Vital Signs Thresholds: What are they, why are they necessary, how do we use them?

Integrating Monitoring Results into Management Workshop

December 7, 2005

Theresa Mau-Crimmins
Sonoran Desert Network

Steven Garman
Northern Colorado Plateau Network

SONORAN DESERT NETWORK
Inventory and Monitoring Program

Vital Signs Thresholds

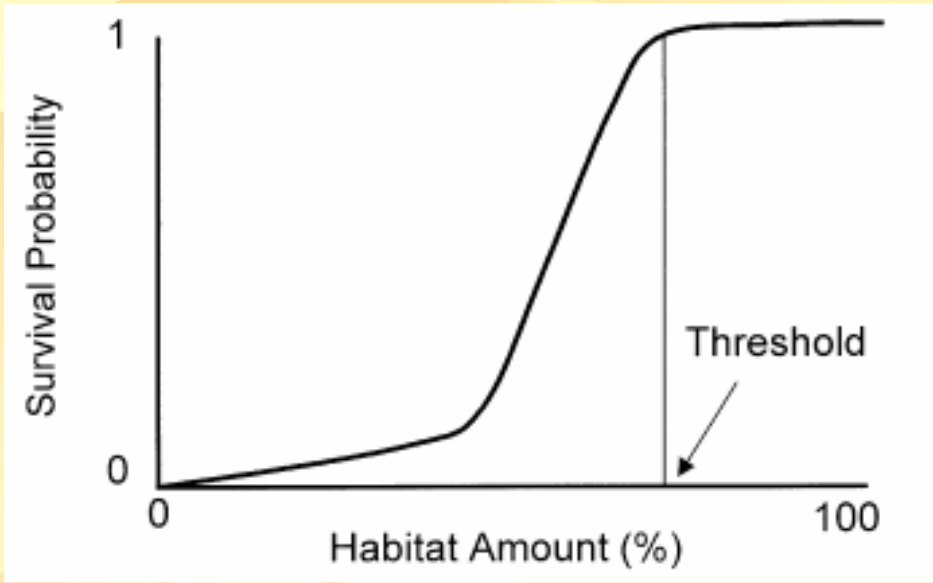
- What is a threshold?
- Why are they important?
- How are they used?
- How are they determined?

What is a threshold?

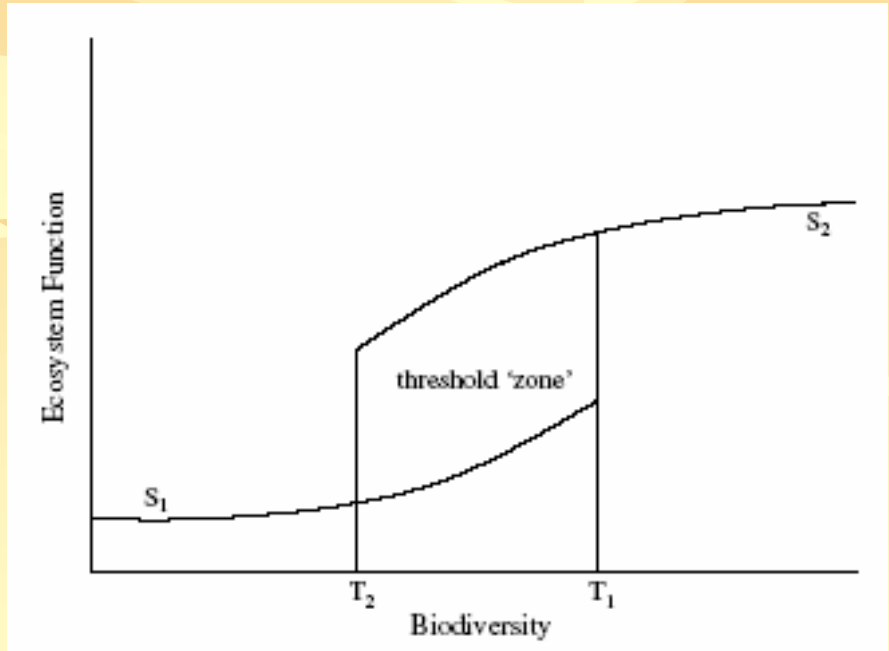
- Point or zone
- Relatively rapid change from one ecological condition to another
- "bifurcation point" (Walker and Meyers 2004)
- "Ecological discontinuity" (Muradian 2001)
- Transition to an alternative stable state
- Often the result of an external forcing

Walker, B. and J.A. Meyers. 2004. *Ecology and Society* 9(2):3.
Muradian, R. 2001. *Ecological Economics* 38:7-24.

Idealized Thresholds

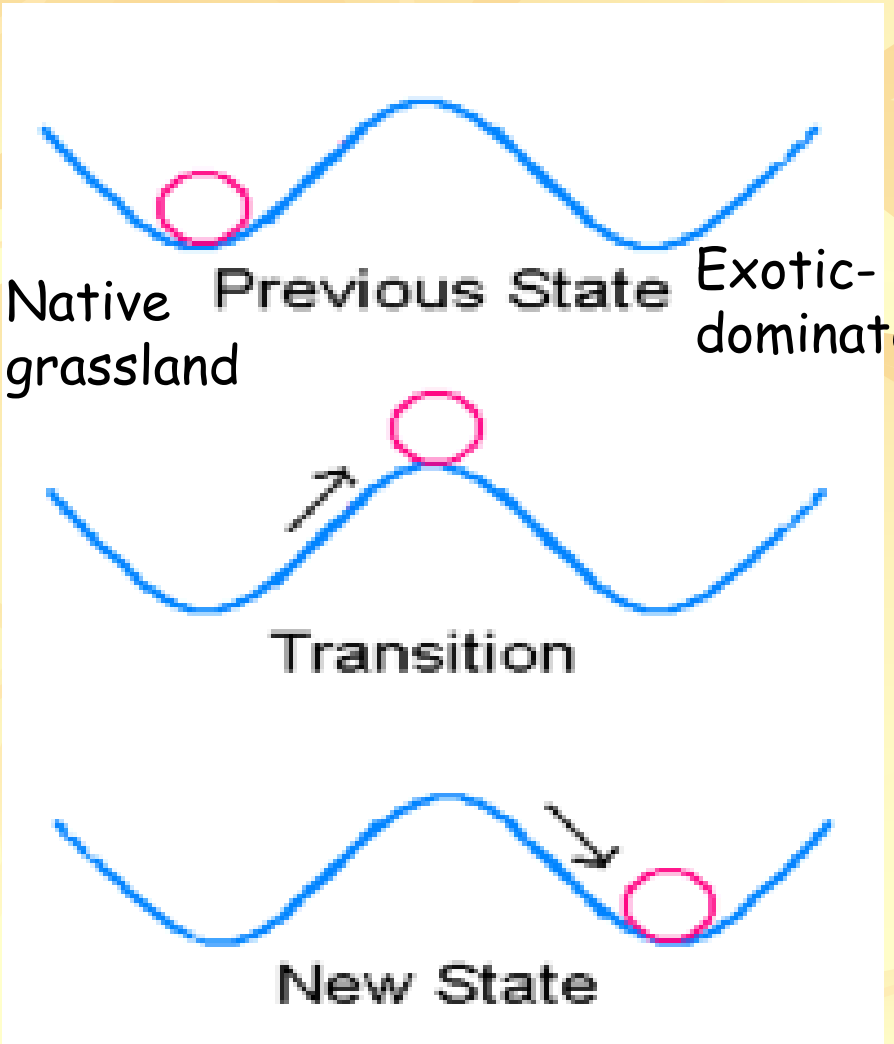


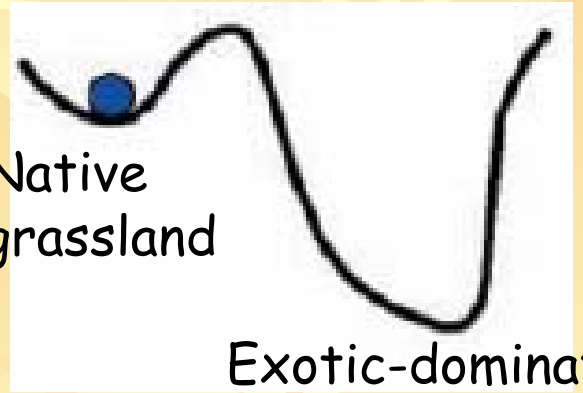
Fahrig, L. 2001.
Biological Conservation 100:65-74.



Muradian, R. 2001.
Ecological Economics 38:7-24.

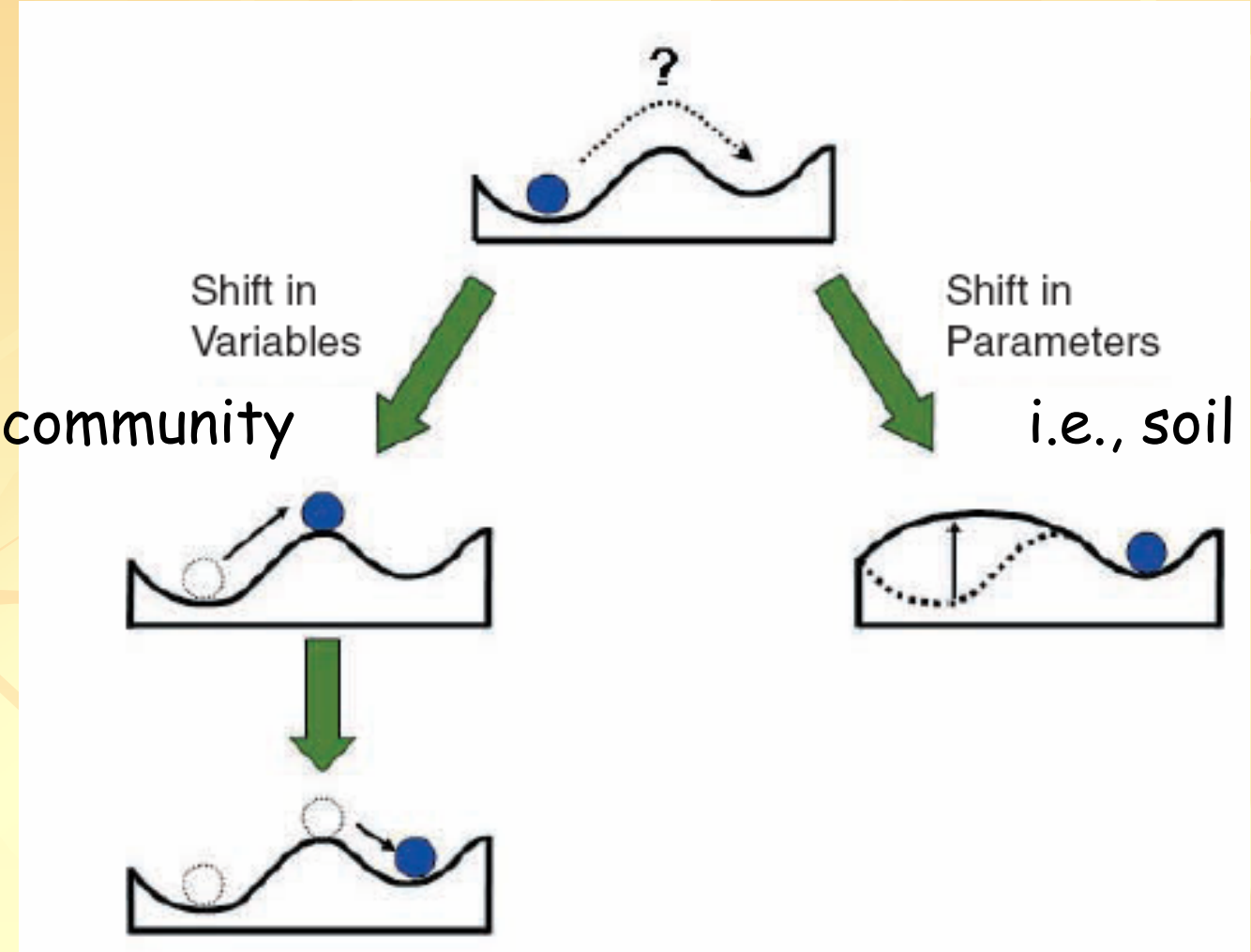
Alternative Stable States





Ecosystem Resilience

Further confusion…



i.e., bird community

i.e., soil stability

Beisner, B.E., D.T. Haydon, K. Cuddington. 2003. *Frontiers in Ecology* 1(7):376-382.

