Habitat Suitability Index Model:

The following habitat suitability index model is the result of information obtained from the consensus of two species experts. Aspects of the model for which the experts failed to reach a consensus are identified as such. We developed this model following the U.S. Fish and Wildlife Service guide to the development of habitat suitability index (HSI) models 103-ESM (USFWS 1981). However, unlike typical HSI models, this model is intended to be used in conjunction with alternative HSI models developed from additional experts and existing literature. This model represents the best estimates of two species experts.

<u>1. Model Applicability</u>:

<u>1.1 Geographic area</u>. This model was developed based on knowledge of masked bobwhite habitat in both Arizona, specifically Buenos Aires National Wildlife Refuge, and northern Mexico.

<u>1.2 Season.</u> This model was developed to evaluate habitat needs of masked bobwhites over the entire year. The suitability of certain variables differs among seasons and these differences are noted and described in the model.

<u>2. Model Description:</u>

<u>2.1 Overview.</u> This model considers the ability of assessed habitat to meet the food, reproductive, and cover requirements of masked bobwhite as an indicator of overall habitat suitability. All components of the model are assessed by vegetative conditions. The

relationship between habitat variables and critical life history requirements of masked bobwhite is illustrated in Figure 1.

2.2 Written Documentation.

The following sections provide a written documentation of the logic and assumptions used to interpret the habitat information for masked bobwhite in order to explain the variables and equations that are used in the HSI model. We present each critical habitat requirement and describe the variables which contribute to it.

1. Reproduction. Available habitat for masked bobwhites must contain adequate cover for nesting and brooding. Perennial bunch grasses of 1-2 feet (.3-.61m) in height are necessary for nesting substrate. Tree cover provides important perches for calling. Optimal values of tree cover are described under “Cover”. Structural diversity is important for providing the appropriate mix of nesting and brooding habitat. If all other cover components are at optimal levels, structural diversity is assumed to be optimal as well.
2. Food. Forb cover is an important source of food for both adults and juveniles. Masked bobwhites use forb foliage directly and indirectly by eating the insects which are associated with forbs. Optimal canopy cover of forbs is approximately 50% from the late summer through the winter whereas the optimum ranges from 35% to 65% in the spring and early summer. Forbs should be 0—6 inches tall to be directly utilized as food. Forb diversity is important for food during all months of the year, primarily because a diverse forb community will result in a diverse insect community. Forbs are also used directly as a food source early in the summer and forb height should be lower during that time to allow for access to the foliage by masked bobwhites. Food-bearing shrubs are an important source of food in the winter when other sources of food are scarce. Structural diversity is important year-round for food. High structural diversity

