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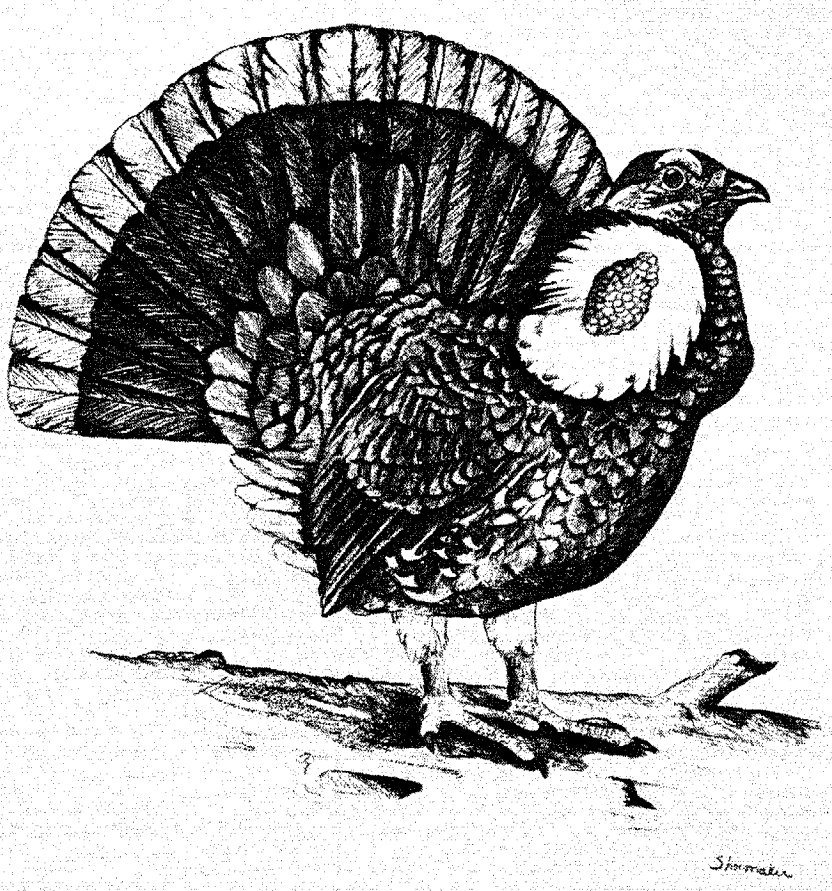
HABITAT SUITABILITY INDEX MODELS: BLUE GROUSE



Fish and Wildlife Service
Department of the Interior

FWS/OBS-82/10.81
August 1984

HABITAT SUITABILITY INDEX MODELS: BLUE GROUSE

by

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PREFACE

This document is part of the Habitat Suitability Index (HSI) Model Series (FWS/OBS-82/10), which provides habitat information useful for impact assessment and habitat management. Several types of habitat information are provided. The Habitat Use Information Section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability. The habitat use information provides the foundation for HSI models that follow. In addition, this same information may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

The HSI Model Section documents a habitat model and information pertinent to its application. The model synthesizes the habitat use information into a framework appropriate for field application and is scaled to produce an index value between 0.0 (unsuitable habitat) and 1.0 (optimum habitat). The application information includes descriptions of the geographic ranges and seasonal application of the model, its current verification status, and a listing of model variables with recommended measurement techniques for each variable.

In essence, the model presented herein is a hypothesis of species-habitat relationships and not a statement of proven cause and effect relationships. Results of model performance tests, when available, are referenced. However, models that have demonstrated reliability in specific situations may prove unreliable in others. For this reason, feedback is encouraged from users of this model concerning improvements and other suggestions that may increase the utility and effectiveness of this habitat-based approach to fish and wildlife planning. Please send suggestions to:

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BLUE GROUSE (Dendragapus obscurus)

HABITAT USE INFORMATION

General

Blue grouse (Dendragapus obscurus) inhabit coniferous forests in western North America, primarily in open habitats with a mixture of deciduous trees and shrubs (American Ornithologists' Union 1983). They prefer coniferous forest edges and aspen groves (Populus tremuloides) in the breeding season, and coniferous forests in the winter (Aldrich 1963). Blue grouse populations consist of two groups, the sooty grouse group, found along the Pacific coast, and the dusky grouse group, found in the Great Basin and Rocky Mountain areas (American Ornithologists' Union 1983).

