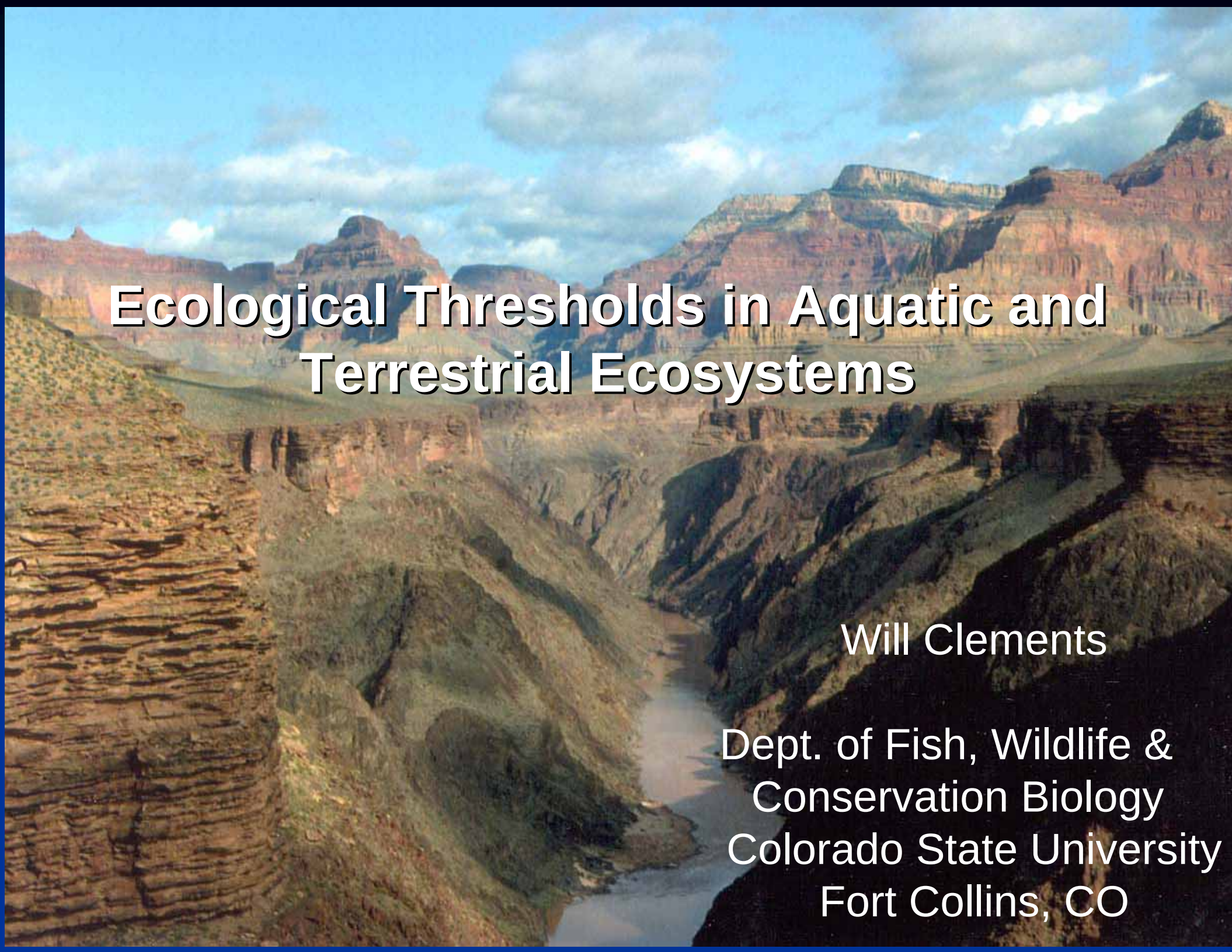




Ecological Thresholds in Aquatic and Terrestrial Ecosystems

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Overview

1. What are ecological thresholds?
2. How have ecological thresholds been applied (or misapplied) in the literature?
3. How to detect ecological thresholds
→ example from a long-term monitoring program
4. Research questions

Ecological Threshold

The point at which there is an abrupt change in an ecosystem quality, property or phenomenon; where small changes in an environmental driver produce large responses in the ecosystem

Goffman et al 2006

Sudden change in any property of an ecological system as a consequence of smooth and continuous change in an independent variable

Muradian 2001

Transition from One Stable State to Another

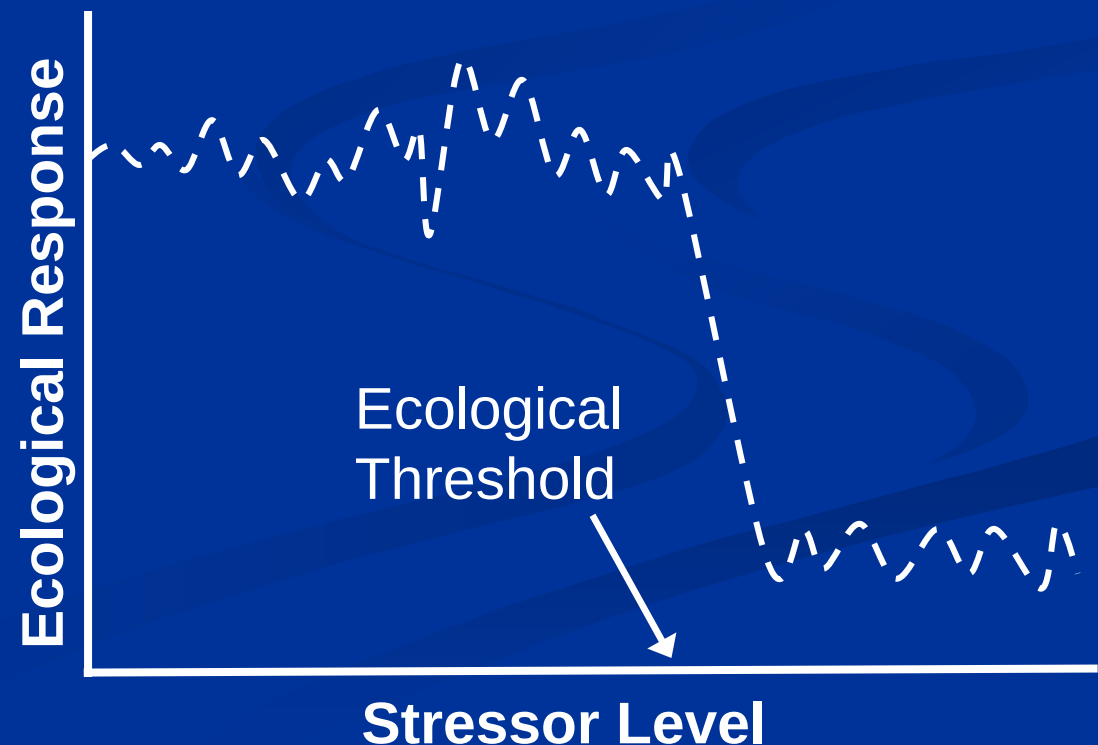
Physical Sciences

John Dalton (1801): change from liquid to vapor

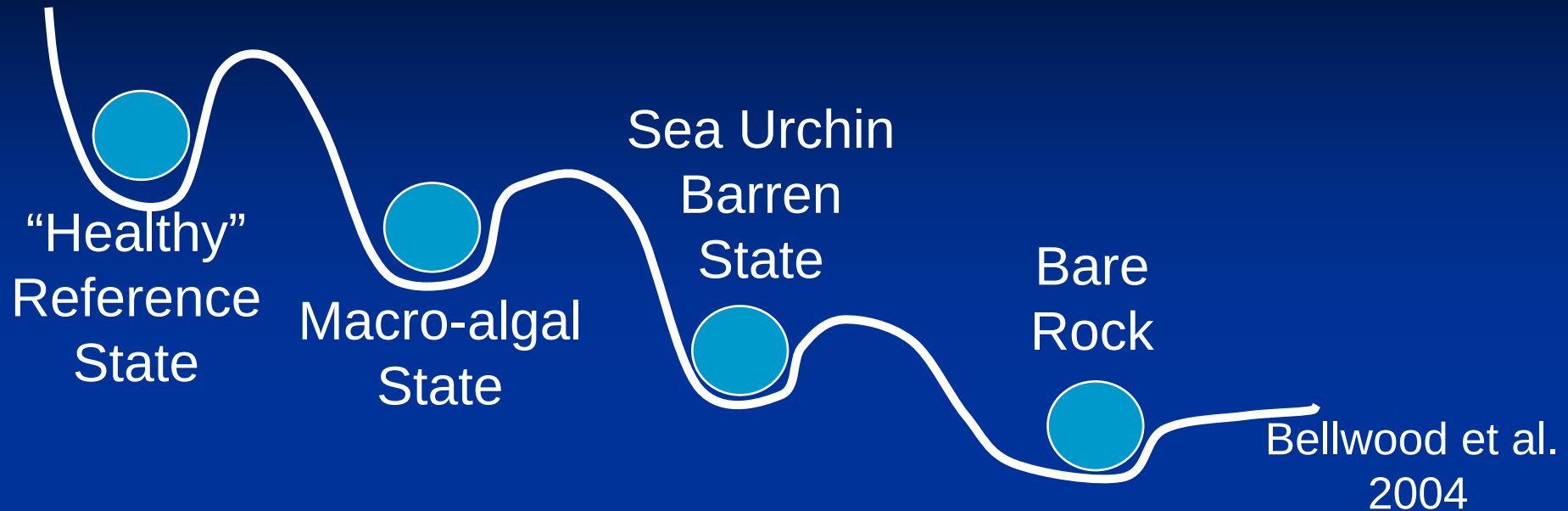
Human Demography

Gompertz (1825): age-specific mortality rates

Ecological Sciences



Coral Bleaching and Ocean Temperatures



Diverse Terminology in the Ecological Literature

Ecological thresholds

Ecological discontinuities

Critical thresholds

Environmental thresholds

Changepoints, breakpoints

Tipping points

“...at this state of knowledge, the ecological science is more able to predict the magnitude of change than the threshold values.” Muradian 2001

Although thresholds may be useful from an explanatory perspective, *“in most instances they are likely to be of limited value in a predictive sense”* Lindenmayer et al. 2005

“Anyone claiming to know for sure when a particular tipping point will be reached should be treated with suspicion” Nature, 2006

Potential for Misapplication of Threshold Concept

Are ecological thresholds a potentially
“*dangerous minimalist approach*”?

