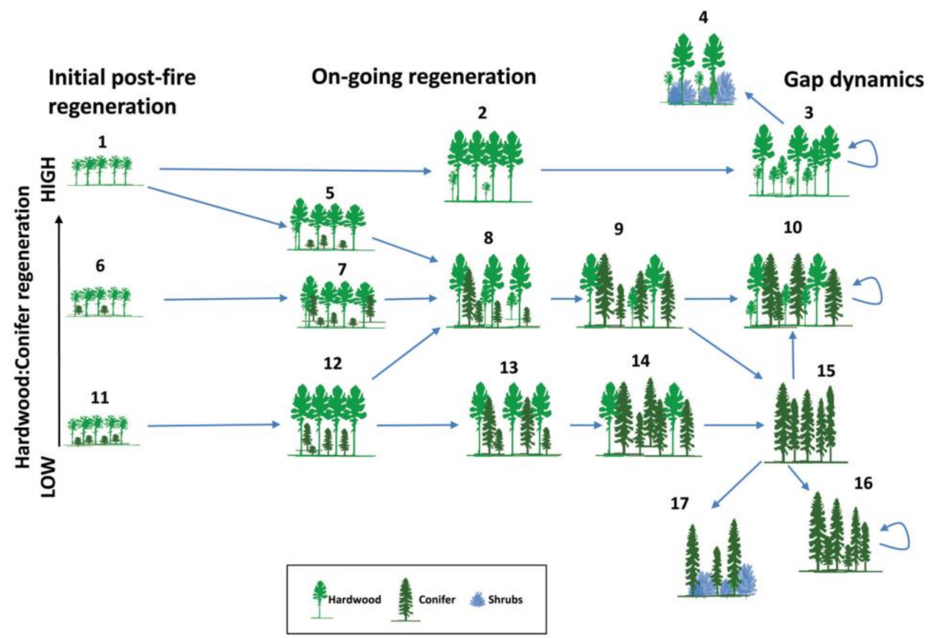
Forest succession



A: Site factors influencing fire

B: factors influencing post-disturbance regeneration

C: Factors influencing ongoing stand development



Disturbances and communities

- Disturbances
  - System resets (spatial, temporal scale)
    - Frequency, intensity, extent
  - Influence community composition
  - Influence community dynamics
  - Modifies resource availability
    - Increase or decrease
  - Modifies competition

How do disturbances influence community diversity

- Intermediate disturbance hypothesis (IDH)
- Connell 1978
  - Diversity in plants and sessile animals
    - Trees and corals
  - Diversity predicted to be highest at intermediate frequencies or intensities of disturbance

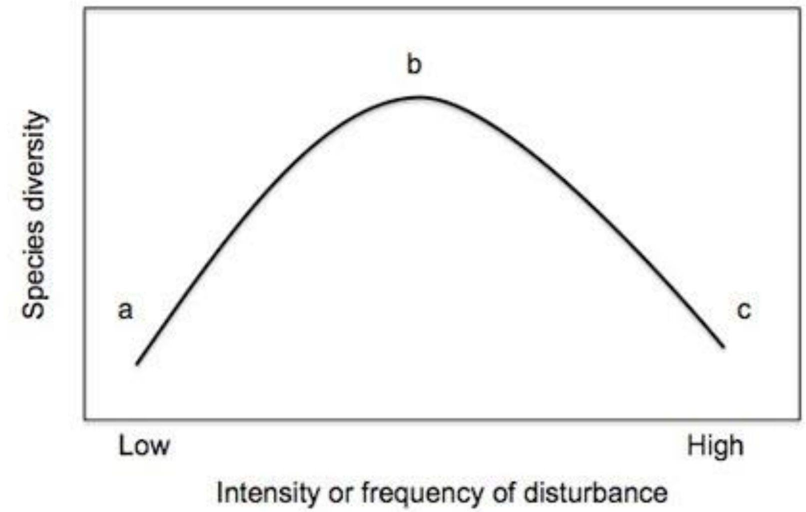
Diversity in Tropical Rain Forests and Coral Reefs

High diversity of trees and corals is maintained only in a nonequilibrium state.

