**Habitat Suitability Index Model: Published Literature**

The following is a habitat suitability model developed solely from published literature pertaining to the masked bobwhite (*Colinus virginianus ridgwayi*). The model is divided into five sections: 1) model applicability (where and when does this model apply), 2) a written description of the model and parameters, 3) a graphical model showing the relevant habitat variables and their relationship to life history requisites, 4) a graphical representation of the relationship between habitat suitability and each habitat variable, and 5) a mathematical representation of the model.

**Section 1.Model Applicability:**

1.1 Geographic area. This model describes optimal habitat for masked bobwhites in northern Sonora, Mexico and southern Arizona, United States. The Rancho el Carrizo area of Sonora, Mexico was the primary location for data collection in Mexico. In Arizona this model describes optimal habitat within Buenos Aires National Wildlife Refuge (BANWR).

1.2 Season. This model describes optimal habitat during all time of the year but much of the literature is focused on habitat conditions during the summer and fall.

**Section 2. Model Description**:

2.1 Overview. The purpose of this model is to consider the ability of assessed habitat to meet the food, reproductive, and cover requirements of masked bobwhite as an indicator of overall habitat suitability.

2.2 Written Documentation.

The following section provides 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

2.2.1 General Habitat Description

The availability of habitat for masked bobwhites must be maximized in both space and time (Guthery 1997, 2000, and 2001). For a species that utilizes different habitat components at different times of the year, such as masked bobwhites, quantifying optimal habitat can become a difficult and data intensive process. Unfortunately, very little empirical data exists for the masked bobwhite and much (if not all) of the data was collected on populations which were in severe decline during the sampling period. Therefore, habitat suitability descriptions included in this document describe the best available habitat for masked bobwhites at the time of sampling and may not represent optimal habitat conditions for masked bobwhites.

The general habitat of masked bobwhites is described in the early literature, although these documents only provide very general habitat descriptions. Grinnell (1884) and Brown (1885) describe the general habitat as mesas, valleys, and possibly foothills but not canyons or mountains. This description was later echoed by Van Rossem (1945) and Moson and Phillips (1964) who described their habitat as “tall-grass mesquite plains.” Ligon (1952) described the habitat as “deep-grass-weed” and Gallizioli et al. (1967) concluded that dense stands of perennial grasses are important. In his review of the early literature Tomlinson (1972) concluded that open grasslands with adjoining brushy areas at elevations between 305m and 1220m were preferred by masked bobwhites. Tomlinson also concluded that denser grasses, such as sacaton, are primarily used for hiding whereas associations of mixed grammas (*Bouteloua spp.*) and three-awns (*Aristida spp.*) are preferred for loafing and feeding.

There is likewise only limited information on the feeding habits of masked bobwhites from the early literature. The diet of masked bobwhite is composed of insects ranging in size from 1mm – 2.5cm, seeds, and vegetation (Brown 1885). Table 1 is excerpted from Tomlinson (1972) and summarizes the most prevalent stomach contents from 10 masked bobwhites collected in Northern Sonora, MX in October 1931 (Cottam and Knappen 1939).

Table 1. From Tomlinson (1972). The stomach contents of 10 masked bobwhites collected in Northern Sonora, MX, in October 1931.

|  |  |  |
| --- | --- | --- |
| Food Source | Number of Birds (of 10) | % of Total Food |
| *Acacia angustissima* | 8 | 18.8 |
| *Physalis spp.* | 10 | 16.3 |
| *Panicum halli* | 8 | 12 |
| *Panicum stramineum* | 8 | 2.3 |
| *Panicum arizonicum* | 8 | 0.3 |
| Miscellaneous Grasses |  | 3.4 |
| *Commelina elegans* | 9 | 10.8 |
| *Phaseolus ritenesis* | 4 | 3.8 |
| *Abutilon cripsum* | 9 | 1.9 |
| *Abutilon incanum* | 9 | 1 |
| *Abutilon arizonicum* | 9 | Trace |
| *Cassia leptodena* | 6 | 2.5 |
| *Ipomoea spp* | 5 | 2.3 |
| *Galactea spp* |  | 2.2 |
| *Melanoplus spp* (grasshopper) | 1 | 8.8 |
| *Romalea spp* (grasshopper) | 3 | 7.1 |
| Unknown Grassopper | 4 | 2.5 |
| Unknown Orthoptera | 4 | .9 |
| Miscellaneous Insect |  | 1.6 |

