Developing a habitat suitability index model for masked bobwhite; Project Update

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Photo by Roy Tomlinson

Habitat Suitability Index Models (HSI)

- Developed by the USFWS in 1981 to better evaluate fish and wildlife habitat needs
- Contain quantitative relationships between key environmental variables and habitat suitability
- Typically reference numerous literature sources and consolidate information
- Typically used as hypotheses of species-habitat relationships
  - Serve as a basis for improved decision making
  - Increase understanding of habitat relationships through testing and refinement
- Can be used to generate maps of ranked habitat units

Application to Masked Bobwhite

- A habitat suitability model could be very valuable for masked bobwhite recovery
  - Can inform the search for existing masked bobwhite populations
  - Can help identify the best places to release captive bred bobwhites
  - Can inform land management decisions

Masked Bobwhite Literature

1. Early descriptive papers
   – Reviewed and described by Roy Tomlinson(1972)
     - General description of the species and range
     - Description of the habitat but little quantification
     - Some description of the diet

2. Captive Breeding and Release Papers
   – Not focused on habitat issues

Masked Bobwhite Literature

3. Habitat Use Papers
   - Restricted to a small number of variables
     - Woody Vegetation (Guthery et al. 2000, 2001; Ellis et al. 1993)
     - Bare Ground (Guthery et al. 2000, 2001)
     - Cover (Guthery et al. 2000, 2001)
     - Temperature (Guthery et al. 2000, 2001)
     - Herbaceous Vegetation (Guthery et al. 2000, 2001)
     - Invasive species (Kuvleski 2001)
   - Do not incorporate seasonal differences in habitat needs
   - Typically focused on the breeding season
   - Based on small samples in questionable habitat
4. Northern Bobwhite Papers
   - Not necessarily applicable to masked bobwhites

Expert Opinion

- Expert opinion has been used to develop models for many species
  - Best used for species where data is limited (Pearce et al. 2001)
  - Frequently used for habitat suitability models (Johnson and Gillingham 2004)

Project Goals

1. Interview species experts to determine important habitat features

2. Quantify the relationships between important habitat features and habitat suitability for masked bobwhite

3. Translate the various bivariate relationships between habitat features and masked bobwhite into a suite of mathematical habitat suitability models

Project Goal #1

Important Variables

Habitat Variable	Rank	Weight-1
Climate	1	-2.166667
Leguminous Shrubs	2	2.25
Thermal Refugia	3	2.5
Winter Food	4	2.75
Herbaceous Species Diversity	5	3
Woodland /Grassland Edges	6	3.5
Vegetation Structural Diversity	7	3.5
Brush and Shrub Cover	8	3.666667
Bare Ground	9	4
Grass Cover	10	4
Tree Cover	11	4
Avian Predators	12	-4.333333
Forb Cover	13	4.333333
Mammalian Predators	14	-4.666667
Arthropod Diversity and Abundance	15	5
Invasive Plant spp	16	6.5
Vegetation Height (herbaceous)	17	9

Variables to Models

How do we get from a list of important variables to functional habitat suitability models?

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1. Focus on measurable variables

Variables to Models

How do we get from a list of important variables to functional habitat suitability models?

1. Focus on measurable variables

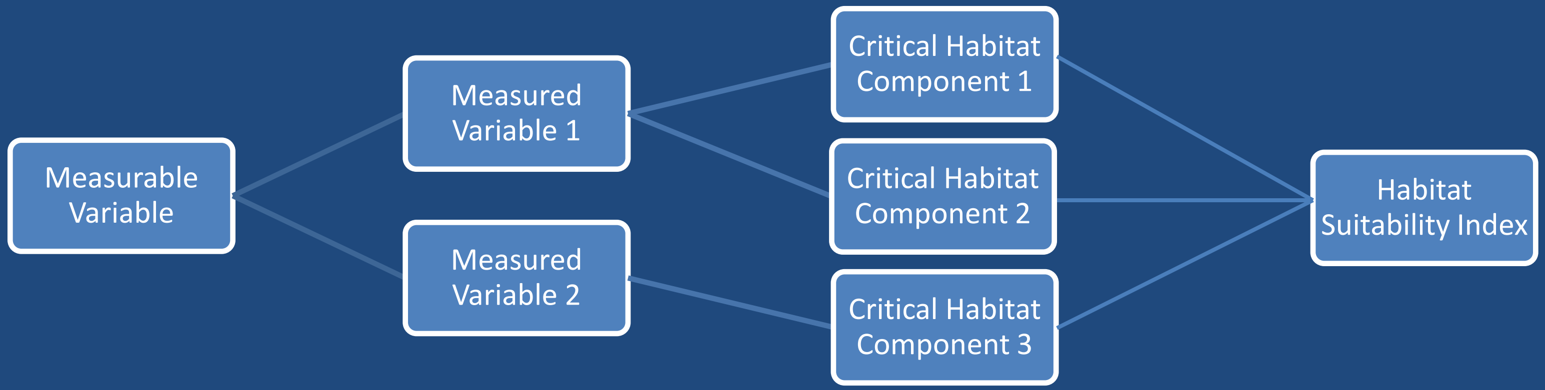
2. Measurable variables should be able to address all of the critical life history requirements of masked bobwhite:
   - Reproduction
   - Food
   - Thermal refuge
   - Predator Protection

Measurable Variables

Habitat Variable	Rank	Weight^{-1}
Shrub Cover	1	2.25
Forb Diversity	2	3
Grass Diversity	3	3
Woodland /Grassland Edges	4	3.5
Vegetation Structural Diversity	5	3.5
Bare Ground	6	4
Grass Cover	7	4
Tree Cover	8	4
Forb Cover	9	4.333333
Brush Piles	10	?
Grass Height	11	9
Shrub Height	12	?
Forb Height	13	?
Leaf Litter	?	?