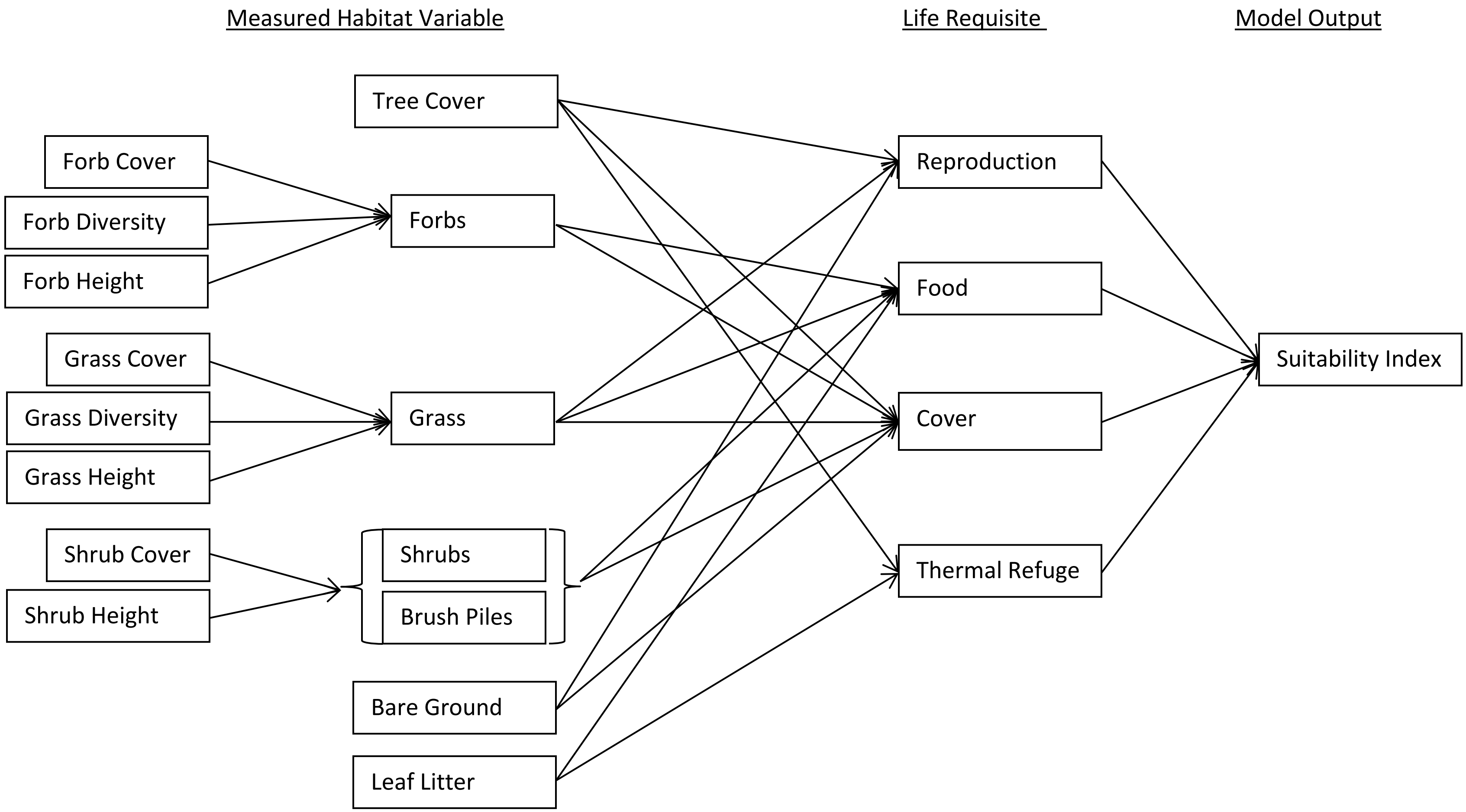
creates a wide array of micro-habitats which increases species richness of insect prey and diversity of herbaceous plants. Woodland-grassland edges improve habitat quality by providing a greater variety of options for food within a relatively small area. Leaf litter can provide additional food by improving insect abundance.

3. Cover. The height of forbs in the fall and winter should be at least 6 inches (15.24 cm) tall but forbs taller than 20 inches (50.8cm) are optimal to provide adequate cover. Forbs provide cover for masked bobwhites with optimal values for percent cover described above under “Food”. Shrubs are also an important component of cover. Optimal values of shrub canopy cover differed between the two experts. Both experts stated optimal cover should be 10-60%; however one expert stated any value between these two would be optimal whereas the other expert believed that 40% cover is the optimal value with diminishing suitability above and below 40%. Both experts agreed that shrubs should be between 2 and 5 feet (0.91 and 1.5 m) tall with an optimal height of 4 feet (1.22m). Brush piles can substitute for shrubs when shrub cover is suboptimal. Brush piles should be approximately 50 feet (15.24 m) in diameter and 50 yards (46 m) apart, however, these figures can vary without affecting suitability. Brush piles should be low (<6 feet tall, <1.8 m tall) and dense. Brush piles should be placed in areas lacking natural cover, near natural cover and in uplands to provide additional cover during breeding. Perennial bunch grasses are important year round for cover. Optimal canopy cover of perennial grasses is 55%. Annual grasses also provide an important cover for masked bobwhite in the summer and fall with an optimal canopy cover of 45%. The proportion of perennial grasses to annual grasses should be approximately 80:20. The optimal height of grasses differed between the two experts. One expert stated optimal grass height is 4-5 feet (1.22-1.5m) tall whereas the other

expert stated optimal grass height is 2-5 feet (.61-1.5m) tall. Trees are used as cover and provide structural complexity. Low tree cover is optimal (5% of canopy cover in the uplands and 30% in arroyos). Small trees can provide suitable cover in the absence of shrubs. Structural diversity is important during all months of the year and helps ensure adequate cover. Woodland-grassland edges provide a greater variety of options for cover within a small area. Bare ground is important during all seasons of the year for mobility of masked bobwhite but is most important in the fall to provide escape corridors after chicks begin to disperse. Areas with 25% bare ground are optimal.