2.2.2 Quantified Habitat Metrics

1. Cover-

Cover serves two important roles for masked bobwhites, protection from predators and thermal regulation. Masked bobwhites appear to alter their habitat preference during different periods of the year. These periods can be broken down into the fall and winter covey season, the spring pair formation season, and the summer breeding season. A quantitative analysis of optimal cover values was undertaken by Simms (1989), King (1998), and Guthery et al. (2000 and 2001).

Simms (1989) compared habitat conditions on core use areas to conditions on home ranges and representational transects within the Buenos Aires National Wildlife Refuge. She found that masked bobwhites generally selected bottomland grass and tree-shrub habitat. Simms found masked bobwhites preferred areas with higher aerial and basal cover of grass and greater visual obstruction from all vegetation at 0-1 dm. Simms also found masked bobwhites preferred lower percent cover of tree and shrub cover in core areas when compared to the entire home range. However, she also found that masked bobwhites spent more time in areas with higher density of trees between 0 and 5m tall and that small trees were favored over half-shrubs. Simms speculated that small trees provided better cover than dense half-shrub species which do not have adequate space under the crown.

Nina M. King (1998) compared the vegetation at sites used by masked bobwhites to random sites located within the Buenos Aires National Wildlife Refuge. During the covey season, Nina found masked bobwhites preferred taller vegetation and greater vegetation biomass than found at random sites. King also found limited evidence that bobwhites preferred lower levels of herbaceous cover (32% cover selected vs 42% cover randomly available) and bare ground (11% cover selected vs 16% cover randomly available)and higher levels of woody stem density cover (47 stems/ selected vs 42% cover randomly available) than was typically available on the landscape. King found no preference related to woody cover, number of grasses, or grass and forb richness during the covey season. King also found that quail were positively associated with Lehmann’s lovegrass (*Eragrostis lehmanniana*), snakeweed (*Gutierrizia spp*), and mesquite (*Prosopis spp*). The association with the exotic Lehmann’s Lovegrass may be a result of the relative persistence of this grass during dry periods (Kuvleski et al. 2001). During the pair formation/breeding season King (1998) found bobwhites preferred greater woody canopy cover than was found at random sites. Bobwhites were also positively associated with a greater total amount of half-shrubs and tree species than found at random sites.

Overall, king found that bobwhites selected sites with greater structural diversity than was typically available and taller vegetation than was found at random sites. King also found that bobwhites selected sites with less bare ground, and therefore areas which were less patchy, than was randomly available. At release sites, King found that sites with greater total cover had higher survival rates for released bobwhites.

Guthery et al. (2000) compared the vegetative features at sites used by masked bobwhites to randomly selected sites in both Arizona and Sonora. They also compared these features to sites in Texas which were utilized by the related Texas bobwhite. The Arizona sites included in Guthery et al. may have been identical to those analyzed by King (1998) since King is included as an author but this is not explicitly stated. Guthery et al. did not differentiate habitat use by season and included data from both the summer breeding season and winter covey season. Additionally, they introduce a measure of cover that is directly related to the vulnerability to predators and evaluate this vulnerability at two levels: 1) the disc of vulnerability assesses the vulnerability to terrestrial predators at ground level, and 2) the cone of vulnerability assesses the vulnerability to aerial predators. The method and rationale for calculating these metrics can be found in Kopp et al. (1998). To relate to the work by King (1998), the disc of vulnerability can be compared to the mean vegetation structure at 15cm and 50cm whereas the cone of vulnerability can be compared to the mean vegetation structure at 1m and 2m. Despite these differences in sampling methodology they found similar trends among used versus random sites to those of King (1998). In general, masked bobwhites selected areas with greater amounts of tall vegetation, woody vegetation, and lower temperatures at ground level than were randomly available. Guthery et al. (2000) speculate that the selection of tall vegetation and woody vegetation is a function of the high density of avian predators and the need for lower operative temperatures. They recommend increasing the amount of both woody and herbaceous cover (with a focus on herbaceous cover) to address both predation and thermal regulation. Guthery et al. (2001) also investigated habitat use under a multivariate perspective and found compensatory effects such that, under appropriate levels of all other cover variables, the optimal level of any one cover variable widened. For example, optimal levels of woody cover ranged from 15% to 40% unless other variables were in an acceptable range in which case the optimal range expanded to between 0% and 45%.