Model Development

- We have developed a separate model for each expert
- Each model consists of 4 parts:
    1. Measurable variables (the same for all experts)
    2. Measured variable (can vary by expert)
    3. Critical Habitat Components (can vary by expert)
    4. Habitat suitability index (the result)



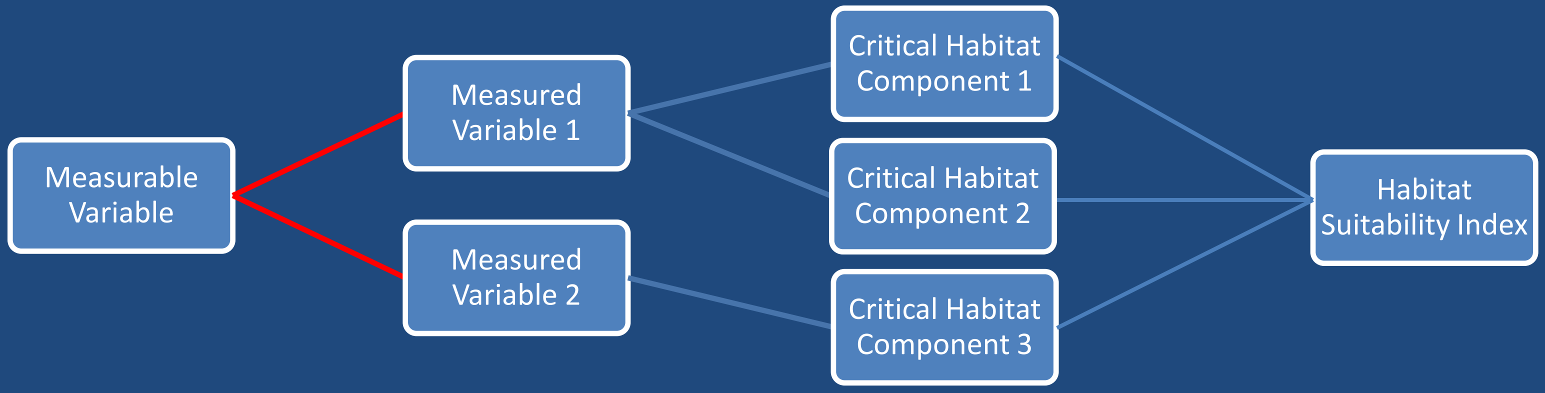
Suitability Equations: How to Measure?

The same variable may be measured in multiple ways or times depending on which latent variable equation it is included in. This allows incorporation of seasonal differences within a single model.

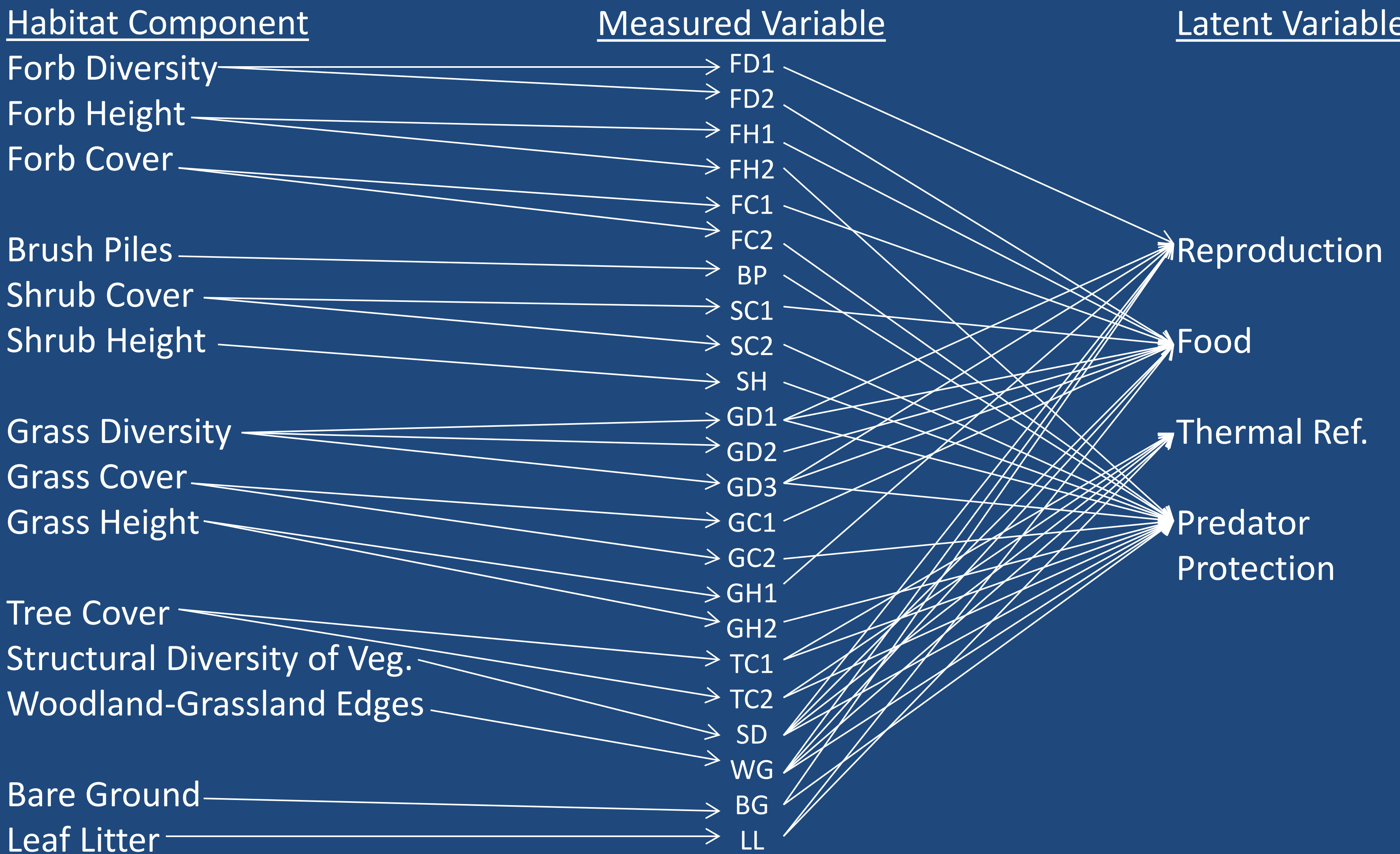
- For example “Forb Height”
    - Measured in Fall -> Predator Protection, Reproduction
    - Measured in Spring/ Summer -> Food

- Another example “Tree Cover”
    - Different values are optimal depending on where on the landscape this variable is measured