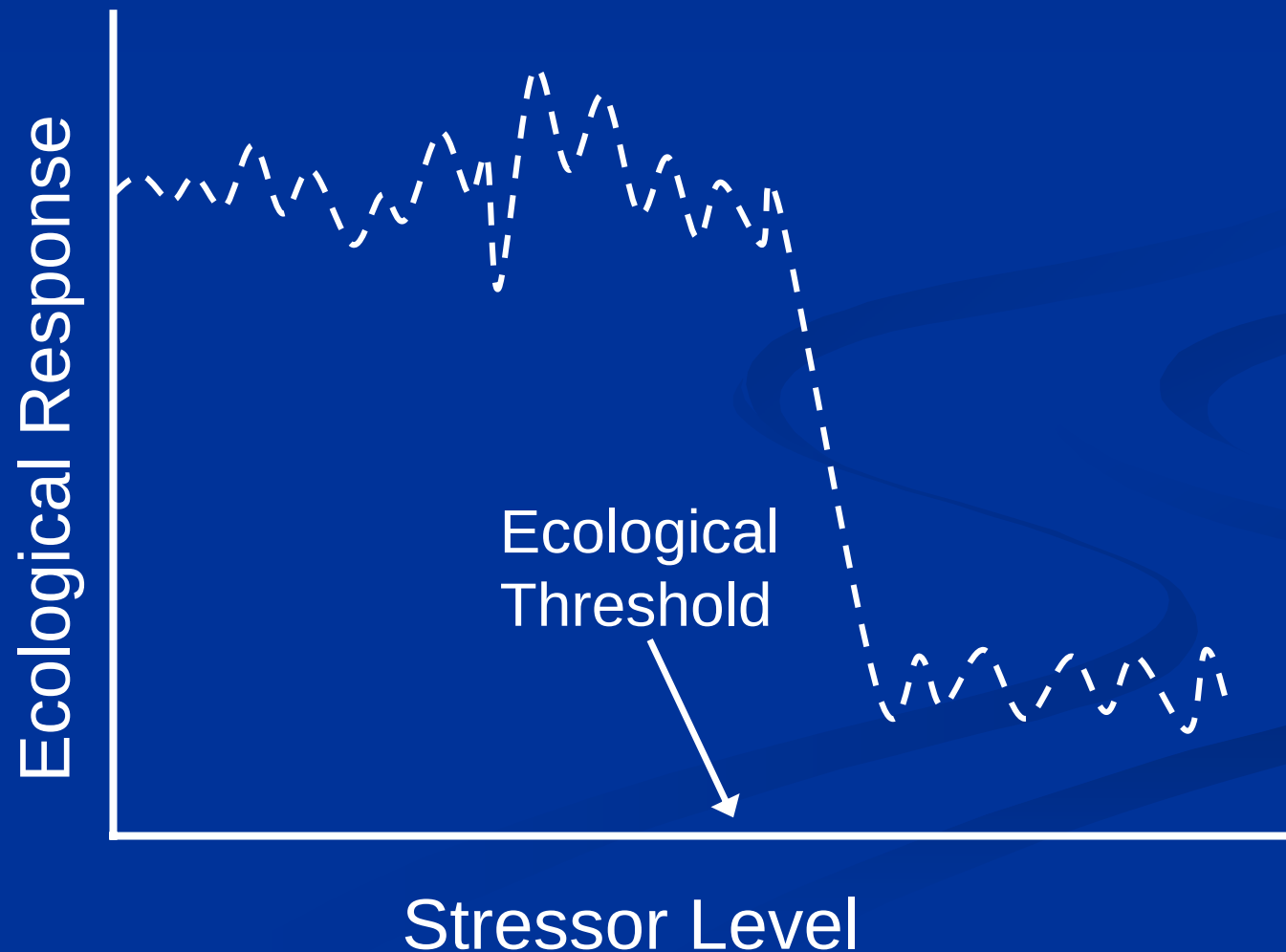
(Lindenmayer & Luck 2005)

Used to set benchmarks for management
purposes

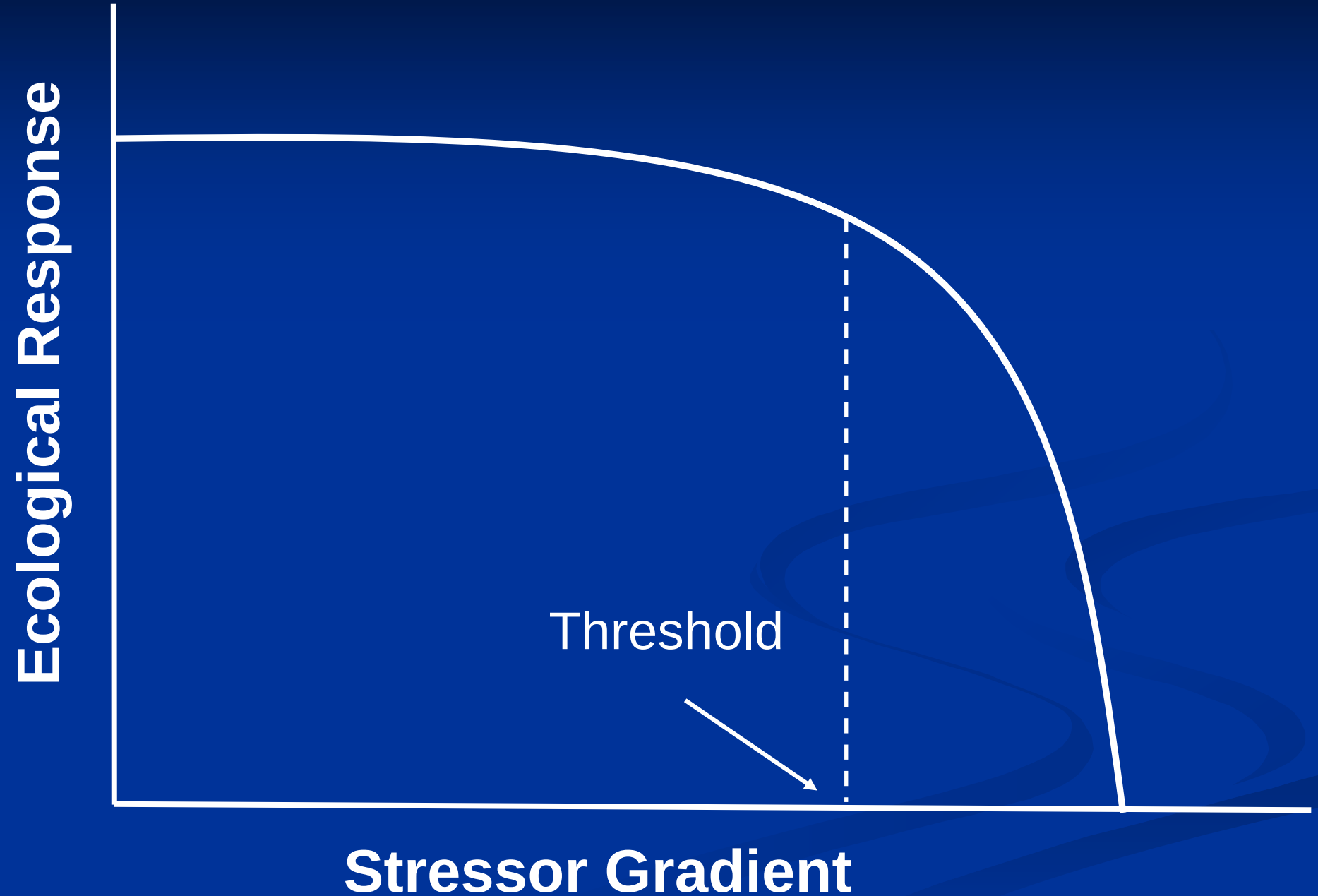
- Clearing of native vegetation to 30%
- Impervious surface
- Nutrient criteria

Theoretical Foundation for Ecological Thresholds

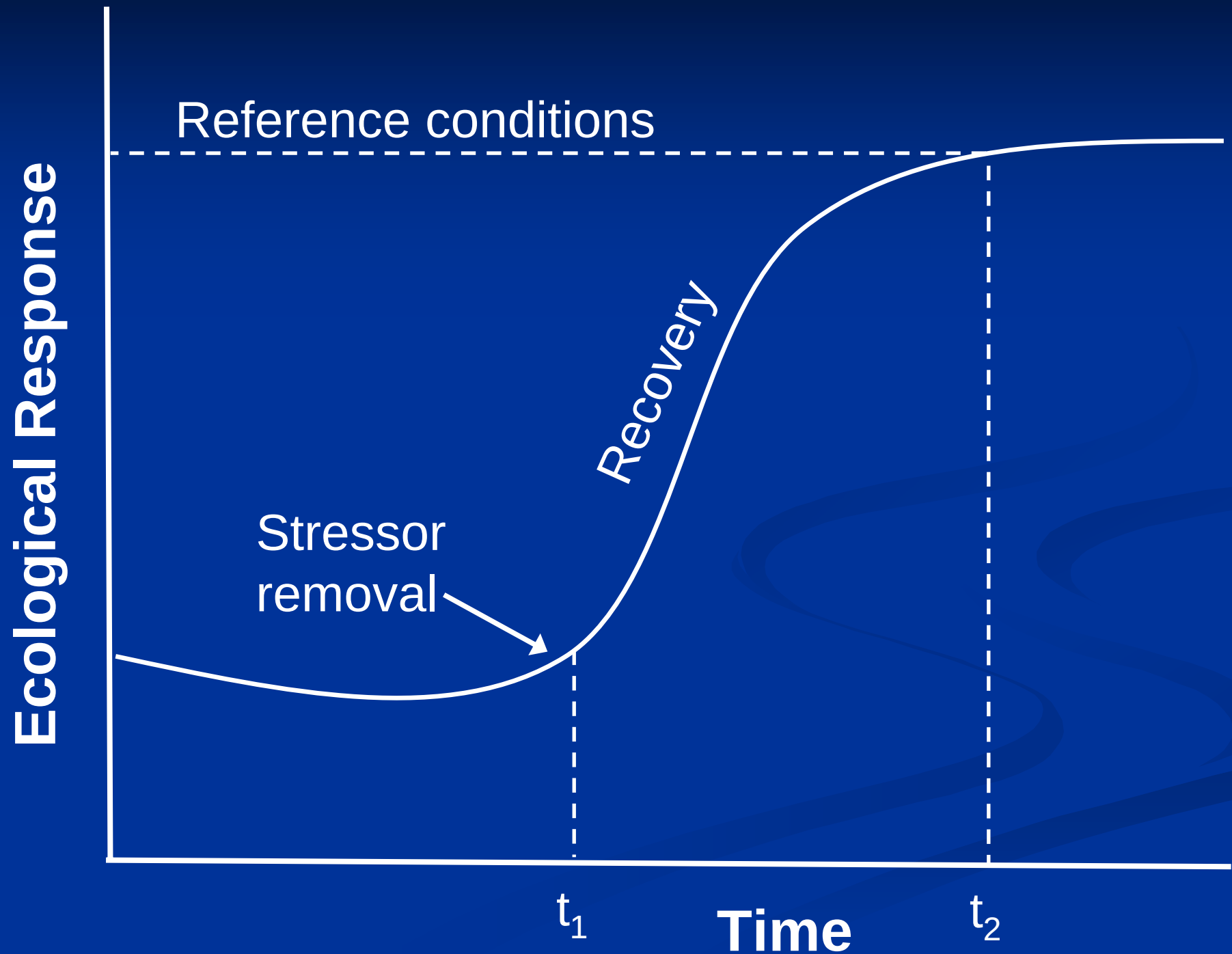
- Resistance and Resilience Stability
- Diversity-Ecosystem Function Relationships