1. Reproduction-

During the Breeding season King (1998) found that masked bobwhites preferred areas with a higher percentage of woody cover (18.17% vs 6.99%, *P=*.002) and trees (1 vs .99, *P=*0.05). Similar to the non-breeding season, King also found that masked bobwhites preferred areas with taller vegetation, preferentially using areas with greater amounts of vegetation structure at 50cm, 1m, and 2m from the ground. King also found that breeding masked bobwhites preferred areas with a greater number of forbs (3.8 vs 0.43, *P=*.059) and half-shrub species (0.82 vs. 0.66, *P=*0.040) than were randomly available on the landscape.

1. Food-

King (1998) found masked bobwhites preferred areas with greater numbers of native grasses than was randomly available. This might be related to food availability but there is no direct evidence to support this aside from the early records of the diet of masked bobwhite described above (table 1). Kuvleski at al. (2001) also speculated that native grasses and forbs may provide a better source of food for masked bobwhites than exotic grasses. Simms (1989) noted that although masked bobwhite utilized bufflegrass for cover they were never far from native grasses and forbs and speculated that this was likely because they were necessary as a source of food.

**Section 3. Graphical Representation**

**Figure 1.** This figure is to represent the relationship between measured habitat variables, critical life history requirements, and habitat suitability for masked bobwhites. Measured habitat variables listed below are described in section 4.

Measured Habitat Variable Life Requisite Model Output

WSD

WC

Woody Cover

Reproduction

TSC

Visual Cover

NT

VC

Food

Forbs

DV

Suitability Index

Cover

CV

NF

Grasses

FD

Half-shrub Cover

FC

HC

Bare Ground

GC

Operative Temp.

LLC

GCB

**Section 4. Suitability Functions and Graphs**

This section provides specific relationships between each habitat variable and suitability of the habitat for masked bobwhites while holding all other variables constant at their optimal levels. Several variables included here are redundant measures of the same effect habitat component but since the measures are functionally different they are still included.