4. Thermal Refuge. Tree cover and shrub cover provides an important source of shade and perch sites for thermoregulation of masked bobwhites. Leaf litter is also important for thermoregulation by retaining moisture.

Figure 1. The relationship between measured habitat variables, critical life history requirements, and habitat suitability for masked bobwhites.

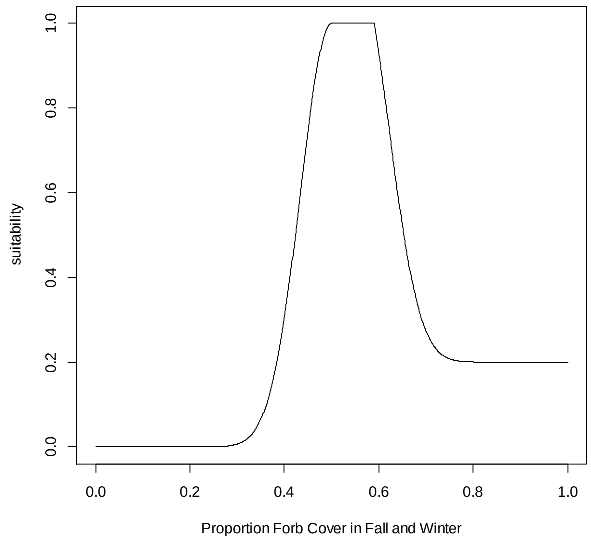


3. Suitability Functions and Graphs

Variable	Description	Suitability Function	Suitability Graph
FC	Forb cover measured as the average percent canopy cover dominated by forbs. The optimal canopy cover of forbs differs between the fall/winter and spring/summer.	Late Summer/Fall/Winter:	

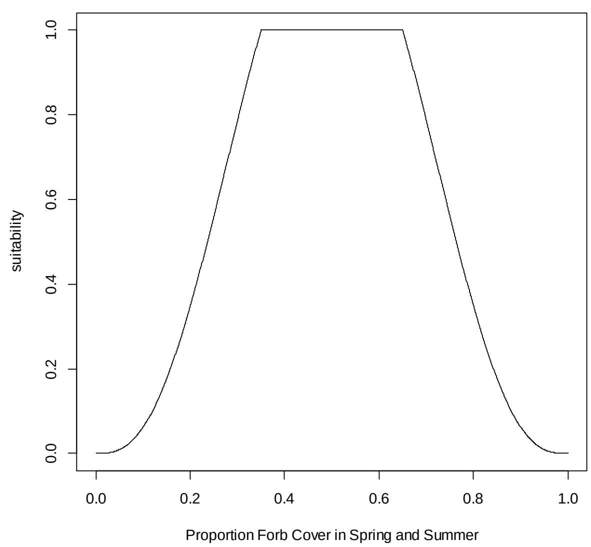
Late Summer/Fall/Winter:

$$F\ x = \begin{cases} \dfrac{x^{29}(1-x)^{29}}{B\ 30{,}30\ \ 6.15}, x \leq .5 \\ 1, \quad .5 < x < .6 \\ 0.2 + \dfrac{x^{29}(1-x)^{23.5}}{B\ 30{,}24.5\ \ 6.3}, x \geq .6 \end{cases}$$



Spring/ Summer:

$$F\ x = \begin{cases} \dfrac{x^{3}(1-x)^{3}}{B\ 4{,}4\ \ 1.65}, & x \leq .35 \\ 1, & .35 < x < .65 \\ \dfrac{x^{3}(1-x)^{3}}{B\ 4{,}4\ \ 1.65}, & x \geq .6 \end{cases}$$

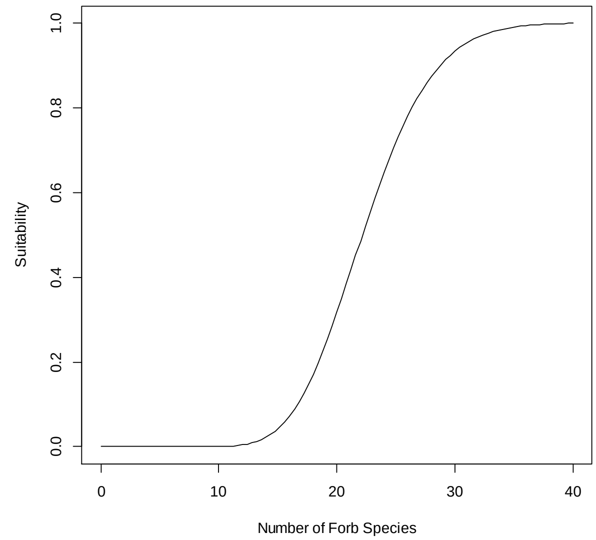


FD

Forb Diversity measured as the total number of forb species on a typical home range (10.9 ha) throughout the year.