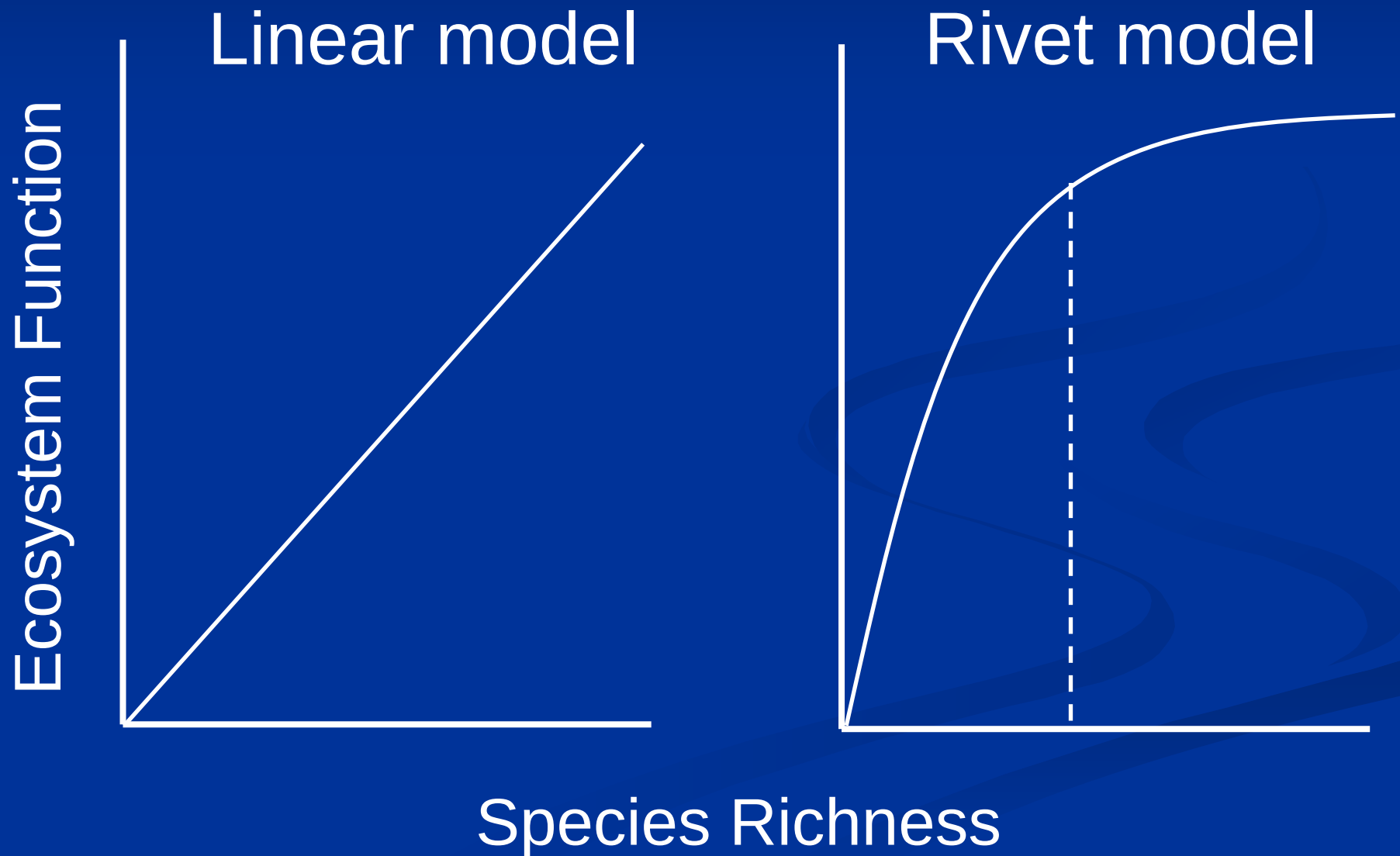
Stressor Resistance (= persistence)



Stressor Resilience (= elasticity)



Species Diversity, Ecosystem Function & Ecological Thresholds



Applications

- Responses of aquatic ecosystems to pollution

Ex) establishment of critical nutrient loads

- Critical habitat requirements for wildlife

Ex) decline in bird species richness
below 20-30% habitat cover

- Ecosystem responses to climate change

Tipping Point (Malcolm Gladwell)

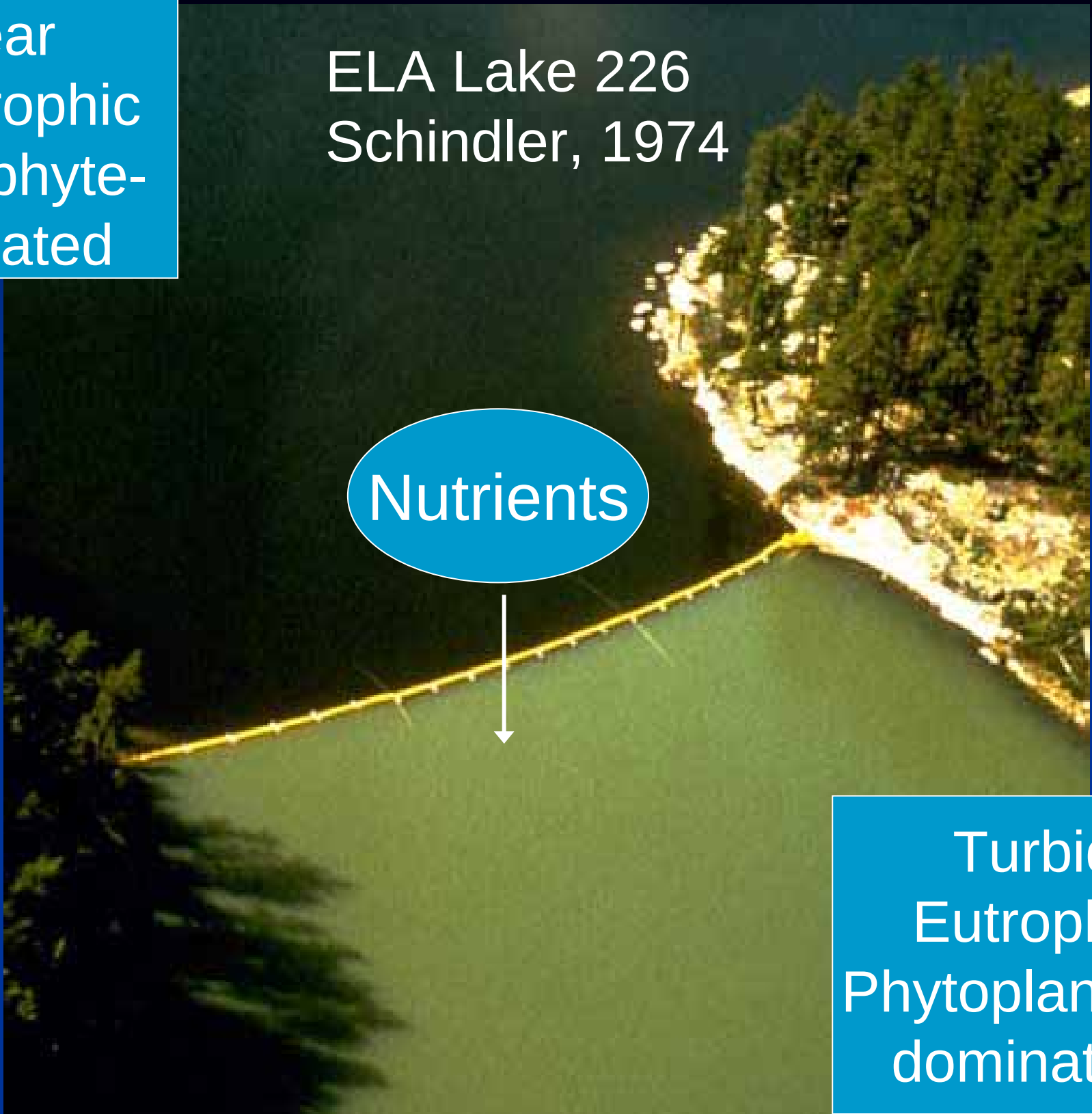
Clear
Oligotrophic
Macrophyte-
dominated