What is a threshold?

Natural states & pathways

shrubs + native grasses + biological soil crust

native grasses + biological soil crust

shrubs + biological soil crust

Shrubsteppe states

Adapted from M. Miller 6/03

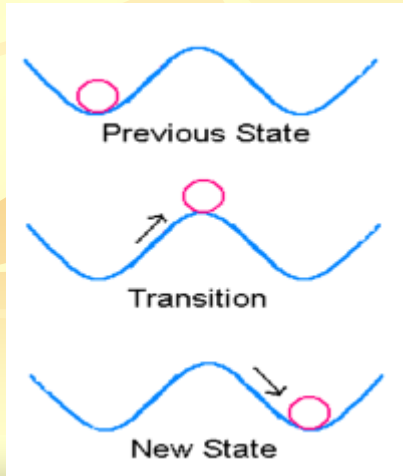
"Ergodic" states & pathways

cheatgrass ↔ Russian thistle

bare ground

Eroded annual weed states

- State & Transition
- Alternative stable states



What is a threshold?

Natural states & pathways

shrubs + native grasses + biological soil crust

native grasses + biological soil crust

shrubs + biological soil crust

Shrubsteppe states

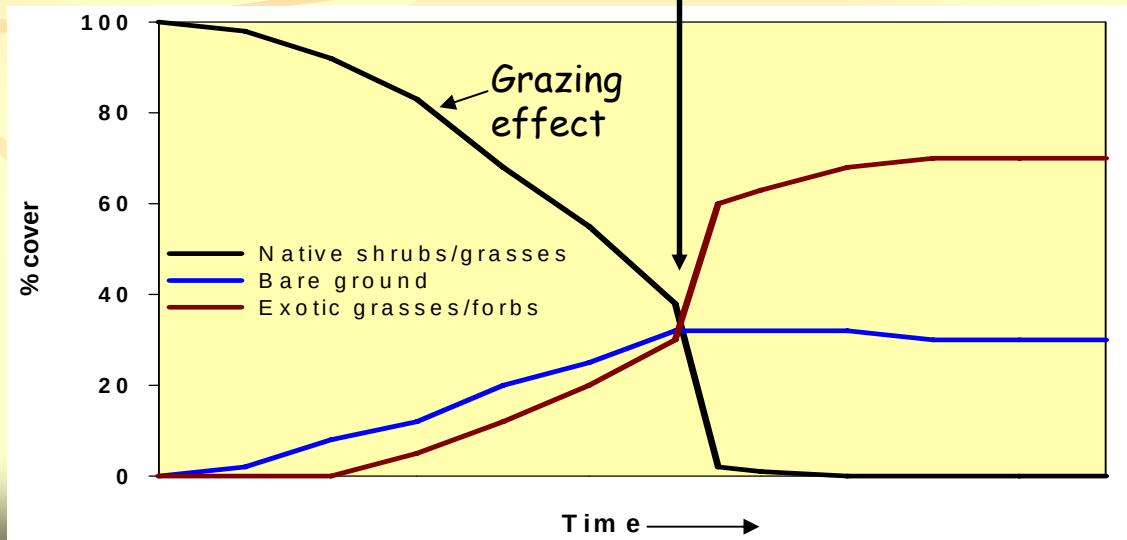
Adapted from M. Miller 6/03

"Ergodic" states & pathways

cheatgrass ↔ Russian thistle

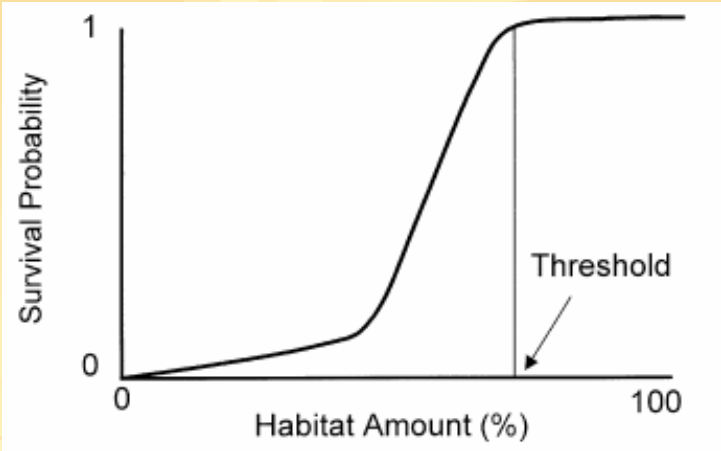
bare ground

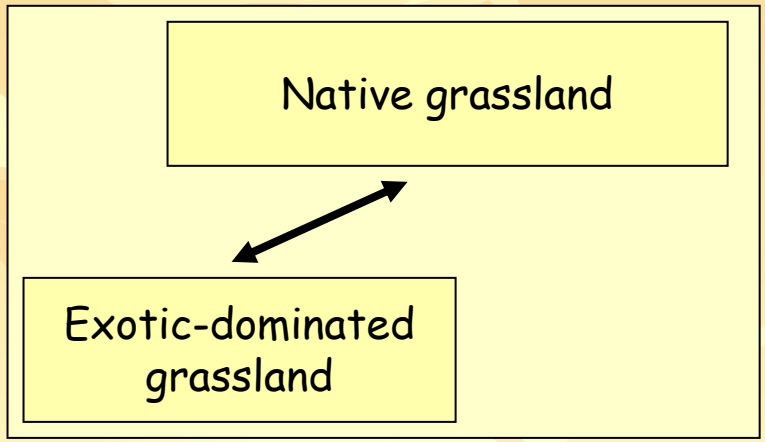
Eroded annual weed states



Models for Conceptualizing Thresholds

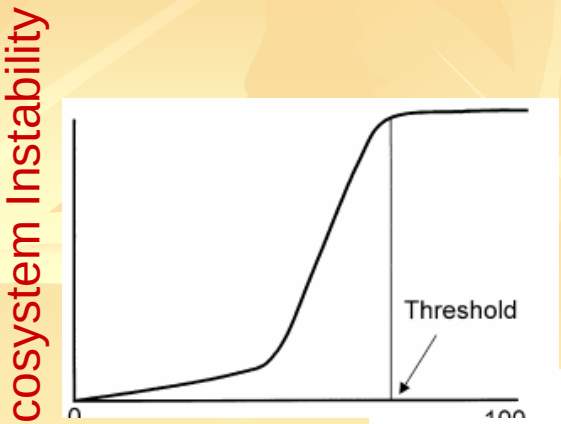
Model:



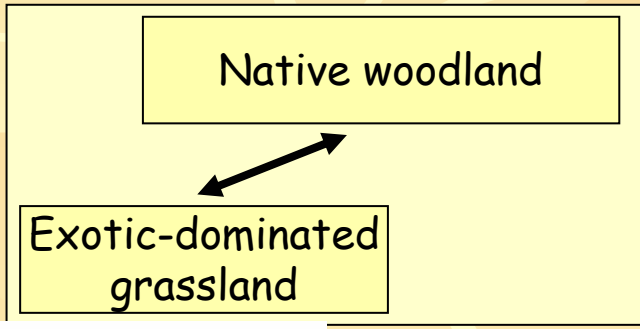


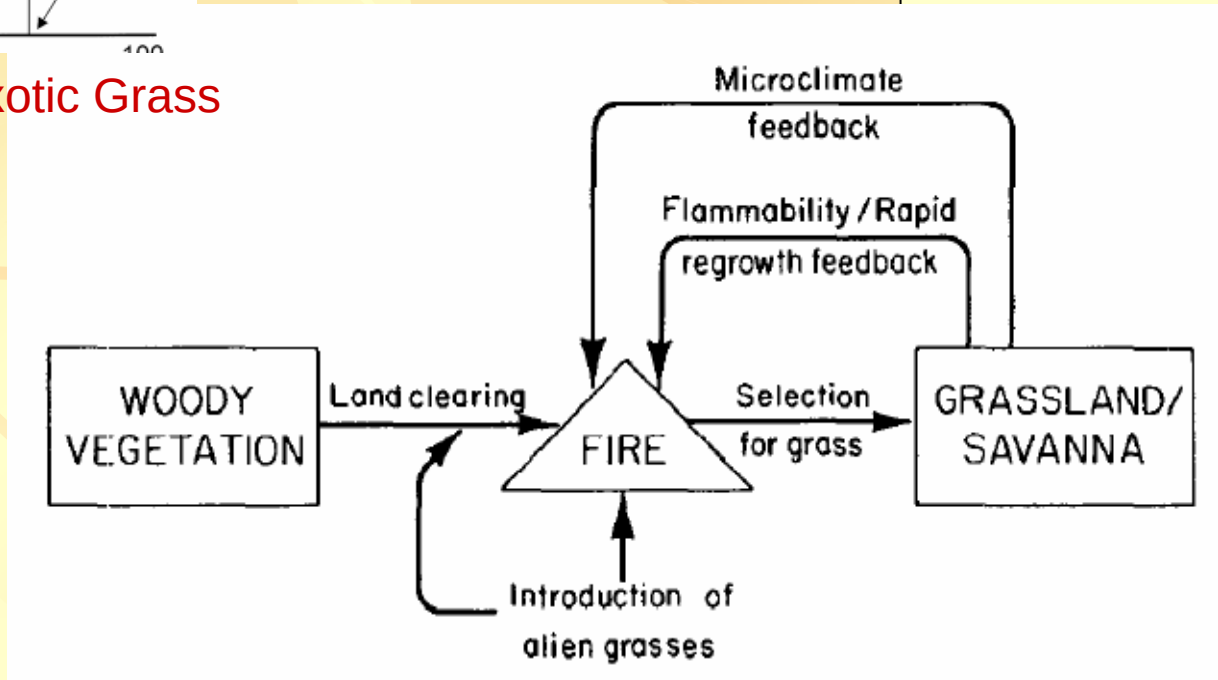
Response: Single parameter Community

Grassland Conceptual Model



- Climate: rainfall, temp, etc
- Human actions
- Fire incidence
- Abundance of exotic spp.