Joseph H. Connell

Intermediate disturbance hypothesis

- Low disturbance frequency
  - Species diversity is expected to be low because competitively dominant species exclude competitively inferior species
- High disturbance frequency
  - Species diversity predicted to be low because only "weedy" species that quickly colonize and reach maturity are able to survive
- Intermediate disturbance frequency
  - Expected mix of colonizers and competitors co-exist



a: Competitive exclusion

b: Mix of good colonizers and good competitors

c: Only good colonizers or highly tolerant species can

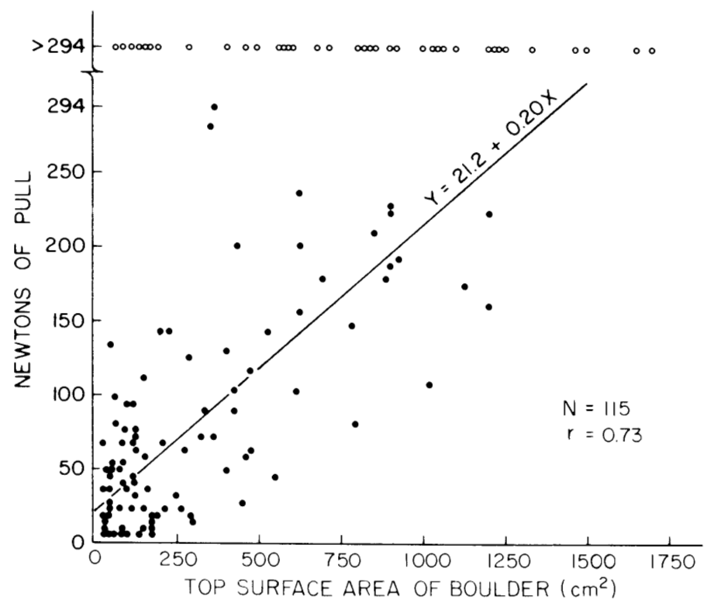
Intermediate disturbance hypothesis

Ecology, 60(6), 1979, pp. 1225–1239

DISTURBANCE IN MARINE INTERTIDAL BOULDER FIELDS: THE NONEQUILIBRIUM MAINTENANCE OF SPECIES DIVERSITY[1]

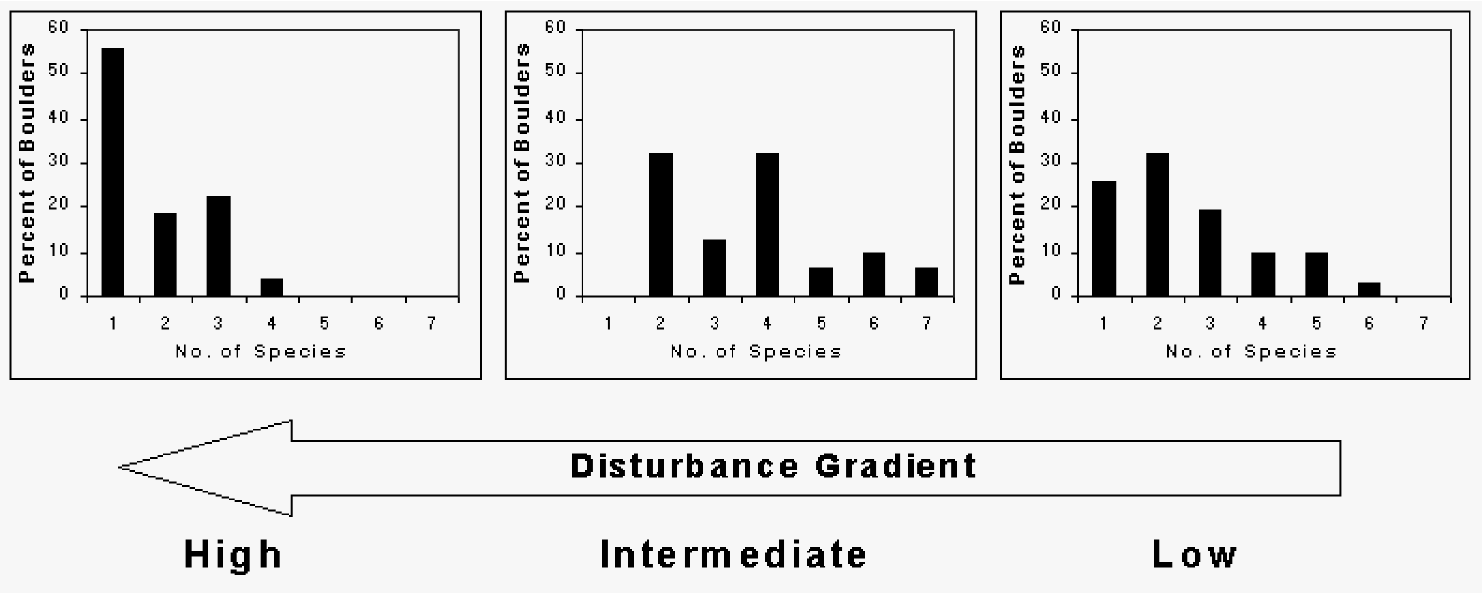
WAYNE P. SOUSA
Department of Zoology, University of California, Berkeley, California 94720 USA