ELA Lake 226
Schindler, 1974

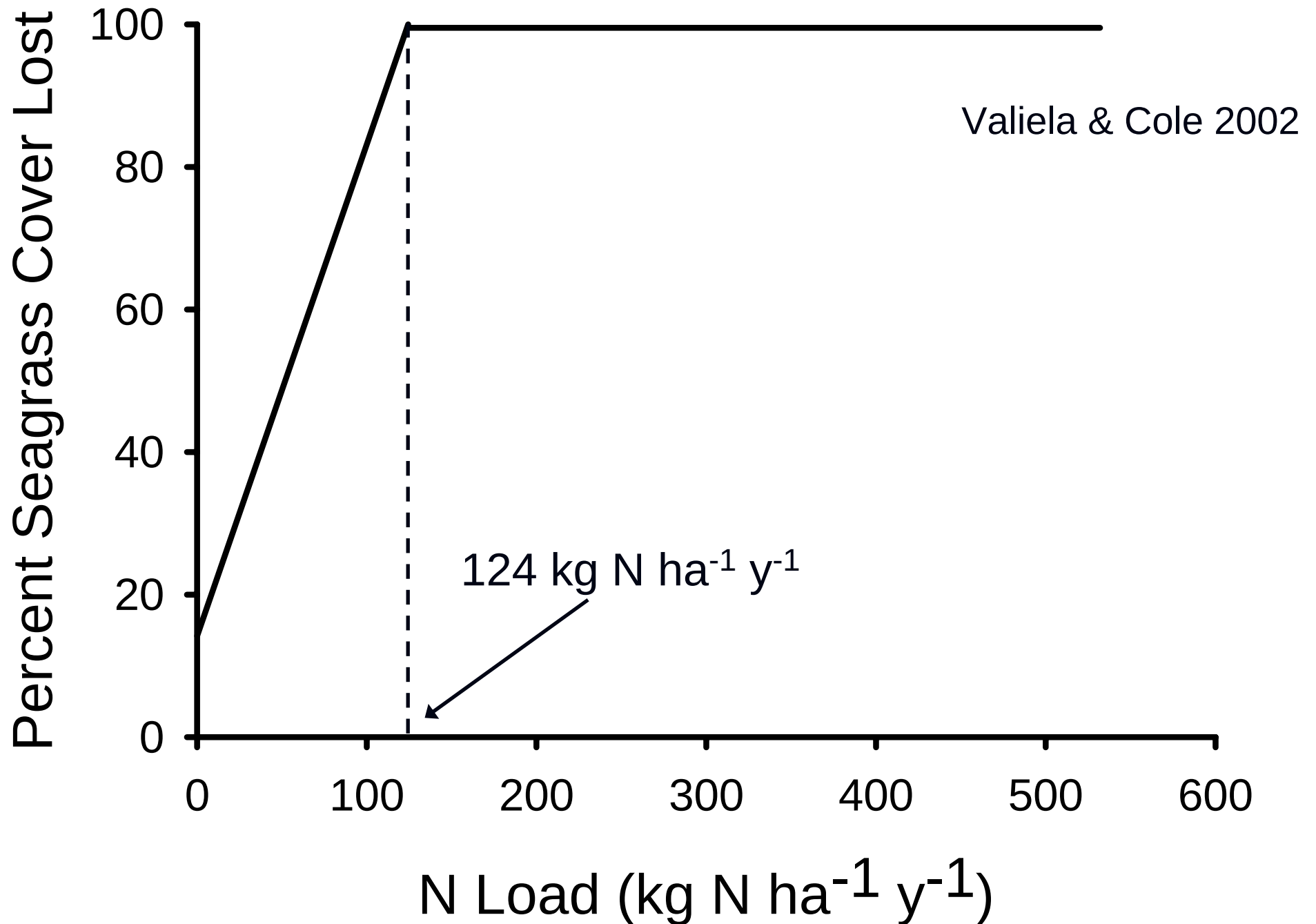
Nutrients



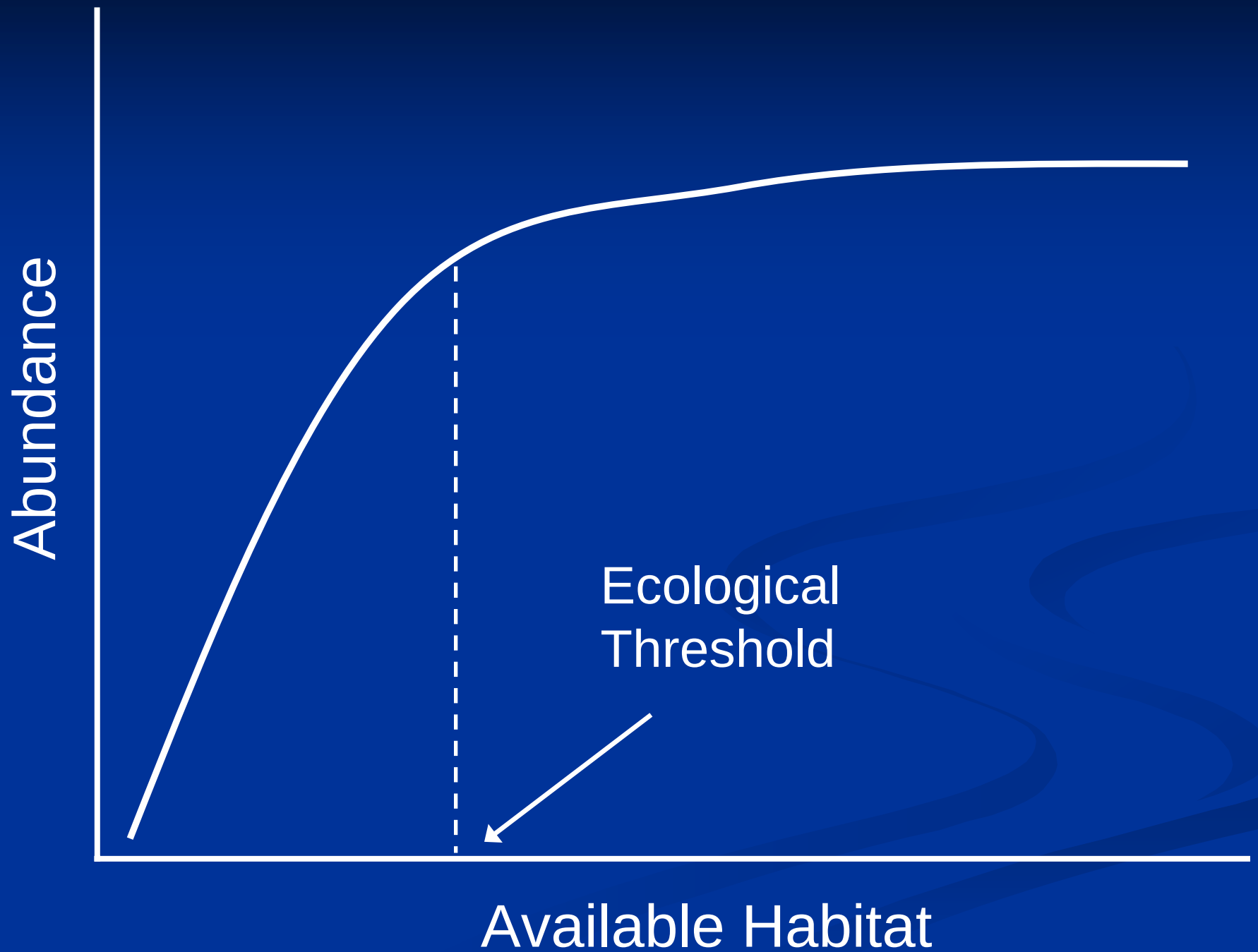
Turbid
Eutrophic
Phytoplankton-
dominated



