

Ecological Statistics



Resource Selection

- We often infer that species will select resources that maximize its fitness (i.e., survival, reproduction)
- Availability of resources is not uniform in space or time
- Resources are “selected” when they are used in higher proportion to their abundance

Resource Selection

- Example questions
 - Is old growth forest required for red cockaded woodpecker?
 - Do reef fish choose their location based on reef composition and proximity to open water?
 - Does an exotic fish favor different prey than our native fishes?

Resource Selection

- Types of Resources
 - Habitat
 - Food
- Goal is to understand how organisms select resources
- Common studies in all of ecology



Resource Selection

- Three types of study designs
 1. Population level assessment
 - used and unused areas determined
 - individual animals not recorded
 - resource availability measured with random sampling or GIS

Resource Selection

2. Individual animals identified and resource use measured for an area
 - telemetry methods, and resources used are documented at regular time steps
 - relocations of marked individuals compared to estimates of habitat availability in the area

Resource Selection

- Individual animals identified and resource use and availability measured for each individual animal
 - animals radio collared, and resources used are documented at regular time steps
 - habitat availability measured for each animal, usually within its home range

Resource Selection

- Approaches
 - Indices for resource selection
 - Building Resource Selection Functions (RSF's) in a statistical framework
- Both used in the literature

Resource Selection Indices

- Selection Index (Savage 1931)

$$w_i = \frac{o_i}{l_i}$$

Where: w_i = Selection index for species (or habitat) i
 o_i = Proportion of species (or habitat) i used by the animal
 l_i = Proportion of species (or habitat) i in the environment

Resource Selection Indices

- Example
 - 65% of bobwhite quail found in fenceline habitat
 - Fenceline represents 10% of total habitat

$$w_i = \frac{0.65}{0.10} = 6.5$$

Values above 1 indicate selection, below 1 indicate avoidance
 Index can range from 0 to ∞ , which makes interpretation difficult

Resource Selection Indices

- Often standardize all w_i 's to sum to 1

$$B_i = \frac{w_i}{\sum_{i=1}^n w_i}$$

where: B_i is the standardized selection index.

Values of $(1/\text{number of resources})$ represent no preference, above represents selection, etc.

Resource Selection Indices

Habitat Type	Available l_i	Utilized o_i	w_i	B_i
I	0.2	0.2	1.0	0.15
II	0.7	0.3	0.43	0.08
III	0.1	0.4	4.0	0.62
IV	0.1	0.1	1.0	0.15
Sum	1	1	6.43	1

Neutral selection would be $1/4$ habitats = 0.25 for B_i
 The species in question strongly selects Habitat III, negatively selects the others

Resource Selection Indices

- Statistical tests?
- To test the hypothesis that animals are selecting resources at random?

Resource Selection Indices

- Chi-square test of homogeneity
- G test
- Both commonly used

Resource Selection

- Other indices
- Manly's α
- Chesson's α
- Murdoch's index

Resource Selection

▪ Manly's α

$$\alpha_i = \frac{r_i}{n_i} \frac{1}{\sum_{j=1}^m (r_j/n_j)}$$

Where:

α_i = Manly's index for dietary (or habitat) type (e.g., a plant species)
 r_i, r_j = proportions of dietary type i and j in the diet
 n_i, n_j = proportion of dietary type i and j available
 m = number of potential dietary (or habitat type) categories

Standardized to ranges from 0 to 1
Neutral selection at $1/m$, positive at $> 1/m$, negative at $< 1/m$

Resource Selection

- Some Examples



Resource Selection

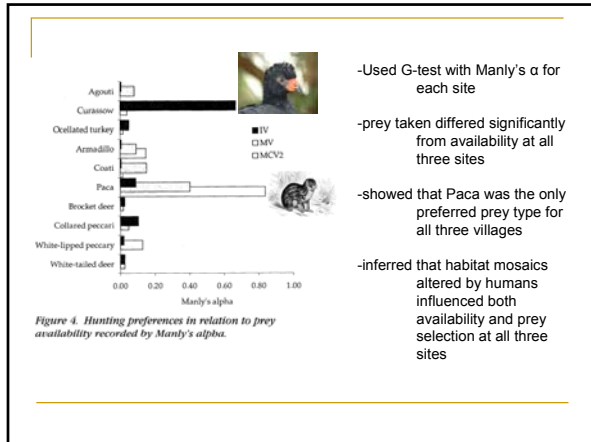
Habitat Mosaic, Wildlife Availability, and Hunting in the Tropical Forest of Calakmul, Mexico

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Conservation Biology (2000) 14:1592-1602

Quantified prey types for humans around several villages
Measure prey availability