$$F(x) = \frac{\int_0^x t^{21.5} e^{-t} dt}{\Gamma(22.5)}$$

(Gamma CDF with α=22.5, β=1)



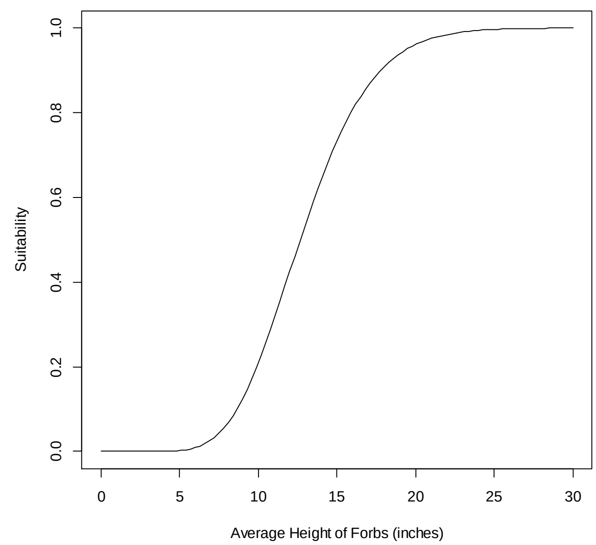
FH

Forb height measured as the average height of forbs. Optimal forb height differs between the spring/summer and the fall/winter.

<u>Fall/ Winter:</u>

$$F(x) = \frac{\int_0^x t^{12} e^{-t} dt}{\Gamma(13)}$$

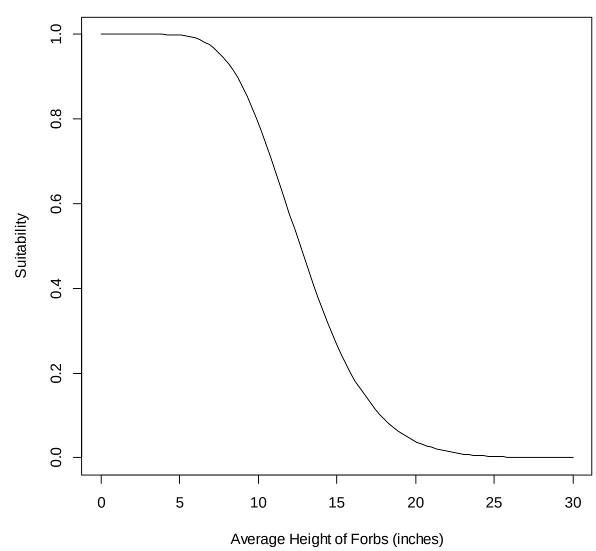
(Gamma CDF with α=13, β=1)



<u>Spring/ Summer:</u>

$$F(x) = -\frac{\int_0^x t^{12} e^{-t} dt}{\Gamma(13)} + 1$$

(Gamma CDF with α=13, β=1)

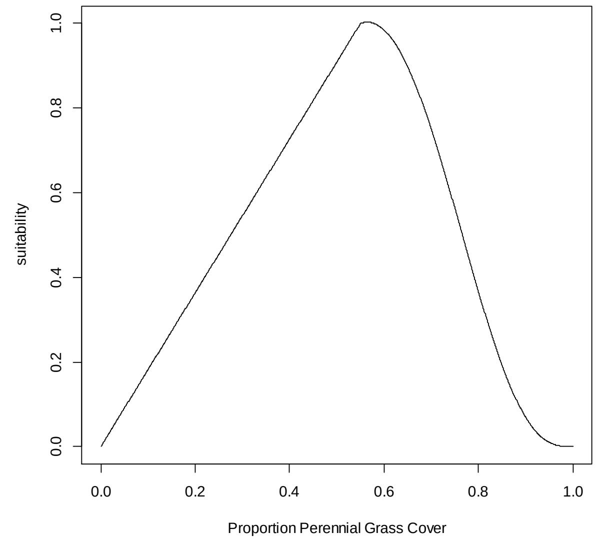


GC

Grass cover measured as the percent canopy cover of grass. The optimal canopy cover of grass differs between perennial and annual grasses.