This will produce multiple sub-variables for each measureable variable



Suitability Pathways Revisited



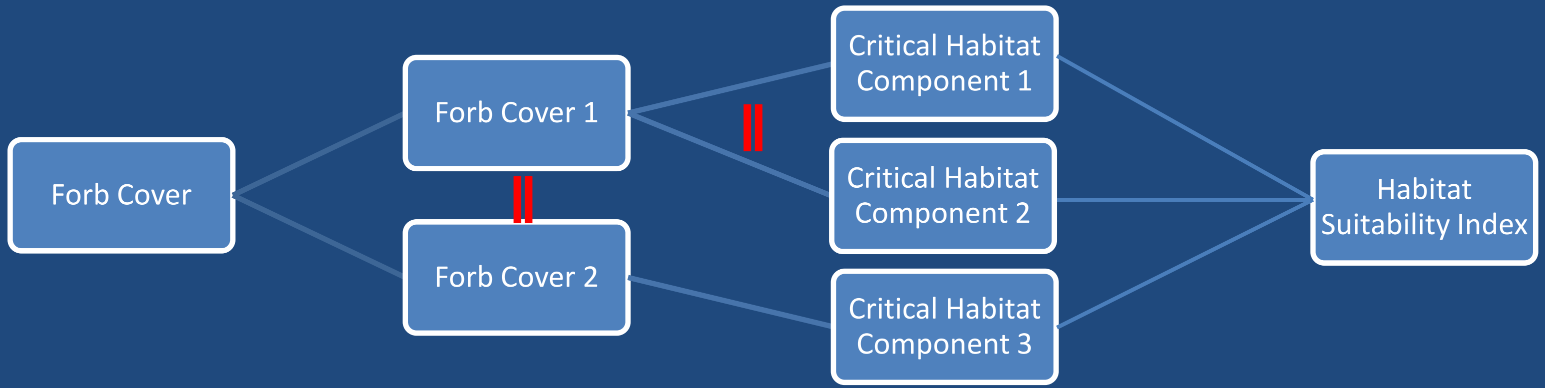
What a Mess!

We can simplify the model if optimal values of measured variables are equivalent within a category

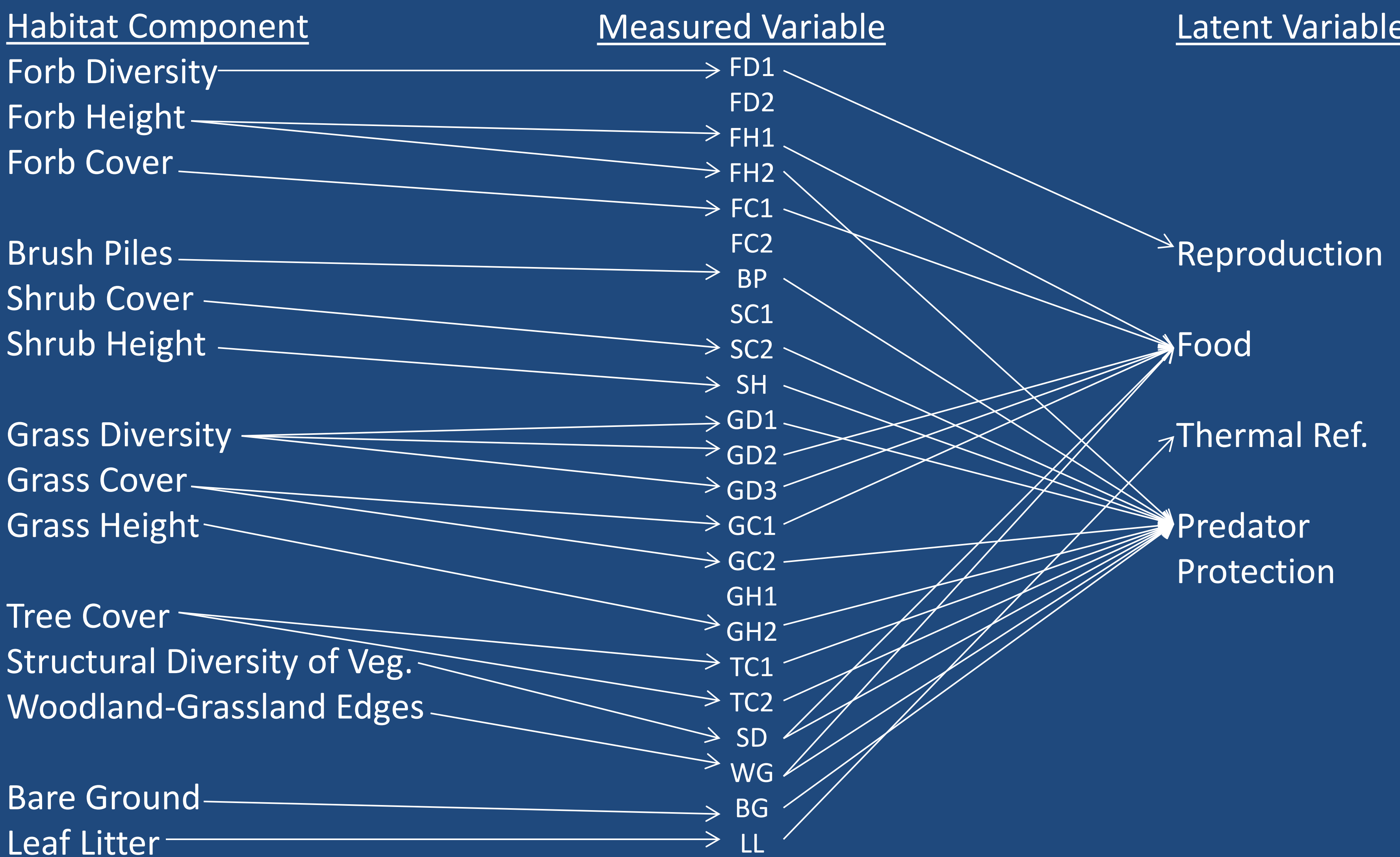
For example, in this model the distribution of suitable values of “Forb Cover” are equivalent for both measured variables and for both latent variables.

FC1 = FC2 = 50% (+/- 15%) which is optimal for both Food and Protection

- Warning! Have to be careful that measured variables are equivalent
- Eliminating redundant relationships is somewhat arbitrary



Suitability Pathways Simplified



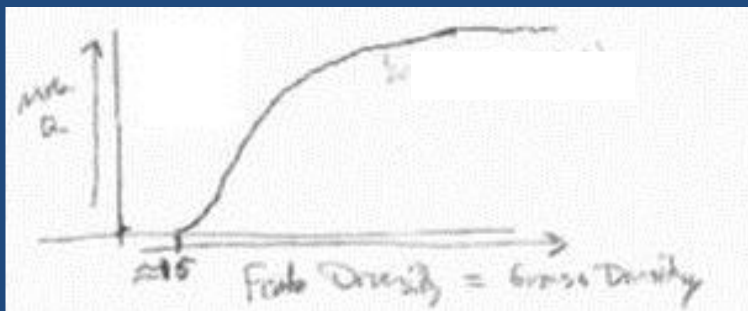
This simplified model assumes equivalence of certain measured variables