Boulder size, disturbance frequency, and use



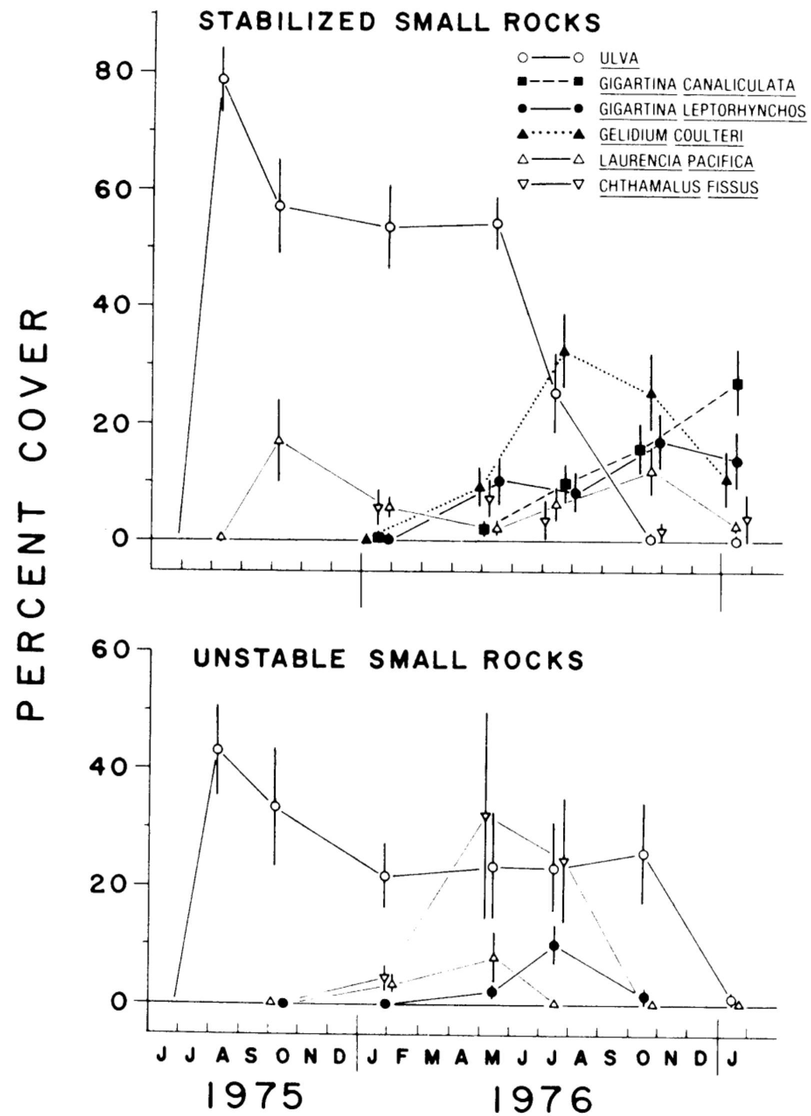
Intermediate disturbance hypothesis

- Characterize sections and rock size
- Record number and type of species
  - Opportunistic early successional algae
  - Late successional red algae



Intermediate disturbance hypothesis

- Experimental reduction in disturbance frequency
- Stabilization of small rocks
  - Increased cover
  - Increased diversity