Food

The food habits of the blue grouse vary from a simple winter diet consisting primarily of coniferous needles, to a summer diet consisting of a variety of green leaves, fruits, seeds, flowers, animal matter, and conifer needles (Stewart 1944). The yearly diet of blue grouse in Washington and northern Idaho consisted of 98% plant food and 2% animal matter (Beer 1943). Sixty-four percent of the plant material was conifer needles, mostly from firs (Abies spp.) and Douglas-fir (Psuedotsuga menziesii); 17% was berries, primarily from currants (Ribes spp.), serviceberries (Amelanchier spp.), blackberries (Rubus spp.), huckleberries (Vaccinium spp.), and bearberry (Arctostaphylos uva-ursi); and 17% was miscellaneous plant materials. The youngest birds fed almost exclusively on insects, and the availability of an adequate supply of insects is important during the first month of growth of blue grouse chicks.

The major spring and summer food items of blue grouse in British Columbia were conifer needles, broad-leaved vegetation, flowers, fruits, and invertebrates (King and Bendell 1982). Huckleberry was a preferred food in another British Columbia study and provided 60% of the food consumed by juveniles that were 10 days to 6 weeks of age (King 1973). As grouse in Idaho moved from their winter range to lower elevation Douglas-fir forests during May and June, their diet consisted primarily of the flowering parts of various plants (Marshall 1946). These grouse moved to lower elevations along streams during July and August, and their diet shifted to the fruits and leaves of various shrubs. Forest habitats that are in early stages of second growth vegetation provide important summer foods for adults and chicks (Fowle 1960).

The winter diet (from October through April) of blue grouse consists almost entirely of conifer needles (Beer 1943). The winter and spring diet of blue grouse in British Columbia was comprised of the needles, twig tips, and cones of conifers, especially those of mountain hemlock (Tsuga mertensiana), pine (Pinus spp.), and fir (King 1973). The needles and buds of Douglas-fir provided 99% of the winter diet of grouse in Idaho (Marshall 1946). Fall use of conifers by dusky blue grouse in Wyoming (in terms of percent frequency) consisted of lodgepole pine (P. contorta), 39.3%; juniper (Juniperus spp.), 21.4%; limber pine (P. flexilis), 17.9%; Douglas fir and subalpine fir (A. lasiocarpa), 8.9%; and Engelmann spruce (Picea engelmannii), 5.4% (Harju 1974). Zwickel and Bendell (1972) believed that winter food supplies were generally adequate for blue grouse. It appears that spring densities are not determined by winter food supplies, but are related to the quality of the breeding range (Zwickel et al. 1968). Winter habitat preferences of blue grouse are only recently being studied, and it is possible that the quality and quantity of winter habitat may be a limiting factor for blue grouse (Hoffman pers. comm.).

Water

Dusky blue grouse in Colorado occur at elevations between 1,830 and 3,874 m (6,000 and 12,700 ft) in areas where either free water or succulent vegetation is available (Rogers 1968). Blue grouse in Washington and northern Idaho were generally found near a source of water, either open water or succulent vegetation and berries (Beer 1943). Free water is not required if succulent vegetation or fruit is available.

Cover

Blue grouse in Idaho relied almost totally on conifers for escape cover (Marshall 1946). Male blue grouse in British Columbia utilized small conifer thickets, log tangles, and spaces under logs and stumps for rest and concealment during the breeding season (Bendell and Elliott 1967). In the spring, hens concealed themselves under logs, stumps, and small conifers for cover, in locations similar to those used for nest sites. Hens with broods were found more often in more exposed locations, particularly road edges and moist depressions with lush vegetation. Shrubs and forbs supplied most of the cover during the summer months in Colorado, and dusky blue grouse have not been observed in Colorado where shrubs are lacking (Rogers 1968). Blue grouse in Idaho roosted most frequently in dense stands of trees that were 15.2 to 30.5 cm (6 to 12 inches) dbh and 6.1 to 15.3 m (20 to 50 ft) in height (Caswell 1954).

Winter range is provided primarily by montane forests (Bendell and Elliott 1966) and blue grouse spend most of the winter in coniferous trees, until the snow melt allows ground feeding (Hoffman 1956). In Colorado, most blue grouse observed in the winter were found in conifers, with the use of Douglas-fir occurring in greater proportion than its availability (Cade, in prep.). Blue grouse also used spruce-fir and lodgepole pine forests during the winter where Douglas-fir was absent or scarce. Intensively used conifer stands were structurally similar to less used stands, and within all occupied stands blue

grouse tended to be found in the largest conifers available. Conifer stands that were not suitable for wintering blue grouse included low density [less than 70 trees/ha (28.4/acre)] stands of small conifers and high density [more than 1,200 trees/ha (486/acre)] stands of mature trees.

