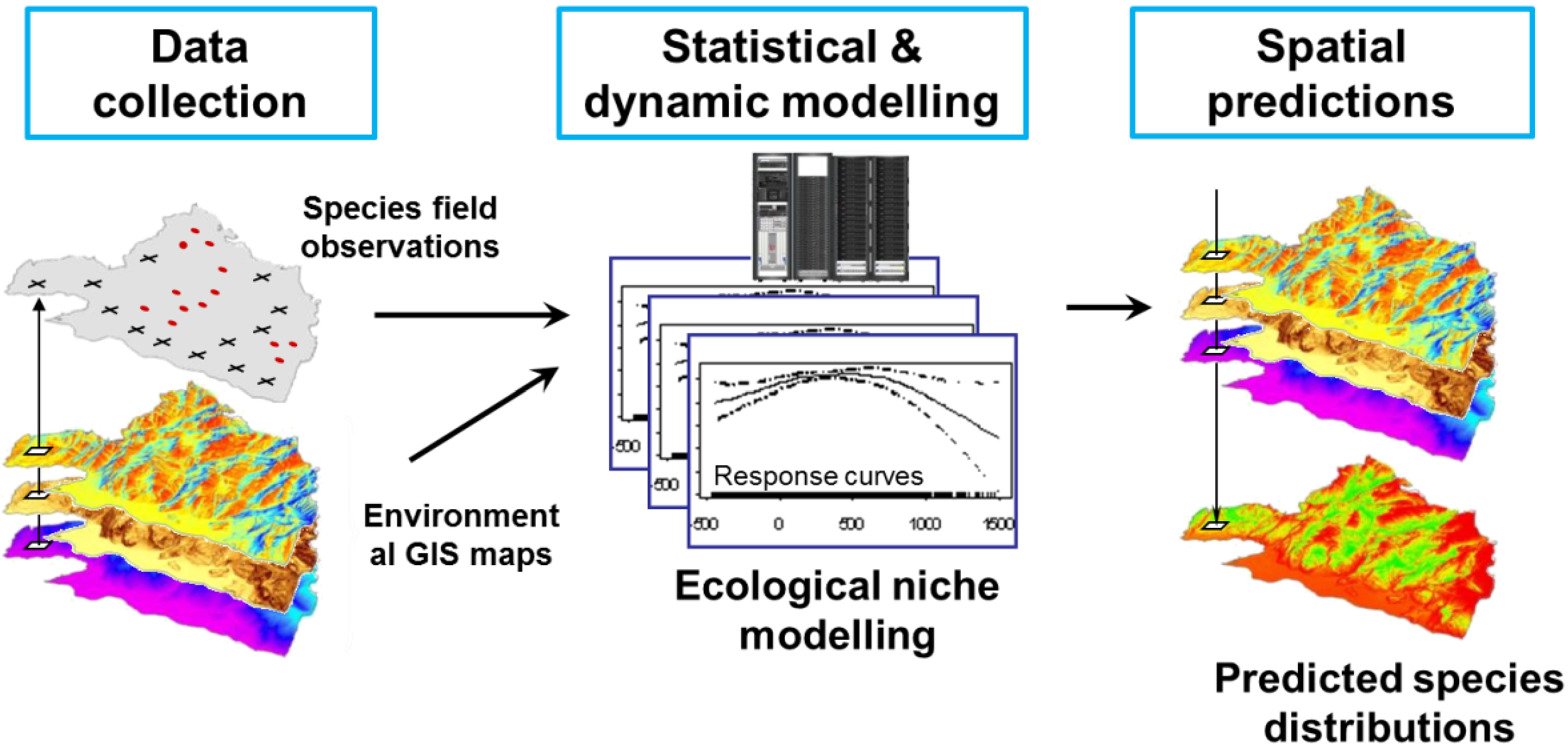
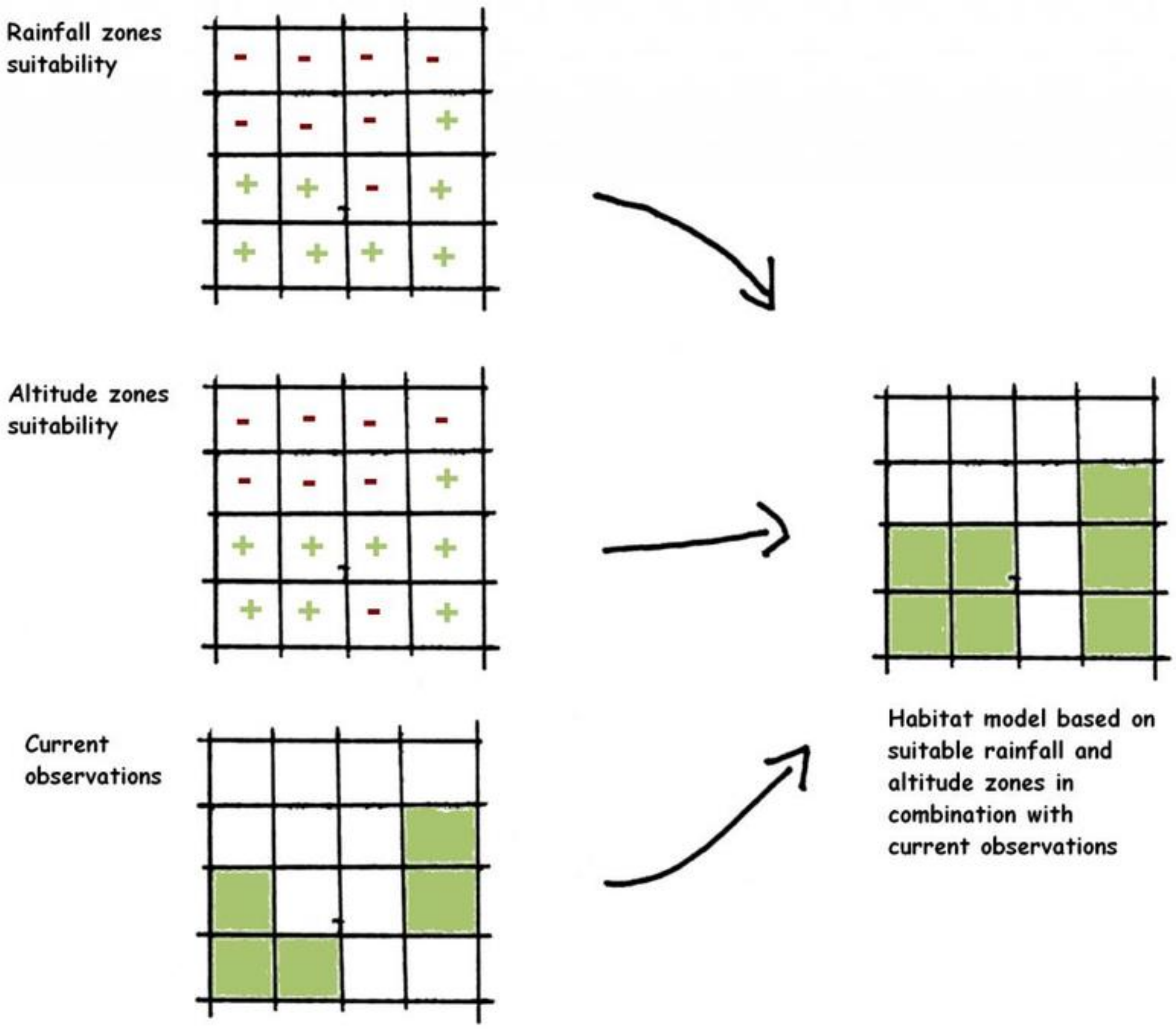
2019.11.28

Chapter 11 – "A Modeling Framework for Restoration Ecology"

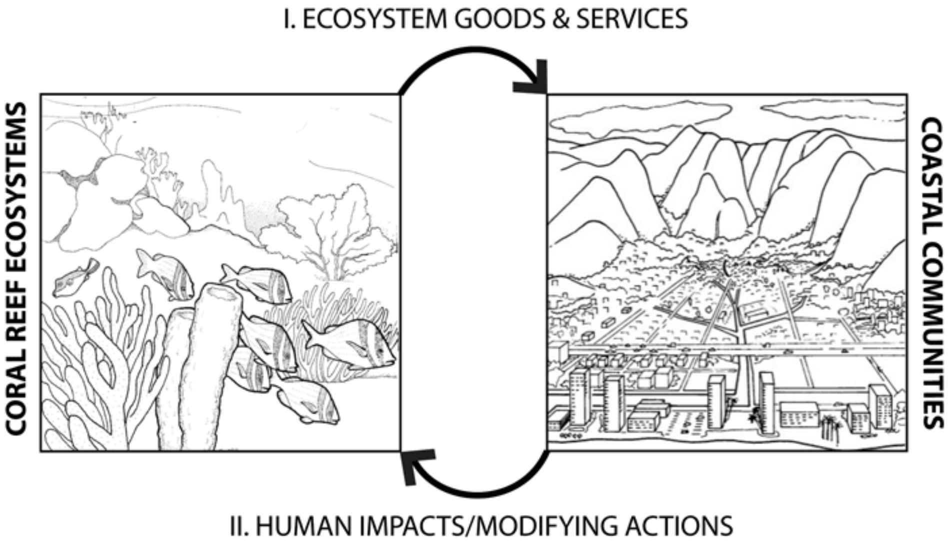


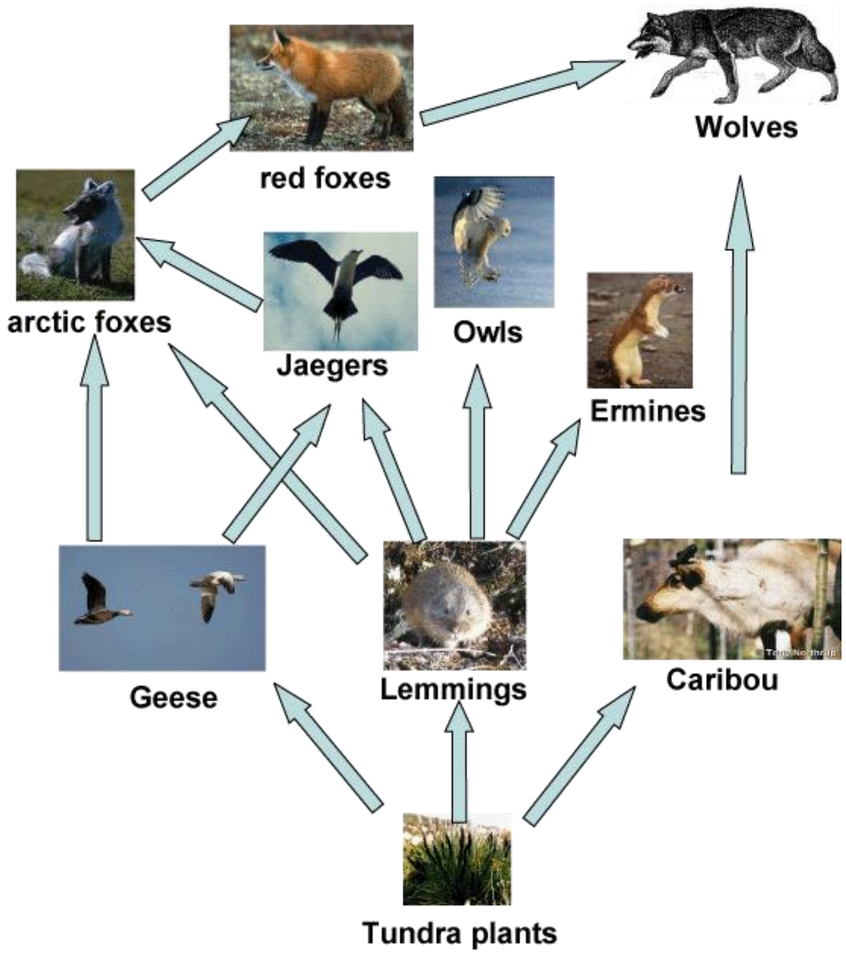
Ecological Niche Modelling



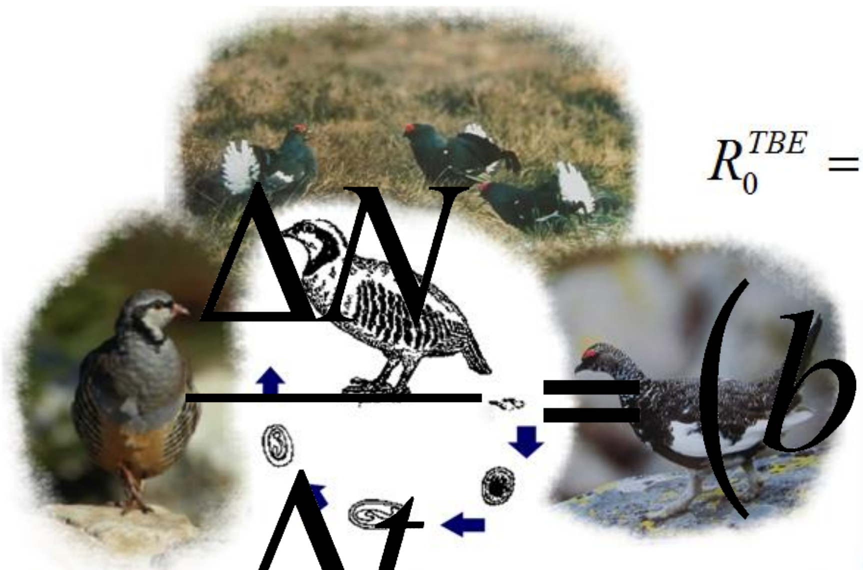
- Example of ecological niche modelling using rainfall, altitude and current species observations to create a model of **possible existence** for a certain species