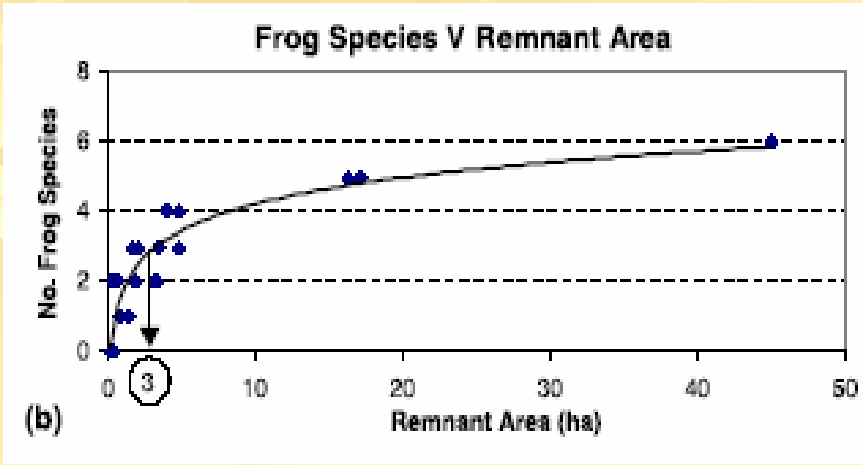


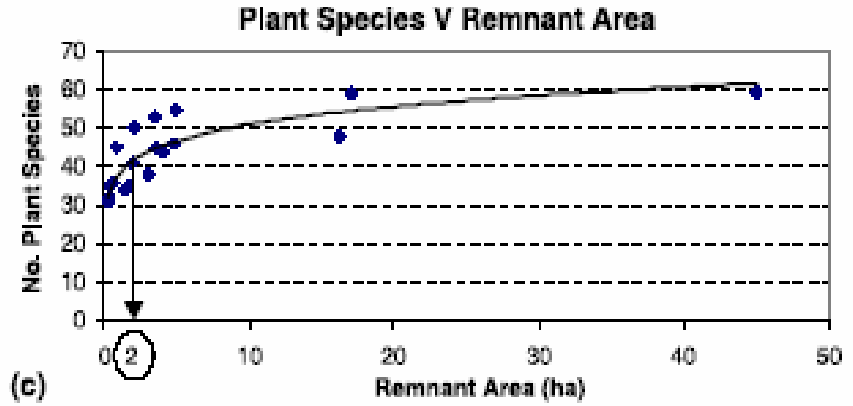
(D'Antonio, C.M. and P.M. Vitousek. 1992. *Annual Review of Ecology and Systematics* 23:63-87.

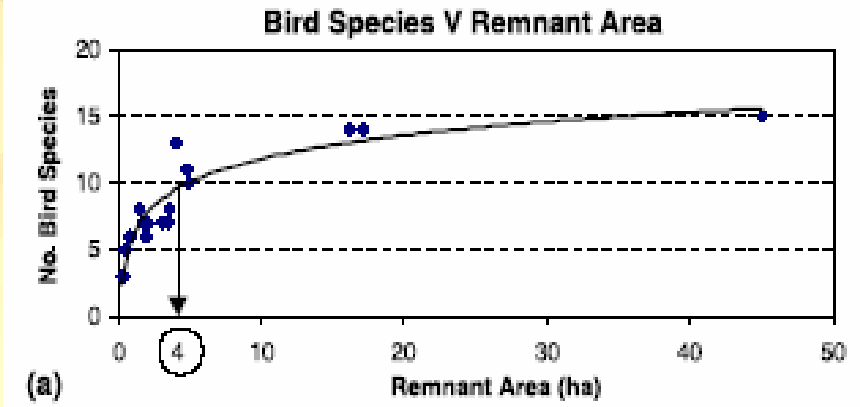
Why are thresholds important?

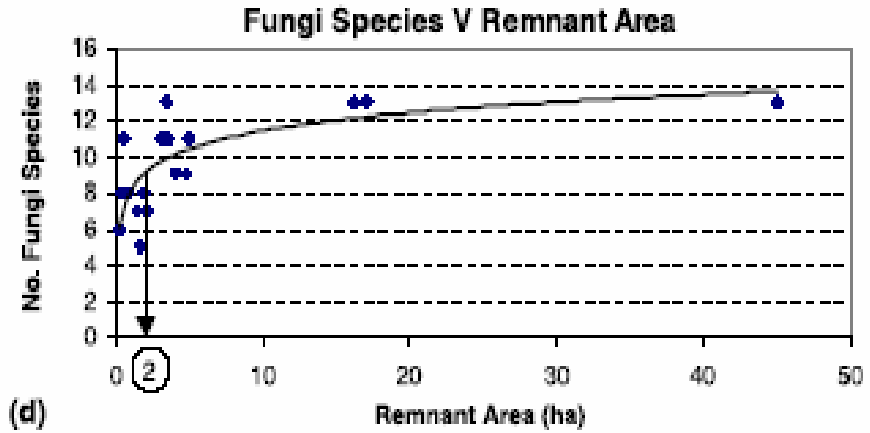
- Crossing thresholds can lead to alternative states with alternative species assemblages
- May not be possible to return to previous state once threshold is crossed
- May be possible to return to previous state with a great deal of effort

Example: Remnant Habitat and Species Richness



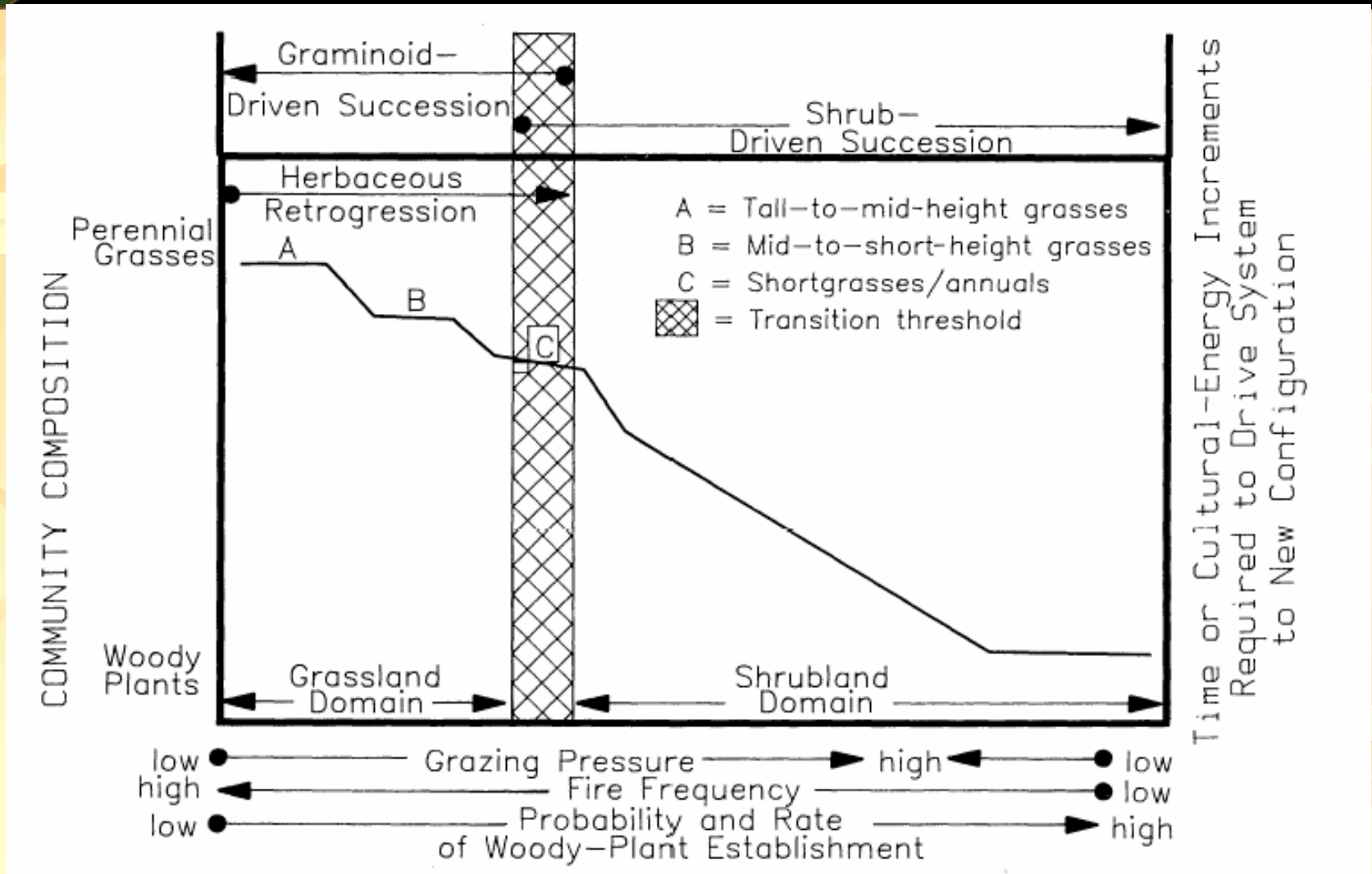






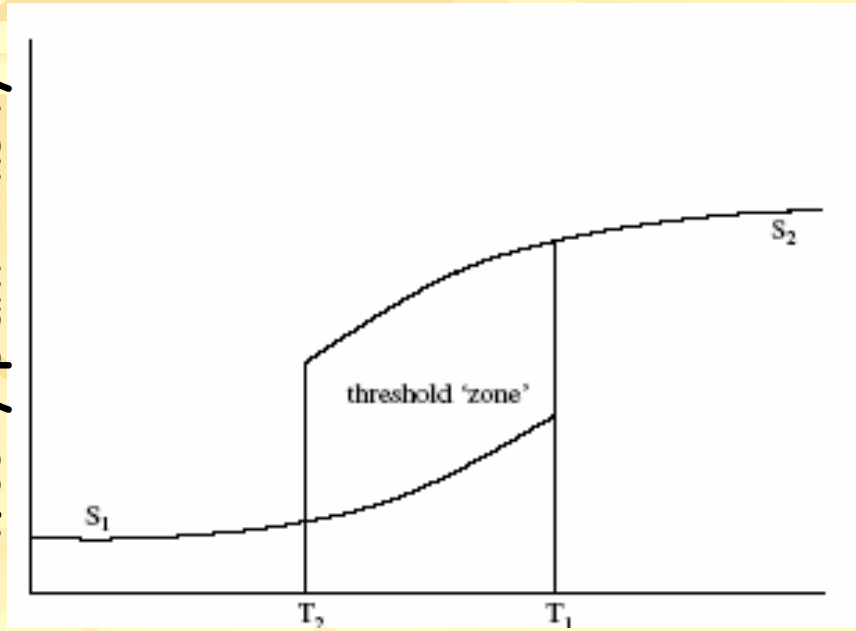
Drinnan, I. 2005. *Biological Conservation* 124:339-349.