Reproduction

Blue grouse in British Columbia preferred very open habitats over very dense habitats during the breeding season (Bendell and Elliott 1966). Very open habitats averaged 15% canopy cover of trees, while very dense habitats were almost totally closed. Forests with 50% tree canopy cover that contained a discontinuous and patchy shrub layer supported the highest densities of male blue grouse in another British Columbia study area (Donaldson and Bergerud 1974). Established territories in Alberta generally had 50% tree canopy cover overall, with trees occurring in clumps and surrounded by openings (Boag 1966). Habitats became less acceptable to territorial males as canopy cover deviated from this condition. In general, blue grouse populations decline rapidly as canopy cover of conifers approaches 75% (Redfield et al. 1970). The density of hooting males in a British Columbia study area declined from 40 to 0 in 8 years, as the vegetation changed from open to dense (Bendell and Elliott 1966). Once occupied, a territory is generally used by a male grouse throughout his lifetime, even if the habitat becomes very dense. However, new adults and yearlings will not occupy dense areas, and show habitat selection for more open areas.

Blue grouse breed throughout their range in Colorado in a variety of forest and mountain shrub vegetation types from the foothills to timberline, and do not appear to be restricted to any specific habitat types within this elevational range (Hoffman 1981). Common features of blue grouse territories in Colorado included: (1) some type of tree cover; (2) shrub thickets; (3) open areas; and (4) openness in the canopy and the understory vegetation. The structural features of the vegetation appear to be more important than species composition in breeding habitat selection. The location and size of male blue grouse territories in Alberta was dependent on the presence of suitable cover and not on the species of trees present (Boag 1966). Blue grouse males established territories in Douglas-fir, aspen, lodgepole pine, and white spruce (Picea glauca) forests. Dusky blue grouse in Colorado preferred display sites that were on small, flat, open areas near slopes and dense vegetation (Rogers 1968). The position of male territories in open cover types in British Columbia was influenced by the presence of areas that were higher than the surrounding land (Bendell and Elliott 1967).

Habitats consisting of a logging mosaic of all aged Douglas-fir, with openings of salal (Gaultheria spp.), grass, and rock outcrops, had the highest density of breeding males in a British Columbia study area (Donaldson and Bergerud 1974). Even-aged, closed canopy forests had the lowest grouse densities on this study area. Three habitat components that may be important to males establishing territories are: (1) openings in the tree canopy; (2) openings in the shrub layer; and (3) variation in tree size . Openings in the tree canopy increase visibility for hooting males. However, habitat that is too open increases vulnerability to predators. A partially closed canopy

with a patchy shrub layer offers the best combination of protection from weather and predators, while providing good visibility during courtship activities. However, blue grouse in Vancouver, British Columbia occur in areas that have been burned or clearcut, where trees are almost absent, and shrub cover is very low (Zwickel, pers. comm.).

Blue grouse territories in a Montana study area all contained small thickets of conifers, used for nesting and escape cover (Martinka 1972). Territories contained an average of 0.08 ha (0.2 acre) of thickets, with 206 m (677 ft) of edge between the thickets and openings. Thickets present outside of territories were 0.04 ha (0.1 acre) in size, with 85 m (278 ft) of edge, significantly different from thickets occurring within territories. Males preferred younger thickets, generally 20 to 40 years in age, with an average tree dbh of 12.4 cm (4.9 inches). Thickets in territories contained an average of 105 trees greater than 20 cm (8 inches) dbh/0.4 ha (1.0 acre), while nonterritory thickets contained an average of 248 such trees/0.4 ha (1.0 acre). Douglas-fir thickets tended to provide better protection than thickets of ponderosa pine (Pinus ponderosa). A high degree of discrimination between territories and nonterritories was shown when thicket size, amount of edge, and average thicket tree dbh were used in a discriminant function analysis.