Conceptual (Heuristic) Modeling



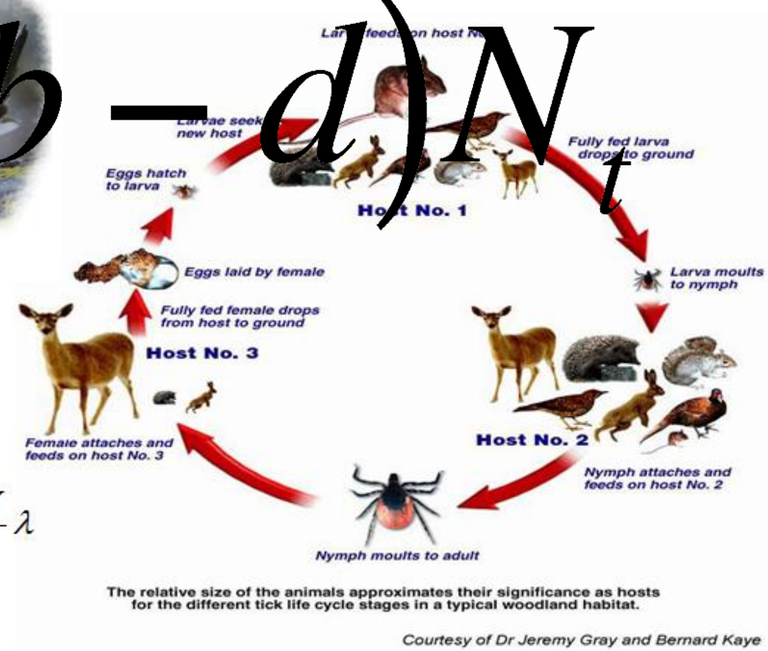


Statistical (Mathematical) Modeling



$$R_0^{TBE} = p^L \cdot q^N + \frac{m^L \beta_1^N H_1}{d^N + \beta^N} \cdot \frac{\lambda_{LN} \beta_1^L L_Q}{\sigma^N}$$

$$\frac{\Delta N}{\Delta t} = (b - d) N_t$$



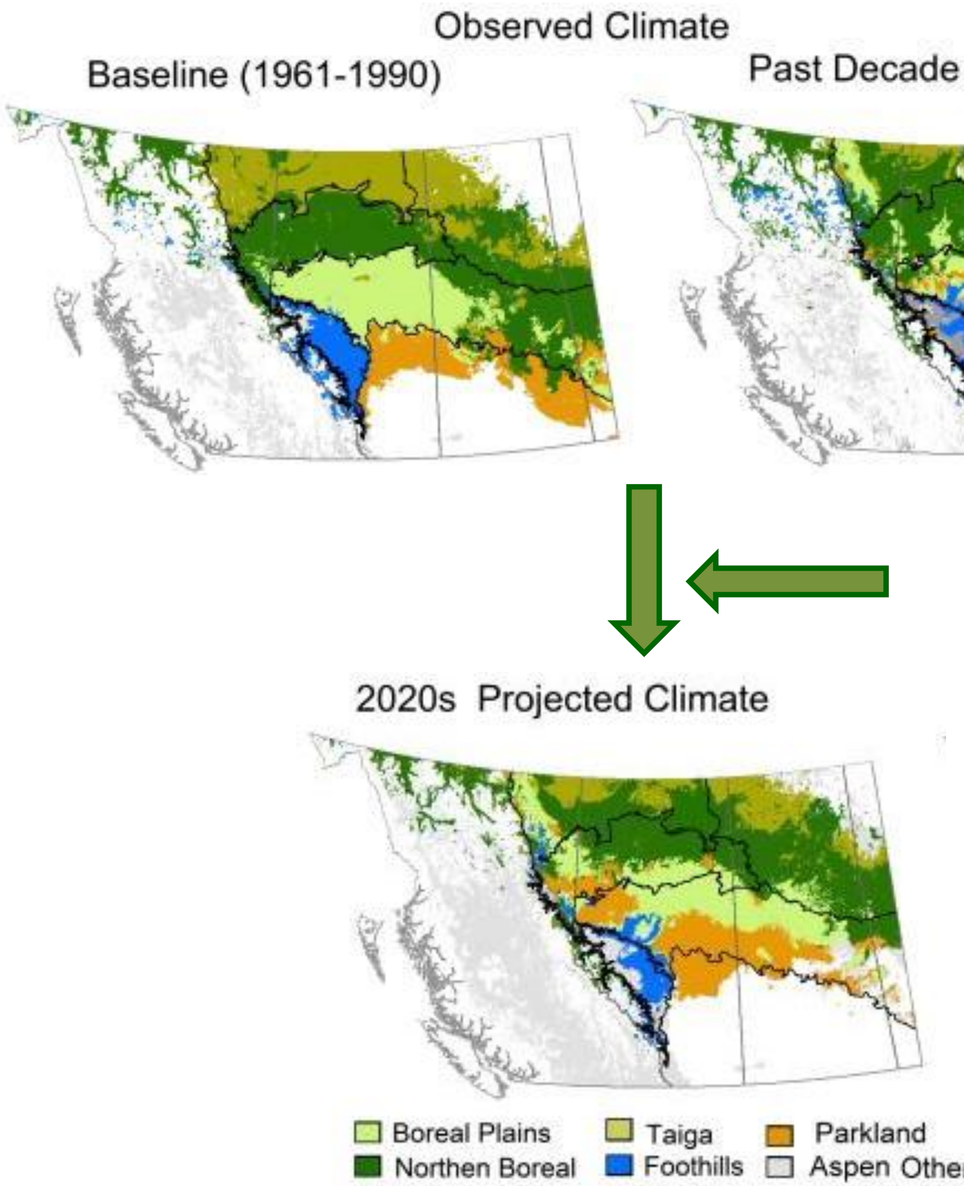
$$\frac{dN}{dt} = N(\beta[1+(A-1)(1-\xi)]^{\frac{x}{A-1}} - \mu - \nu N)$$

$$\frac{dx}{dt} = x(-\sigma - \beta[1+(A-1)(1-\xi)]^{-\frac{x}{A-1}}) + \theta\psi W$$

$$\frac{dA}{dt} = -(A-1)(\sigma + \frac{\theta\psi W}{x}) + \beta x[1+(A-1)(1-\xi)]^{-\frac{x}{A-1}} + \frac{\theta\psi W}{x}\lambda$$

$$\frac{dW}{dt} = hNx - \delta W - \theta W N$$

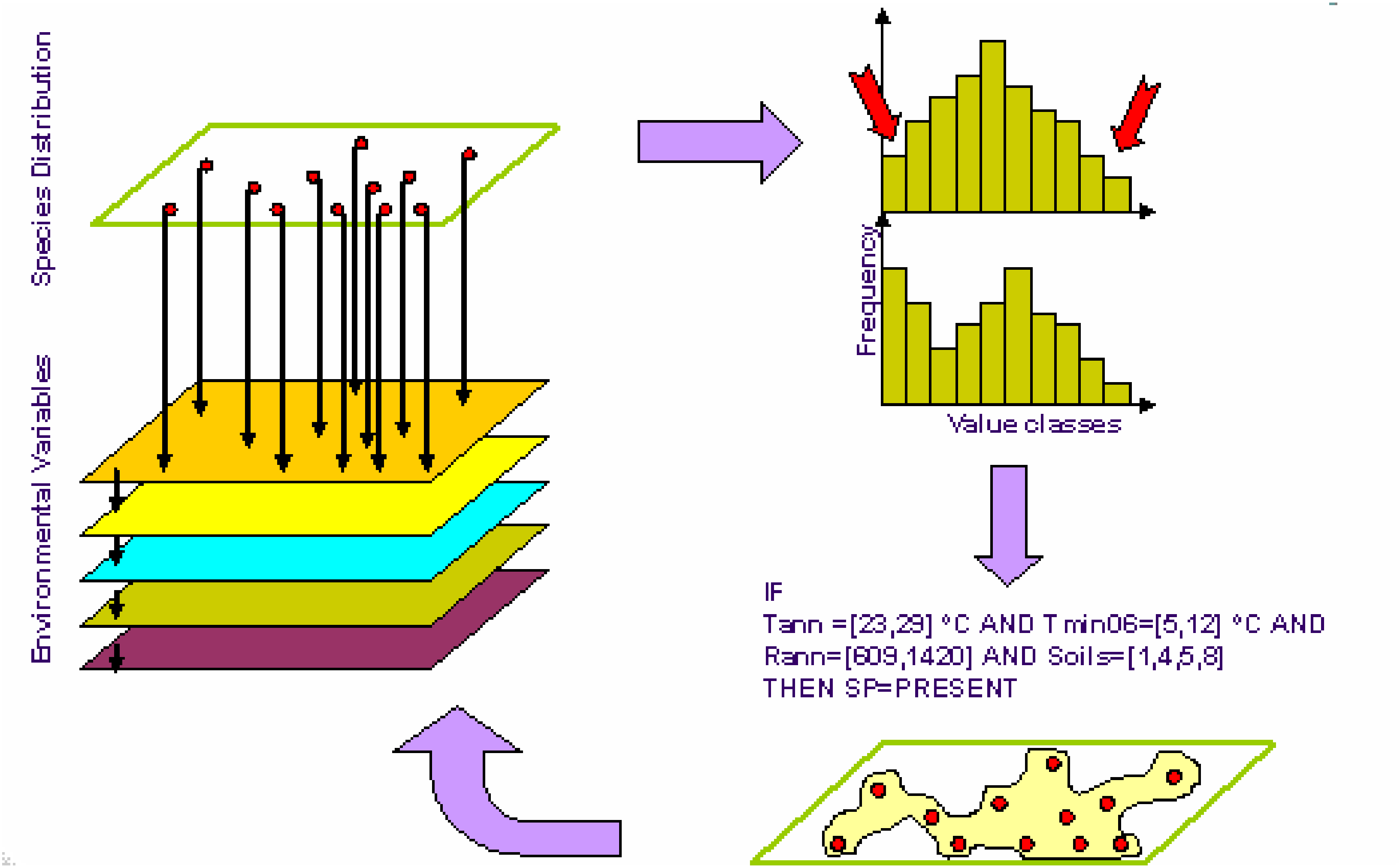
Simulation Modeling



– Climate data
– Current species distribution
– Future climate scenarios

Bioclimate Envelope Model

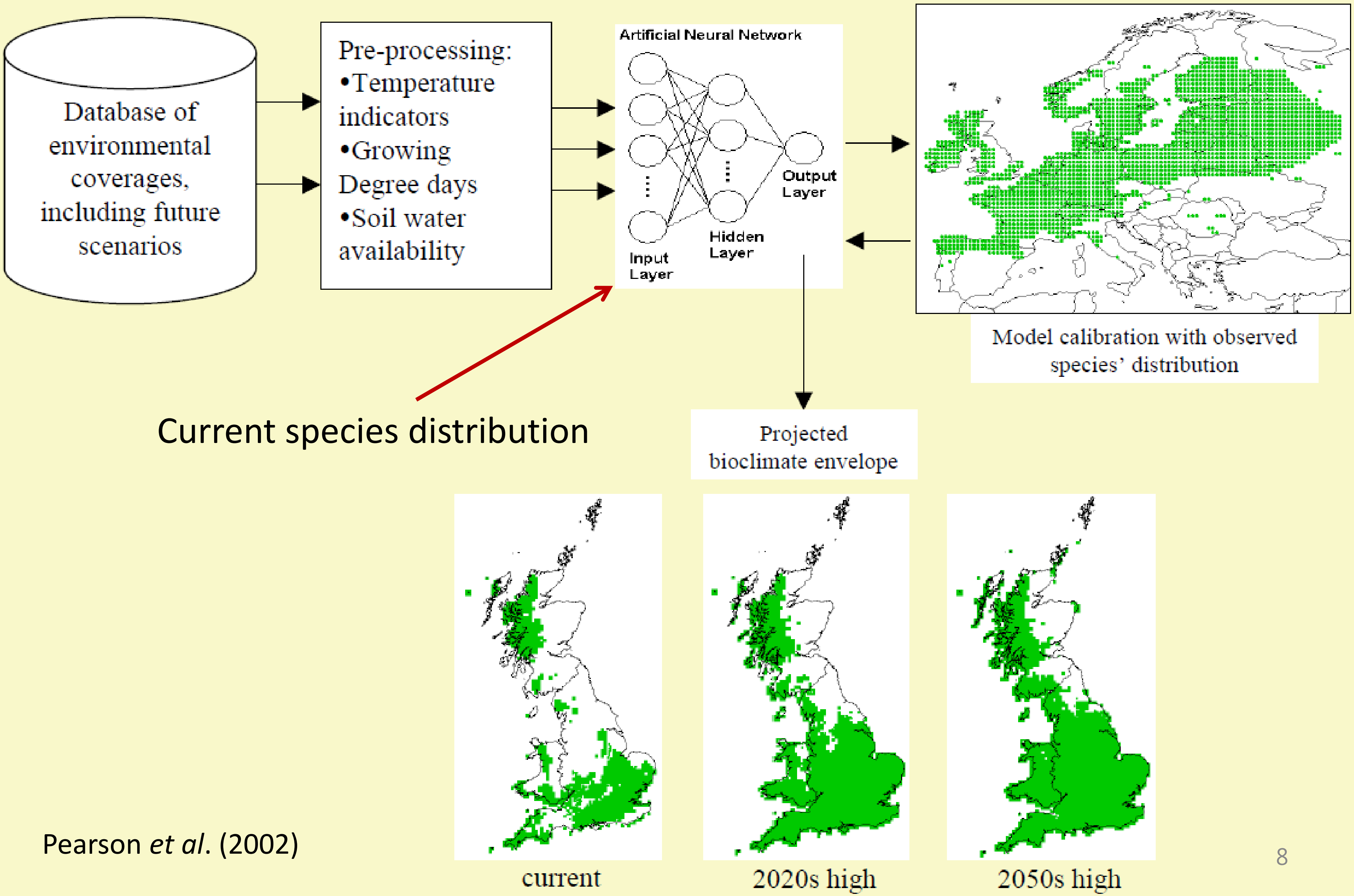
(*Ecological Niche Model or Species Distribution Model*)