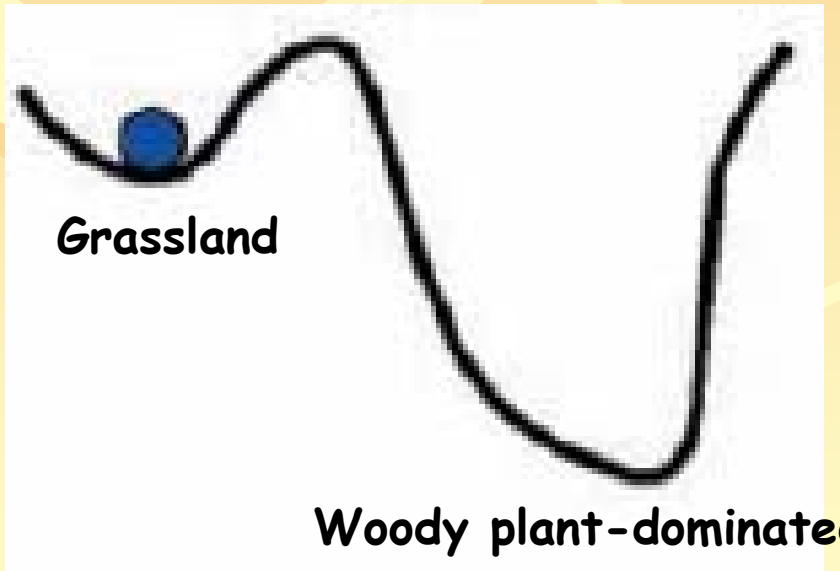
Example: Southern TX Savannas



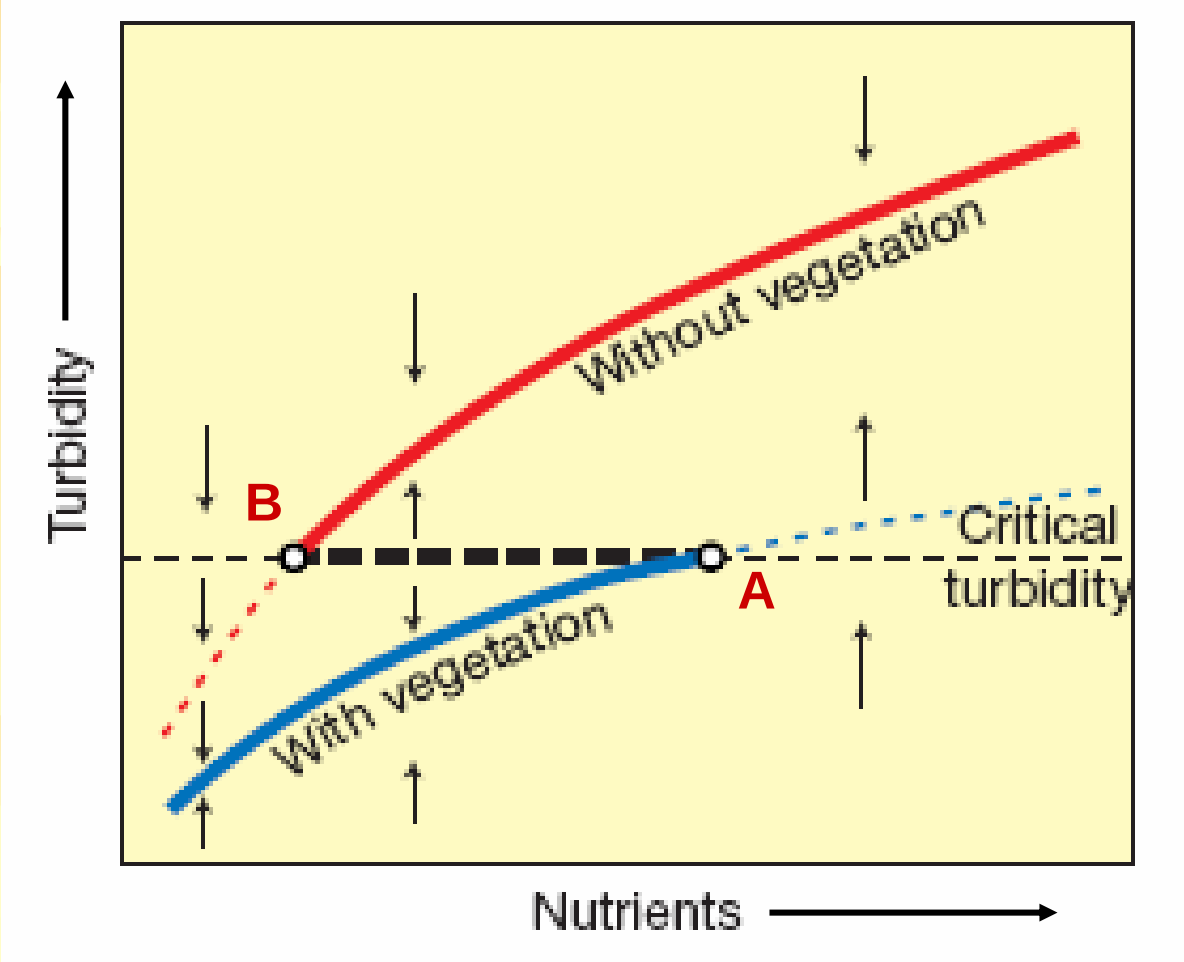
Archer, S. 1989. *The American Naturalist* 134:545-561.

Conceptualizing Archer (1989)





Example: Lake Turbidity



A. With vegetation, can tolerate high nutrient levels with low turbidity
B. Without vegetation, nutrients much lower to reach low turbidity
A→B: Hysteresis

Scheffer, M., S.H. Hosper, M.L. Meijer, B. Moss. 1993. *Trends in Ecology & Evolution* 8:275-279.

How are they used?

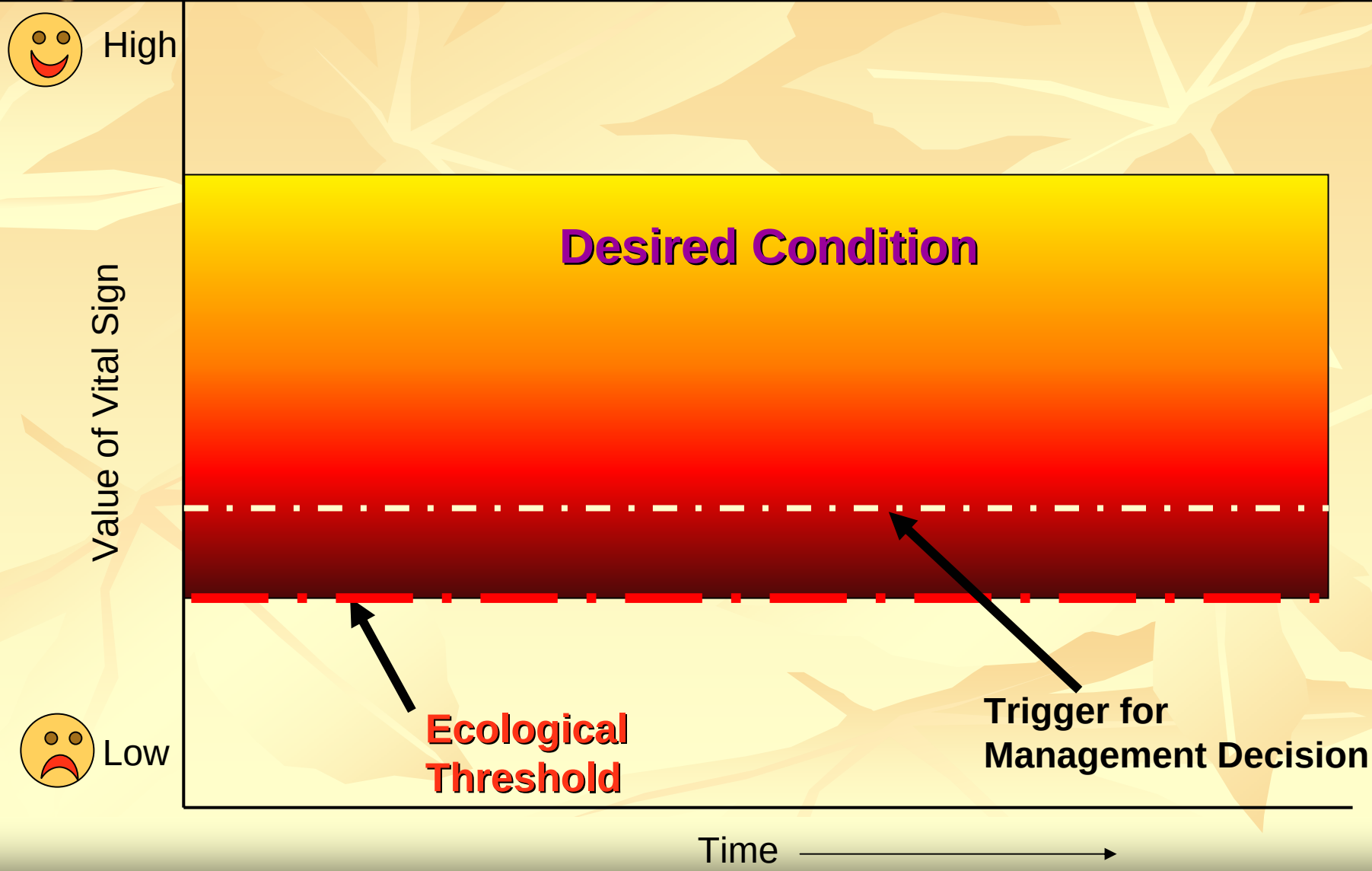
- Inform management
- Determine sampling design

How are they used?

Alert management of impending system transition:

- Implement remediation to avoid system degradation (assumes understanding of proximate factors) – well integrated monitoring should provide evidence for factors
- OR, invoke research to understand reasons for system dynamics