Areas used by dusky blue grouse during the spring in Wyoming were frequently in or near aspen or lodgepole stands with adjacent openings (Harju 1974). Trees in grouse use areas averaged 10.5 m (34.5 ft) tall and 17.8 cm (7.0 inches) dbh, compared to averages of 15.4 m (50.5 ft) and 28.9 cm (11.4 inches) in random samples of the total area. Canopy cover of low shrubs and herbaceous cover in grouse use areas averaged 32%. Open areas in blue grouse territories in Montana contained herbaceous cover with scattered shrub cover (Martinka 1972). Small amounts of shrub cover may be useful for resting and escape cover, but areas with dense continuous shrub cover obstruct visibility and are avoided. Breeding blue grouse males in Idaho occupied open vegetation types with 40 to 70% cover of tall shrubs and trees (Stauffer 1983). Breeding areas with about 50% tree cover had more grouse than areas with less trees.

Blue grouse nests in Utah were located on the ground adjacent to or beneath shrubs (Weber et al. 1974). The nests consisted of shallow depressions in the ground, lined with twigs and feathers. Almost all nests were located near the territories of male blue grouse (Weber 1975). Broods in this Utah study area were most often found in mule ears (Wyethia amplexicaulis)-sagebrush (Artemisia spp.) vegetation near trees or tall shrub cover. Broods were not found further than 46 m (150 ft) from woody cover. Broods and hens foraged most often in good concealing cover that was 30.5 to 38.1 cm (12 to 15 inches) tall.

Blue grouse females with broods in Montana used grass-forb areas in early summer, and, as vegetation dried out by late July, broods increased their use of deciduous thickets (Mussehl 1960). In British Columbia, females with broods were mostly found in grassy open habitats in logged areas, particularly in moist meadows bordered by forest (Donaldson and Bergerud 1974). The most important habitat features for females with broods were the presence of an

extensive herb layer and proximity to cover. Broods in an Idaho study area occupied areas with greater than 50% cover of herbaceous vegetation that was greater than 50 cm (19.7 inches) in height (Stauffer 1983).

Broods in Colorado and Montana utilized areas where the interspersion of plants of various life forms provided a high degree of cover (Mussehl 1963; Hoffman 1981). Homogeneous grass stands were used very little (Mussehl 1963). Herbaceous cover is very important to chicks in their first 6 weeks of life. The best herbaceous growth for blue grouse broods provides a dense canopy of acceptable height, a mixture of plants of various life forms, and small amounts of bare ground. Herbaceous cover used by broods consistently averaged 17.8 to 20.3 cm (7 to 8 inches) in height and had an average canopy cover of 57% in a drought year and 71.5% in years of normal precipitation. The herbaceous cover contained both grasses and forbs, with grasses slightly more abundant. Bare ground (from 8 to 20%) provided travel lanes for broods. Large areas of herbaceous vegetation may not be needed by broods, because broods were most often found within 46 m (150 ft) of woody cover. The value of woody cover for feeding, resting, and escape increased as the chicks matured.

Dusky grouse brood habitat in Wyoming averaged 59.5% canopy cover of low shrub and herbaceous cover and was dominated by grasses (Harju 1974). A wide variety of plant species was present in brood use areas, and actual species composition was probably not important in brood habitat selection.

Zwickel and Bendell (1972) compared blue grouse densities, population parameters, and habitat characteristics from several areas. They concluded that, although breeding densities of blue grouse varied among the different areas, population parameters, such as death rates, clutch size, and late summer brood size, did not vary. The differences in breeding densities could not be explained by the vegetative structure or plant succession on the different sites, although populations were generally lower in habitats containing dense or very dense conifer cover compared to those with open conifer cover. Populations of grouse were declining on some areas that appeared to be structurally identical to areas that supported very high densities. Habitat features were apparently important primarily in setting broad limits of tolerance in areas within which the blue grouse was found. Actual densities of grouse at a particular time may have been related to the genetic quality of animals in the population.

Interspersion

Blue grouse generally winter on high, fir-covered mountain slopes; in the spring, they migrate down to open brushy habitats to breed, nest, and raise their broods (Weber et al. 1974). In the fall, they reverse this movement and migrate back up to the conifer forests. This autumn migration appears to be a dispersal, as members of a specific breeding population may winter miles apart (Bendell and Elliott 1967). Movements from summer to winter range in Utah were up to 8 km (5 miles) (Weber et al. 1974), while movements in a British Columbia study ranged from 1.6 to 16.1 km (1 to 10 miles), with an average of 5.8 km (3.6 miles) (Bendell and Elliott 1967). Autumn migrations up to 49.9 km (31 miles) were recorded in Washington, although most migrations were less than 16.1 km (10 miles) (Zwickel et al. 1968). A female grouse in another

Washington study moved 62.8 km (39 miles) to winter range, although most grouse movements in this study were less than 16.1 km (10 miles) (Bauer 1962). Breeding populations of blue grouse may contain individuals that move long distances to winter range, as well as individuals that winter directly adjacent to their breeding areas (Cade 1982, in prep.). From July through September, most broods in a Montana study moved 0.8 km (0.5 mile), or less, but later dispersed over a very large winter range (Mussehl 1960).