Bioclimate Envelope Model

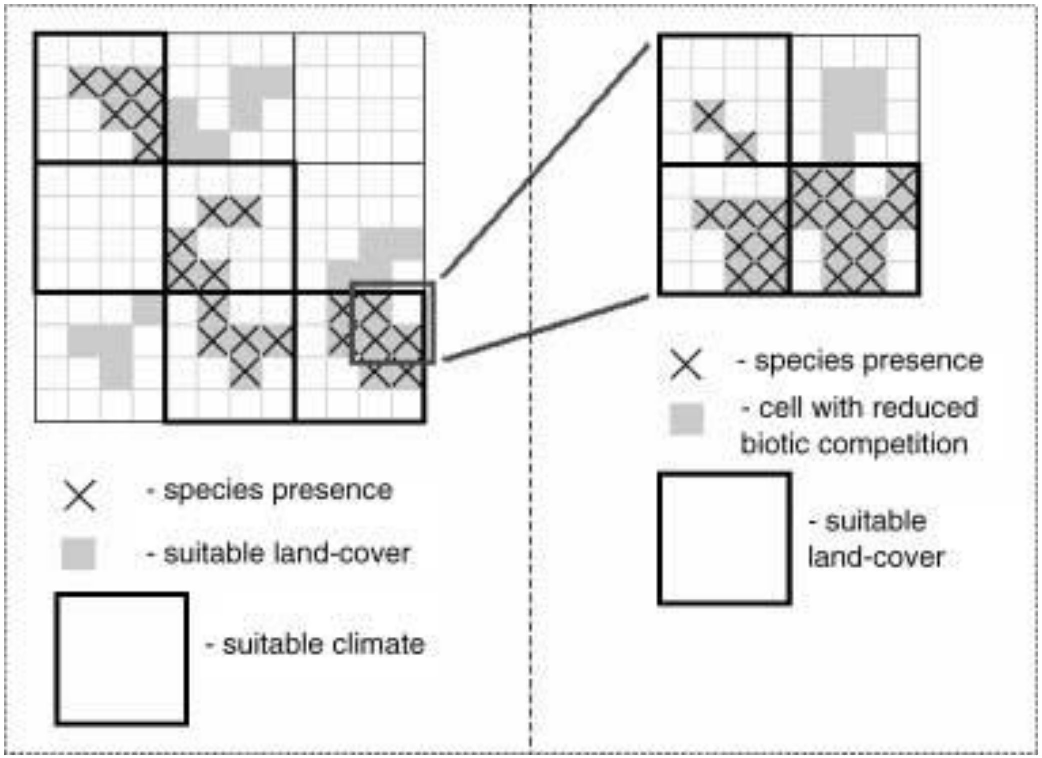
- It predicts geographical ranges of organisms as a function of climate → it *'correlates current species distributions with climate variables'*
- It assumes current distribution gives a good indicator of *'ecological requirements'*
- Having identified a species' climate envelope, the application of scenarios of future climate change enables the potential *'redistribution of the species' climate space'*

Bioclimate Envelope Model



Pearson *et al*. (2002)

A Hierarchical Bioclimate Envelop Model



At large scale (> 1,000 km)   At small scale (1 – 100 km)

Pearson & Dawson (2003)

Sources of Uncertainty of Bioclimate Envelop Models

Ecological versus Algorithmic

- Dispersal limitation
- Biological interactions
- *In situ* adaptation

- Model-based uncertainty
- Thresholding
- Climate scenarios

Four Fundamental Tasks of Restoration

The process of returning a degraded system to a healthier, more "normal" state

1. Pose **a model** about how we think the ecosystem behaves ecologically
2. Assess the current state of the system
3. Management experiments
4. Monitoring (postmanagement assessment)

Aims of Modeling

- To serve as an integrating framework
- To explore the implications of various management decisions or alternative scenarios
- To design sampling or monitoring schemes
- To extrapolate understanding across spatial or temporal scales
- To provide forecasts (predictions)

"Exploration; Extrapolation; Forecasting"

Three Classes of Models

- **Heuristic** models
  – Schematic diagrams and conceptual models – our working understanding of the ecosystem behavior

- **Statistical (Mathematical)** models
  – Various forms of regressions (equations)
  – (e.g.) multivariate models like ordinations

- **Simulators (Simulation)** models
  – Implemented as numerical algorithms and "solved" by simulation

Heuristic (or conceptual) models

- What management interventions might "move" a degraded site toward the desired "natural" condition?
- What measurable indicator variables define these axes?

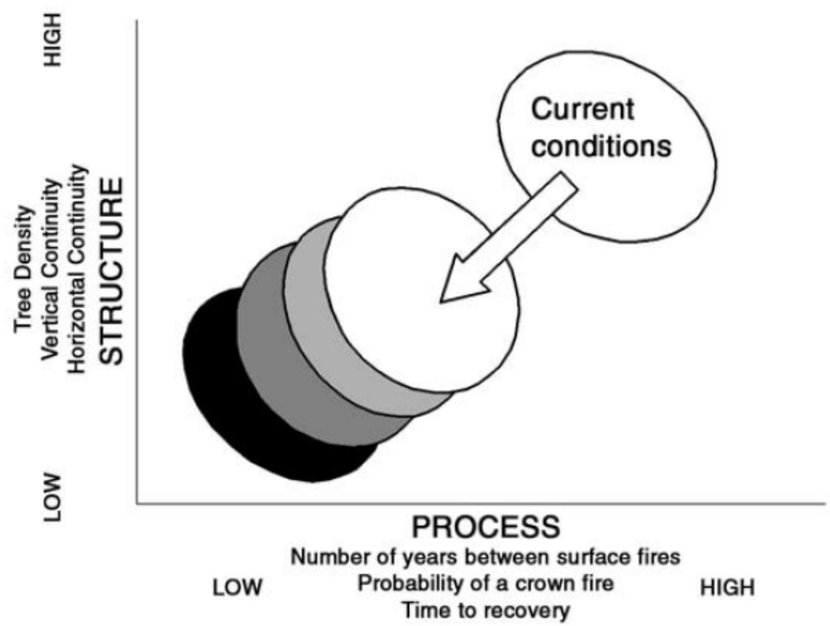
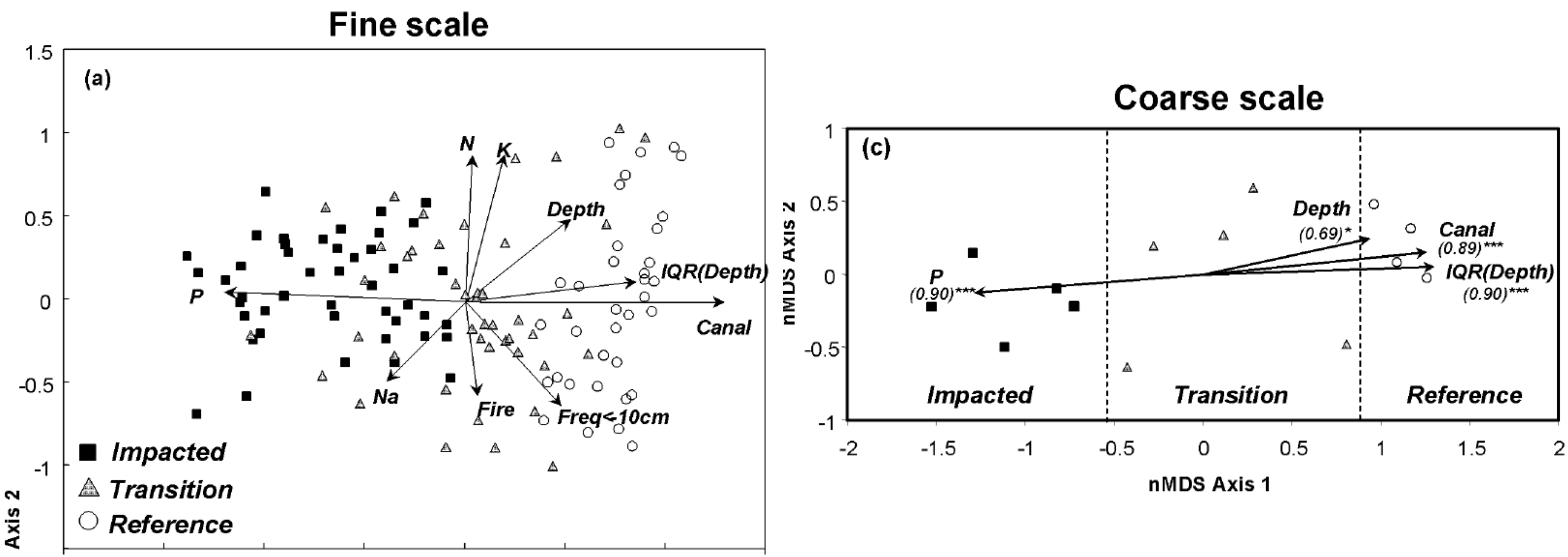


FIGURE 11.1 Schematic diagram of a conceptual, heuristic model for ponderosa pine forest restoration in the southwestern United States (from Allen et al. 2002, reprinted with permission).

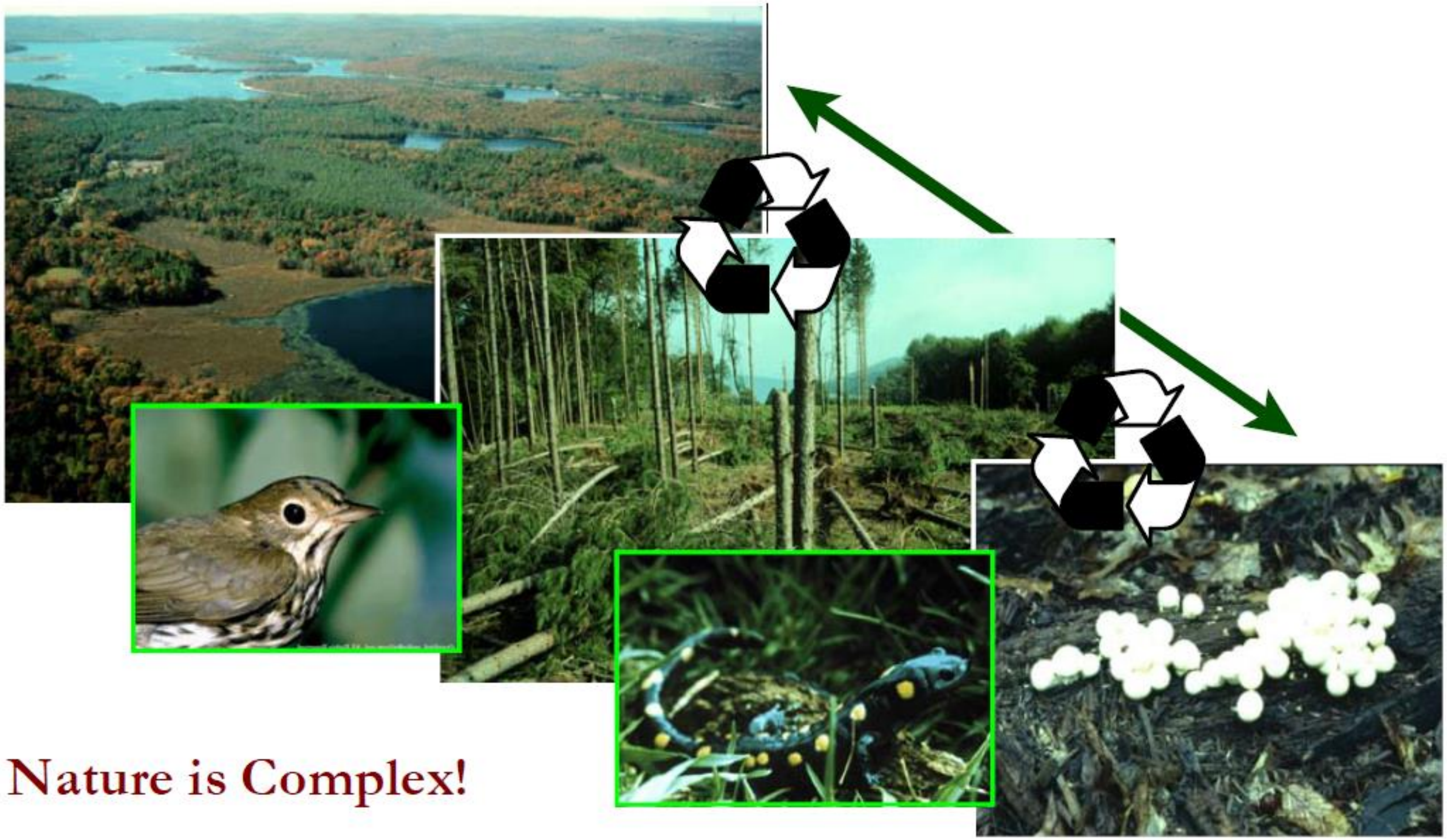
Statistical models

- Ordination methods (multidimensional scaling)



A statistical model of wetlands of the Everglades: vegetation response to increased phosphorus availability from agricultural runoff

Multivariate Statistics – An Ecological Perspective



Nature is Complex!