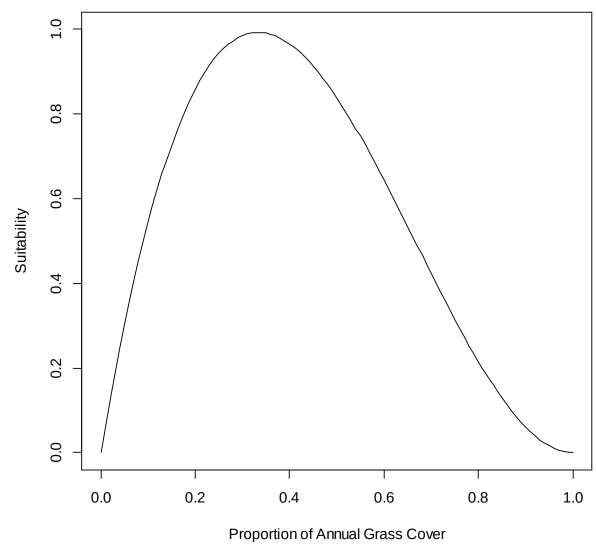
Perennials:

$$F\ x\ =\ \begin{matrix} 1.82x, x \leq .55 \\ \dfrac{x^{4}(1-x)^{3.09}}{B\ \ 5{,}4.09\ \ 2.35} \end{matrix}$$



Annuals:

$$F\ x\ =\ \frac{x^{1}(1-x)^{2}}{B\ \ 2{,}3\ \ 1.79}$$



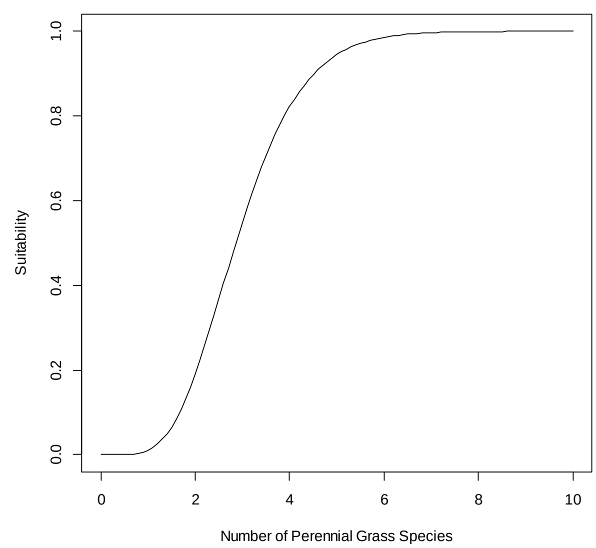
GD

Grass diversity measured as the total number of grass species found on a typical home range (10.9 ha). The optimal number of species differs between perennial and annual grasses.

Perennials:

$$F\ x\ = \frac{\int_{0}^{x} 2.33\, t^{6} e^{-t} dt}{\Gamma\ \ 7}$$

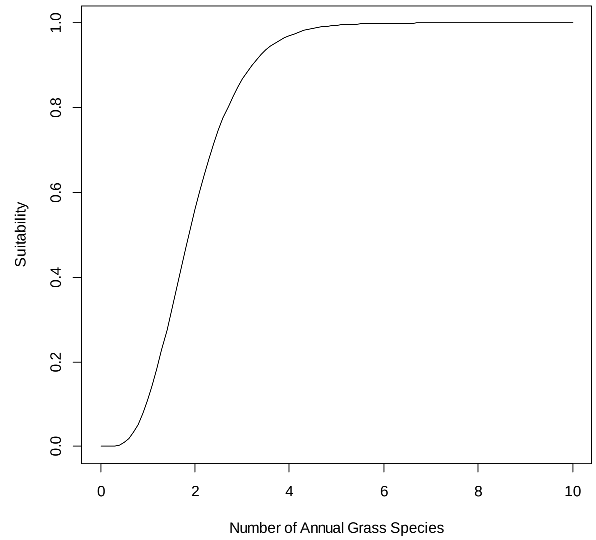
(Gamma CDF with α=7, β=2.33)



Annuals:

$$F(x) = \frac{\int_0^{x} 2.5\, t^4 e^{-t}\,dt}{\Gamma(5)}$$

(Gamma CDF with α=5, β=2.5)