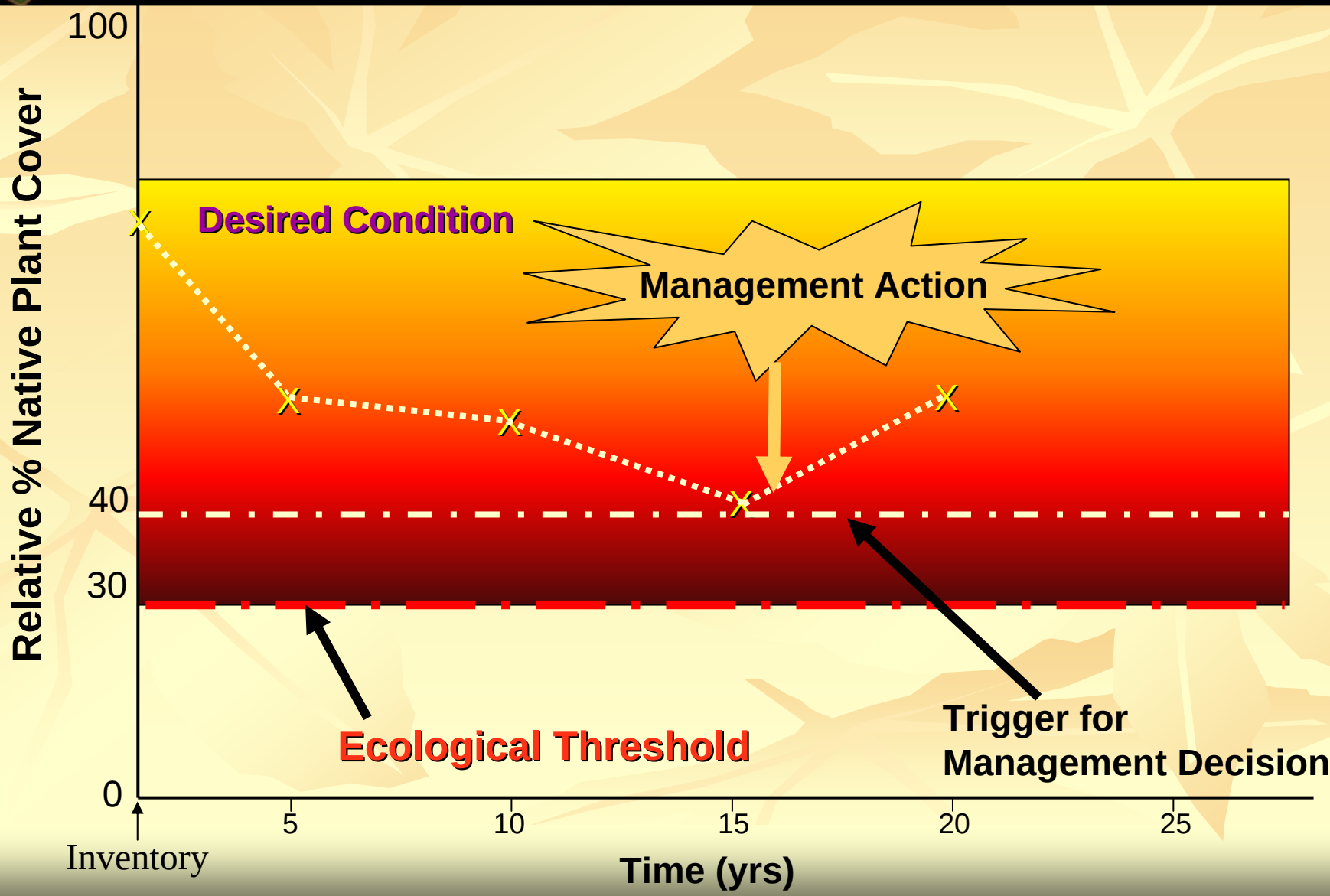
Putting Monitoring Results into Context



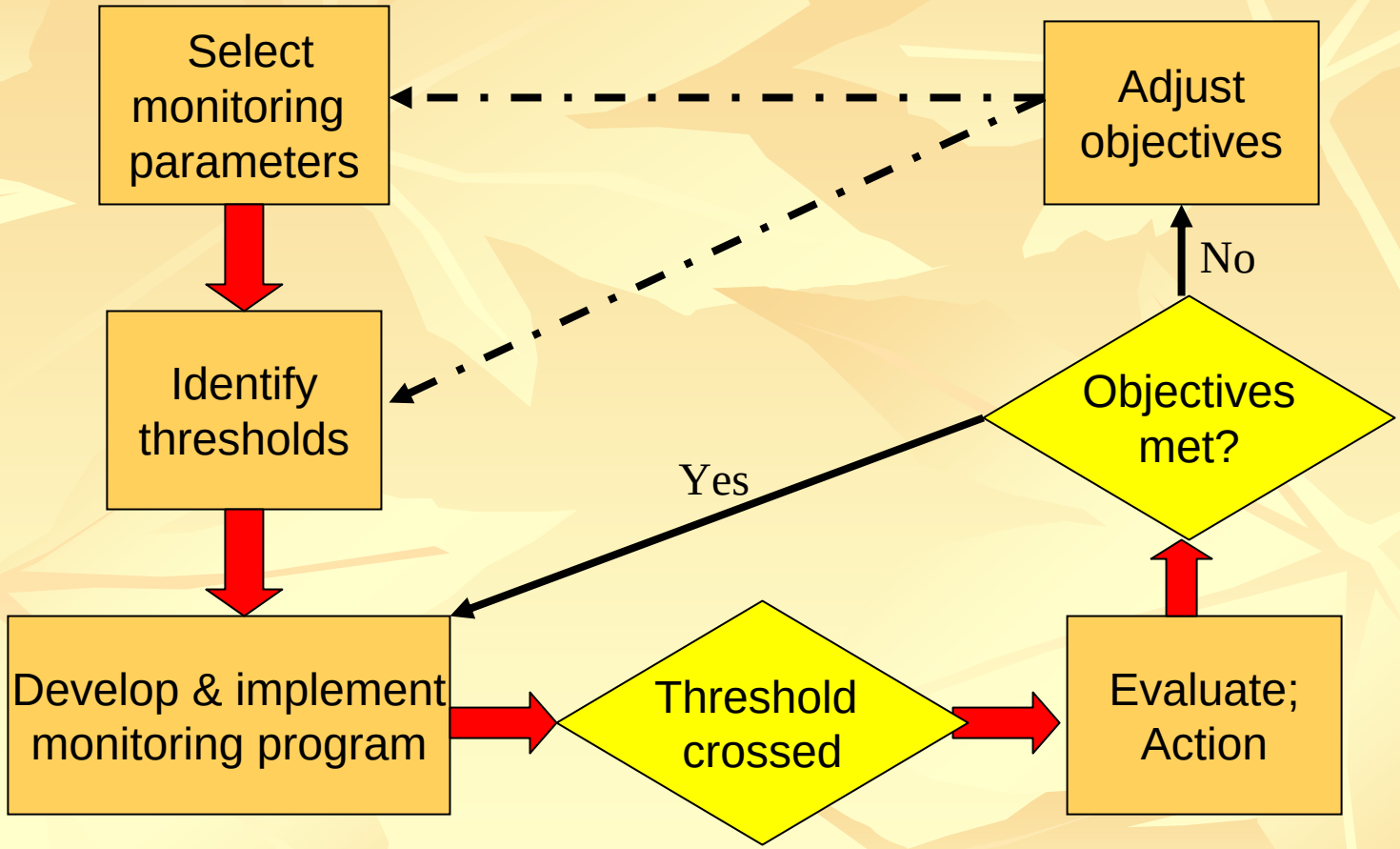
Management Triggers

- **Management triggers:** taking action before threshold is crossed
- Decision could be no action
- Need to consider at an appropriate scale (spatial and temporal)

Plant Cover Example



Proposed Approach: Linking monitoring and management



Adapted from: Biggs, H.C. and K.H. Rogers, 2003. An adaptive system to link science, monitoring, and management in practice. Pages 59-80 in: J. T. du Toit, K. H. Rogers, and H. C. Biggs. The Kruger experience: ecology and management of savanna heterogeneity. Island Press, Washington, D.C.

Use of Thresholds in Sampling Design

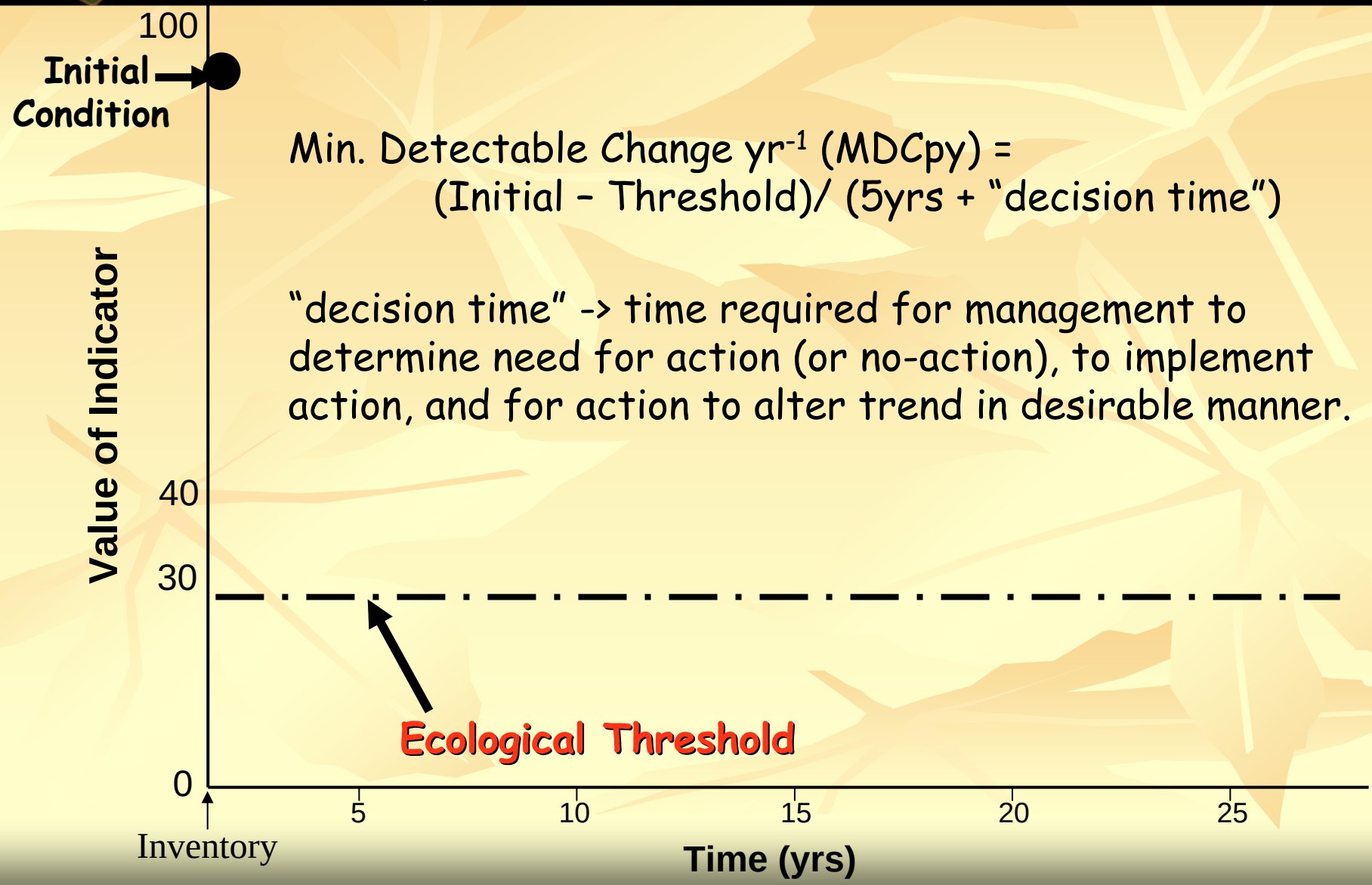
- Indicator must be estimated with sufficient precision and accuracy so that when an ecologically significant change has occurred, the likelihood it will be detected is high
- Further complicated with nonlinear changes in vital signs being monitored

Analytical Approach to Deriving a Sampling Objective Using Thresholds

A Sampling Objective states:
the minimum, statistically detectable change given a probability to detect a change when one occurs (Power), an acceptable probability of a false positive (Type I error), and a reference time frame (e.g., x% change per yr or per x yrs).