What is **Multivariate Statistics**?

Model	Techniques
y = x1 + x2 + … xj →	Regression Analysis of Variance Contingency Tables
y1 + y2 + … yi = x →	Multivariate ANOVA Discriminant Analysis CART,MRPP,MANTEL
y1 + y2 + … yi = x1 + x2 + … xj →	Canonical Corr. Analysis Redundancy Analysis Can. Correspond. Analysis
y1 + y2 + … yi →	Ordination Cluster Analysis

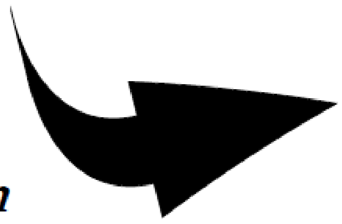
Multivariate Statistics

Example 1 – Environmental Gradient

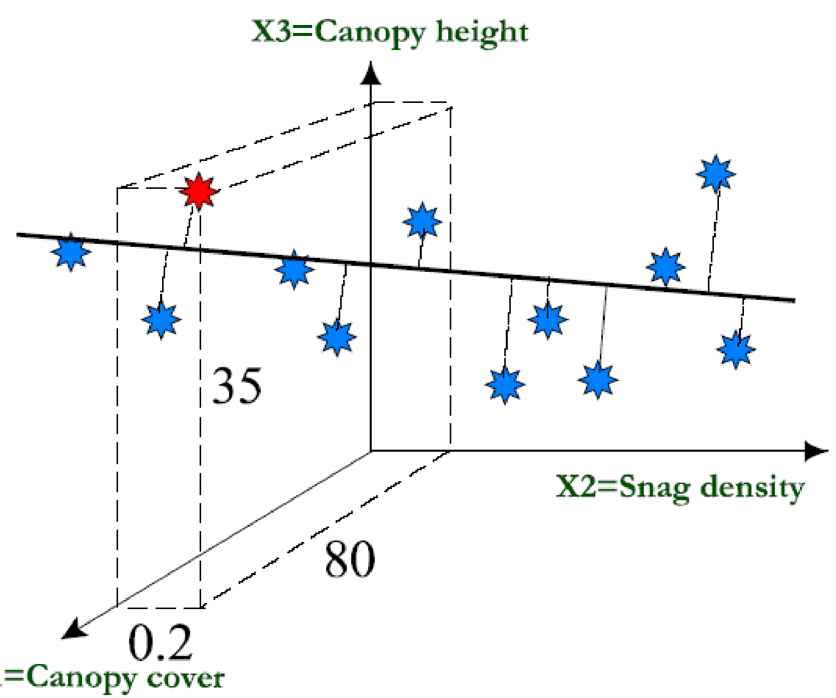
Data Matrix

Obs	Canopy Cover	Snag Density	Canopy Height
1	80	0.2	35
2	75	0.5	32
3	72	0.8	28
.	.	.	.
.	.	.	.
12	25	0.6	15

Ordination



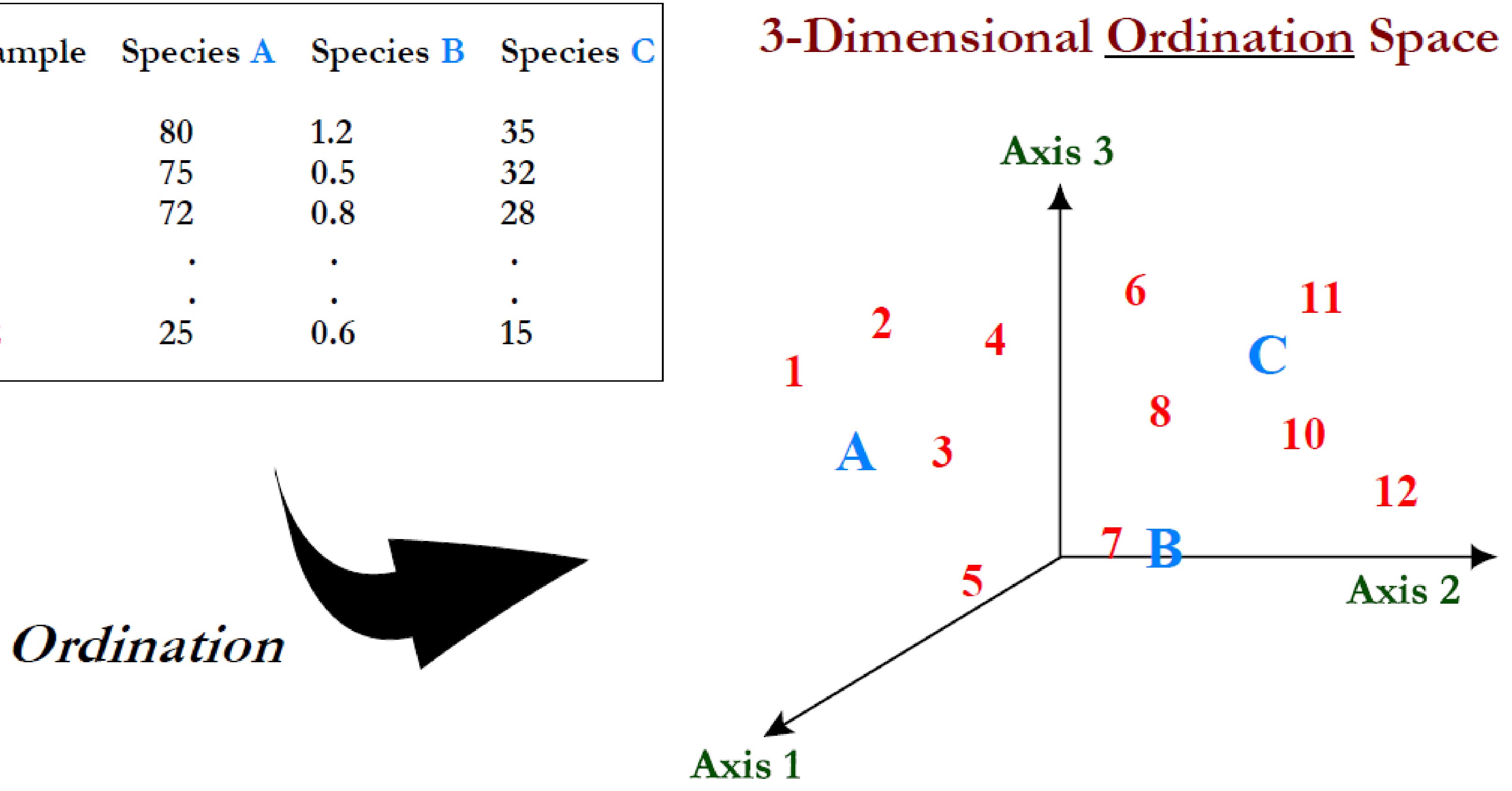
3-Dimensional Data Space



Example 2 – Community Structure

Data Matrix

Sample	Species A	Species B	Species C
1	80	1.2	35
2	75	0.5	32
3	72	0.8	28
.	.	.	.
.	.	.	.
12	25	0.6	15



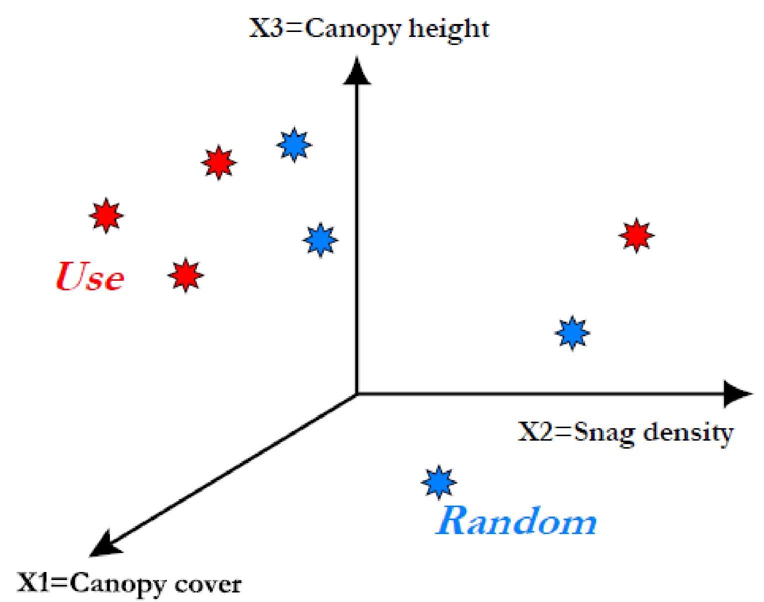
Example 3 – Habitat Use

Data Matrix

Obs	Group	Canopy Cover	Snag Density	Canopy Height
1	Use	80	1.2	35
2	Use	75	0.5	32
3	Use	72	0.8	28
4	Use	35	3.3	15
.	.	.	.	.
31	Random	5	2.1	5
32	Random	68	3.4	2
33	Random	25	0.6	15
34	Random	70	1.3	33
.	.	.	.	.

Ordination

3-Dimensional Data Space



What is **Multivariate Statistics**?

- It involves cases involving multiple **“dependent”** variables
- All multivariate problems can be conceptualized geometrically as a **data cloud** in a multidimensional **data space**, where the dimensions (or axes) are defined by the variables of interest
- It is the shape, clumping, and dispersion of this cloud that multivariate techniques seek to describe

Simulation models

Modeling and Monitoring Tools to Assess Recovery Status and Convergence Rates between Restored and Undisturbed Coral Reef Habitats

Diego Lirman[1] and Margaret W. Miller[2]