The density of blue grouse on two 14.6 ha (36 acres) study areas in British Columbia was 1.09 birds/ha (0.44 bird/acre) (Bendell and Elliott 1967). Average male territory size was 0.4 to 0.8 ha (1 to 2 acres) in Utah (Weber et al. 1974). Territory size in densely populated areas in British Columbia ranged from 0.4 to 0.8 ha (1 to 2 acres), while maximum male territory size was an estimated 3.2 ha (8 acres) (Bendell and Elliott 1967). Territories of males in Alberta averaged 0.6 ha (1.5 acres) and did not overlap (Boag 1966). Adult females ranged over areas averaging 17.4 ha (43 acres); these ranges overlapped the ranges of other males and females. Adult females in British Columbia constricted their home ranges from 6 to 2 ha (14.8 to 4.9 acres) and yearlings from 20 to 2 ha (49.4 to 4.9 acres) during the period from early to late spring (Hannon et al. 1982). The average winter home range size of adult blue grouse in Colorado was 3.4 ha (8.4 acres) (Cade, in prep.).

Preferred territories for male blue grouse contained abundant edge between openings and conifer cover (Martinka 1972; Donaldson and Bergerud 1974).

Special Considerations

Nesting and brood rearing habitats of blue grouse are often intensively used for spring and early summer grazing by domestic livestock (Marshall 1946). The types, time, and intensity of grazing can have a significant effect on the structure and species composition of the vegetation during the brood rearing season (Mussehl 1963). Ground cover that was ungrazed provided better brood cover than ground cover that was grazed.

Blue grouse densities in mature coastal forests are low, but populations generally increase quickly following logging or burning (Redfield et al. 1970). This population increase is followed by 10 to 25 years of stability and then a rapid population decline due to increased forest density. This relationship is apparently not true in southeast Alaska, where mature forests contain higher breeding densities than clearcut areas (Zwickel, pers. comm.). Selective logging may be beneficial to blue grouse when it opens the canopy and allows for regeneration in the form of thickets (Martinka 1972). However, existing thickets may be destroyed during road building and log removal operations, and large areas of slash left after logging are not used by blue grouse.

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area. There are two major groups of blue grouse, the sooty (coastal) group and the dusky (interior) group. Sooty grouse tend to occupy

denser coniferous areas, while dusky grouse utilize conifers, aspen, and sagebrush-grass areas. It is assumed in this model that these differences are a function of the availability of cover types and are not related to distinct habitat preferences of the two groups of grouse. Inadequate data exist to develop different models for these two groups of the blue grouse. The variables and ranges of suitability in this model were chosen to best accommodate the structural habitat needs of all groups of blue grouse. Therefore, this model is intended for application within the range of all subspecies of the blue grouse.

Season. This model was developed to evaluate the breeding season habitat needs of the blue grouse. Winter habitat requirements of the blue grouse are not well known (Hoffman, pers. comm.), and, therefore, are not included in this model.

Cover types. This model was developed to evaluate habitat quality in Evergreen Forest (EF), Deciduous Forest (DF), Evergreen Tree Savanna (ETS), Deciduous Tree Savanna (DTS), Evergreen Shrubland (ES), Deciduous Shrubland (DS), Evergreen Shrub Savanna (ESS), Deciduous Shrub Savanna (DSS), Grassland (G), Forbland (F), and Pasture and Hayland (P/H) areas (terminology follows that of U.S. Fish and Wildlife Service 1981).

Minimum habitat area. Minimum habitat area is defined as the minimum amount of contiguous habitat that is required before a species will occupy an area. Specific information on minimum areas required for blue grouse during the breeding season was not found in the literature.