- Used G-test with Manly's α for each site
- prey taken differed significantly from availability at all three sites
- showed that Paca was the only preferred prey type for all three villages
- inferred that habitat mosaics altered by humans influenced both availability and prey selection at all three sites

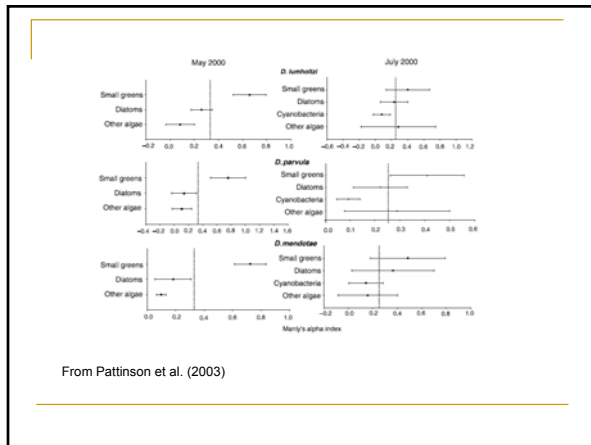
Resource Selection

Freshwater Biology (2003) 48, 233-246

Invasibility of a reservoir to exotic *Daphnia lumholtzi*: experimental assessment of diet selection and life history responses to cyanobacteria

K. R. PATTINSON, J. E. HAVEL AND R. G. RHODES
Department of Biology, Southeast Missouri State University, Springfield, MO, U.S.A.

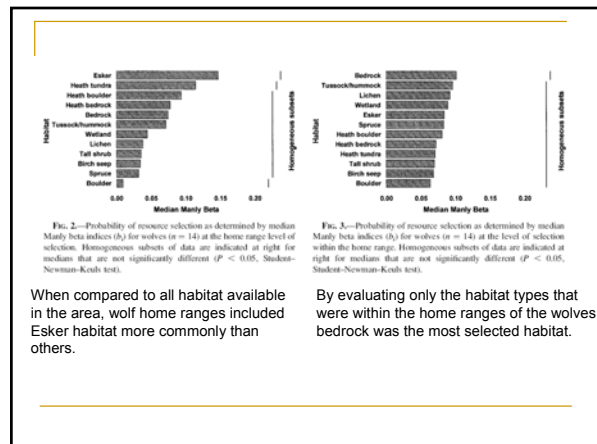
Hypothesized that an invasive zooplankter could have an advantage over native species by utilizing cyanobacteria



Resource Selection

- Found high diet overlap between the invasive and native *Daphnia*
- Lumholtzi* showed similar negative preference to blue-green algae as native *Daphnia*

Indicated that the exotic species was not using blue-green algae to an advantage relative to native species

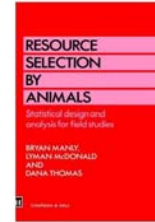


Resource Selection

- Krebs (1999) shows some nice examples of using selection indices
- Many studies use the index as the response variable, then apply statistics to evaluate uncertainty
- Indices are a valid approach

Resource Selection

2. Building Resource Utilization Functions (RUF's) with statistical models



Resource Selection

- Rephrase the question to quantify the probability of an animal using a range of resources
- Resource Selection Function (RSF) is any function that is proportional to the use of a resource
- Can represent a wide range of statistical approaches

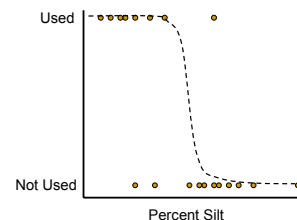
Resource Selection

- Can be modeled as presence/absence via a wide range of predictor variables
- Can model presence/available (e.g., occupancy rates as a function of habitat proportion)

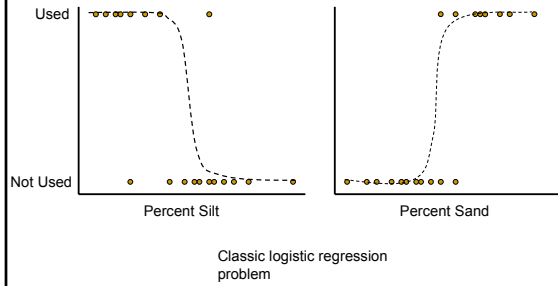
Resource Selection

- Example
- Assess substrate types used by nesting smallmouth bass in a lake (e.g., percent silt, gravel, etc.) during spring
- Measure substrate at random points that are expected to represent "available" substrate types, and those where fish were found to be nesting

Resource Selection



Resource Selection



Building RSF's

- can identify habitat/diet preference
- predict the probability of habitat use
- more useful to management than an index, the uses are intuitive
- common approach
- what are the problems?