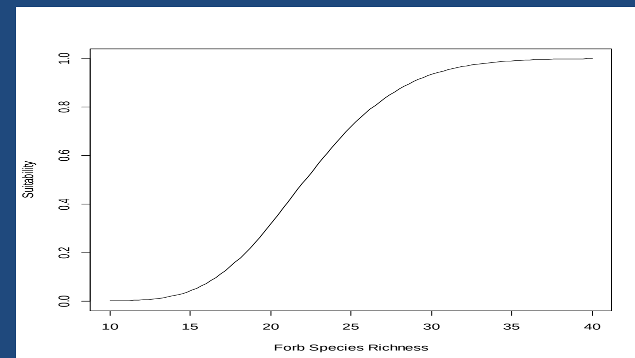
Suitability Functions of Measured Variables

- Asking experts to define measured variables and draw distributions of the suitability of these variables
- Creating theoretical probability density graphs which closely match expert estimates
- Combining probability densities into complete Habitat Suitability Models (HSI) for each expert

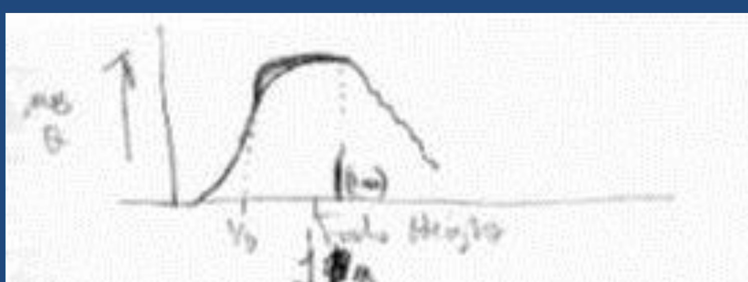
Creating Suitability Indices for Measured Variables

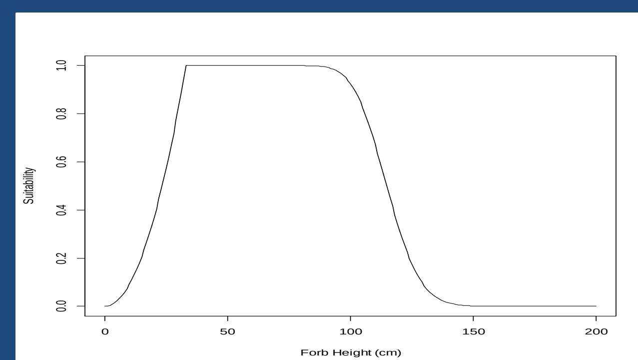
Forb Diversity*





Forb Height*





*Drawings from Dave Ellis

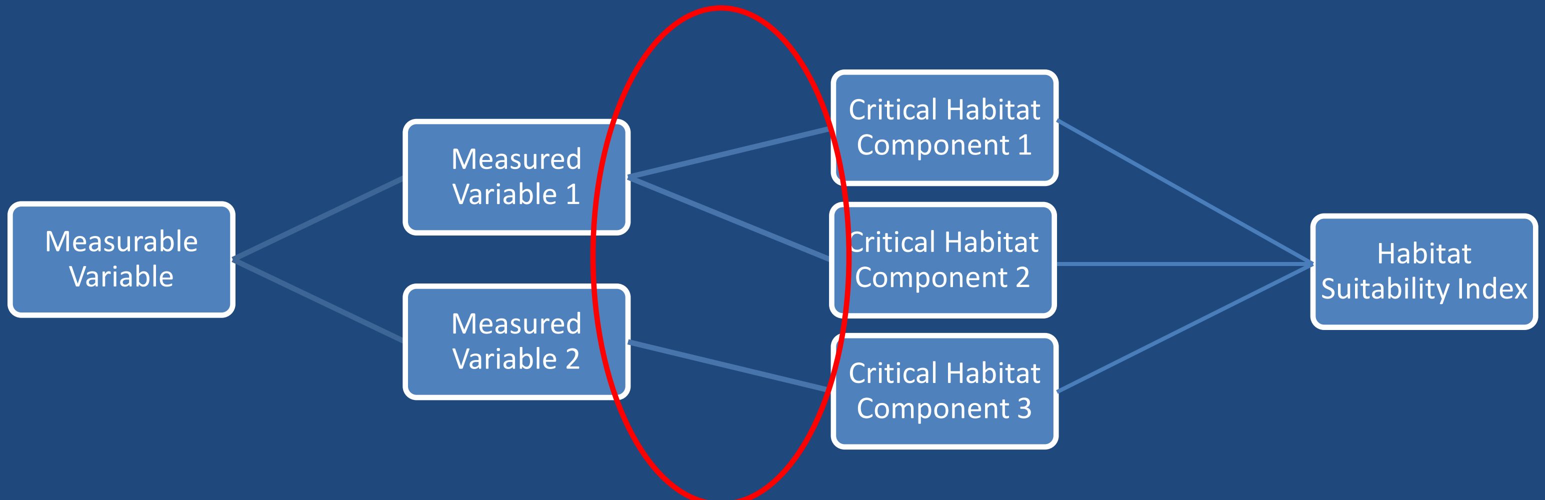
Suitability Equations

Reproduction = Forb Cover + Grass Diversity + Grass Cover + Tree Cover + Structural Diversity + Bare Ground

Food = Forb Diversity + Forb Height * Forb Cover + Shrub Cover + Grass Diversity + Structural Diversity + Woodland-Grassland Edges + Leaf Litter

Thermal Refuge = Tree Cover + Leaf Litter

Predator Protection = Forb Height * Forb Cover + Brush Piles + Shrub Cover * Shrub Height + Grass Diversity + Grass Cover * Grass Height + Tree Cover + Structural Diversity + Woodland Grassland Edges + Bare Ground



Suitability Equations: Additive or Interaction Terms?