MAITLAND ELPIS

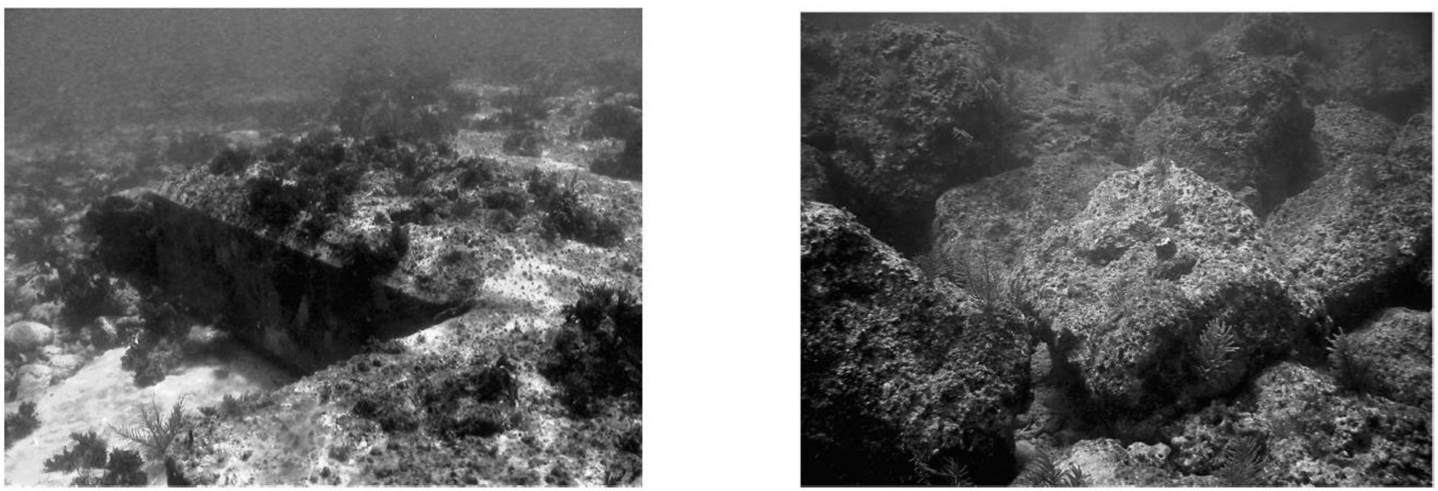
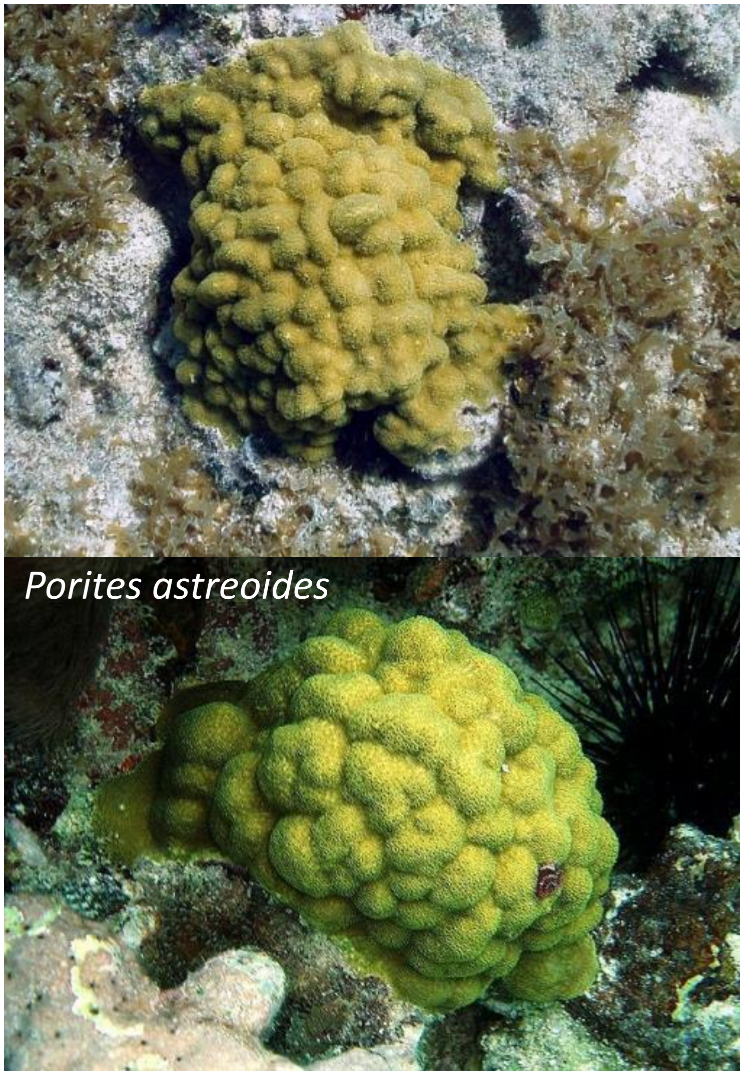


Figure 1. Photographs of the two grounding and restoration sites surveyed in 1998 and 2001 showing the restoration structures deployed at the Maitland (depth, 2.5 m) and Elpis (depth, 9–11 m) sites.

- The restoration structures were deployed during 1995 year

Coral Population model



- A size-structured transition matrix model:
  $X_{(t+1)} = A * X_{(t)} + r$

  – X: a column vector with the population size structure
  – A: a matrix of transition probabilities calculated from field observations
  – r: a recruitment vector

- Five size classes with tagging

Field Surveys of Restored Coral Populations

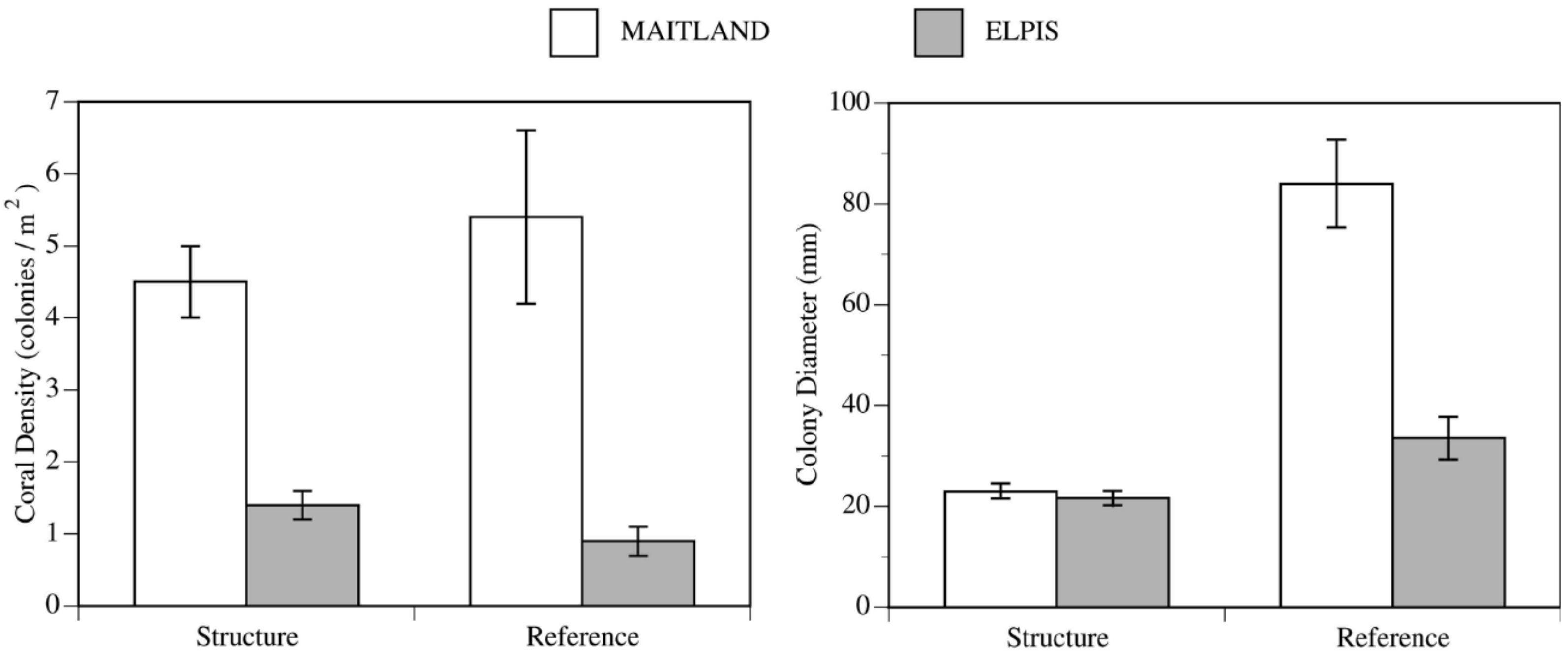


Figure 2. Mean density and colony diameter (± SEM) of *Porites astreoides* at the Maitland and Elpis restoration sites in 2001.

Field Surveys of Restored Coral Populations

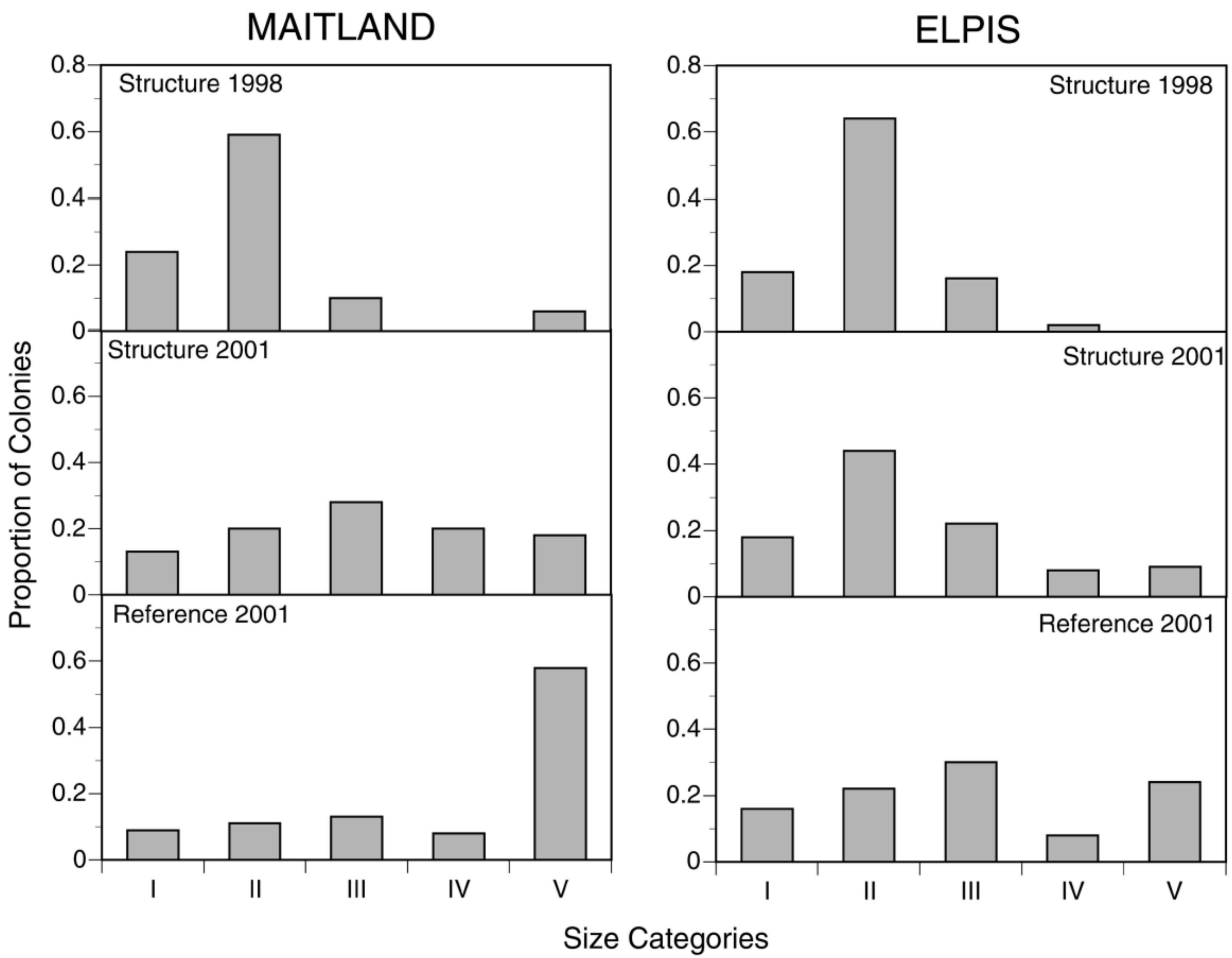
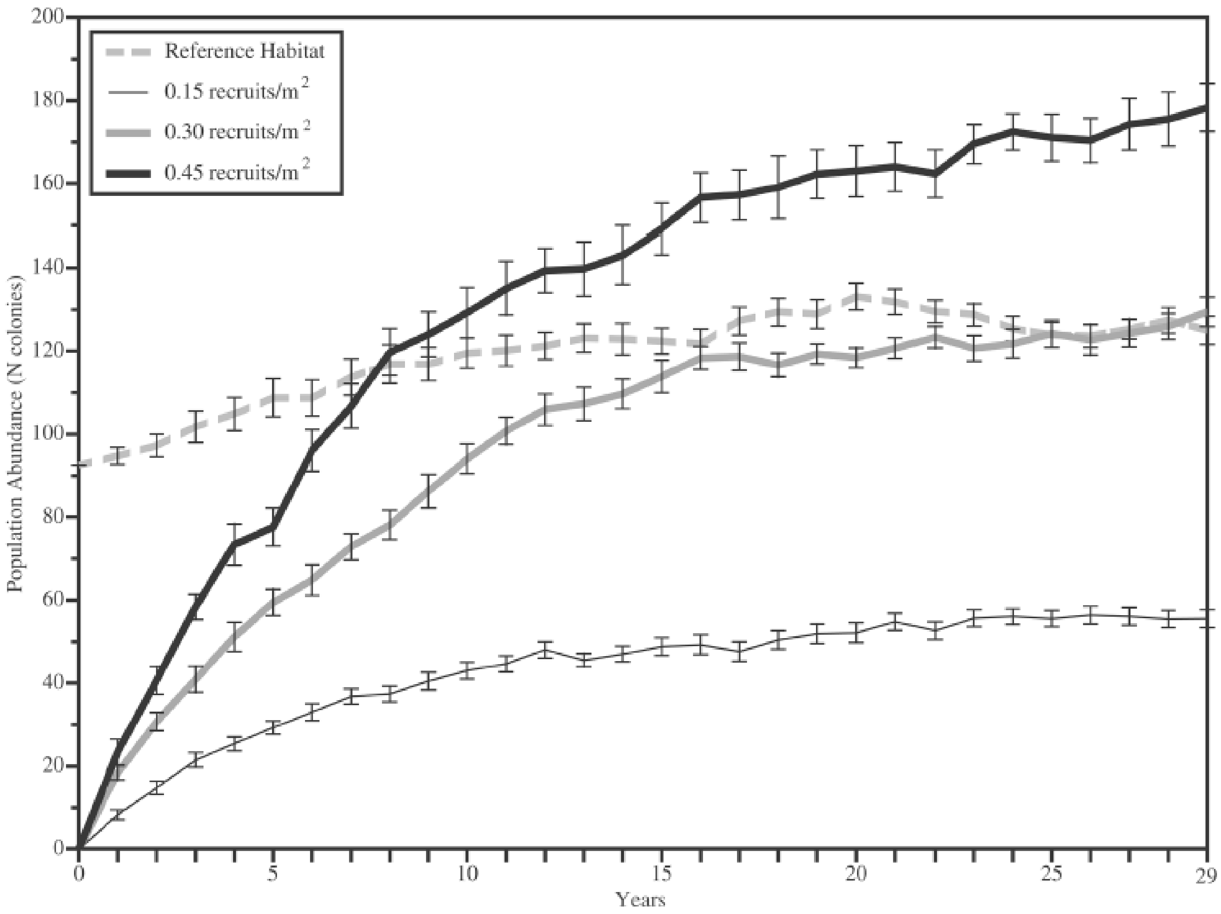


Figure 3. Size structure of the *Porites astreoides* population found at the Maitland and Elpis restoration sites using the size categories used in the population model.