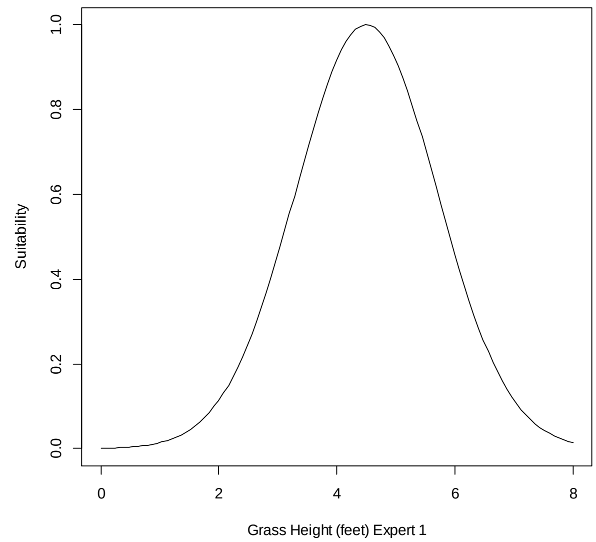


GH

Grass height measured as the average height of grass on a typical home range (10.9 ha). The two experts differed on their assessment of optimal grass height.

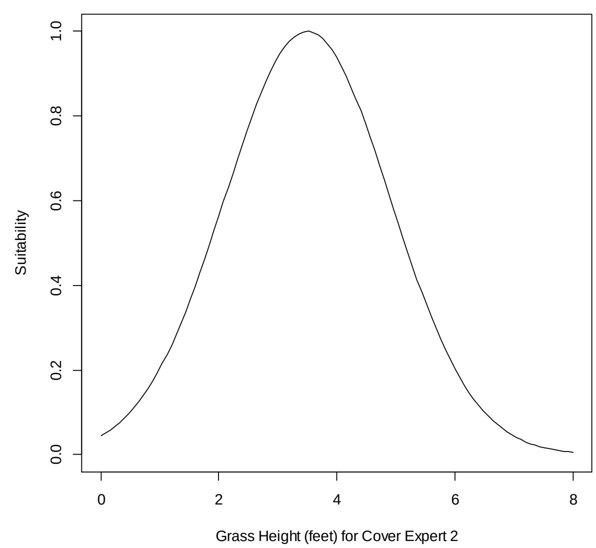
Expert 1:

$$F(x) = 3.01 \frac{e^{-\frac{(x-4.5)^2}{2.4}}}{\sqrt{2.4\pi}}$$



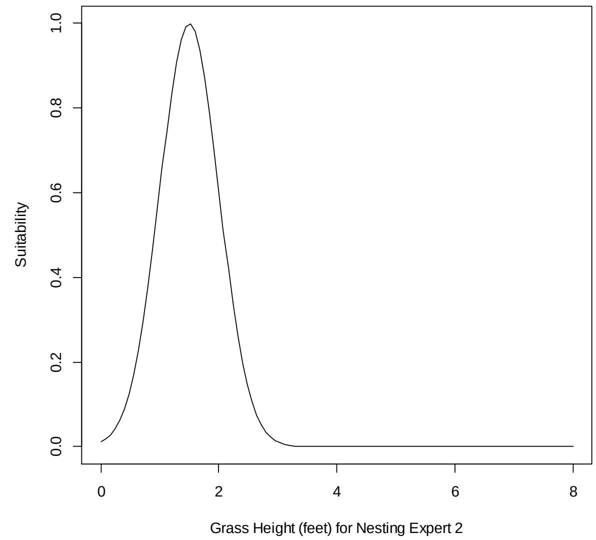
Expert 2 Cover:

$$F(x) = 3.51 \frac{e^{-\frac{(x-3.5)^2}{2.8}}}{\sqrt{2.8\pi}}$$



Expert 2 Nesting:

$$F(x) = 1.25\frac{e^{-(x-1.5)^2}}{\sqrt{\pi}}$$

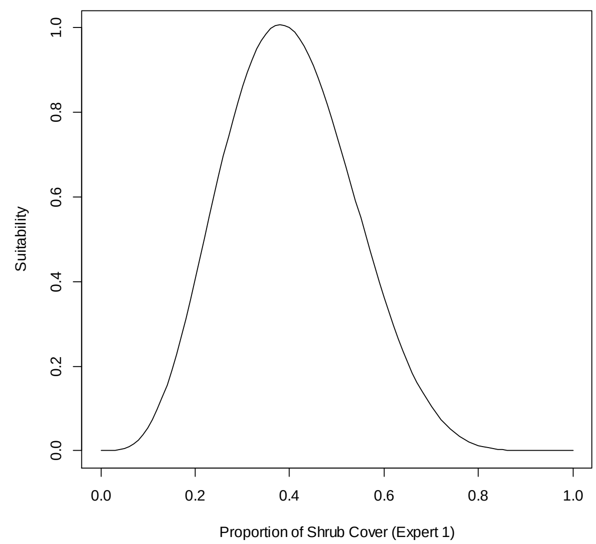


SC

Shrub cover measured as the average canopy cover of shrubs. The two experts differed in their assessment of optimal shrub cover.

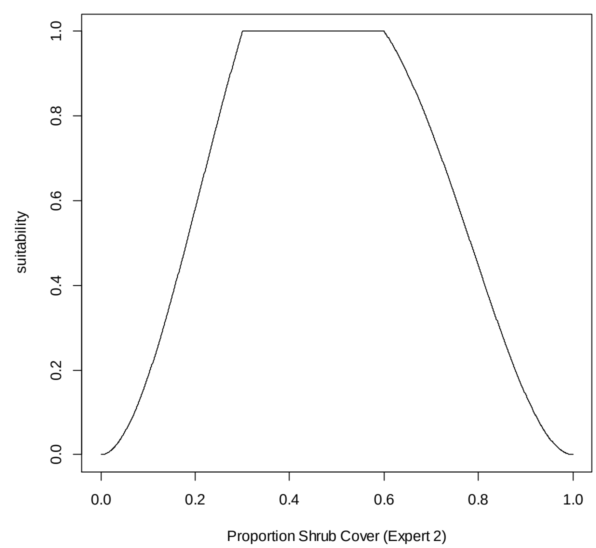
Expert 1:

$$F(x) = \frac{x^4(1-x)^{6.5}}{B(5,7.5)}$$



Expert 2:

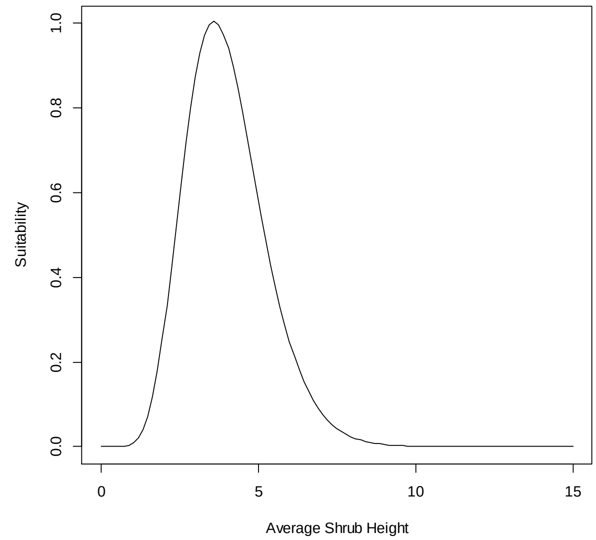
$$F(x) = \begin{cases} \frac{x^2(1-x)^2}{B(3,3)\,1.32}, & x \le .3 \\ 1, & .3 < x < .6 \\ \frac{x^2(1-x)^2}{B(3,3)\,1.73}, & x \ge .6 \end{cases}$$



SH

Shrub height measured as the average height of shrubs.

$$F(x) = \frac{3.05x^9 e^{-x/2.5}}{\Gamma(10)2.5^{10}}$$

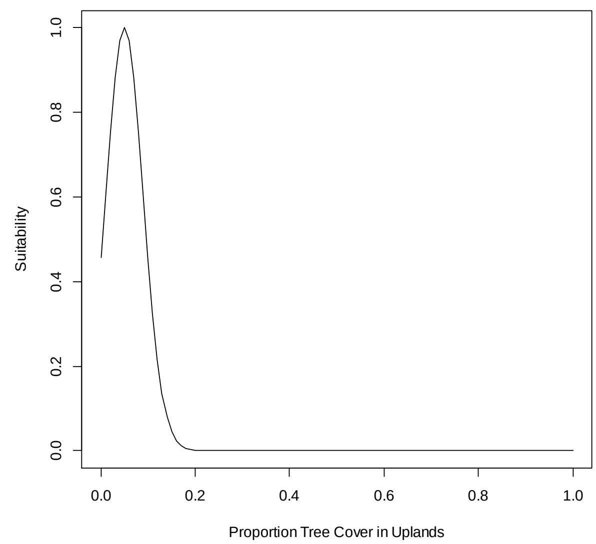


TC

Tree cover measured as the average canopy cover of trees. The optimal value of tree cover differs between the uplands and arroyos.