N Loading and Seagrass Loss

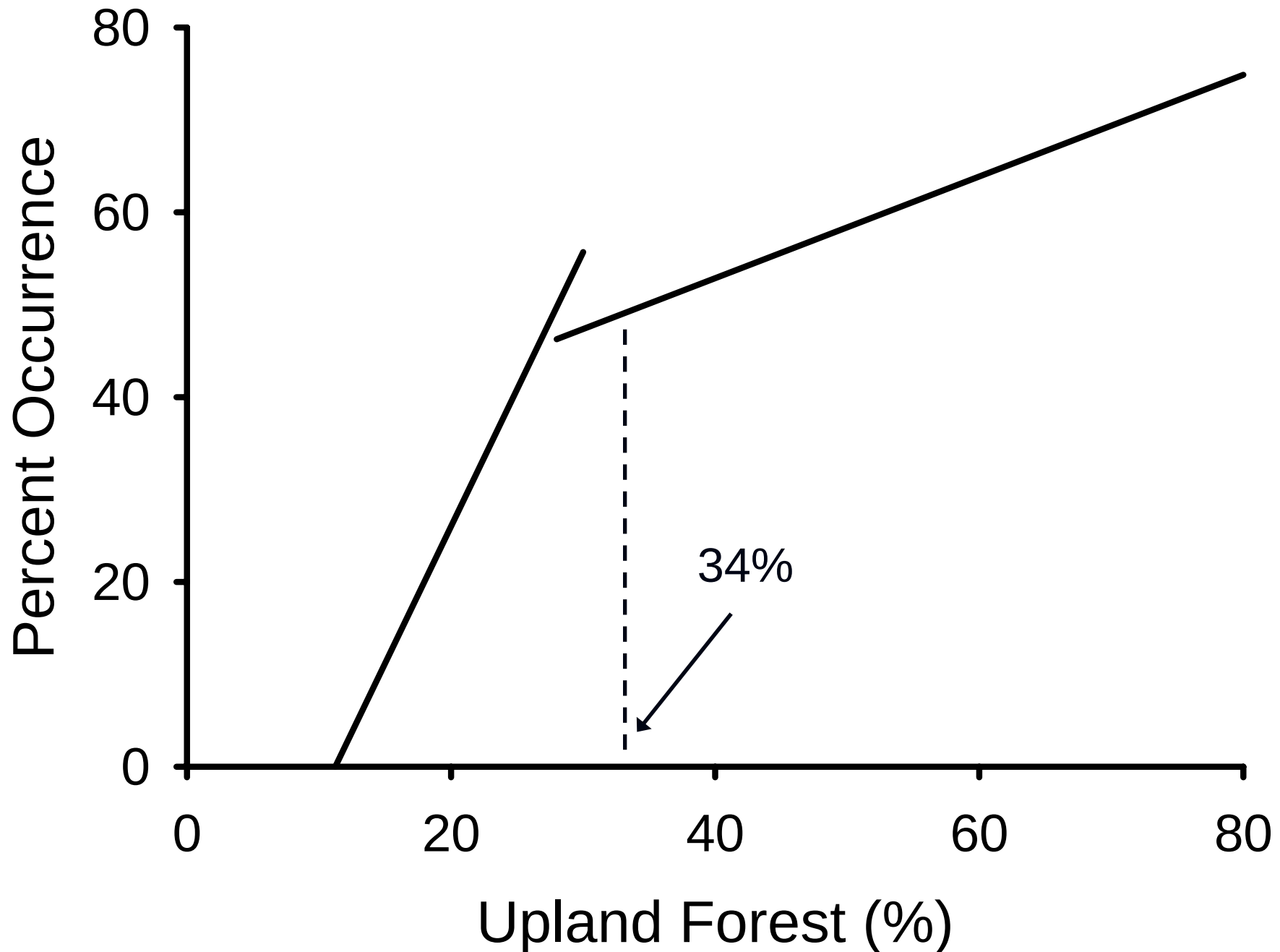


Habitat Loss for Birds and Mammals



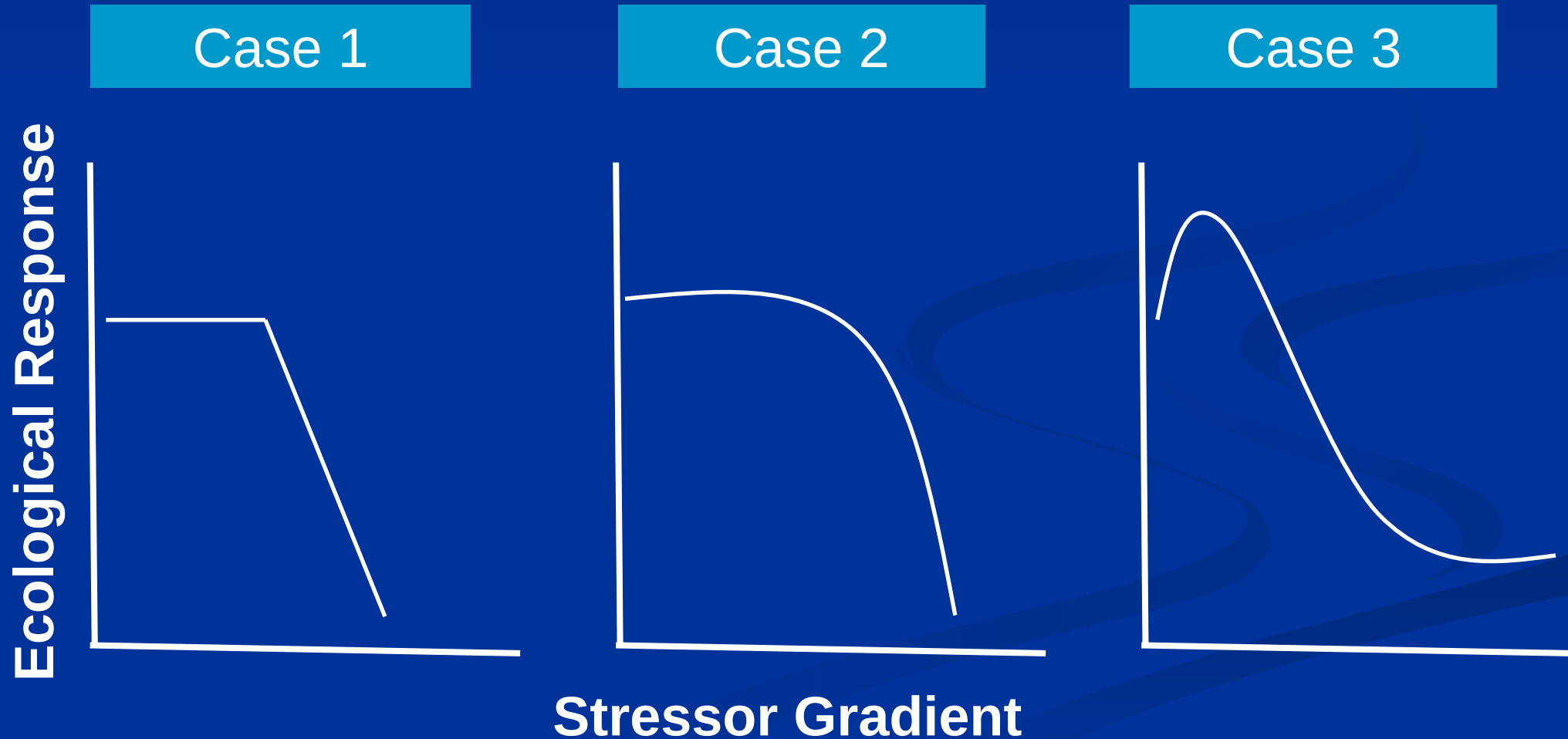
Critical Thresholds for Spotted Salamanders

Homan et al 2004

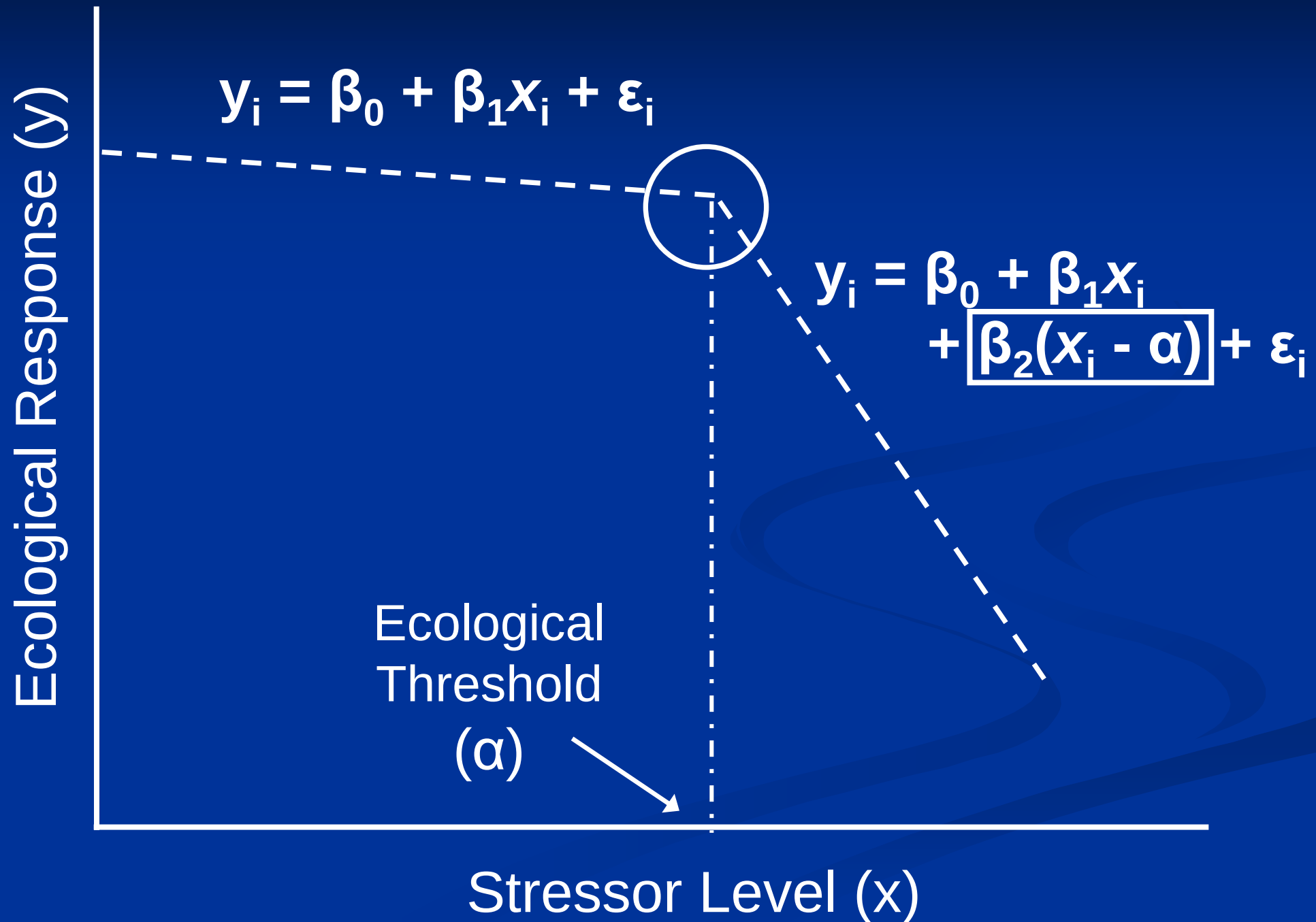


Detecting Ecological Thresholds is Challenging

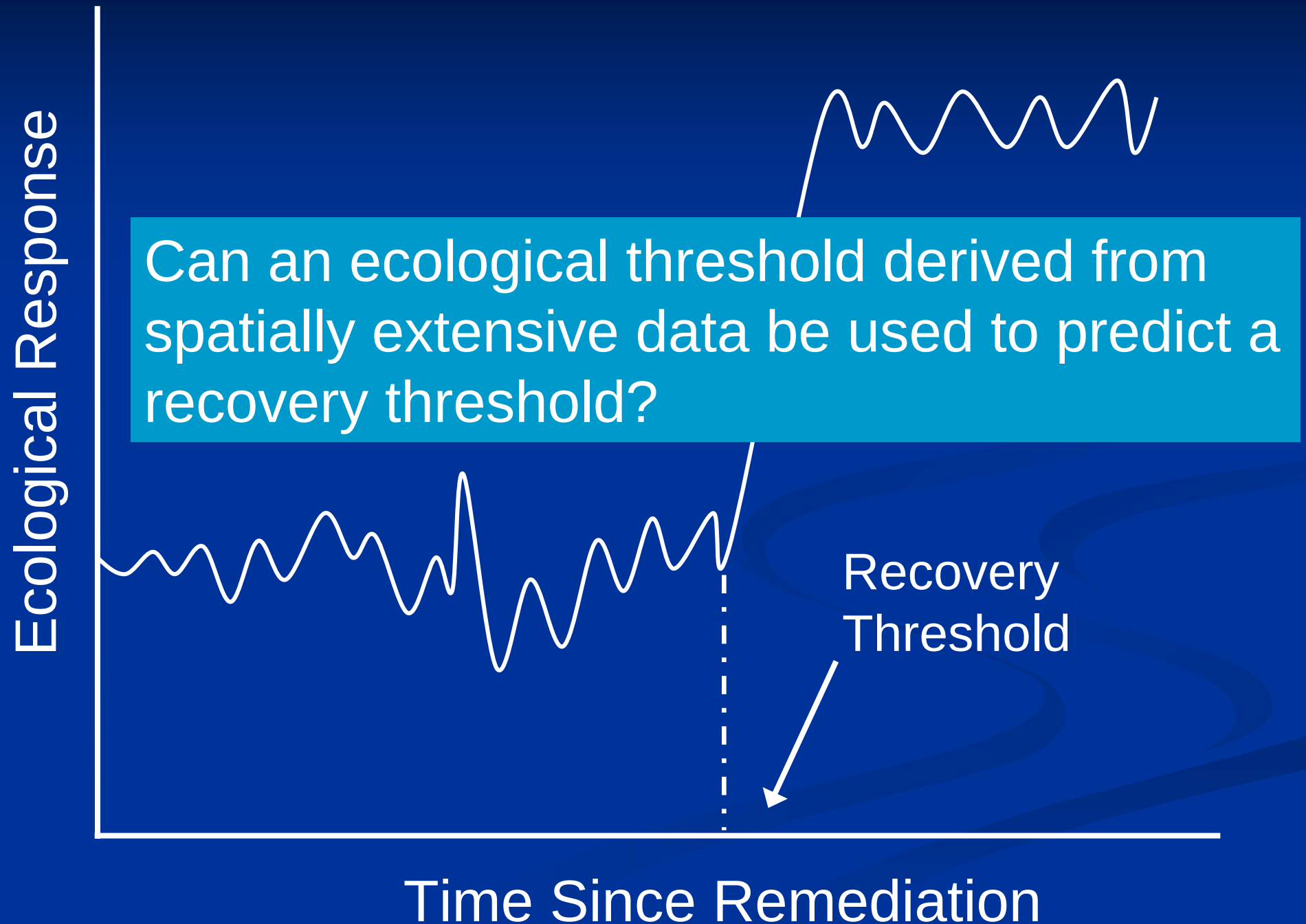
Influenced by the stressor-response relationship