Resource Selection

- Detection probability (p) assumed to be one, or that the p doesn't change across habitats
- Big issue is that detection probability often varies with the habitat types we are interested in, which can cause extreme bias in parameters (and model selection) of a RSF
- Detection can also be influenced by other factors (weather, visibility) that are not of interest

Invited Paper

Modeling the Probability of Resource Use: The Effect of, and Dealing with, Detecting a Species Imperfectly

DARRYL I. MACKENZIE,¹ Proteus Wildlife Research Consultants, Dunedin, New Zealand

Abstract

Resource-selection probability functions and occupancy models are powerful methods of identifying areas within a landscape that are highly used by a species. One common design/analysis method for estimation of a resource-selection probability function is to classify a sample of units as used or unused and estimate the probability of use as a function of independent variables using, for example, logistic regression. This method requires that resource units are correctly classified as unused (i.e., the species is never undetected in a used unit), or that the probability of misclassification is the same for all units. In this paper, I explore these issues, illustrating how misclassifying units as unused may lead to incorrect conclusions about resource use. I also show how recently developed occupancy models can be utilized within the resource-selection context to improve conclusions by explicitly accounting for detection probability. These models require that multiple surveys be conducted at each of a sample of resource units within a relatively short timeframe, but given the growing evidence from simulation studies and field data, I recommend that such procedures should be incorporated into studies of resource use. (JOURNAL OF WILDLIFE MANAGEMENT 75(2):367-374; 2006)

Table 1. Effect of detection probability (p^*) on the expected proportion of resource units correctly classified as used by the fictitious Mickey Moose [$E(w_i)$] and apparent selection ratios (\hat{w}_i) for resource units categorized as forested, river/swamp or grassland, under 3 different scenarios: 1) detection probability is equal across all units; 2) detection probability is positively correlated with level of use; and 3) detection probability is negatively correlated with use. Included is the true proportion of used units (w_i^*) and selection ratios (w_i).

	Forested	River/Swamp	Grassland	Overall
w_i^*	0.7	0.5	0.3	0.5
w_i	1.4	1.0	0.6	
Scenario 1				
p^*	0.8	0.8	0.8	
$E(w_i)$	0.56	0.40	0.24	0.40
\hat{w}_i	1.4	1.0	0.6	
Scenario 2				
p^*	0.9	0.8	0.5	
$E(w_i)$	0.630	0.400	0.150	0.392
\hat{w}_i	1.607	1.020	0.383	
Scenario 3				
p^*	0.5	0.5	0.9	
$E(w_i)$	0.350	0.400	0.270	0.328
\hat{w}_i	1.067	1.220	0.823	

From MacKenzie (2006)

-shows bias in the selection index (w_i) resulting from varying detection across habitat types, which are the metric of interest

Resource Selection

- Methods to evaluate detection probability are usually very important, especially when detection varies by habitat, prey type, or animal abundance
- Often the case!

Resource Selection

$$w_i^* = \frac{\exp(\beta_0 + \beta_1 x_{1,i} + \dots + \beta_r x_{r,i})}{1 + \exp(\beta_0 + \beta_1 x_{1,i} + \dots + \beta_r x_{r,i})}$$

where:

w_i^* = probability of use (used/available sites)
 x_i = predictor variables (e.g., habitat characteristics)

Parameters estimated with logistic regression

Resource Selection

$$p_{ij} = \frac{\exp(\theta_0 + \theta_1 x_{1,j} + \dots + \theta_r x_{r,j} + \theta_{r+1} z_{1,j} + \dots + \theta_{r+s} z_{s,j})}{1 + \exp(\theta_0 + \theta_1 x_{1,j} + \dots + \theta_r x_{r,j} + \theta_{r+1} z_{1,j} + \dots + \theta_{r+s} z_{s,j})}$$

where:

p_{ij} = detection probability in habitat i
 x_j = predictor variables of interest (e.g., habitat)
 z_s = covariates that may influence detection
 θ = parameter estimates

Once p_{ij} 's are estimated, can correct your observed counts for detection probability and use logistic regression. Results in unbiased parameter estimates if assumptions are true.

Resource Selection

- Methods to evaluate detection probability are usually very important, especially when detection varies by habitat, prey type, or animal abundance
- Often the case!
- Occupancy models a common way to evaluate resource selection

Resource Selection

Problems with RSF's

- Predicting effects of habitat alterations based on RSF's
 - If you find that a predator strongly utilizes prey type y , can you infer that removing prey type y will reduce populations of the predator?
 - If you find that an animal selects for scrub habitat, does this mean that reduction in scrub habitat will cause population declines?

Resource Selection

Problems with RSF's

- We have been notoriously bad at doing this
 - *Mysis* introduction in lakes intended to reduce algae
 - Common carp introductions worldwide
 - Predicting effects of habitat loss on species abundance and community composition
- Estimating RSF's prior to these perturbations would suggest impacts that have been shown false
- Why?