The Sampling Objective plus an estimate of variance are used to determine the number of monitoring locations (e.g., sampling plots) and the revisit schedule (i.e., frequency of revisits of each monitoring location)

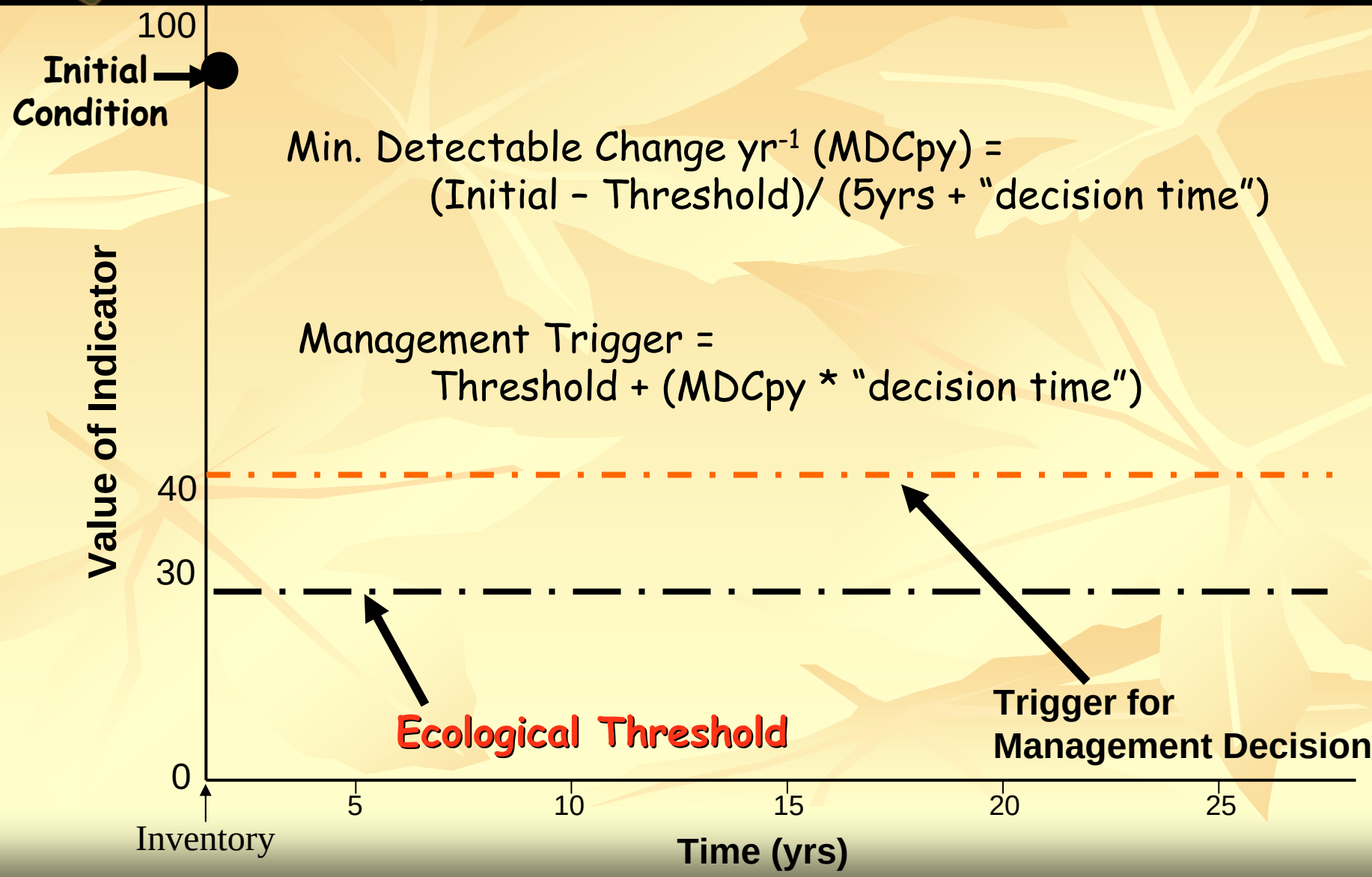
Analytical Approach to Sampling Objective using Thresholds



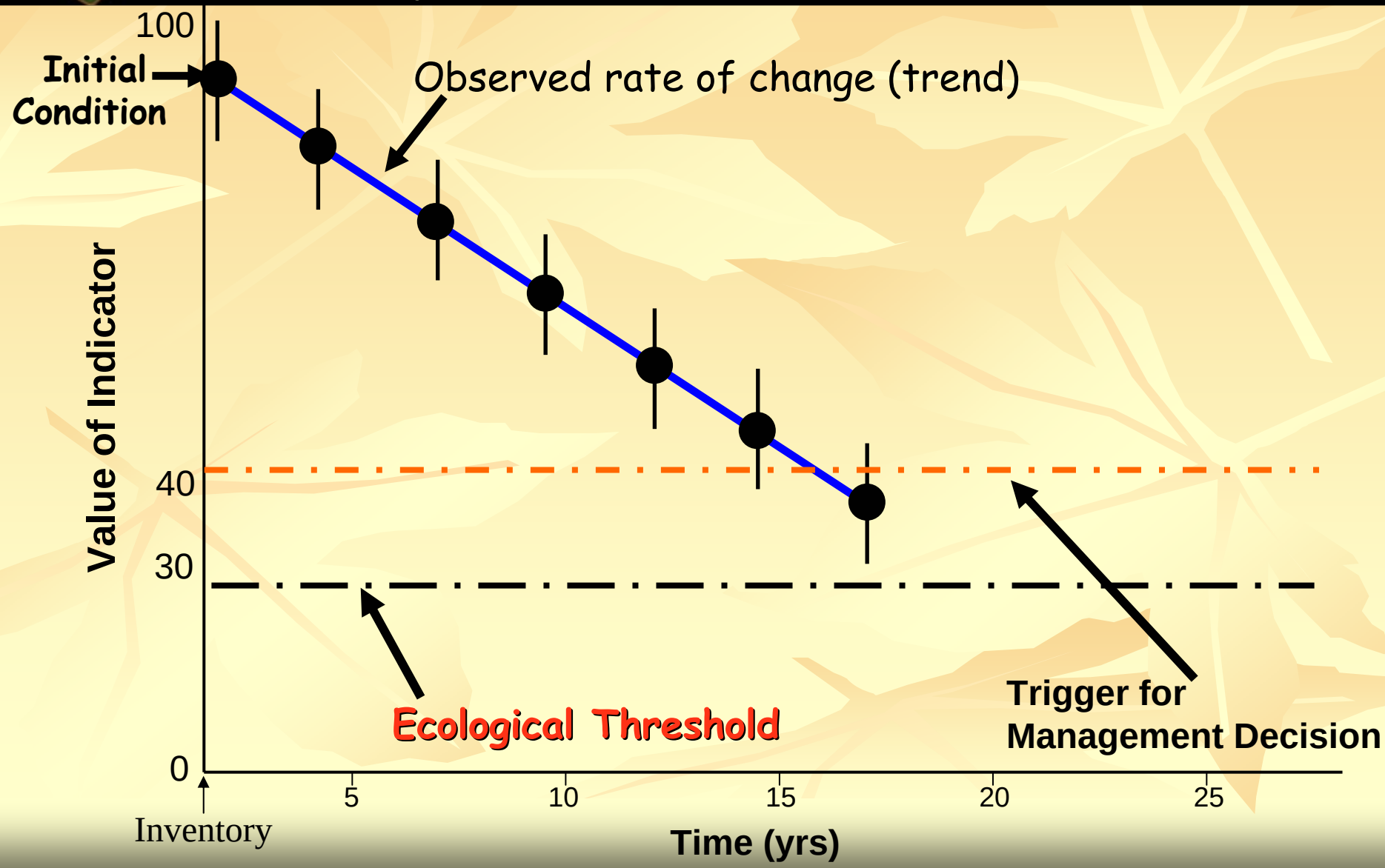
Min. Detectable Change yr^{-1} (MDCpy) =
(Initial – Threshold)/ (5yrs + "decision time")

"decision time" -> time required for management to determine need for action (or no-action), to implement action, and for action to alter trend in desirable manner.

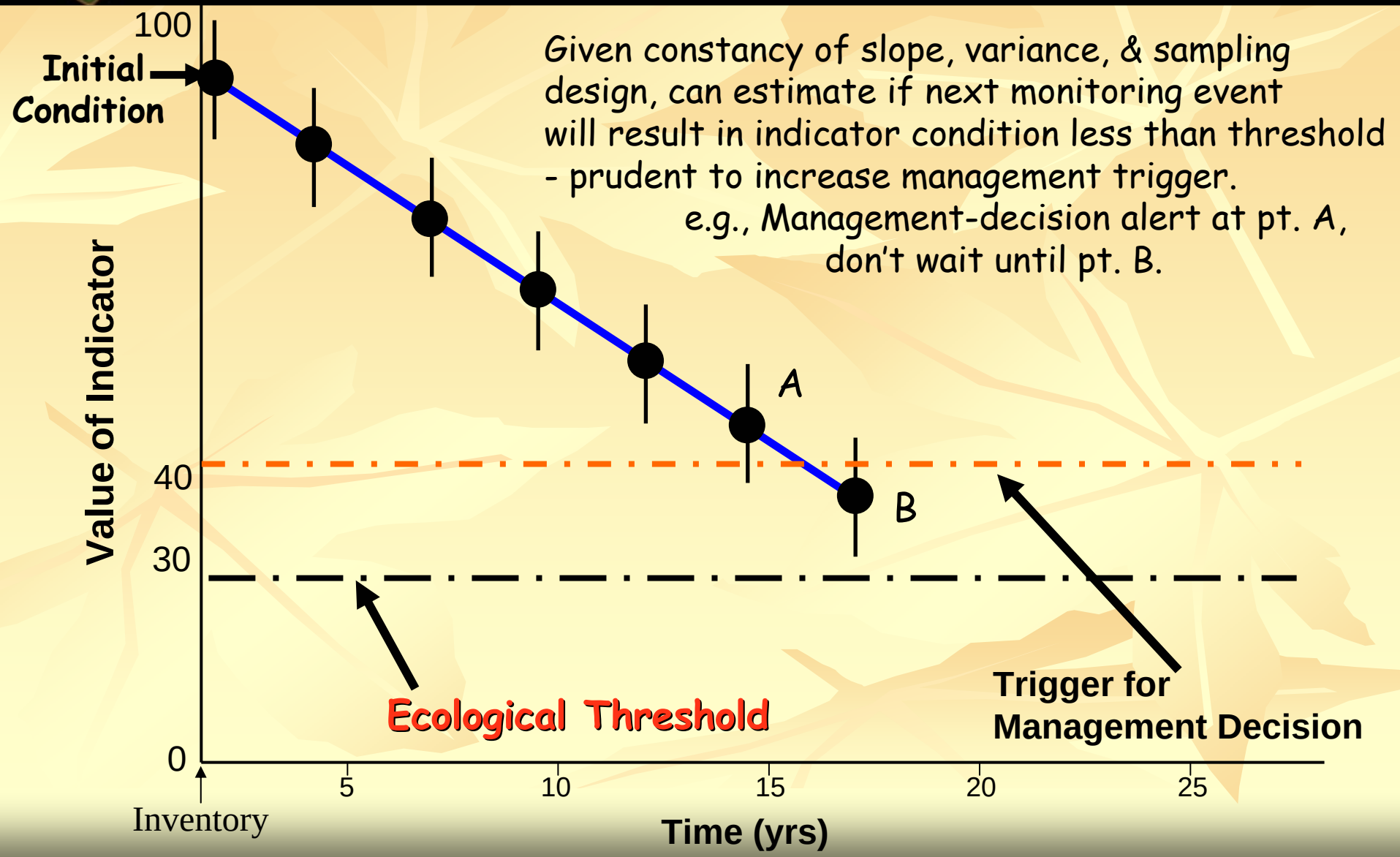
Analytical Approach to Sampling Objective using Thresholds