|  |  |  |  |
| --- | --- | --- | --- |
| Variable | Description | Suitability Function | Suitability Graph |
| WSD | From King (1998): The mean number of woody stems >1m tall per 200 square meters. | \*26.62039 | C:\Users\dominic\Documents\Work\Current Projects\MBQ\Literature_HSI_plots\WSD_King.emf |
| WC | From King (1998): Percent woody cover as measured in a line intercept method (Canfield 1941). | \*4.010919 | C:\Users\dominic\Documents\Work\Current Projects\MBQ\Literature_HSI_plots\WC_King.emf |
| WC | From Guthery (2001): Percent woody cover in Sonora Mexico as measured in a line intercept method (Canfield 1941). |  | C:\Users\dominic\Documents\Work\Current Projects\MBQ\Literature_HSI_plots\WC_Guthery.emf |
| WC | From Guthery (2001): Percent woody cover in Arizona as measured by a line intercept method (Canfield 1941). | \*37.59943 | C:\Users\dominic\Documents\Work\Current Projects\MBQ\Literature_HSI_plots\WC_AZ_Guthery.emf |
| TSC | From Simms (1989): Percent tree and shrub cover as measured by a line intercept method (Canfield 1941). | \*7.519885 | C:\Users\dominic\Documents\Work\Current Projects\MBQ\Literature_HSI_plots\TSC_Simms.emf |
| NT | From Simms (1989): Number of trees with a height between 0 and 5 meters per hectare. | \*37.5994 | C:\Users\dominic\Documents\Work\Current Projects\MBQ\Literature_HSI_plots\TD_Simms.emf |
| VC | From Simms (1989):  Visual cover measured as percent visual obstruction of a vertical range pole (Robel et al. 1970) at a height of 1m and distance of 4m. |  | C:\Users\dominic\Documents\Work\Current Projects\MBQ\Literature_HSI_plots\VO_Simms.emf |
| DV | From Guthery (2000): Visual cover measured as a disc of vulnerability (as described in Kopp (1998)) around a random point. |  | C:\Users\dominic\Documents\Work\Current Projects\MBQ\Literature_HSI_plots\Disc_Guthery.emf |
| CV | From Guthery (2000): Visual cover measured as a cone of vulnerability (as described in Kopp (1998)) measured in millions of cubic meters around a random point. | Mexico | C:\Users\dominic\Documents\Work\Current Projects\MBQ\Literature_HSI_plots\Cone_MX_Guthery.emf |
|  |  | Arizona | C:\Users\dominic\Documents\Work\Current Projects\MBQ\Literature_HSI_plots\Cone_AZ_Guthery.emf |
| NF | From King (1998): The number of forbs counted per 1000 square centimeters (as in a Daubenmire frame (Daubenmire 1959)). |  | C:\Users\dominic\Documents\Work\Current Projects\MBQ\Literature_HSI_plots\NF_King.emf |
| FD | From Simms (1989): Forb diversity as measured by the mean number of forb species as measured by the Daubenmire method (Daubenmire 1959). |  | C:\Users\dominic\Documents\Work\Current Projects\MBQ\Literature_HSI_plots\FD_Simms.emf |
| FC | From Simms (1989): Percent aerial forb cover measured as in a Daubenmire plot (Daubenmire 1959). | \*10.02651 | C:\Users\dominic\Documents\Work\Current Projects\MBQ\Literature_HSI_plots\FC_Simms.emf |
| HC | From King (1998): Percent aerial herbaceous cover measured as in a Daubenmire plot (Daubenmire 1959). | \*6.3919 | C:\Users\dominic\Documents\Work\Current Projects\MBQ\Literature_HSI_plots\FC_King.emf |
| GC | From Simms (1989): Percent aerial grass cover measured as in a Daubenmire plot (Daubenmire 1959). | \*30.07954 | C:\Users\dominic\Documents\Work\Current Projects\MBQ\Literature_HSI_plots\GCa_Simms.emf |
| GCB | From Simms (1989): Percent basal grass cover measured as in a Daubenmire plot (Daubenmire 1959). | \*22.55965 | C:\Users\dominic\Documents\Work\Current Projects\MBQ\Literature_HSI_plots\GCb_Simms.emf |
| GD | From Simms (1989): Grass diversity as measured by the mean number of grass species as measured by the Daubenmire method (Daubenmire 1959). |  | C:\Users\dominic\Documents\Work\Current Projects\MBQ\Literature_HSI_plots\GD_Simms.emf |
| LLC | From Simms (1989): Percent cover of Lehmann’s lovegrass measured by the Daubenmire method (Daubenmire 1959). |  | C:\Users\dominic\Documents\Work\Current Projects\MBQ\Literature_HSI_plots\LLGC_Simms.emf |
| HSC | From Simms (1989): Percent half-shrub cover measured by the Daubenmire method (Daubenmire 1959). |  | C:\Users\dominic\Documents\Work\Current Projects\MBQ\Literature_HSI_plots\HSC_Simms.emf |
| BG | From King (1998): Percent bare ground as a cover percentage measured by the Daubenmire method (Daubenmire 1959). | \*2.6069 | C:\Users\dominic\Documents\Work\Current Projects\MBQ\Literature_HSI_plots\BG_King.emf |
| BG | From Guthery (2001): Percent bare ground as a cover percentage measured by the Daubenmire method (Daubenmire 1959). |  | C:\Users\dominic\Documents\Work\Current Projects\MBQ\Literature_HSI_plots\BG_Guthery.emf |
| OT | From Guthery (2001): Operative temperature measured as described in Forrester et al (1998). |  | C:\Users\dominic\Documents\Work\Current Projects\MBQ\Literature_HSI_plots\Temp_Guthery.emf |