Observed disturbance and diversity relationships

Ecology Letters, (2007) **10**: 849–864 doi: 10.1111/j.1461-0248.2007.01075.x

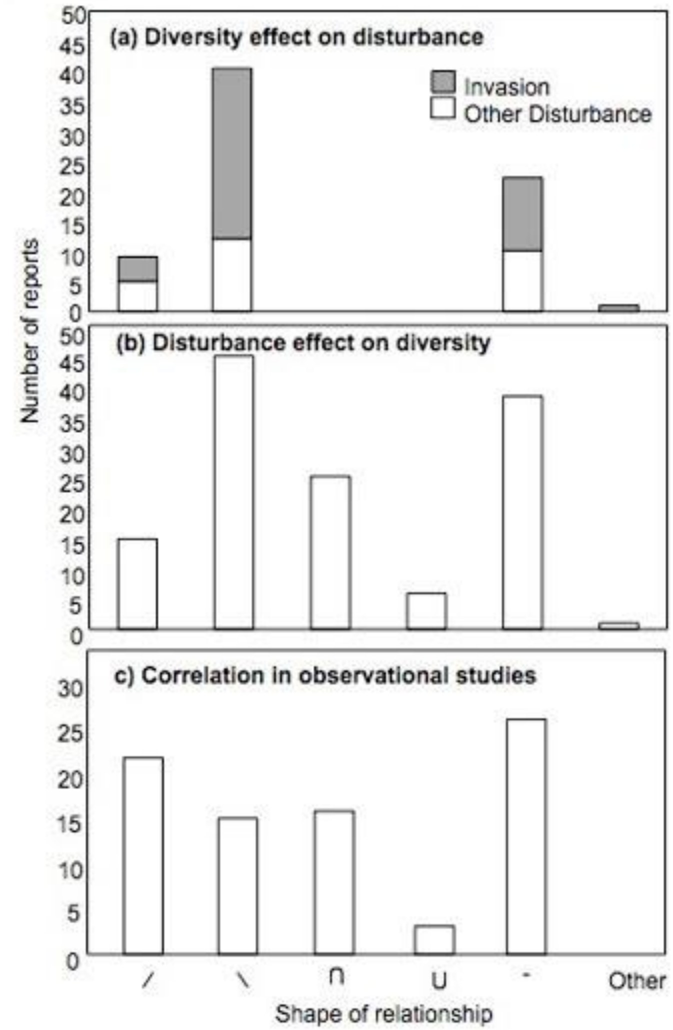
REVIEW AND SYNTHESIS

Reciprocal relationships and potential feedbacks between biodiversity and disturbance

A. Randall Hughes,[1,3]* Jarrett E. Byrnes,[1,3] David L. Kimbro[2,3] and John J. Stachowicz[1]

Abstract
Two major foci of ecological research involve reciprocal views of the relationship between biodiversity and disturbance: disturbance determines community diversity or diversity determines realized disturbance severity. Here, we present an initial attempt to