Analytical Approach to Sampling Objective using Thresholds



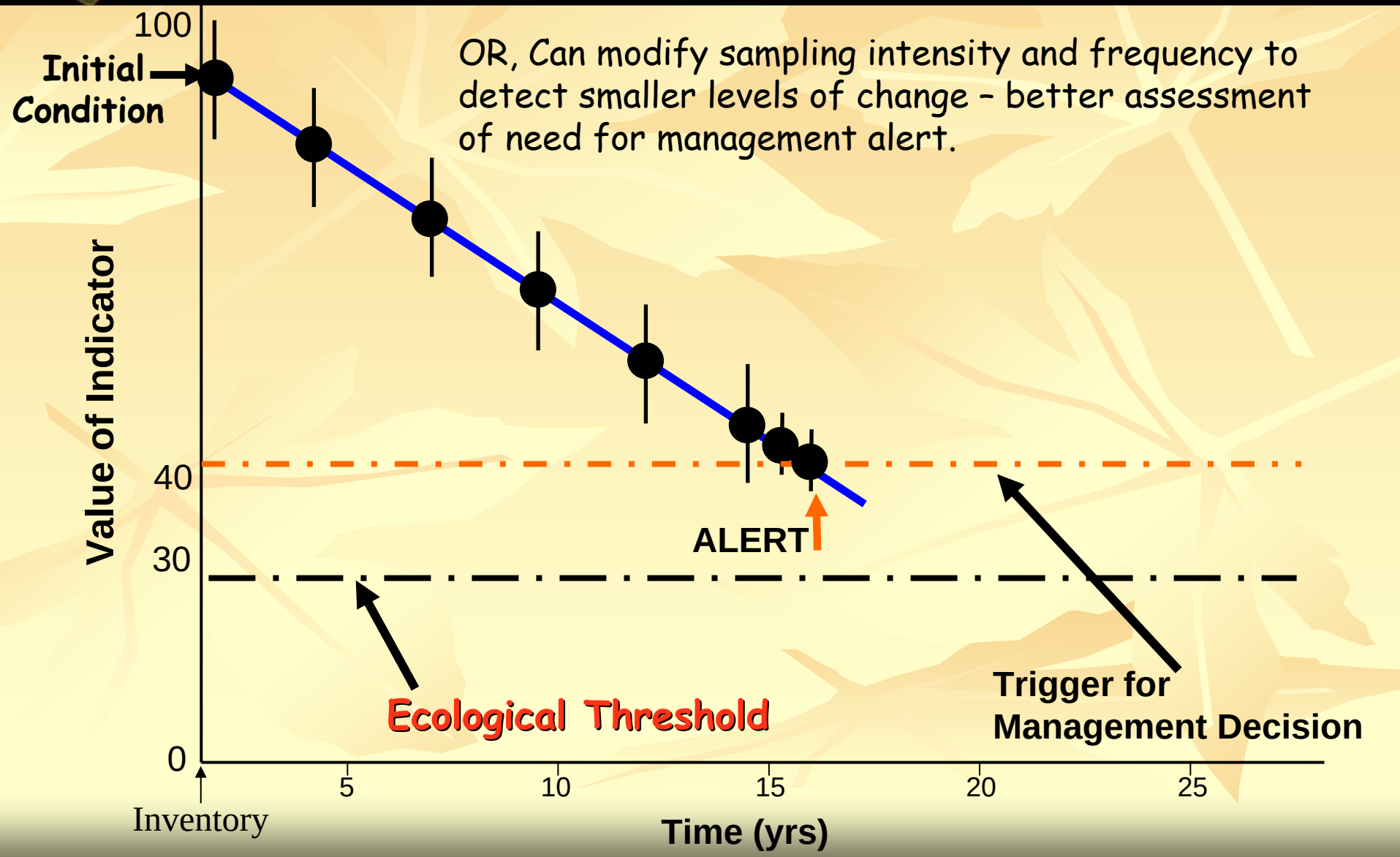
Modifying Management Trigger



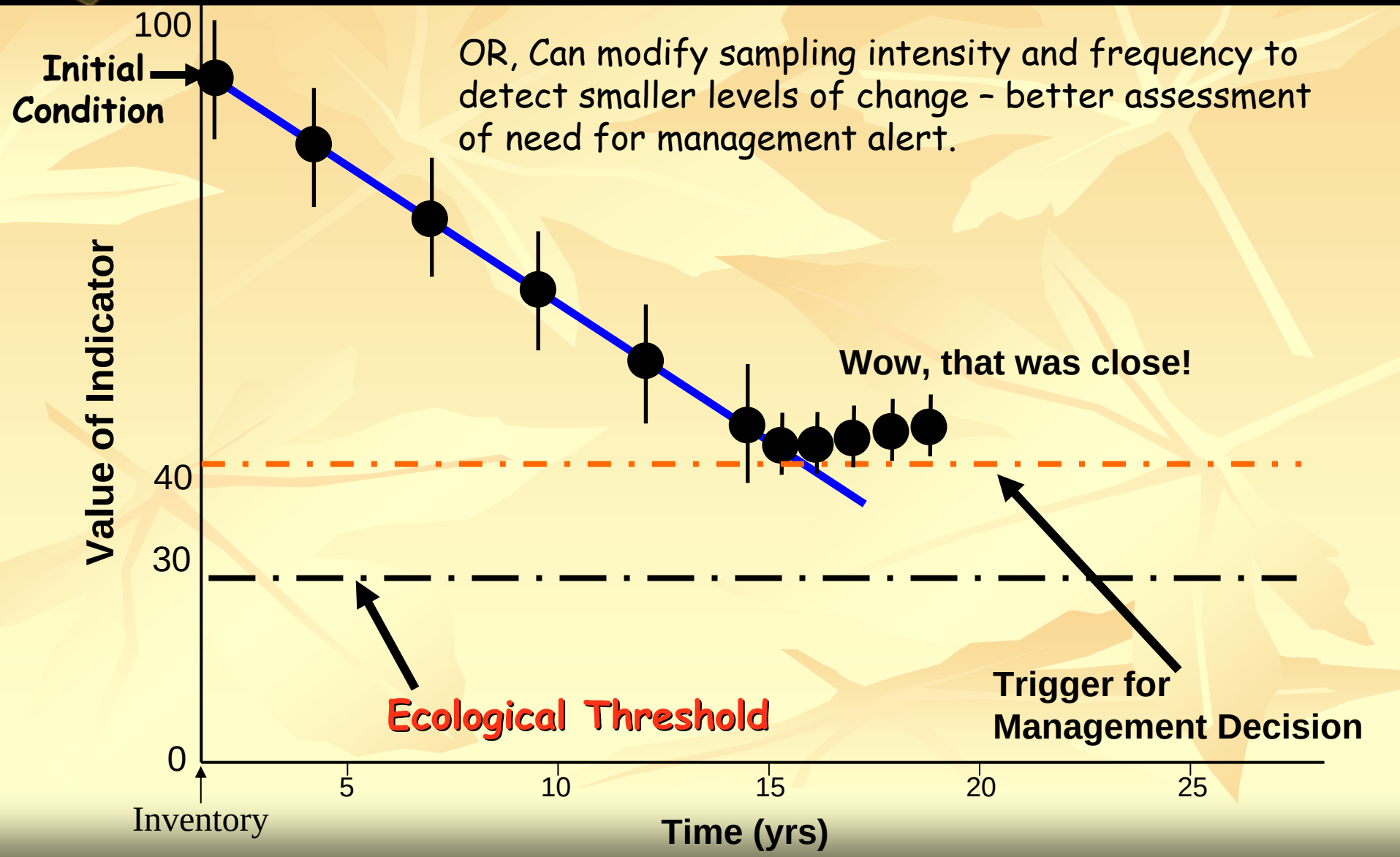
Given constancy of slope, variance, & sampling design, can estimate if next monitoring event will result in indicator condition less than threshold - prudent to increase management trigger.

e.g., Management-decision alert at pt. A, don't wait until pt. B.

Modifying Sampling Design



Modifying Sampling Design



How are they determined?

- Extensive field studies, experimental tests of hypotheses
- Meta analysis of extant studies
- Expert opinion
- Simulation analyses
- SWAG

How are they determined: Meta-analysis; Other studies

Literature-driven identification of management thresholds:

- minimum forest reserve area
- minimum forest patch size

Minimal areas of strict forest reserves

	Minimum area
Based on forest structure research[a]	
Extreme sites	5–20 ha
Mixed forests	10 ha
Beech–oak-forests, Beech forests, Beech–fir-forests	50 ha
Mixed mountain forests, Mixed alpine forests	70–100 ha
Based on faunistic and site studies[b]	
Micro- +Mesofauna (p.p. macrofauna)	50–100 ha
Large mammals/birds	⋙ 100 ha
Typical site mosaic or landscape fraction	100 ha
Concepts and recommendations	
IUFRO Subject Group Virgin Forests (Oslo 1976; Mayer 1976)	Areas sufficient for simultaneous occurrence of all phases
WWF (conclusions of workshop Zvolen 1994; Paulenka and Paule, 1994)	Areas sufficient for maintaining their sustained development
Council of Europe (1986, Workshop Bavarian forest 1986; Heiss, 1987)	>50 ha

Bucking, W. 2003. *Journal of Environmental Management* 67:37-45.

Cross-tabulation

	Minimum patch size	Maximum inter-patch distance
Species 1	30 m^2	50 m
Species 2	100 m^2	75 m
Species 3	75 m^2	75 m
Species 4	200 m^2	100 m

How are they determined: Expert opinion

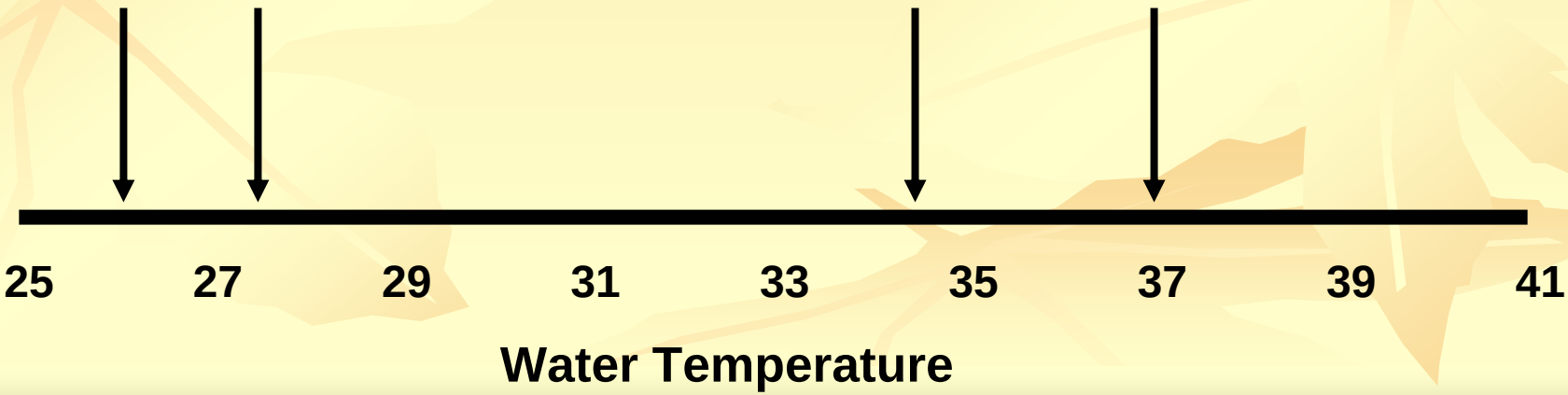
- Conservative estimates: propose a threshold, give justification
- Refine through research, increased understanding

How are they determined: Expert Opinion

- What is a threshold for stream temperature?