Verification level. Previous drafts of this model were reviewed by Richard Hoffman, Colorado Division of Wildlife, Fort Collins, CO, and Fred Zwickel, Department of Zoology, University of Alberta, Edmonton. Specific comments from each reviewer were incorporated into the current model. Both reviewers felt that separate HSI models should be developed for the coastal and inland groups of the blue grouse. However, the information available in the literature did not indicate enough specific differences to develop and document distinct HSI models for each blue grouse group. This apparent lack of difference may be due to a lack of knowledge rather than to an actual lack of difference between the habitat requirements of the two groups. Hoffman (pers. comm.) believed that some of the habitat requirements would be the same for the coastal and inland blue grouse groups, especially those related to habitat structure.

The model presented here is not a statement of proven cause and effect relationships. Rather, the model represents hypotheses of the habitat requirements of the blue grouse.

Model Description

Overview. The structural diversity of tree, shrub, and herbaceous vegetation is a major factor influencing blue grouse habitat suitability. Trees, shrubs, and herbaceous growth provide both food and cover for blue grouse during the breeding season, and optimal habitats are assumed to contain a mix

of tree, shrub, and herbaceous vegetation. Maximum suitability occurs when trees, used primarily by territorial males, are well interspersed with the more open habitats used primarily by hens and broods. It is assumed that nesting and water needs will be met if food and cover are adequate.

The following sections provide a written documentation of the logic and assumptions used to interpret the habitat information for the blue grouse in order to explain the variables that are used in the HSI model. Specifically, these sections cover the following: (1) identification of variables used in the models; (2) definition and justification of the suitability levels of each variable; and (3) description of the assumed relationship between variables.

Food/cover component. Food and cover for blue grouse are provided in habitats that contain trees, shrubs, and herbaceous vegetation. The structural features of these different types of vegetation are more important than species composition in determining habitat values.

Trees are an important factor in blue grouse breeding habitat, and provide both food and cover. It is assumed that aspen and evergreens may provide suitable tree cover. Various reports indicate that blue grouse prefer habitats with a total tree canopy cover ranging from 20 to 50%. Habitat suitability decreases rapidly as tree canopy closure approaches 75%, and is very low at canopy closures exceeding 75%. Habitats with either no trees or 100% tree canopy closure over the entire area are assumed to have no suitability. The relationship between tree canopy cover and a suitability index for blue grouse is presented in Figure 1.

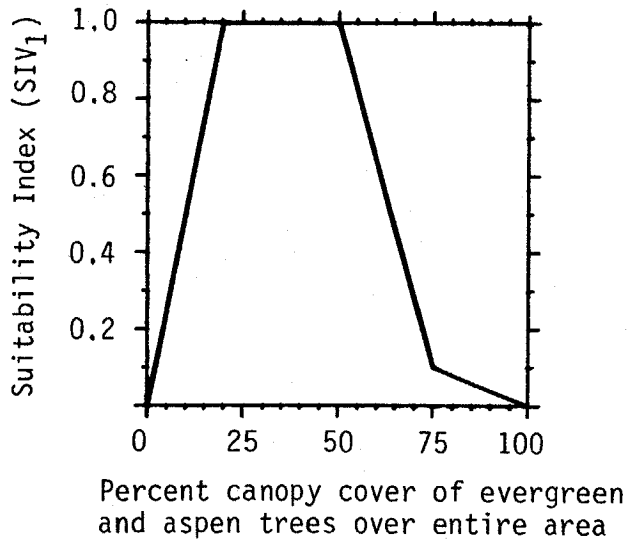

Figure 1. The relationship between the percent canopy cover of evergreen and aspen trees over the entire area and a suitability index for the blue grouse.

Shrubs provide food and cover for blue grouse males, hens, and broods. Overall shrub suitability is assumed to be related to the structure of the shrub component as described by shrub density and height.

Preferred blue grouse habitats contain only a moderately dense shrub cover, and it is assumed in this model that optimum shrub densities occur between 10 and 30% crown cover. Habitats with no shrubs will not be suitable to blue grouse, and habitats with a very dense shrub layer will restrict blue grouse ground movements. It is assumed that habitats with shrub densities exceeding 75% crown cover will not be suitable to blue grouse. The relationship between shrub canopy cover and a suitability index for blue grouse is presented in Figure 2a.