Food = Forb Diversity + Forb Height * Forb Cover + Shrub Cover + Grass Diversity + Structural Diversity + Woodland-Grassland Edges + Leaf Litter

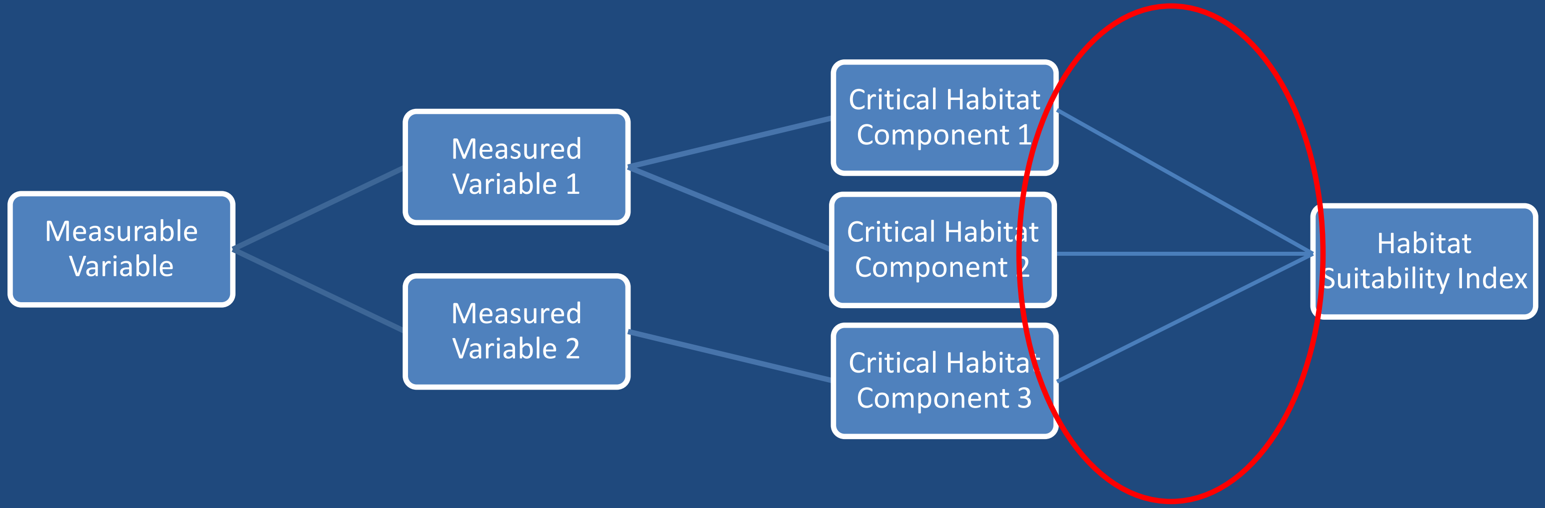
(+) -> If variables can compensate for each other then the relationship is additive.

(*) -> If variables depend on each other then the relationship is interactive

In this example the “Forb Cover” must be at the correct “Forb Height” in order to be suitable

Suitability Equations

Scores from each critical habitat function are combined to give an overall habitat suitability score



Suitability Pathways

Reproduction

Food

Thermal Ref.

Predator
Protection

Habitat Suitability

Equation: Reproduction * Food * Thermal Refugia * Predator Protection

Suitability Pathways

Reproduction

Food

Thermal Ref.

Predator Protection

Habitat Suitability

If the score of any of these critical components is 0 then the entire model is also 0.

Equation: Reproduction * Food * Thermal Refugia * Predator Protection

Progress to Date

- Completed individual HSI models for each expert who agreed to participate (6 HSI models)
- Completed separate HSI model based solely on published literature
- Estimated uncertainty associated with each suitability relationship

Understanding Uncertainty

Understanding the uncertainty is important for making management decisions

- How much uncertainty is associated with each suitability estimate
- What is the source of the uncertainty?
- What is the impact of the uncertainty on recovery?
- How can we reduce the uncertainty?

Understanding Uncertainty

Potential sources of uncertainty:

1. Variable selection uncertainty

2. The nature of the suitability functions

3. The structure of the model
   a) Relationships between variables
   b) Importance of variables relative to one another
   c) Latent variables (Food, Reproduction, etc.)

4. Measurement error of model inputs

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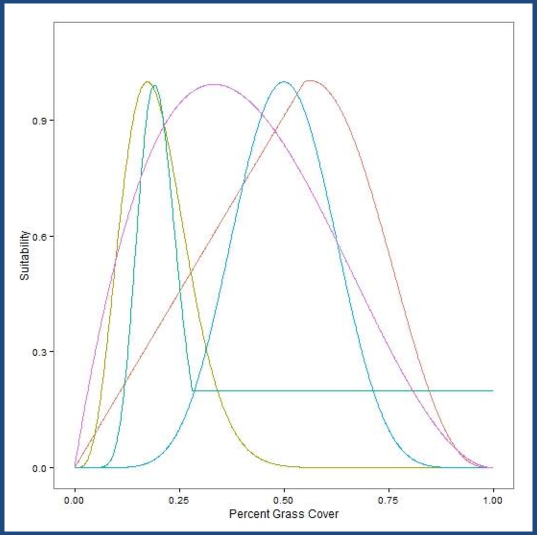
Estimating Uncertainty

Uncertainty of Suitability Relationships:

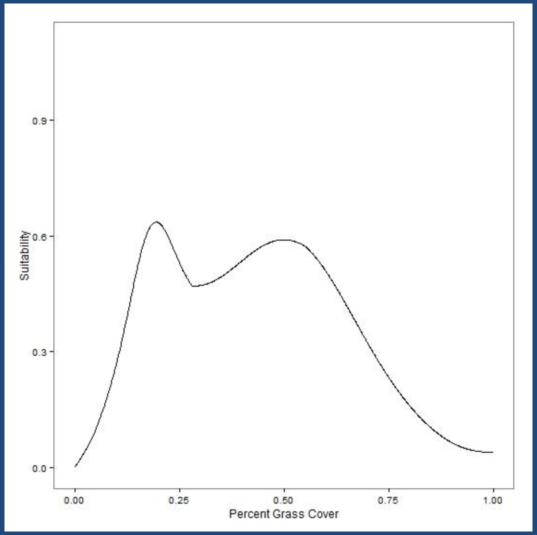
- We used the complete set of expert opinion to quantify uncertainty for each suitability function
  - Assumes the “true” relationship is spanned by the set of expert opinions
  - Assumes experts at the extreme range of the function are either over or underestimating the true relationship
- Provides a tool for understanding where experts agree or disagree