Changepoint Detection using Piecewise Regression



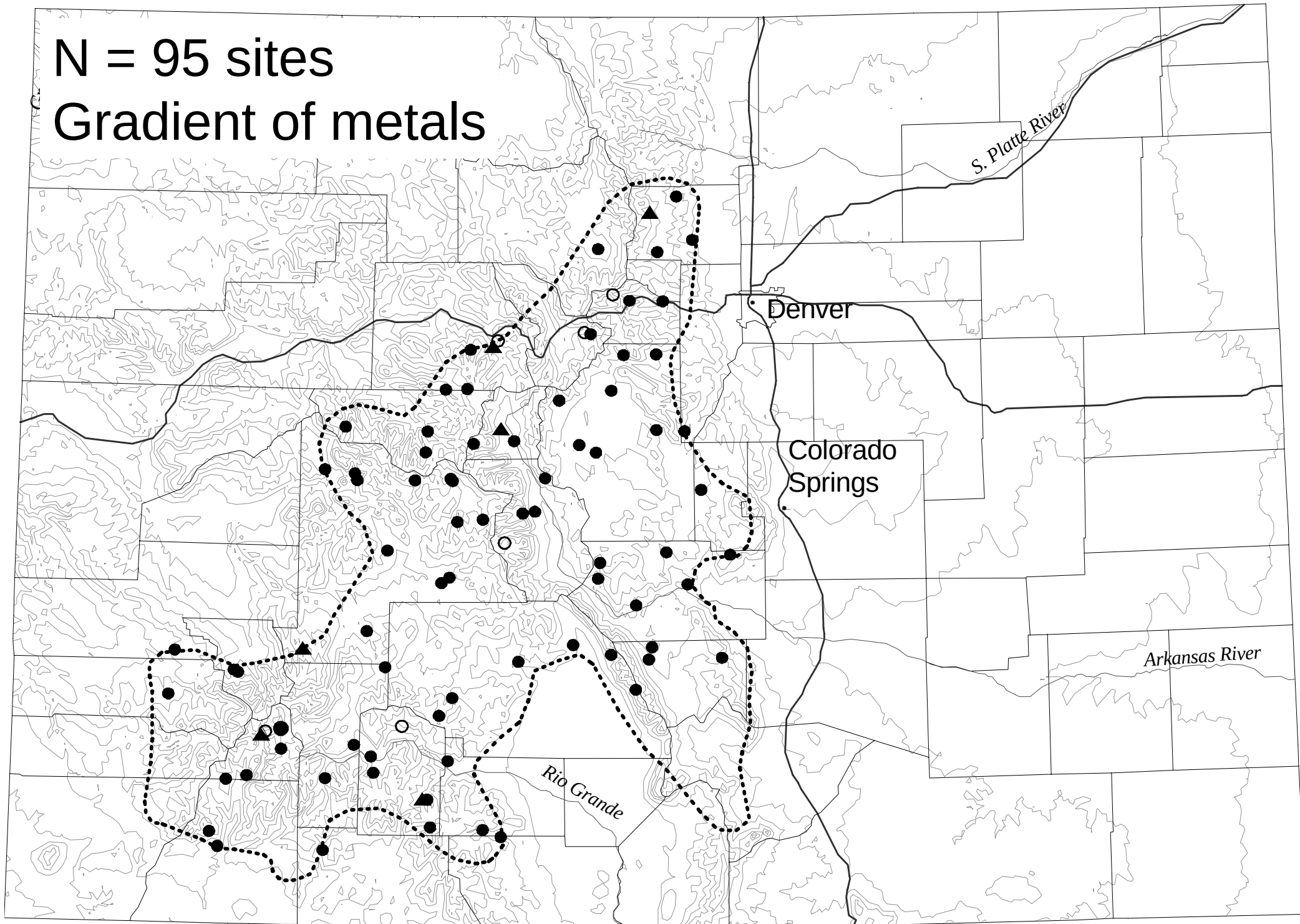
Example: Ecological Thresholds and Recovery



Southern Rocky Mountain Ecoregion, 1994-1995

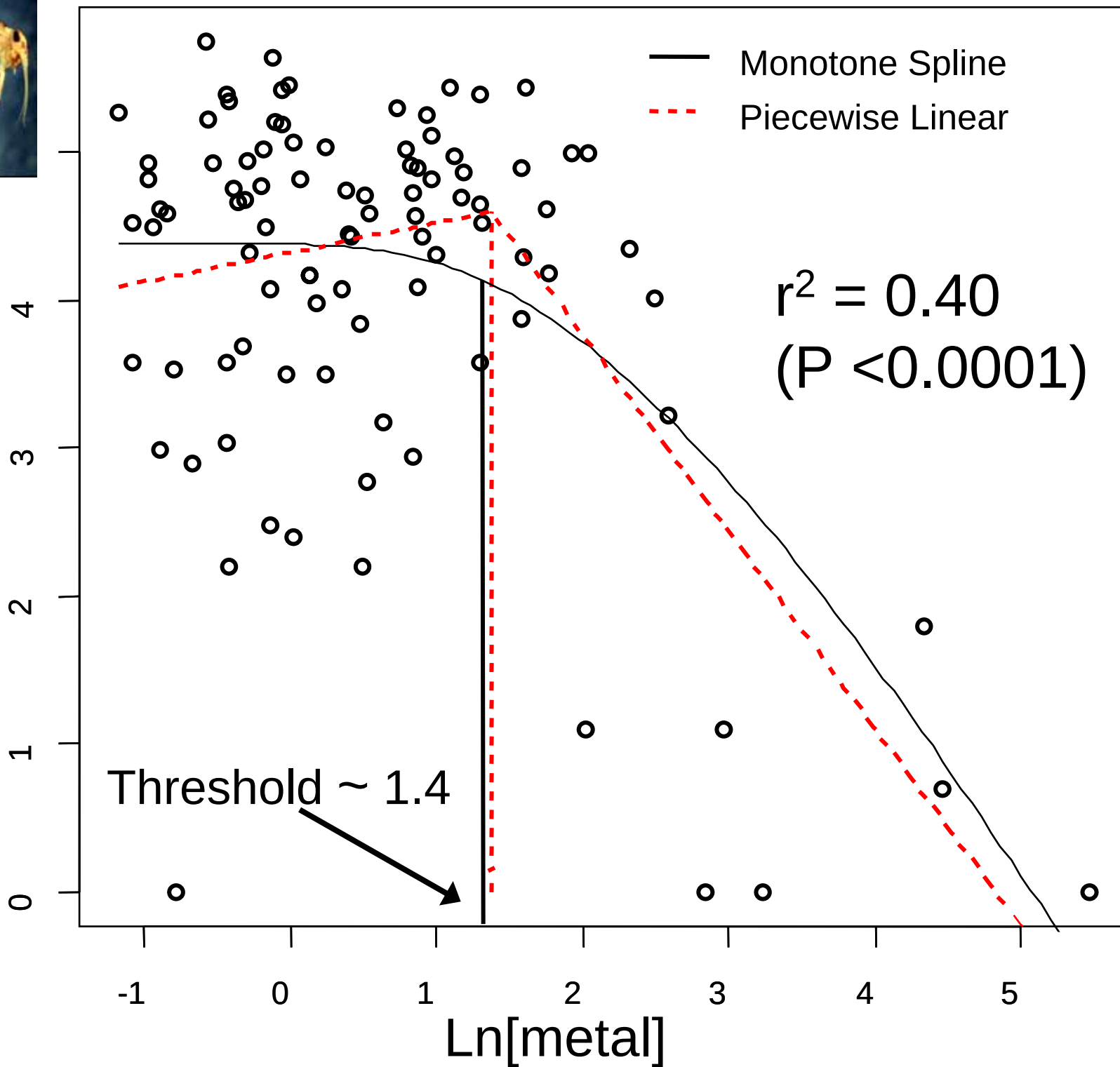
N = 95 sites

Gradient of metals





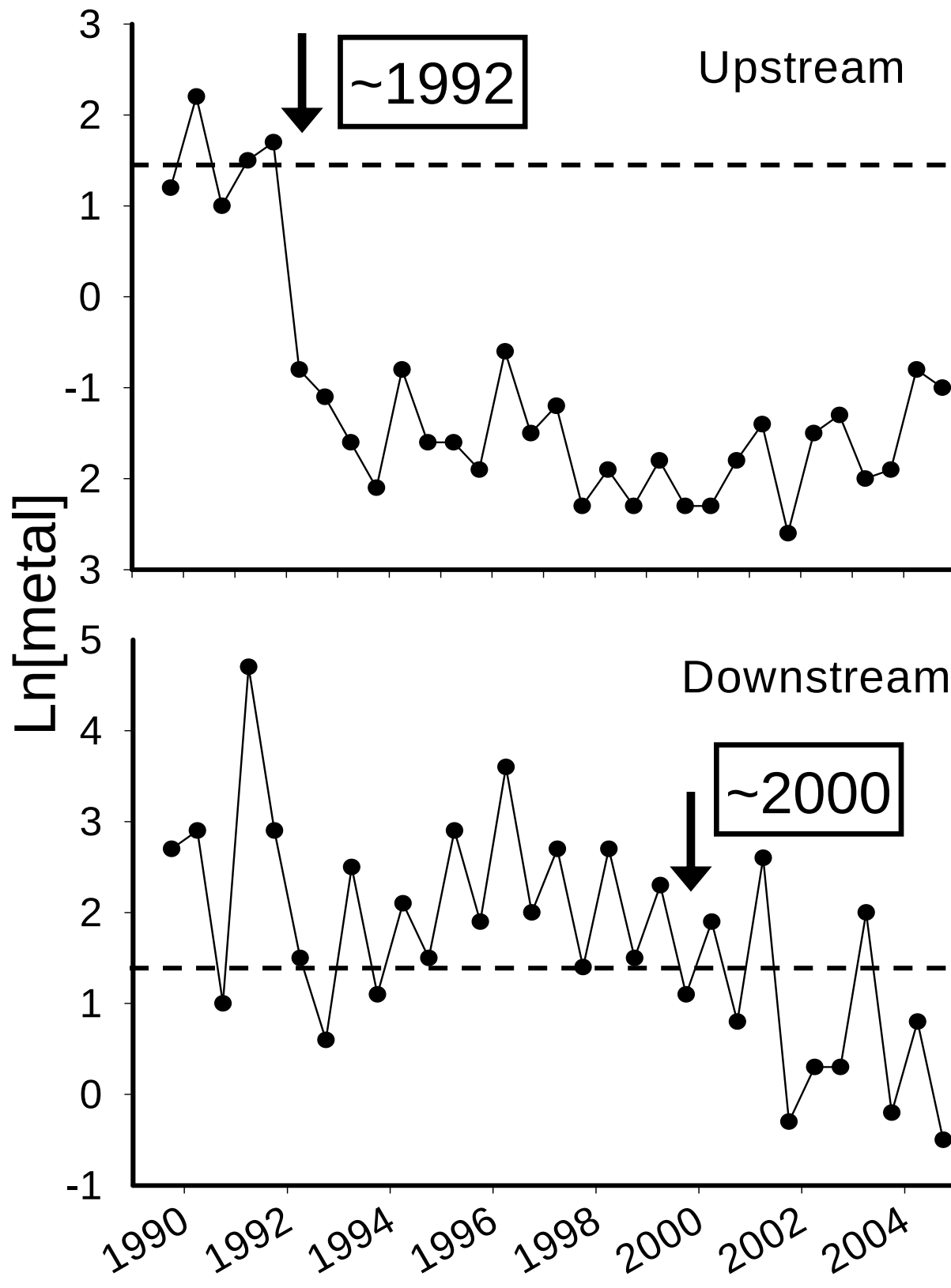
Ln(Mayfly Abundance)