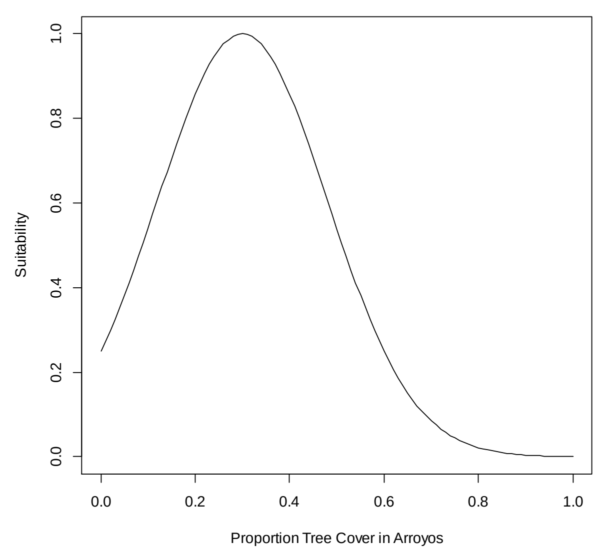
<u>Uplands:</u>

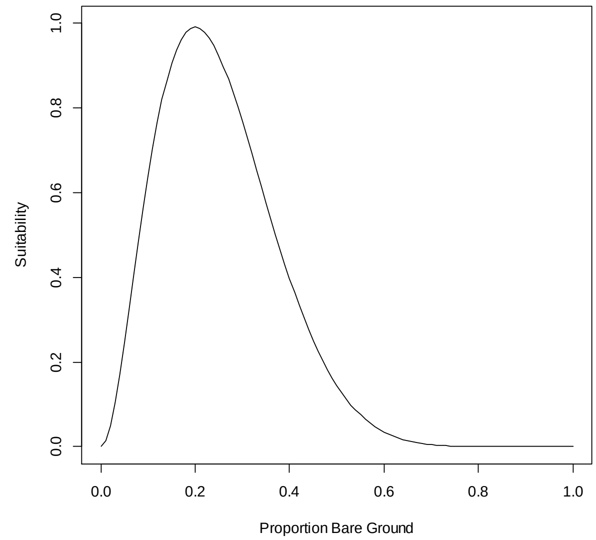
$$F(x) = 9.97\frac{e^{\frac{-(x-0.05)^2}{0.08}}}{\sqrt{0.08\pi}}$$



<u>Arroyos:</u>

$$F(x) = 2.22\frac{e^{\frac{-(x-0.3)^2}{0.26}}}{\sqrt{0.26\pi}}$$



BG	Bare ground measured as the average canopy cover of bare ground. Bare ground should be in the form of a matrix interspersed with other canopy components	$F(x) = \dfrac{x^2(1-x)^8}{B(3,9)\;3.35}$	

Equations.

The final habitat suitability index score is a result of the combination of suitability scores from component variables. The equations which describe this combination are governed by the assumptions and relationships described in section 2.2. Additive equations imply each variable in the equation can compensate for other variables with low scores unless otherwise noted. Multiplication implies a score of zero for any variable results in a suitability score equal to zero (i.e. both variables must have non-zero scores for the habitat to be suitable).

$$Forbs \quad F \;=\; FC * FD * FH^{\frac{1}{3}}$$

$$Grass \quad G \;=\; GC * GD * GH^{\frac{1}{3}}$$

$$Shrubs \quad S \;=\; SC * SH^{\frac{1}{2}}$$

$$Reproduction = \frac{TC + G + BG}{3}$$

$$Food = \frac{F + G + S}{3}$$

$$Cover = \frac{TC + G + F + S + BG}{5}$$

$$Thermal\ Refuge = TC$$

$$HSI = Lowest\ score\ from\ Reproduction, Food, Cover\ or\ Thermal\ Refuge$$