**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).

**Literature Cited**

Brown, H. 1885. Arizona Quail Notes. Forest and Stream. 25(23):445.

Canfield, R.H. 1941. Application of the line intercept method in sampling range vegetation. Journal of Forestry 39: 388-394.

Cottam, C.P. and P. Knappen. 1939. Food of some uncommon North American birds. Auk 56: 138-169.

Daubenmire, R. 1959. A Canopy-coverage method of vegetational analysis. Northwest Science 33: 43-64.

Forrester, N.D., F.S. Guthery, S.D. Kopp, and W.E. Cohen. 1998. Operative temperature reduces habitat space for northern bobwhites. Journal of Wildlife Management 62: 1505-1510.

Gallizioli, S. 1964. Results of a brief investigation of the masked bobwhite in Sonora, Mexico. Special Report to the Arizona Game and Fish Department, Sept: 15pp.

Gallizioli, S., S. Levy and J. Levy. 1967. Can the masked bobwhite be saved from extinction? Audobon Field Notes 2: 571-575.

Grinnel, G.B. 1884. A new quail to the United States fauna. Forest and Stream: 243.

Guthery, F.S. 1997. A philosophy of habitat management for northern bobwhites. Journal of Wildlife Management 62: 291-301.

Guthery, F.S., N.M. King, K.R. Nolte, W.P. Kuvleski Jr., S. DeStefano, S.A. Gall, and N.J. Silvy. 2000. Comparaitve habitat ecology of Texas and masked bobwhites. Journal of Wildlife Management 64: 407-420.

Guthery, F.S., N.M. King, K.R. Nolte, W.P. Kuvleski Jr., S. DeStefano, S.A. Gall, and N.J. Silvy. 2001. Multivariate perspectives on patch use by masked bobwhites. Journal of Wildlife Management 65: 118-124.

King, N.M. 1998. Habitat use by endangered masked bobwhites and other quail on the Buenos Aires National Wildlife Refuge. Thesis. University of Arizona, Tucson.

Kopp, S.D., F.S. Guthery, N.D. Forrester, and W.E. Cohen. 1998. Habitat selection modeling for northern bobwhites on subtropical rangeland. Journal of Wildlife Management 62: 881-895.

Kuvleski, W.P., Jr., T.E. Fulbright, and R. Engel-Wilson. 2002. The impact of invasive exotic grasses on quail in the southwestern United States. Pages 118-128 *in* S.J. DeMaso, W.P. Kuvleski, Jr., F. Hernandez, and M.E. Berger, eds. Quail V: The Fifth National Quail Symposium. Texas Parks and Wildlife Department, Austin, TX.

Ligon, J.S. 1942. The vanishing masked bobwhite. Condor 54: 48-50.

Monson, G. and A.R. Phillips. 1964. A check-list of the birds of Arizona. University of Arizona Press, Tucson. 74pp.

Robel, R.J., J.N. Briggs, A.D. Dayton, and L.C. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23: 295-297.

Simms, K. 1989. Home range, habitat use and movement of reintroduced masked bobwhite. Thesis. University of Arizona, Tucson.

Tomlinson, R.E. 1972. Review of literature on the endangered masked bobwhite. U.S. Fish and Wildlife Service Resource Publication 108.

Van Rossem, A.J. 1931. Report on a collection of land birds from Sonora, Mexico. Transactions of the San Diego Society of Natural History 6: 237-304.