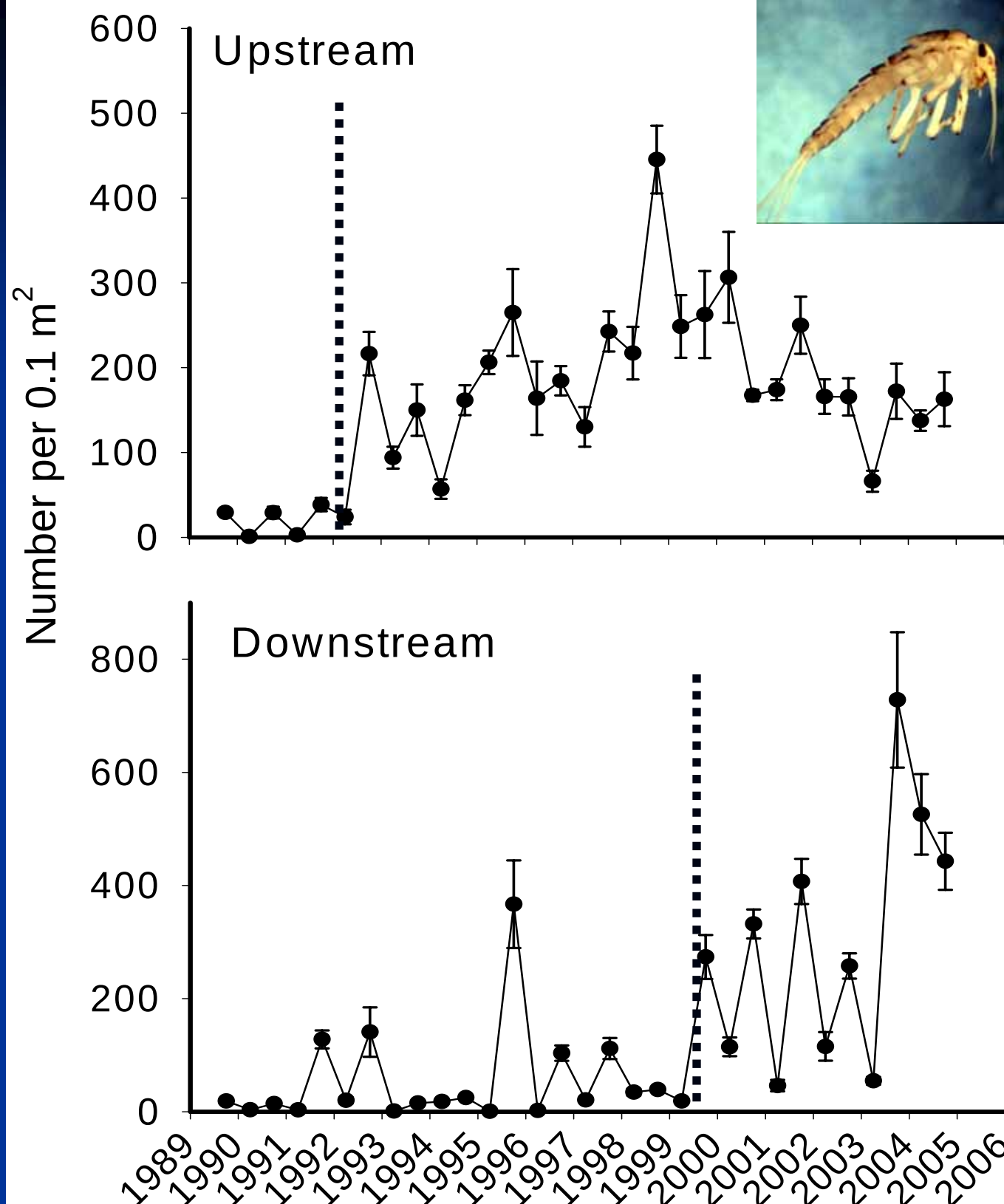


Long-term Data from the Arkansas River, CO

- 1989-2004 (spring, fall)
benthic inverts, physchem
- 5 stations along 60 km reach
upstream, downstream of CG Superfund site
- Remediation began in 1992

California Gulch Superfund Site





Recovery starts
soon after
 $\text{Ln}[\text{metal}]$
reduced below
1.4

“Complete” within
~ 5 years

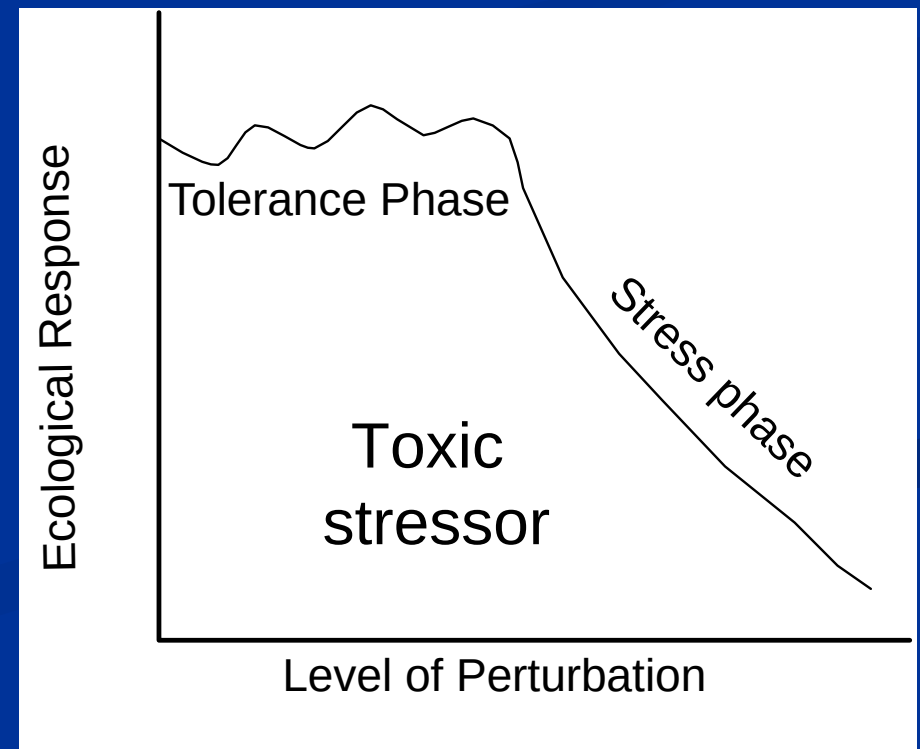
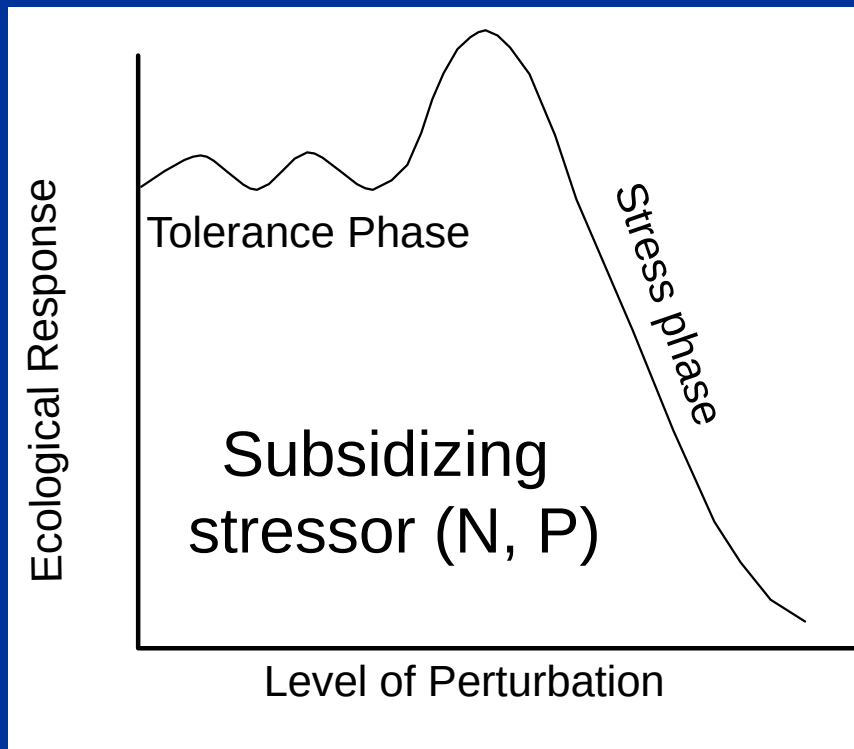
Summary

Ecological thresholds derived from spatially extensive data predicted recovery thresholds for benthic communities



Important Research Questions

1. Can we generalize among ecosystems and stressors?
 - empirical work shows diversity of outcomes
→ some show thresholds, others don't
 - response may be stressor-dependent