An Example

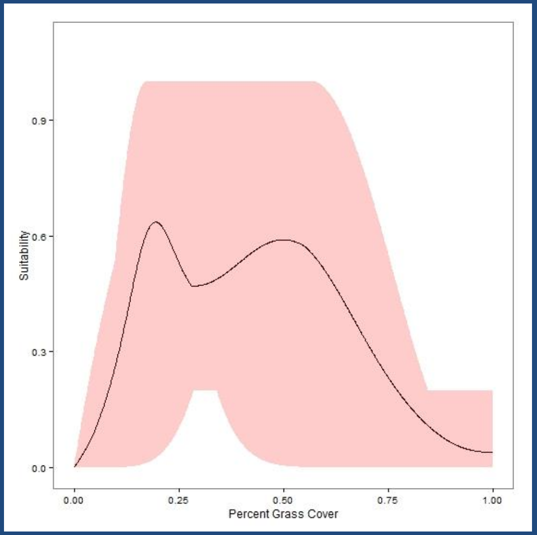
Uncertainty of Proportion Grass Cover



Diversity of Opinions



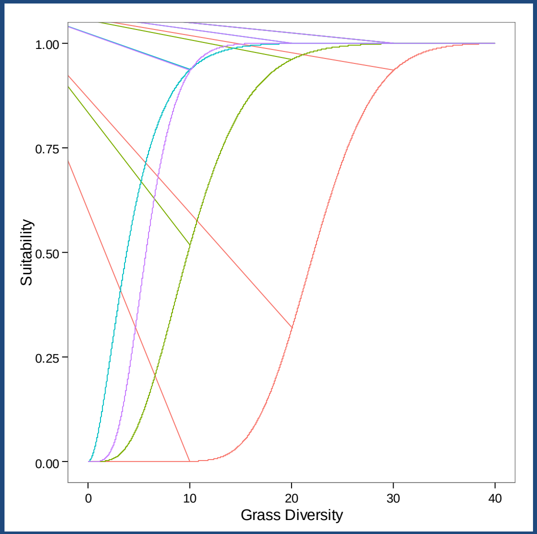
Average Suitability

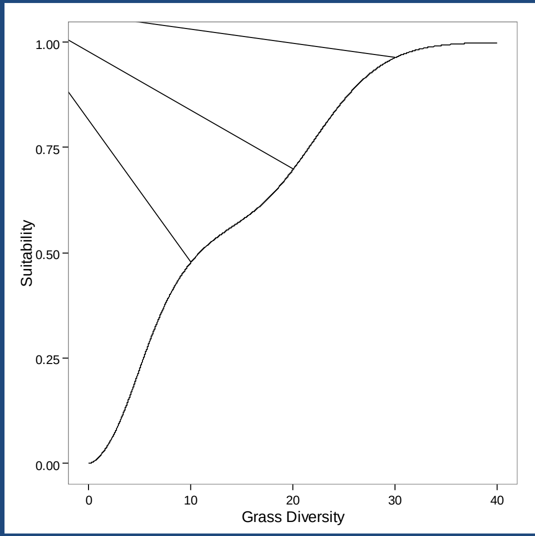


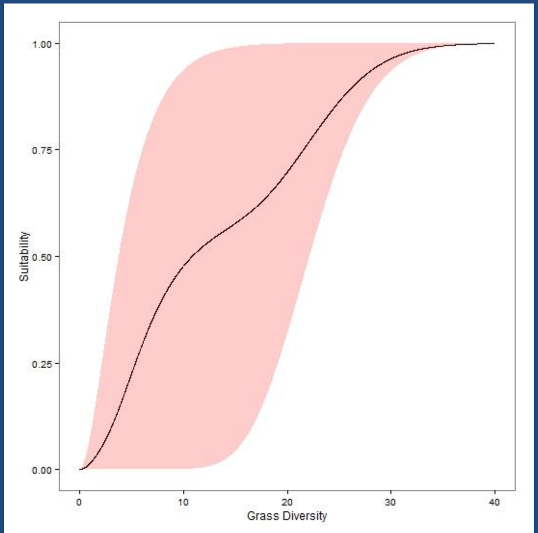
Uncertainty

Another Example

Uncertainty of Grass Diversity





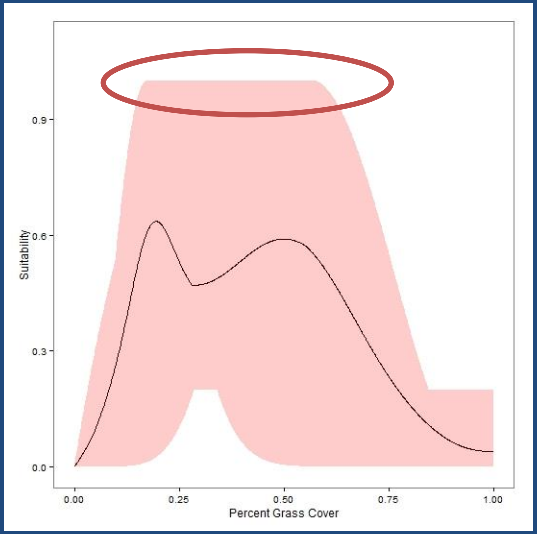


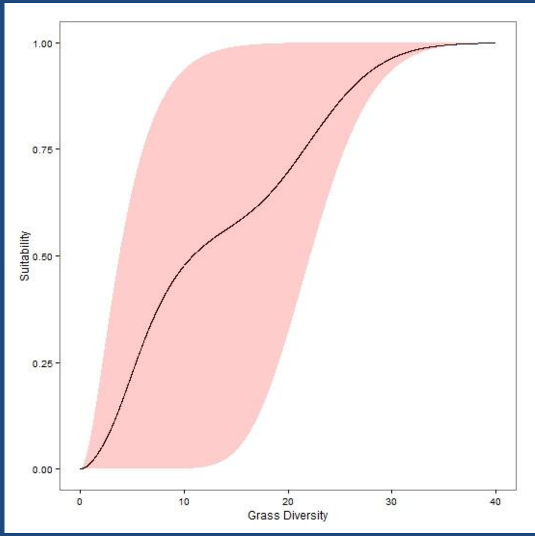
Diversity of Opinions

Average Suitability

Uncertainty

What does this tell us?