Simulation of Restored Coral Populations



A General Framework

- **Shared characteristics of the three models:**

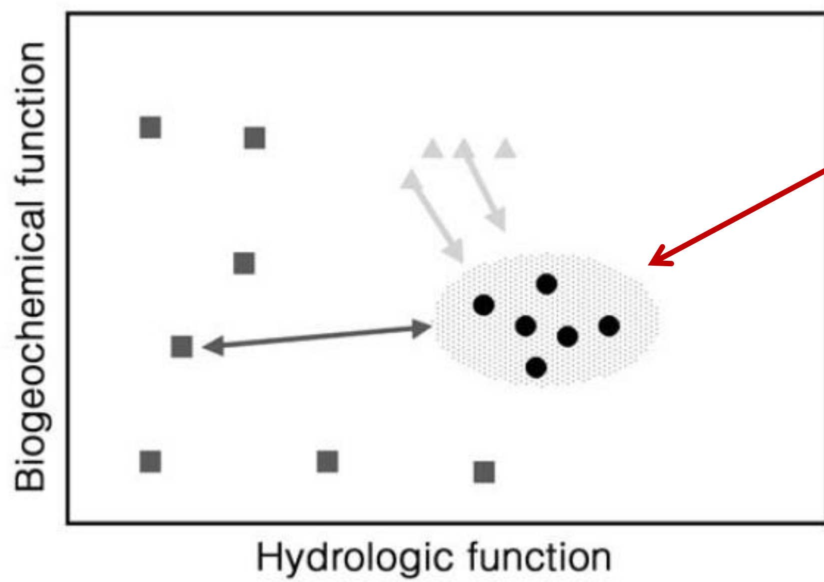
  1. The models speak directly to field data

  2. The applications are multidimensional

  3. Comparisons of the ecological similarity between the managed and reference conditions

A General Framework – **“Ordination Method”**

- Data clustering used in exploratory data analysis
- “Orders” objects that are characterized by values on multiple variables → **multivariate** techniques (**multidimensional** space)
- Similar objects are near each other and dissimilar objects are farther from each other

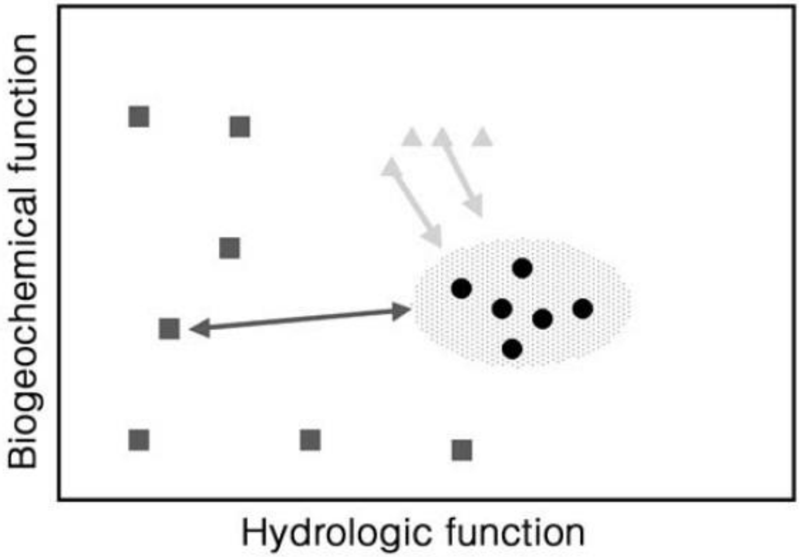


Reference sites

Environmental Assessment in Ordination Space

- A time-series of sampling delineates a trajectory over time, with each "movement" of a sample summarized by a change vector

  – Apply a management intervention to a sample and monitor it over time, does it move in the *direction* of the target (reference) condition?
  – How *fast* does it move? (e.g. vector lengths: rate of recovery)

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산양 서식지 이용특성 연구

❖ 환경요인 별 서식지 이용특성

➢ GIS 분석을 위한 환경변수 선정

- 선행 연구를 참고하여 자연적 요인 8개, 인위적 요인 3개 선정 및 공간자료 구축

환경특성	환경변수	자료원	제공처
자연적 요인	산림 유형	수치임상도	산림청
	수목연령(영급)		
	수목 흉고직경(경급)		
	수관밀도		
	고도	ASTER GDEM	NASA
	경사		
	사면향		
	수계로부터 거리	25000:1 수치지도	국립지리정보원
인위적 요인	주거지로부터 거리		
	경작지로부터 거리		
	도로로부터 거리(탐방로 포함)	25000:1 수치지도 국립공원 탐방로	국립지리정보원 국립공원

❖ 환경요인 별 서식지 이용 특성

➢ 산양 자료 구축

- 산양 서식실태 조사 시 수집된 산양 흔적 위치 자료 및 방사 산양 위치자료 이용

- 산양 흔적 자료

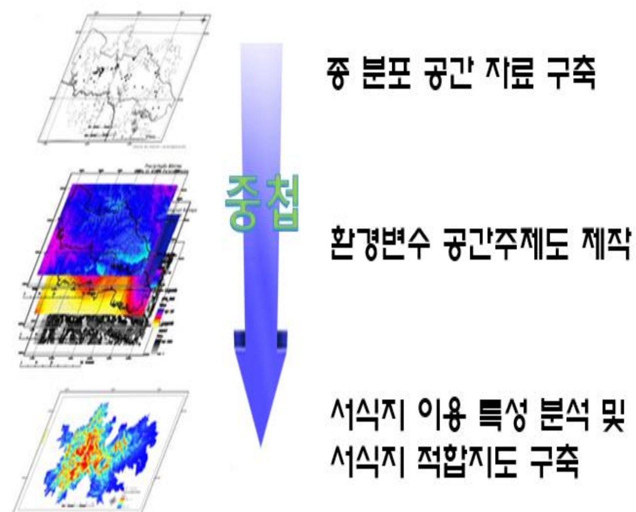
  · 산양 배설물 148지점, 뿔질 5지점, 족적 3지점, 체모 2지점 등 총 158 지점

- 방사산양 위치자료

  · SOM01 개체 31개 지점, SOF02 개체 34개 지점 등 총 71개 지점

➢ 공간 자료 구축 및 분석

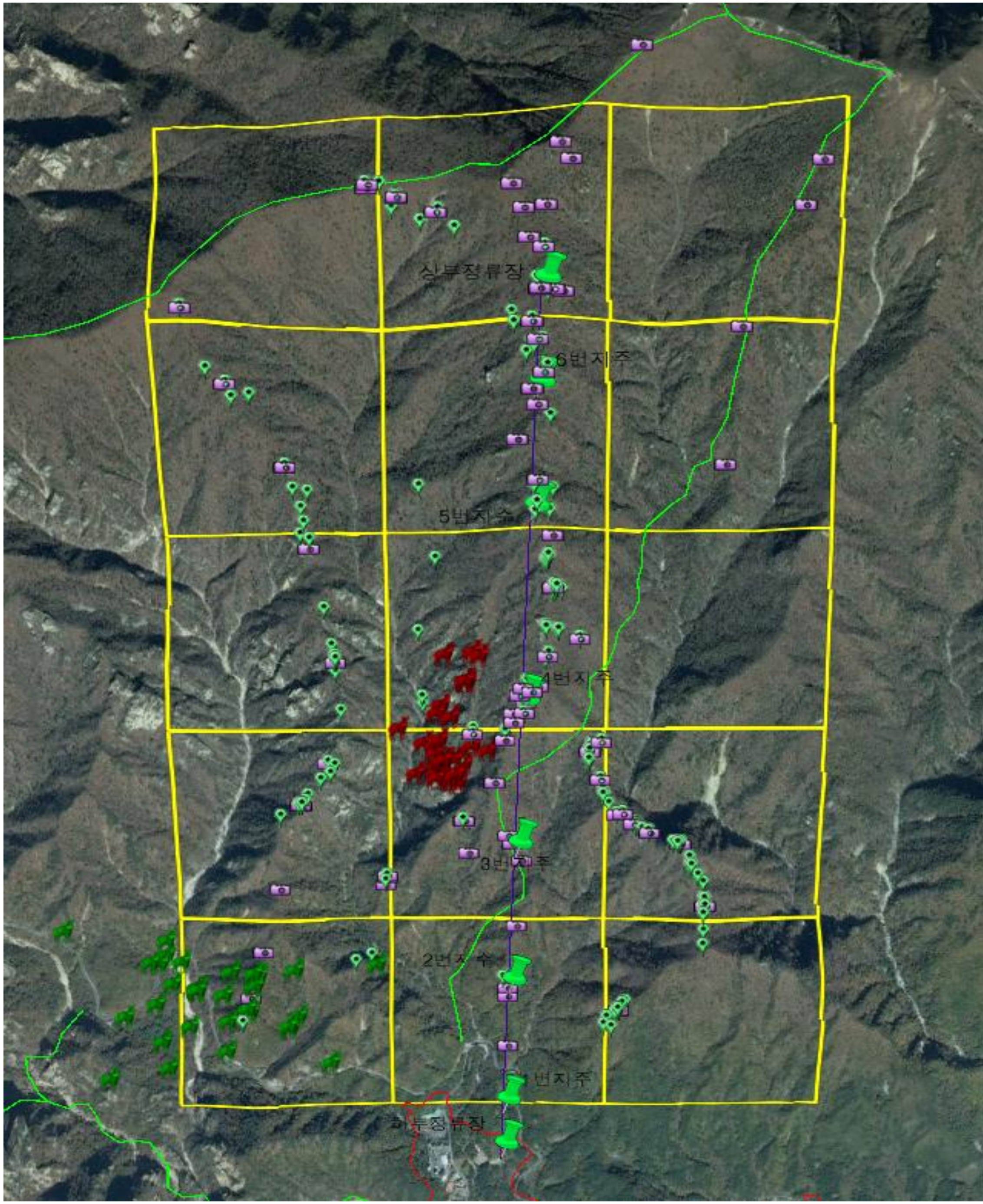
- ArcGIS 10.2(ESRI Inc., U.S.A) 이용 서식지 이용 특성 분석



산양 위치 자료 구축

구 분	산양 흔적 위치 지점						방사 산양 위치 지점	합 계
	배설물	족적	뿔질	체모	기타	소계		
No.	148	3	5	2	0	158	71	229

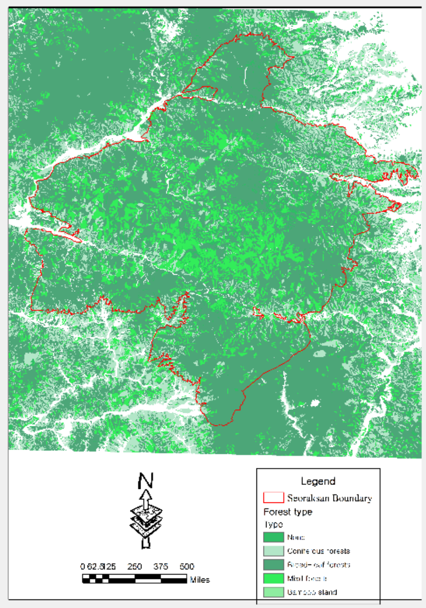
서식지 이용특성 연구



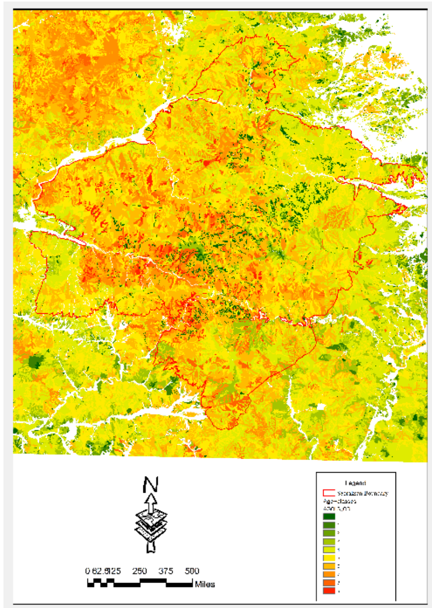
산양 흔적 분포 및 산양 위치 지점 분포 지도

범례

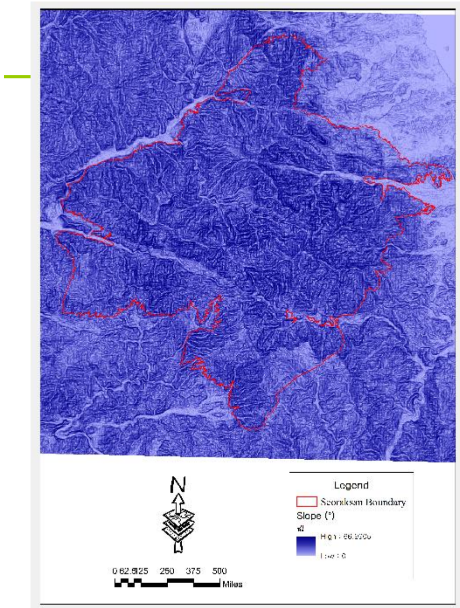
- SOM01(수)
- SOF02(암)
- 흔적 확인 지점
- 카메라 설치 지점
- 조사 격자
- 탐방로
- 지주 지점