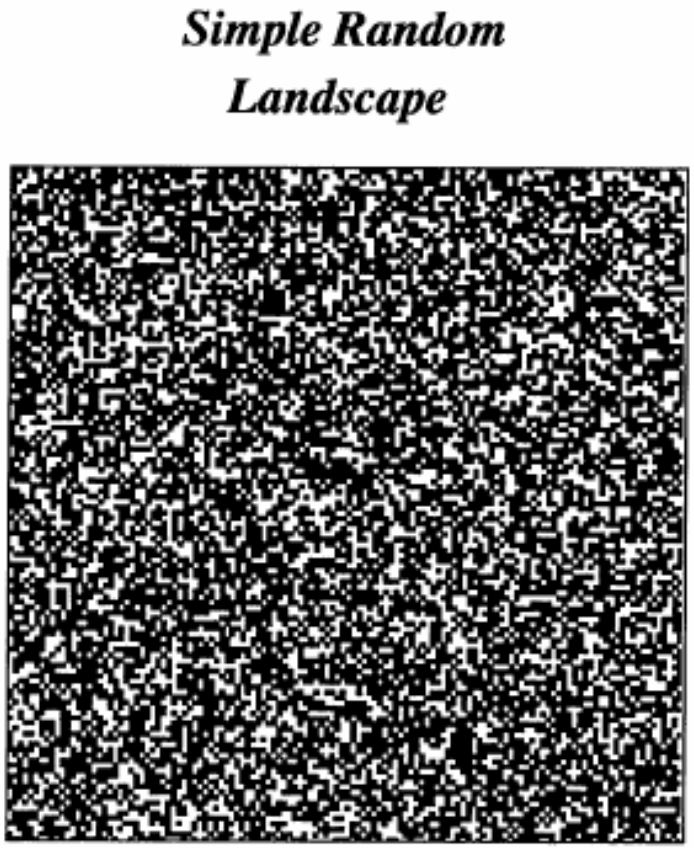
How are they determined: Expert Opinion

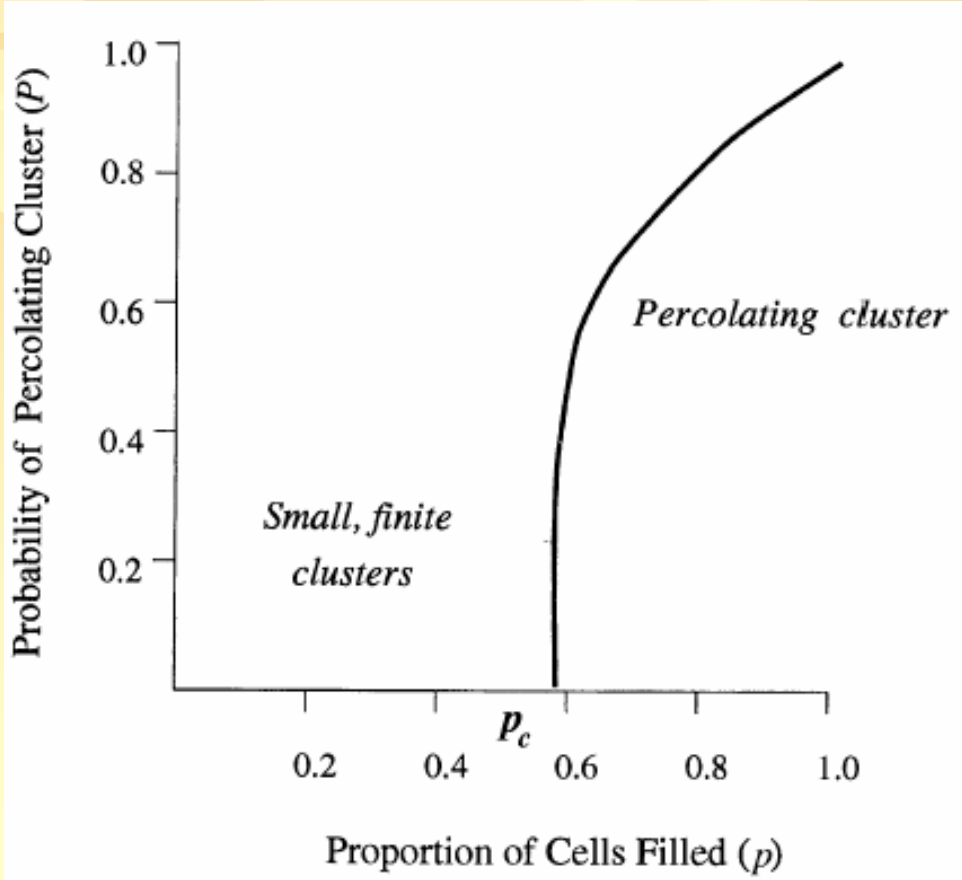
- Do you care if you lose aquatic macroinvertebrate species x?
- Do you care if you lose a minnow species?
- Do you care if you lose cutthroat trout?
- Do you care if you lose a different fish species?



How are they determined: Simulation analyses

Habitat Connectivity Thresholds





With, K.A. and T.O. Crist. 1995. *Ecology* 76:2446-2459.

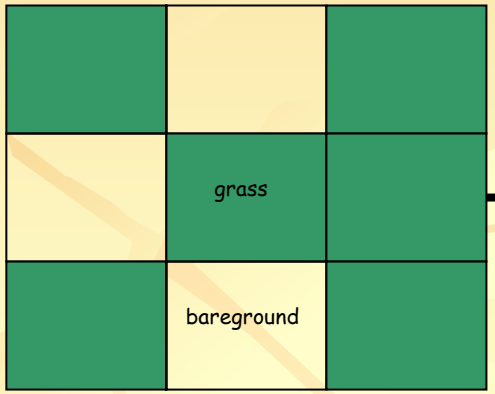
An Example from NCPN

- Determining a threshold value for grass cover to carry a fire at Dinosaur NM

How much grass cover will carry a wildfire?

Simulate fire spread under different environmental conditions, & % grass cover (extent and mass)

Lattice of grass cover – ca. 5K ha



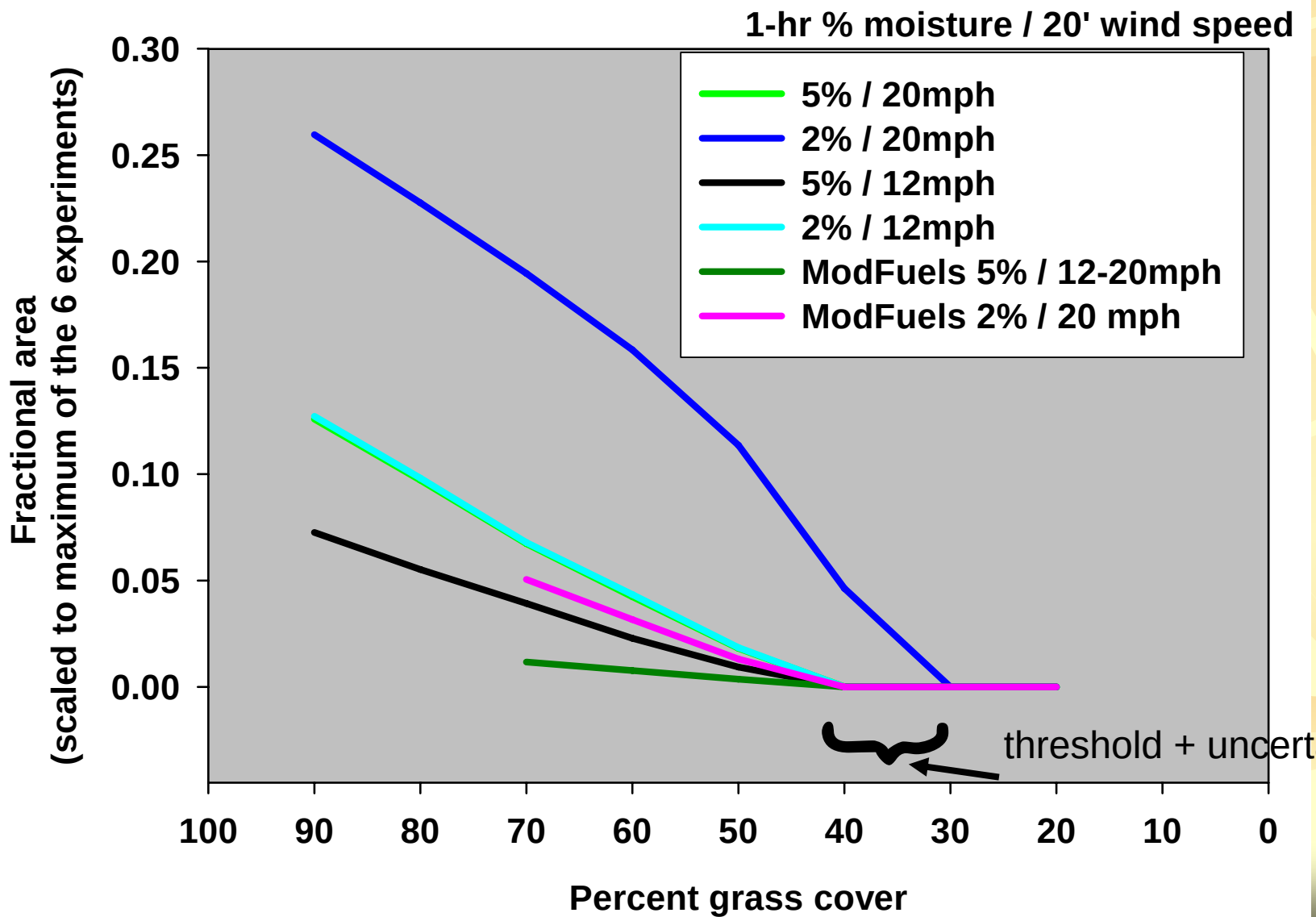
fuel loading, slope, aspect

Spatial variant of BEHAVE, modified to allow fire to 'jump' among cells as a function of flame length (Garman 1992, in prep.)

Experiment with different wind speed & fuel moisture, and grass-cover levels (% cover). Used NFFL Model 1 (short grass)

Delineate thresholds (where fire will not carry) & uncertainty (different env. conditions & assumptions)

How much grass cover will carry a wildfire?



Ultimate Decision: Combination of Approaches

- Compile information from variety of sources
- Propose something reasonable
- Follow up with targeted research, revision based on incoming information

Additional Considerations

- Systems are not static: Resilience changes
- Dynamic system may require revision of threshold/trigger values in future

Disadvantages: Difficulties in determining

- For some species, little evidence for thresholds
- Inadequate knowledge of systems
- Wide variability in species' response to the same variability

Still useful to start with something – can refine as collect more information

Summary of Key Points:

- Thresholds: point/zone of rapid ecological change
- Crossing thresholds can lead to alternative states with alternative species assemblages
- Identifying thresholds can assist in determining management triggers, sampling design
- Determined multiple ways:
  - Field studies
  - Meta analysis of extant studies
  - Expert opinion
  - Simulation analyses
  - SWAGs
- Threshold and trigger values can be modified as information is gained

Questions for thought

- Is there a process we can follow to identify ecological thresholds and management decision points for our systems?
- Who should be involved in this process for identification, revision?