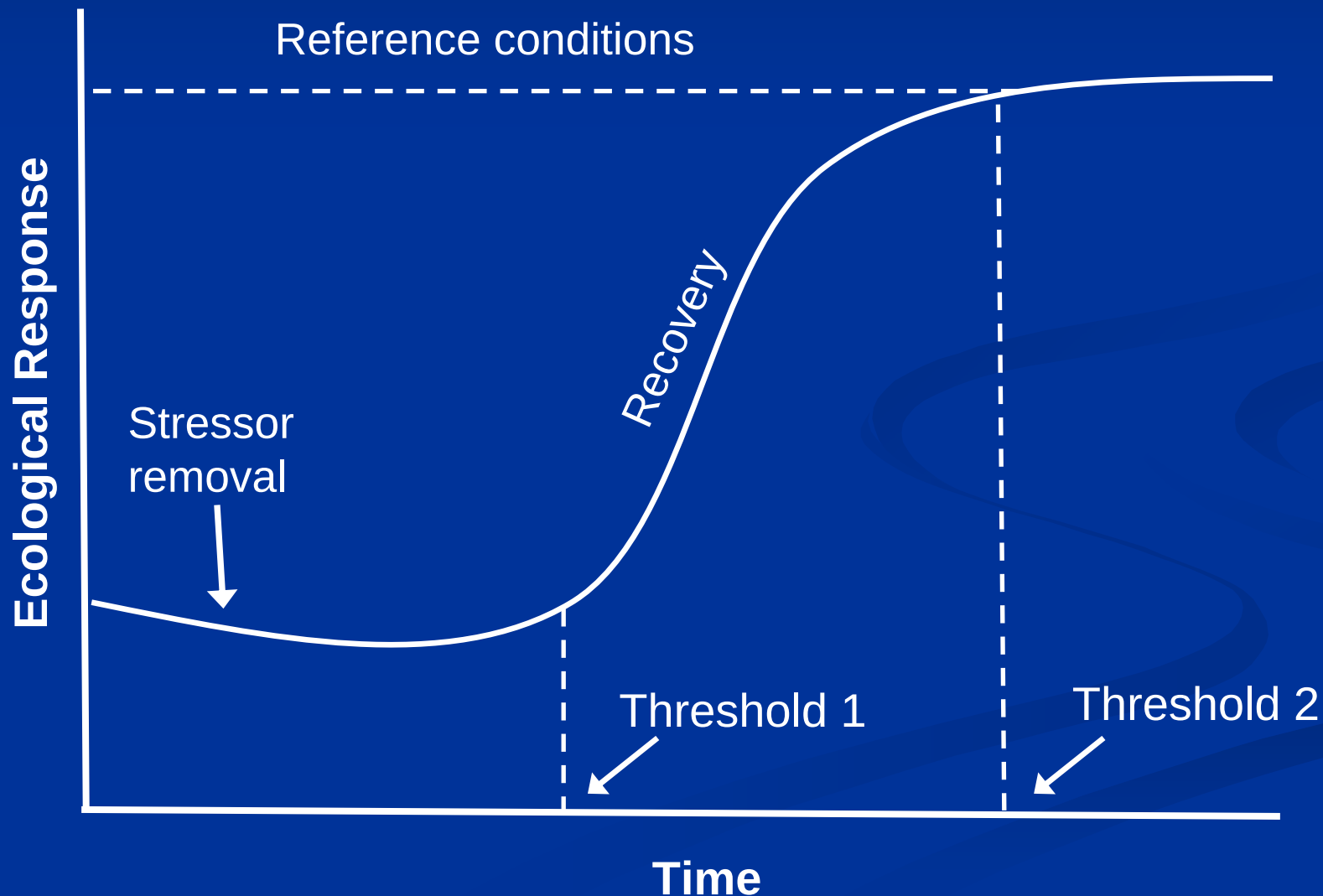


2. What are the most appropriate response variables?

- different thresholds for different response variables
 - variation among trophic levels
- species-specific thresholds do not imply similar thresholds for aggregate measures
 - e.g., species richness, diversity

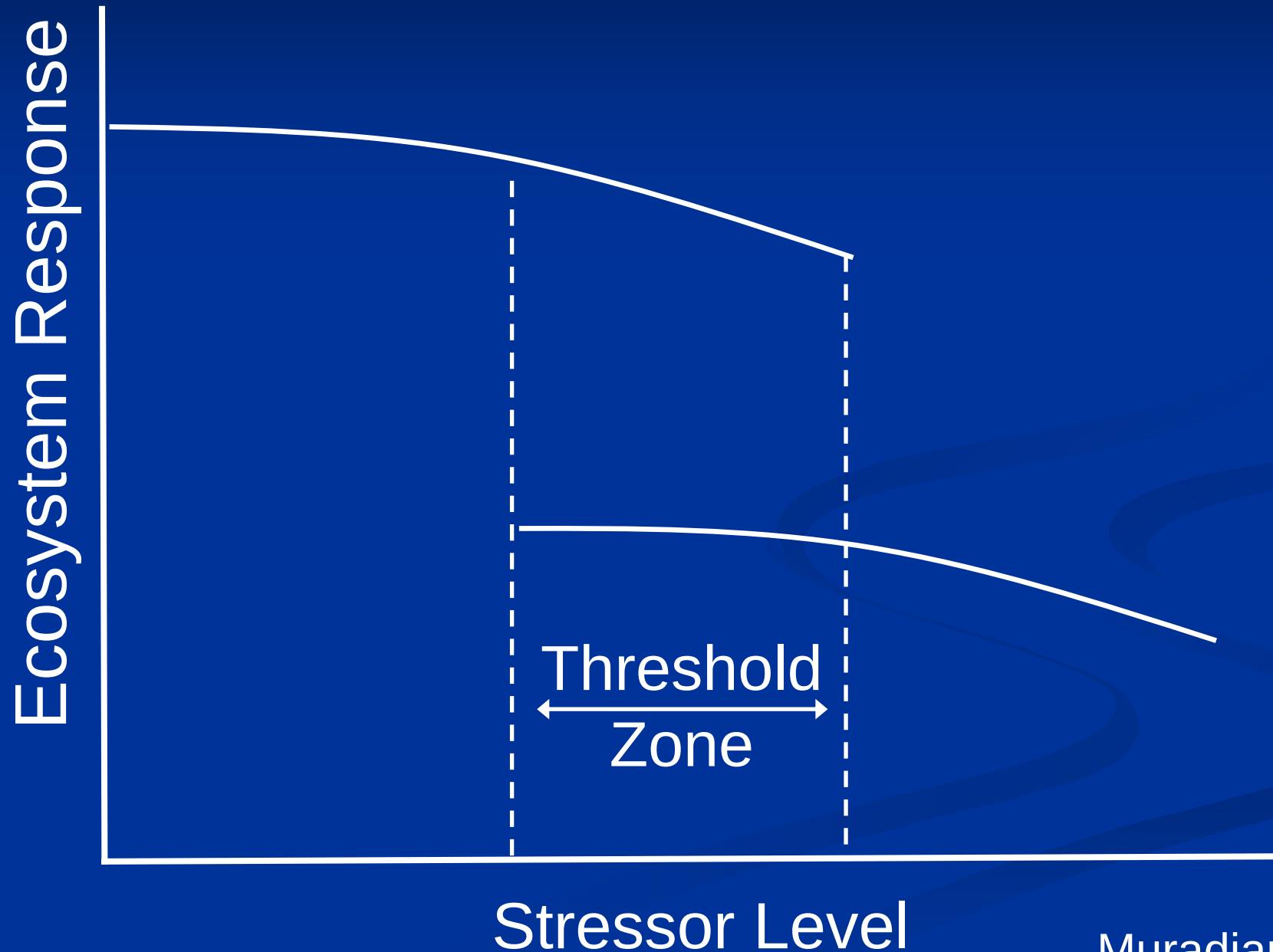
3. Statistical methods

- explain variation among studies
- influence of other variables
- multiple thresholds



3. Statistical methods (continued)

- breakpoints versus threshold zones

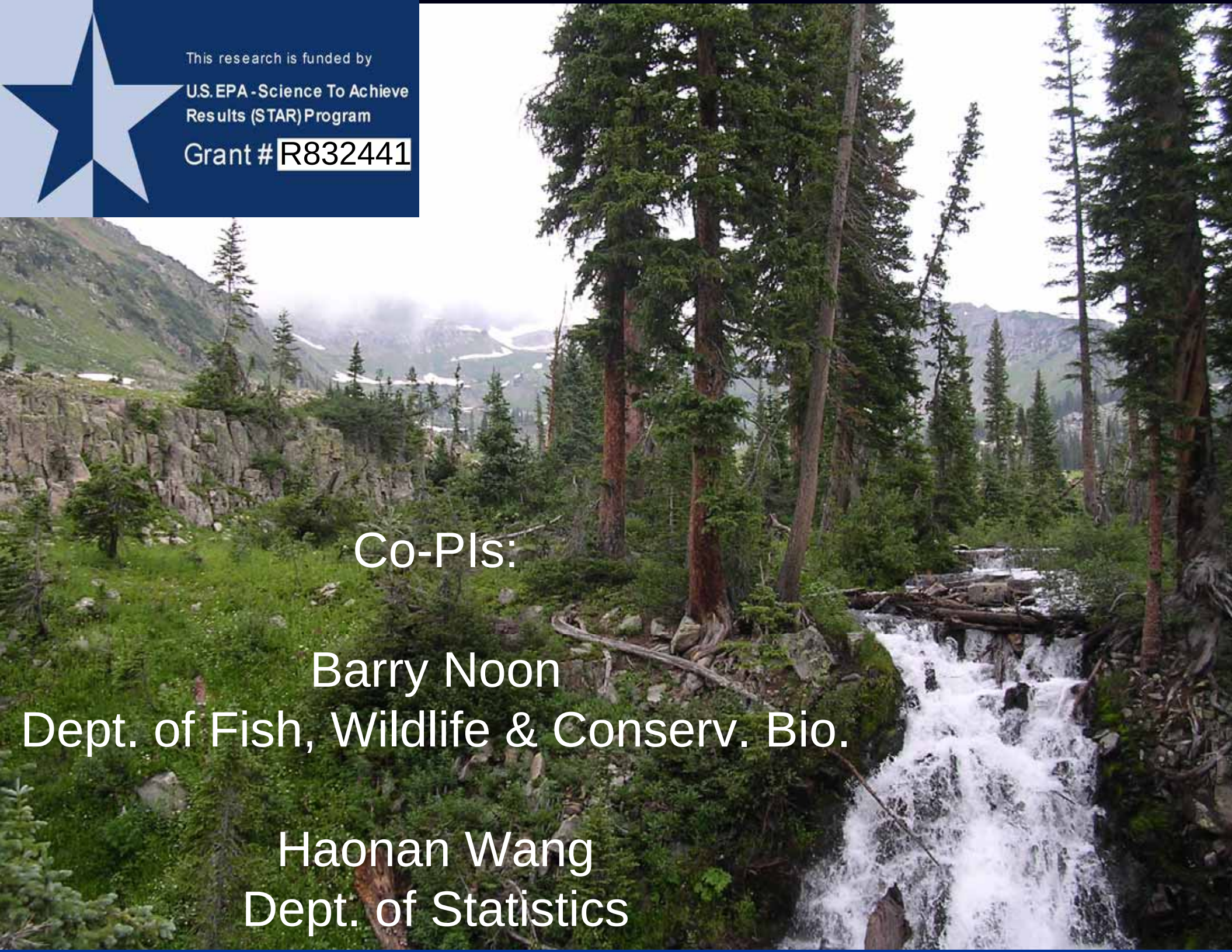




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