Fig. 2a

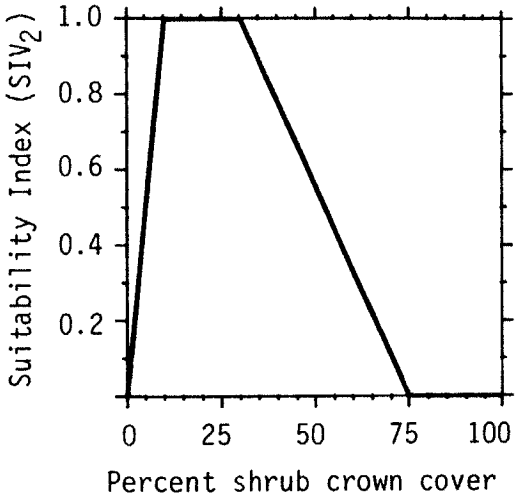

Fig. 2b

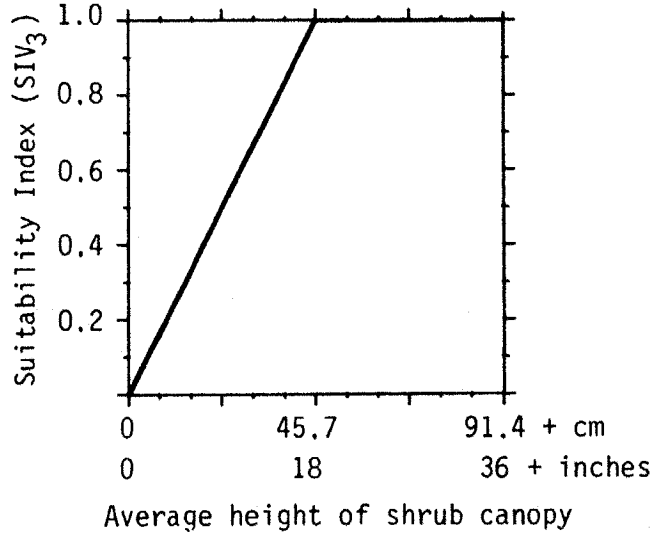

Figure 2. The relationships between habitat variables used to evaluate shrubs and the suitability indices for the variables.

It is assumed that very low growing shrubs will not provide adequate concealing cover for blue grouse. Suitability is assumed to be optimal when average shrub heights exceed 45.7 cm (18 inches), and suitability decreases to zero as shrub heights approach zero. Suitability will not be affected as shrub heights increase above 45.7 cm (18 inches) because tall shrubs may provide useful habitat, similar to small trees. The relationship between shrub height and a suitability index for blue grouse is presented in Figure 2b.

The best blue grouse habitats have shrubs that are both greater than 45.7 cm (18 inches) in height and at densities between 10 and 30% crown cover. Such habitats are assumed to provide ideal shrub cover conditions as well as ample shrub produced foods.

Habitats with shrub heights and/or densities present at levels outside the ranges of optimum described above will not have maximum suitability. In such habitats, it is assumed that the overall suitability of the shrub component will increase as either the height or density suitability values approach optimum levels. For example, a habitat with very low shrub heights and a very sparse canopy cover of shrubs would provide more food and cover for blue grouse if either the height or density of shrubs was increased to a higher suitability level. However, it is assumed that the lower of the two values will have the greatest impact on the final shrub component value. It is further assumed that when shrub height and density are present at the same levels of suitability, the habitat value for the shrub component will also be equal to that level of suitability. This relationship can be expressed mathematically by the following equation:

$$\text{Food/cover component (shrub portion)} = (SIV_2 \times SIV_3)^{1/2}$$

Herbaceous vegetation may provide food, cover, and water, and is especially important to blue grouse females and broods. Suitability of herbaceous vegetation is related to herbaceous canopy cover, height, and diversity. Optimal herbaceous densities are assumed to occur between 40 and 75% canopy cover, and suitability decreases as herbaceous densities approach zero or 100%. Habitats with 100% cover are assumed to provide very low suitability due to the restrictions they cause in grouse movement, while habitats with 0% cover are unsuitable. The relationship between herbaceous canopy cover and a suitability index for blue grouse is presented in Figure 3a.

Optimal herbaceous heights are assumed to occur between 20.3 and 50.8 cm (8 and 20 inches). Habitats with heights less than 20.3 cm (8 inches) will provide lower suitability due to a lack of concealing cover. Suitability will decrease as herbaceous heights approach 152.4 cm (60 inches), and it is assumed that, as herbaceous heights exceed 152.4 cm (60 inches), suitability will not be affected further. The relationship between herbaceous vegetation height and a suitability index for blue grouse is presented in Figure 3b.