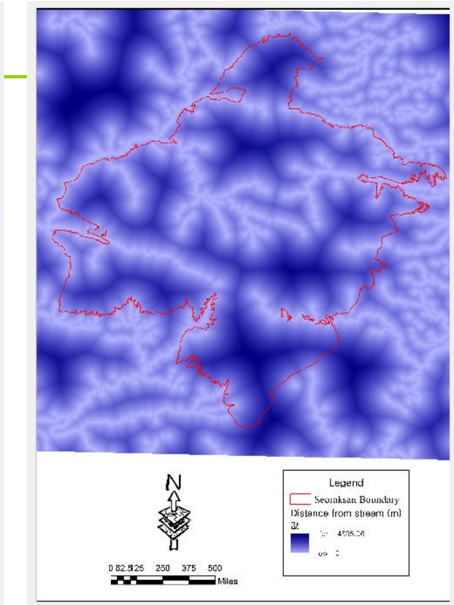
산림 유형



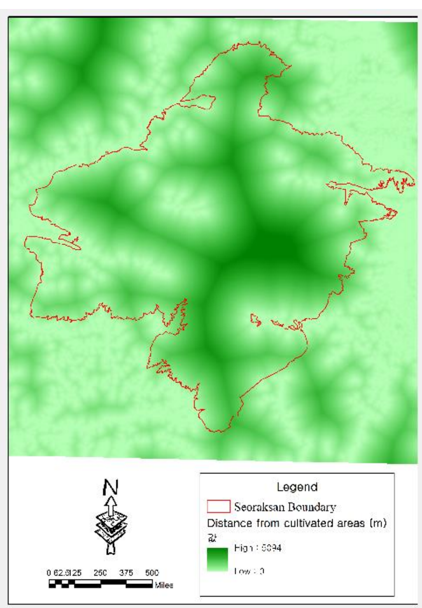
수목 영급



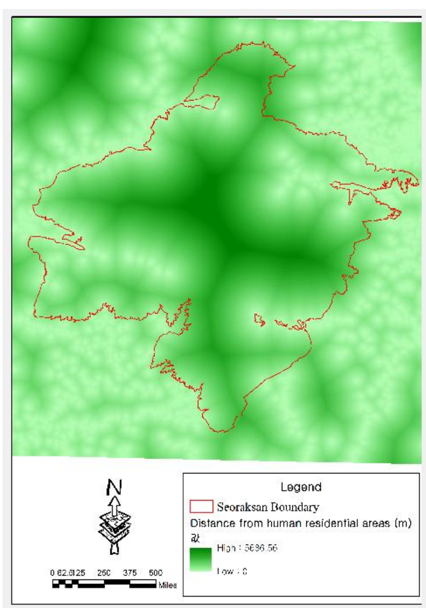
경사도



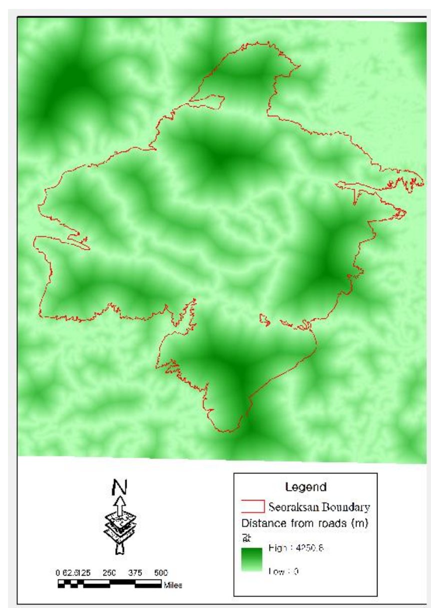
수계로부터 거리



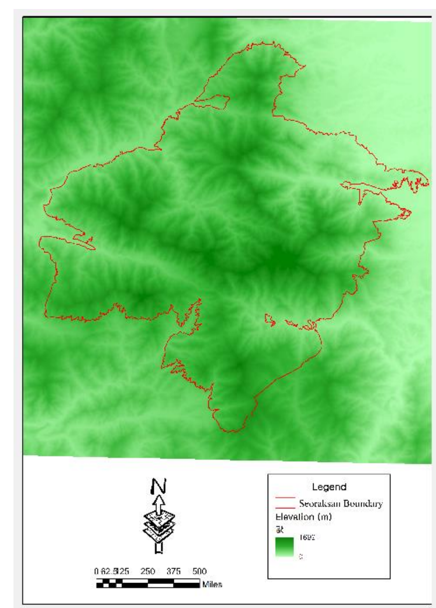
경작지로부터 거리



주거지로부터 거리



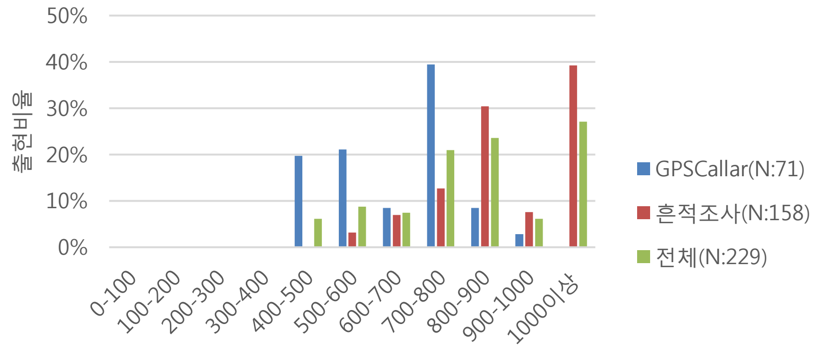
도로로부터 거리



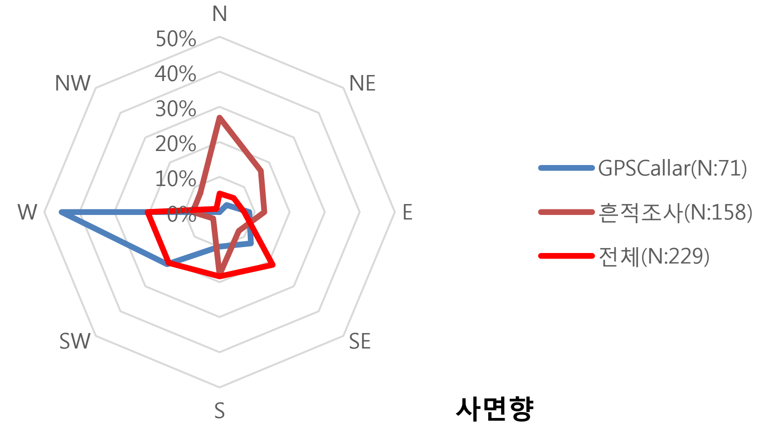
고도

❖ 환경요인 별 서식지 이용특성

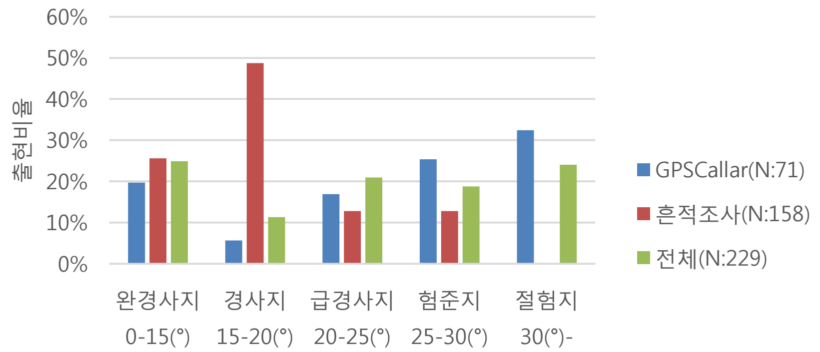
➢ 자연적 요인 이용특성



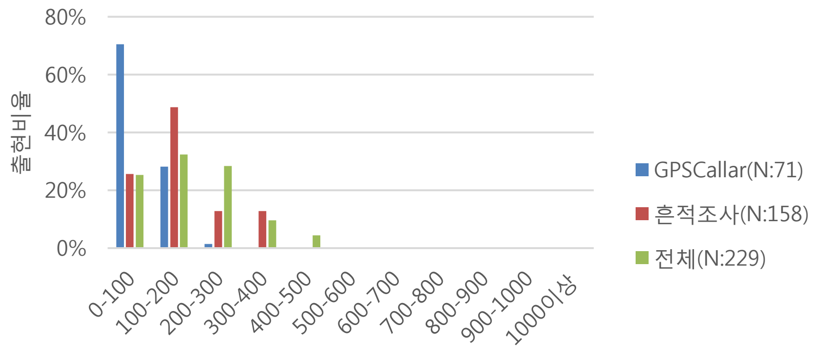
출현고도(m)



사면향



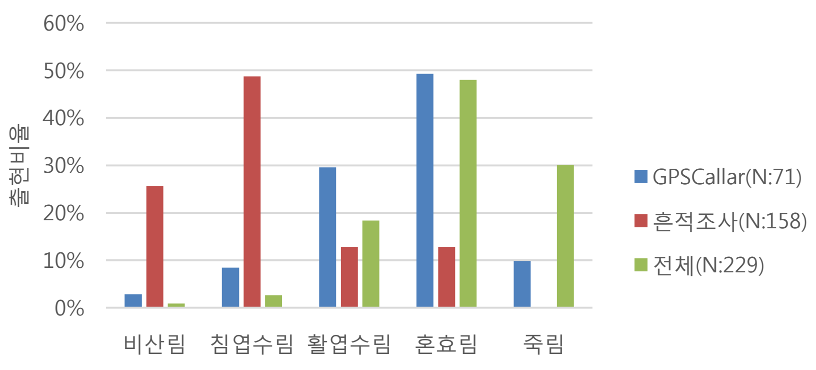
경사도(°)



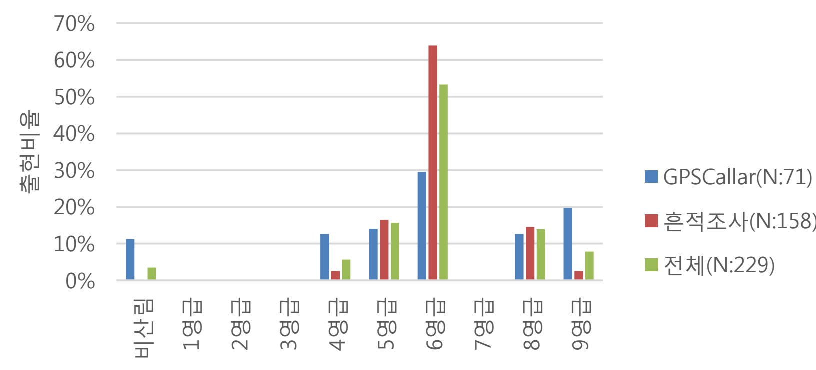
수계로부터 거리(m)