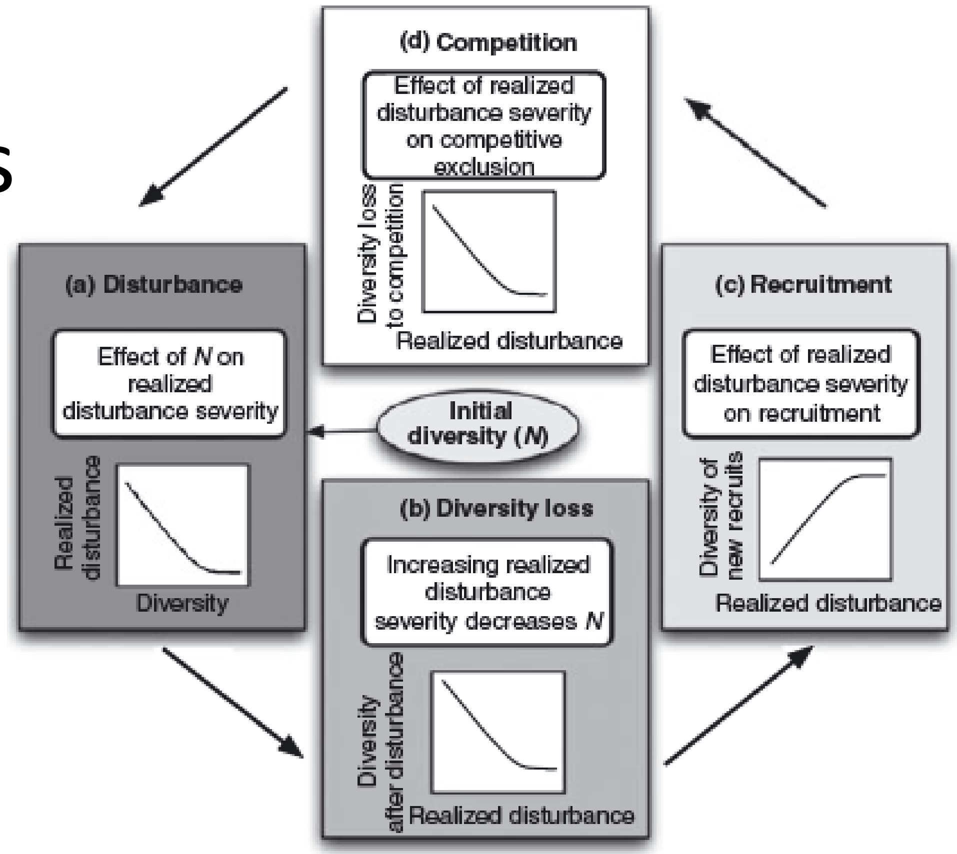
- Meta-analysis
  - Experimental studies
  - Observational studies

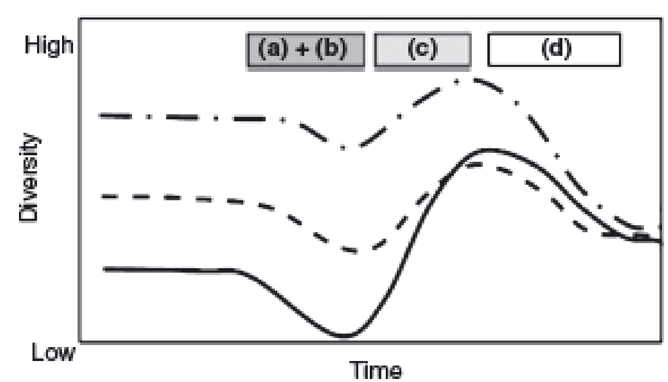


Disturbance and diversity relationships

Conceptual model of diversity-disturbance feedbacks

a) Diversity impacts on disturbance
b) Disturbance impact on diversity
c) Disturbance impact on recruitment
d) Disturbance impact on competition





Disturbance, succession and communities

a) Disturbances influence resource availability
- Frequency, intensity, extent

b) Species physiology and life history traits influence their presence in community
- Dispersal ability
- Competitive ability
- Niche space

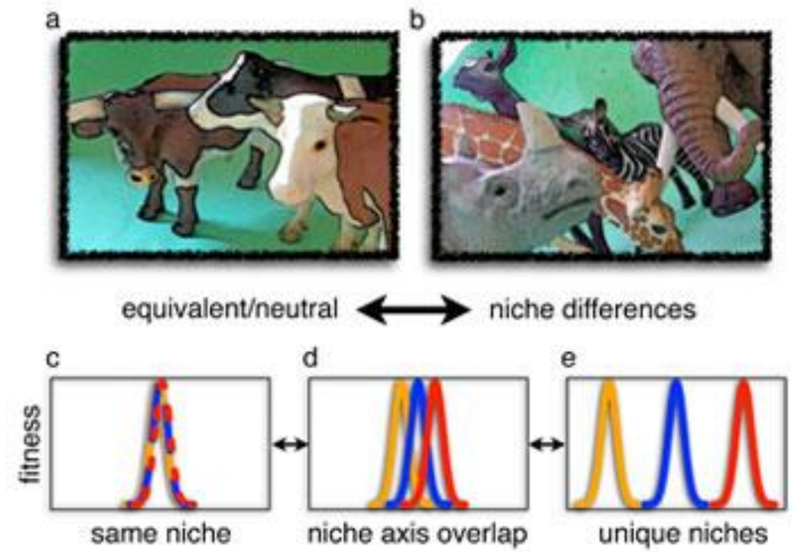
c) Stochastic events
- Regional species pool (position in landscape)
- Random dispersal events