- There is no consensus on the best amount of grass cover

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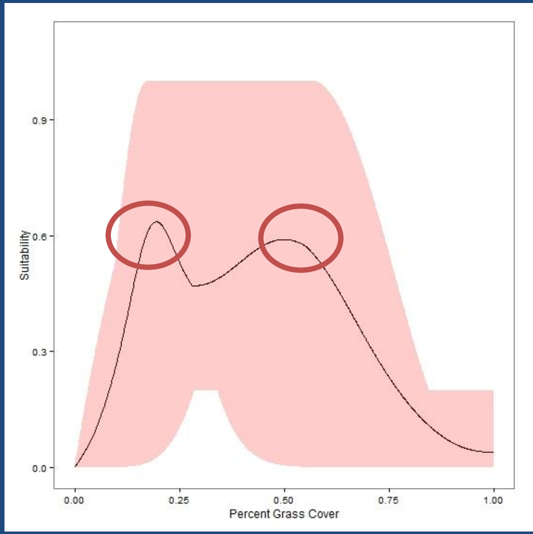

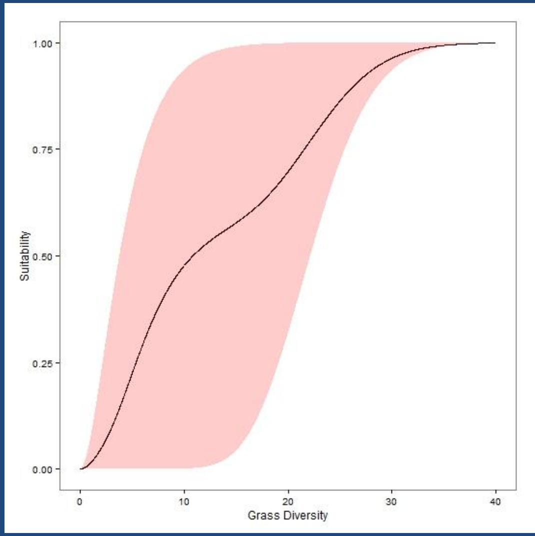

- There is no consensus on the best amount of grass cover
- The mean is bi-modal

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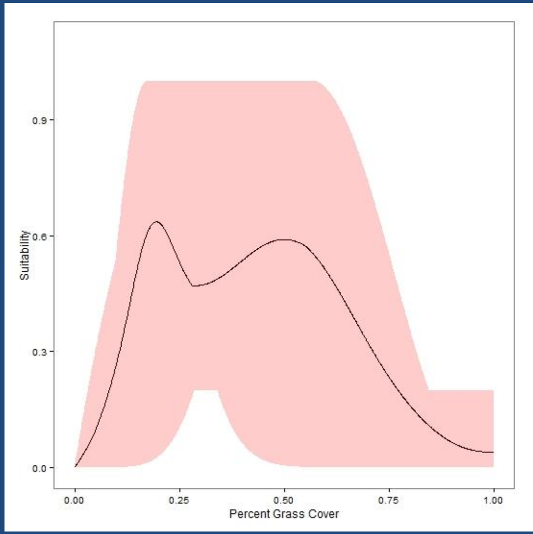

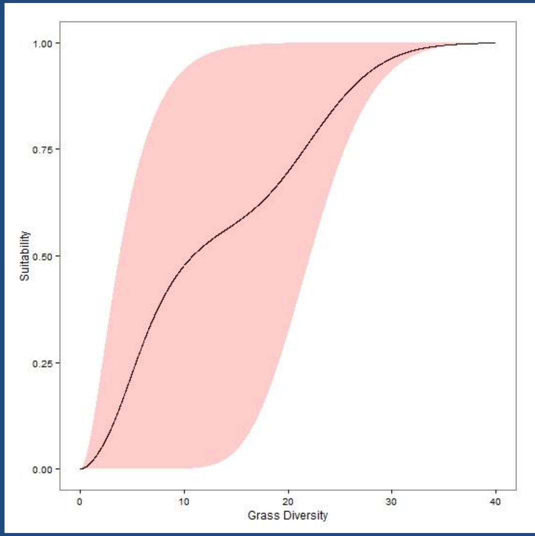

- There is no consensus on the best amount of grass cover
- The mean is bi-modal
- There is a large amount of uncertainty

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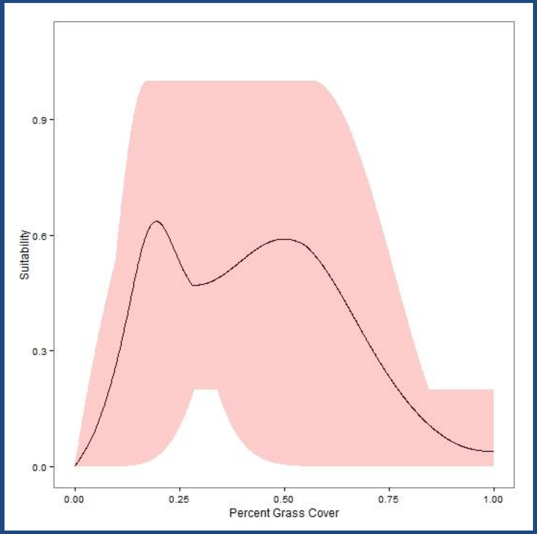

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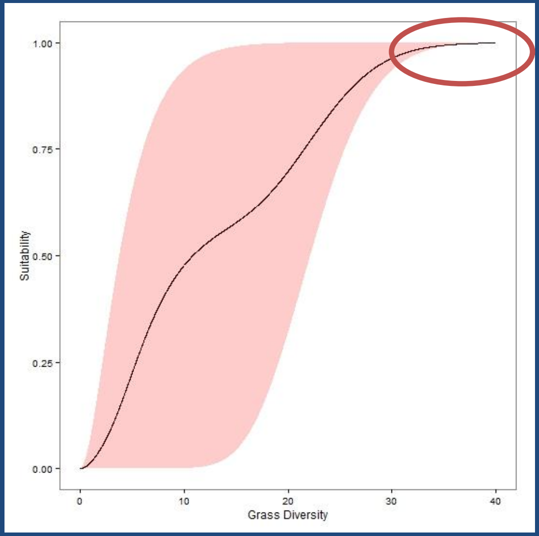
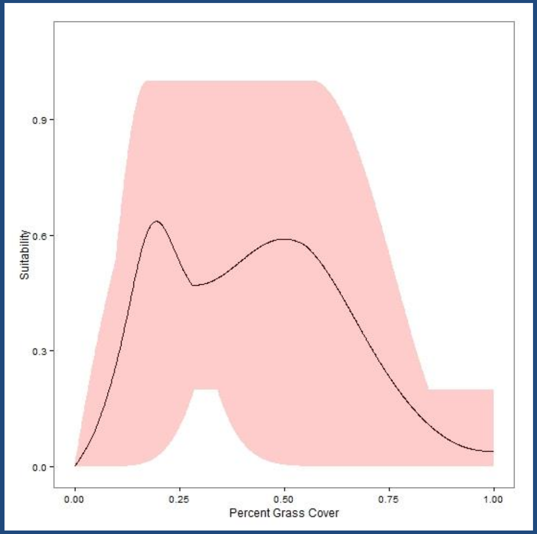


- There *is* consensus on an optimal number of grass species

What does this tell us?