❖ 환경요인 별 서식지 이용특성

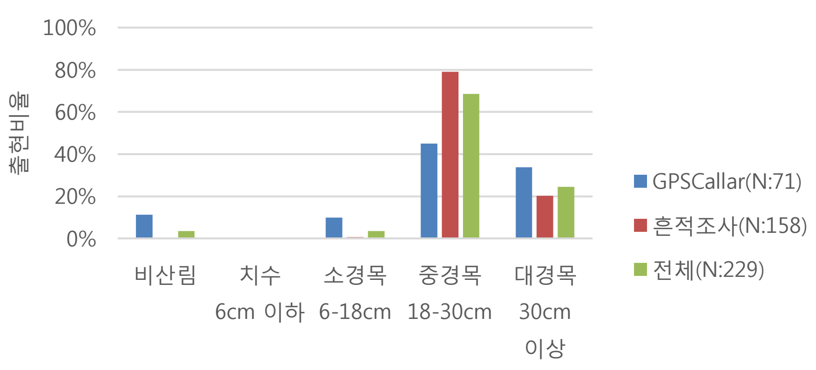
➢ 자연적 요인 이용특성



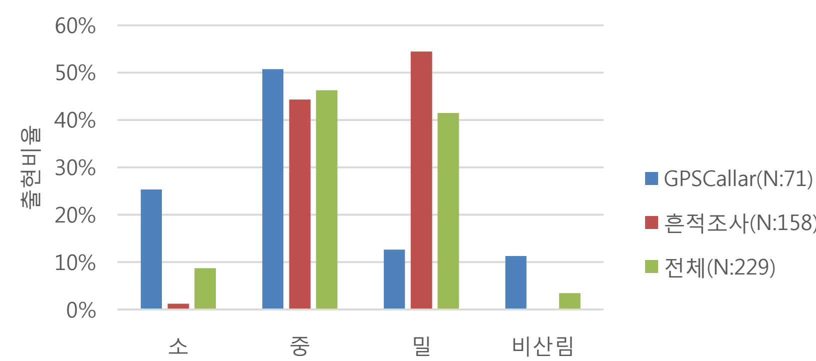
산림 유형



수목영급



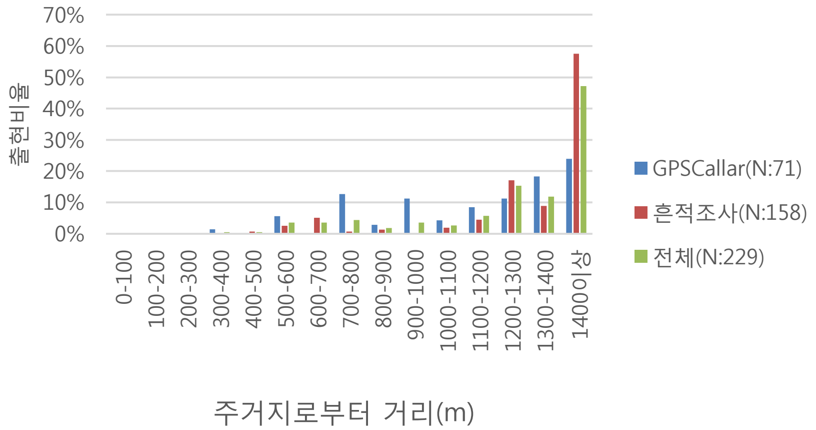
수목 경급

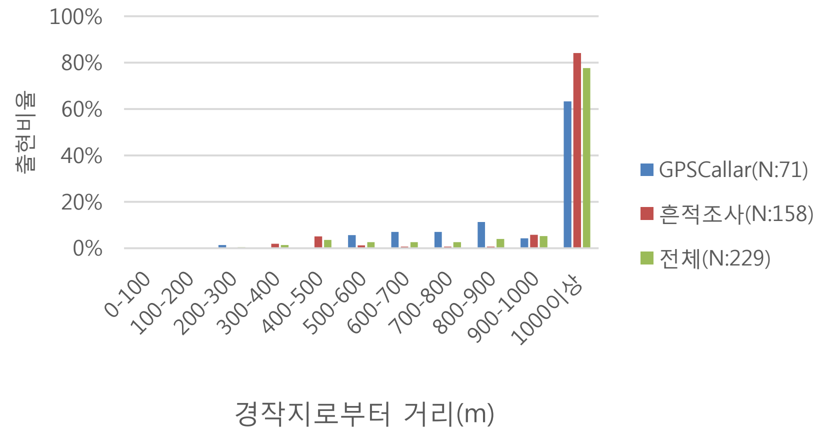


수관밀도

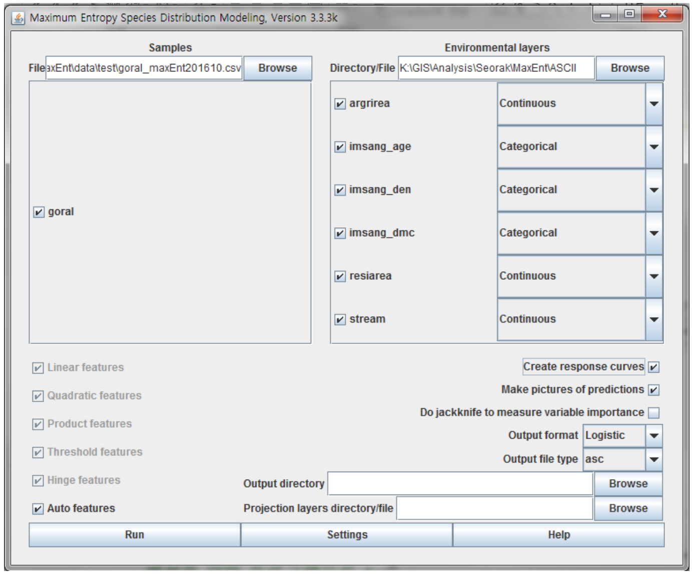
❖ 환경요인 별 서식지 이용특성

➢ 인위적 요인 이용특성





❖ 서식지 적합성 지도



- 자료 구축
  - 환경요인 : 11 개 변수 이용

    - 자연적요인 : 8개 변수

      산림 환경(산림유형, 수목연령, 수목경급, 수관밀도)

      지형(고도, 사면향, 경사도, 수계로부터 거리)

    - 인위적 요인 : 3개 변수

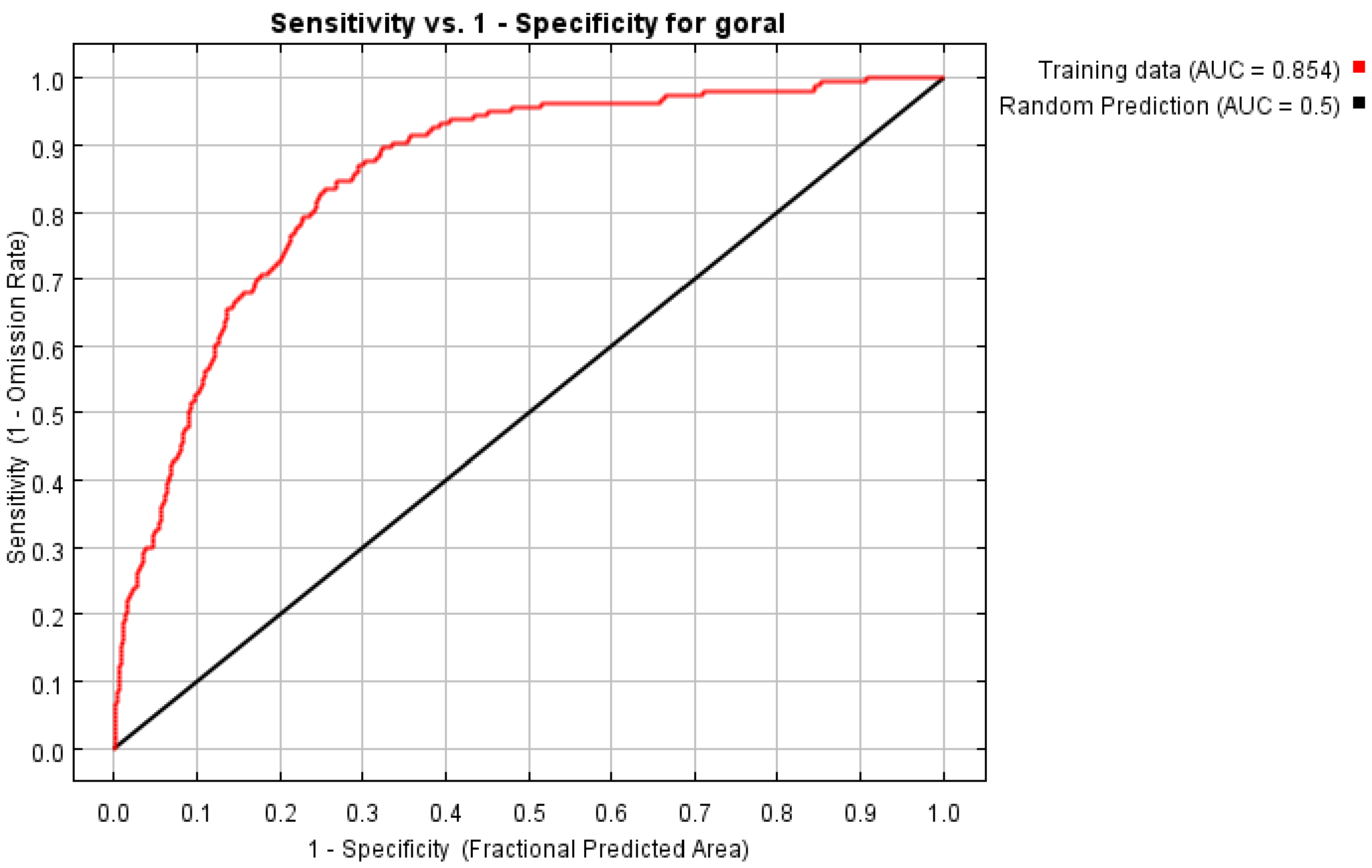
      - 경작지로부터 거리, 주거지로부터 거리, 도로로부터 거리
  - 입력자료 : 229개 좌표(흔적자료 158, 방사산양 71)
- 분석

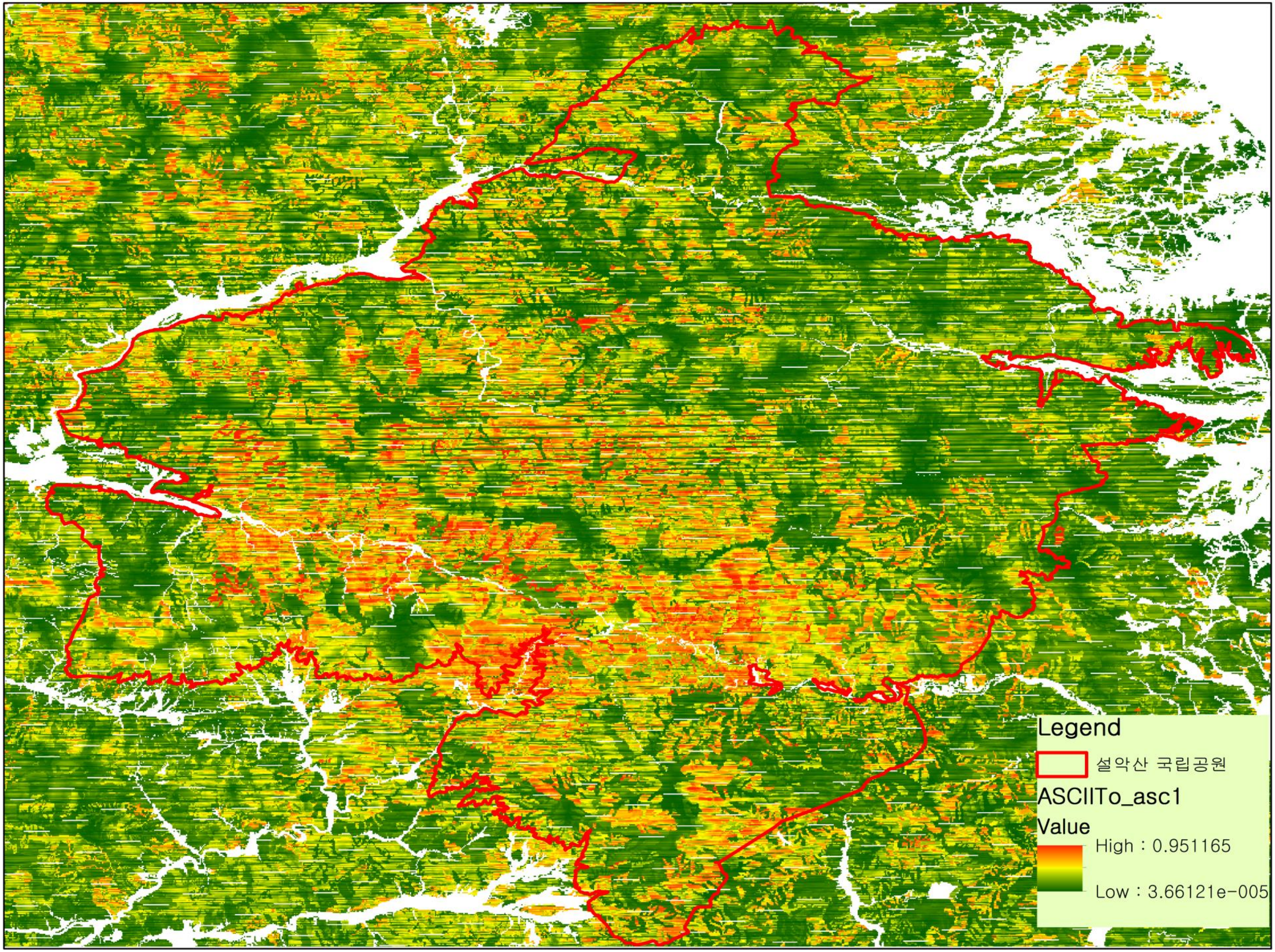
  - 출현자료만을 이용하는 여러 종분포모형(Species Distribution Model) 중 가장 높은 모형 적합도를 보여주는 MaxEnt 기법을 이용

  - 분석을 위한 프로그램으로 ArcGis 10.2.2 와 MaxEnt 3.3 이용

❖ 서식지 적합성 지도

➢ 모델 적합도




Legend
설악산 국립공원
ASCIITo_asc1
Value
High : 0.951165
Low : 3.66121e-005