Resource Selection

Problems with RSF's

- Many factors contribute to resource selection
 - Population density
 - Species interactions (predation, competition)
 - Habitat patch size
 - Scale of the analysis
- Not all of these factors are typically measured, causing predictions to break down when some of them change

Resource Selection

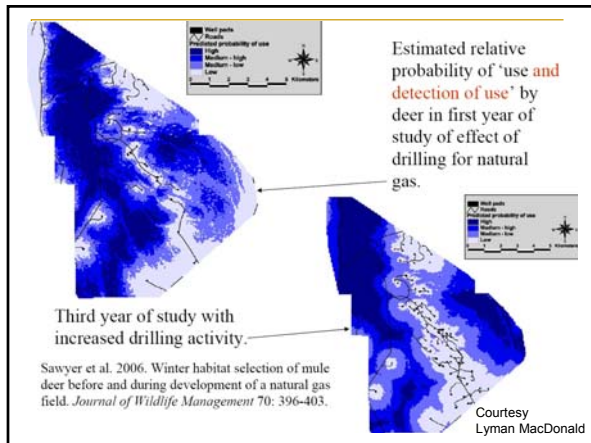
Problems with RSF's

- RSF's themselves don't measure vital rates
 - Survival, growth, recruitment success
- Best if RSF's are tied with measures of these
- Similar to richness and diversity measures

Resource Selection

Problems with RSF's

- When RSF's are used for predictions, important to utilize experiments, include control sites (e.g., BACI), or use a time series over incremental habitat changes
- Example



Resource Selection

Problems with RSF's

- The issue of "Availability"
 - Often assumed that availability is known (e.g., percent area of each habitat, percent of a prey type)
 - Uncertainty in availability often not accounted for
 - GIS has improved this for habitat surveys
- Error in variables problem

Resource Selection

Problems with RSF's

- The issue of "Availability"
- Categories are chosen a priori, such as species of prey, habitat designations, etc.
- Such categories may or may not be meaningful to the species in question, and can lead to spurious results
- Thus, may not reveal the mechanisms

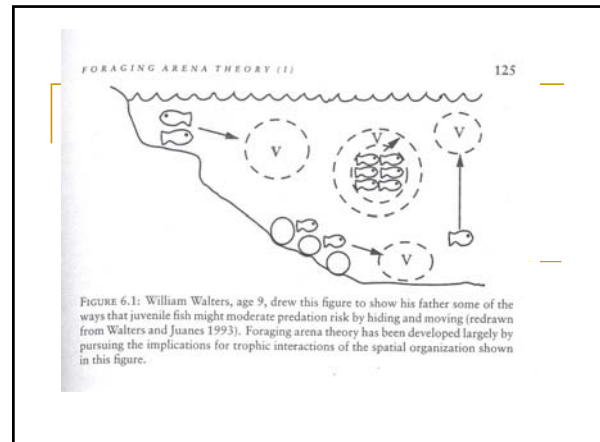
Resource Selection

Problems with RSF's

- The issue of "Availability"
 - Sample gear catch versus what a predator sees
 - Prey types can be cryptic to predators but vulnerable to sampling gear, and vice versa

Foraging Arena Theory

- Animals optimize the way they spend their time, balancing predation risk with growth (foraging)
- An individual's fitness is maximized only if it survives
- Animals therefore must deal with a trade off, where behavior that maximizes growth also maximizes the risk of predation (if you move a lot, you get eaten)
- This idea has a long history of development, even back to Optimal Foraging Theory (Schoener 1971, "time minimizing") and Werner and Hall (1988)



Resource Selection

- Foraging arena theory suggests that our measures of "available" can be misleading
- Animals may not use a habitat due to predation risk, even if it has high food abundance, etc.
- Should consider these issues when interpreting RSF's

Summary

- Which of these questions is most appropriate for RSF's?
- Is old growth forest required for red cockaded woodpecker?
- Do reef fish choose their location based on reef composition and location?
- Does an exotic fish favor different prey than our native fishes?

Summary

- Which of these questions is most appropriate for RSF's?
- Is old growth forest required for red cockaded woodpecker? – careful!
- Do reef fish choose their location based on reef composition and location?
- Does an exotic fish favor different prey than our native fishes?

Summary

- RSF's and selection indices are useful
- Provide a simple link to the plant/animal and it's habitat/prey
- These recommendations can help with interpretation and use of RSF's
 - Consider detection
 - Consider your "available" categories
 - Consider your interpretation

Diet Analyses

- Using RSF's on prey selectivity is very common
- Let's describe some considerations for handling diet data

Diet Analyses

- Four typical types of diet data collected:
 1. Frequency of occurrence
 2. Percent composition by weight
 3. Percent composition by number
 4. Energetic intake