d) Species influence their environment and interactions with other species

Community composition: Niche space or random composition

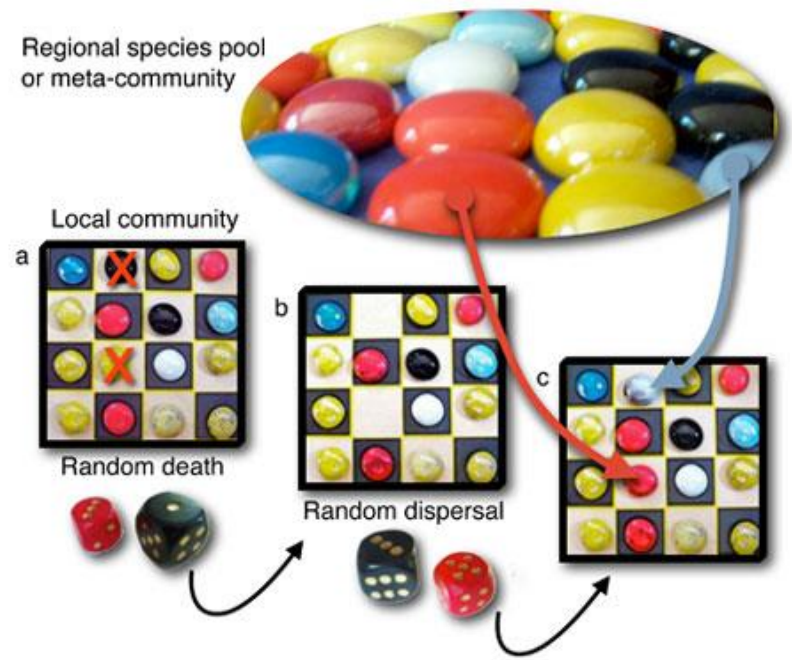
Niche vs. Neutral

- How ecologically different are species?
- How important are those differences for determining biodiversity?
- Neutral theory
  - Species that are trophically similar are equivalent (i.e. the same fitness)
- Niche perspective
  - A species occupies a unique niche
    - i.e. resource acquisition trade-offs
  - It's fitness in an community depends on environmental conditions and species interactions matching its niche requirements
  - Composition of ecological communities reflects available niche space
    - i.e. niche differences maintain biodiversity

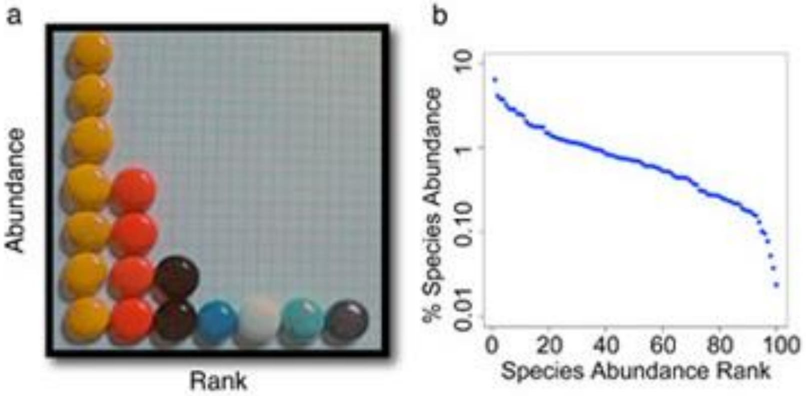


Neutral theory

- Regional species pool
  - Species are equivalent
    - within groups of similarly functioning species (trophically similar)
    - i.e. tree not equivalent to a mosquito
  - Random death leads to “opening” in community
  - Random dispersal of individuals from species pool into opening
  - Long term: ecological drift, species abundance changes randomly over time



Niche vs. Neutral



- Reinvigoration of niche theory

- Current thought
  - Species are different, and niche space influences community composition
  - "Random" processes can be important in determining community composition and structure
    - mortality, dispersal

  - What is the relative importance of niche dynamics vs. stochastic processes?