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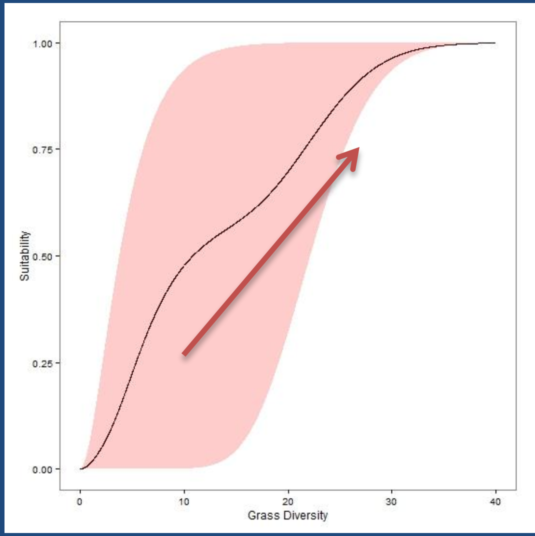
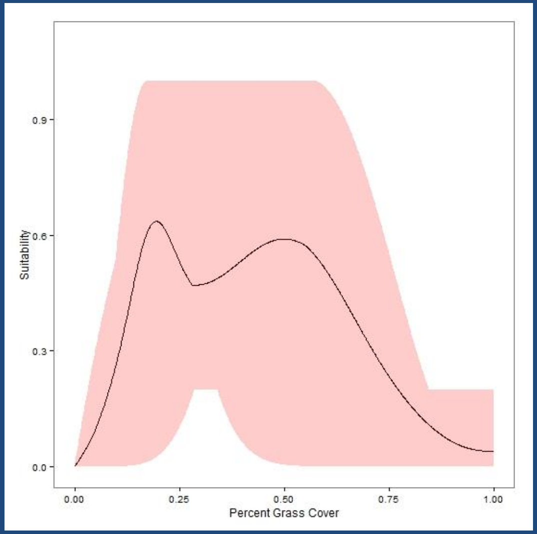


- There *is* consensus on an optimal number of grass species
- The mean is consistent, i.e. one can compare two sites to see which is better

What does this tell us?



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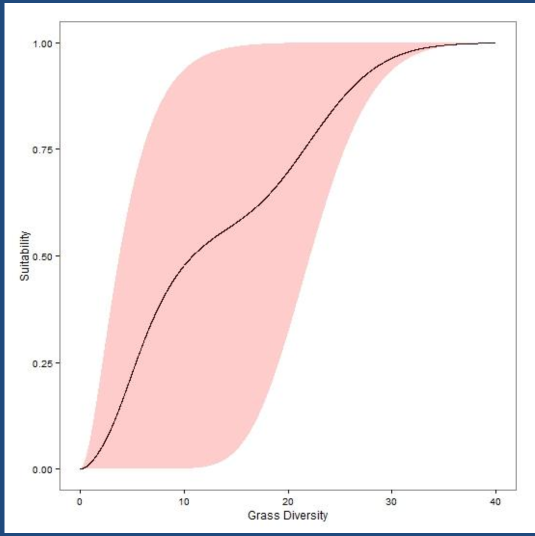
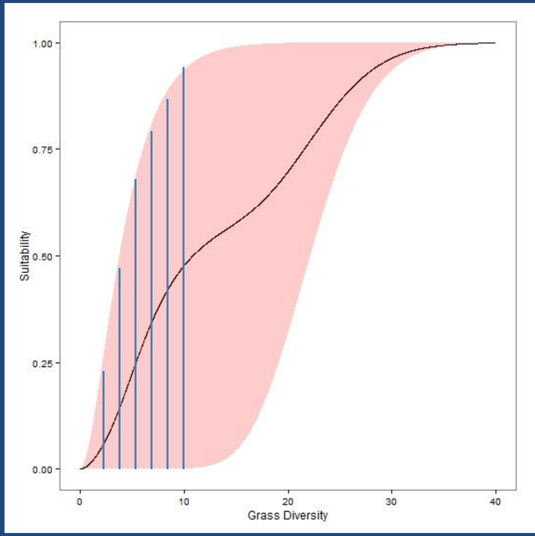


- There *is* consensus on an optimal number of grass species
- The mean is consistent
- There is a less uncertainty

What does this tell us?

We can compare uncertainty between variables by numerically integrating the area of the uncertainty estimate



Three steps:

- Standardize the units among variables
- Integrate
- Rank Variables based on uncertainty

Uncertainty of Suitability Functions

Habitat Variable	Uncertainty	Habitat Variable	Uncertainty
Forb Diversity	751.4589	Annual Grass Diversity, MX	549.9952
Shrub Cover: MX, Summer	681.4633	Annual Grass Diversity, AZ	549.8661
Shrub Cover: MX, Winter	681.4633	Forb Height in the Spring	530.6362
Forb Height in the Fall	680.5916	Tree Cover: MX, Arroyos, Summer	527.6743
Shrub Cover: AZ, Summer	669.5275	Perennial Grass Diversity, MX	527.2701
Tree Cover: MX, Uplands, Winter	649.679	Perennial Grass Diversity, AZ	524.865
Shrub Cover: AZ, Winter	635.0047	Tree Cover: MX, Uplands, Summer	523.689
Tree Cover: AZ, Arroyos, Winter	632.0208	Tree Cover: AZ, Arroyos, Summer	522.2229
Tree Cover: AZ, Uplands, Winter	603.743	Grass Height for Nesting	511.7814
Perennial Grass Cover, MX	602.9204	Forb Cover: AZ, Winter	500.3264
Annual Grass Cover, MX	601.5158	Tree Cover: AZ, Uplands, Summer	480.8542
Annual Grass Cover, AZ	592.9706	Forb Cover: MX, Winter	466.7073
Perennial Grass Cover, AZ	587.2909	Forb Cover: MX, Summer	425.4503
Tree Cover: MX, Arroyos, Winter	586.0451	Shrub Height	127.2489
Grass Height for Cover	557.5849	Proportion of Bare Ground	125.2965
Forb Cover: AZ, Summer	552.1541		

Future Work

- Determining uncertainty associated with entire model
- Field testing the models (with Steve Sesnie and Lacrecia Johnson)
  - How well do they discriminate between habitats?
  - How different are they from each other when scoring particular areas?
  - What can be done to improve the method?

Questions and Feedback?