Habitats with a high diversity of herbaceous plant species are preferred by blue grouse. Areas with low species diversity may provide some suitability if herbaceous height and density are adequate. The relationship between herbaceous vegetation diversity and a suitability index for blue grouse is presented in Figure 3c.

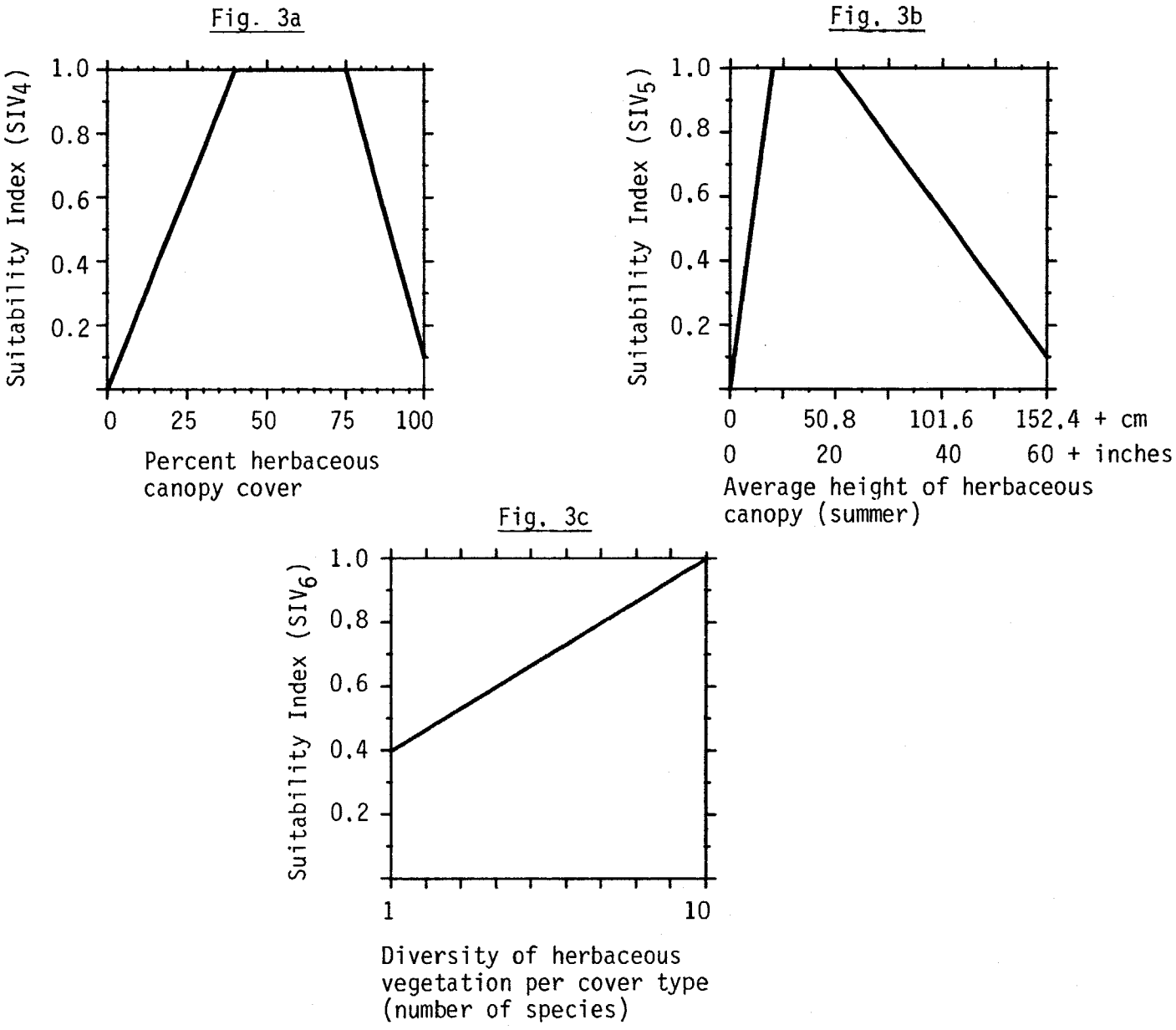

Figure 3. The relationships between habitat variables used to evaluate herbaceous vegetation and the suitability indices for the variables.

The best blue grouse habitats have herbaceous growth that is diverse, between 40 and 75% canopy cover, and between 20.3 and 50.8 cm (8 and 20 inches) in height. Such habitats are assumed to provide the best herbaceous cover conditions as well as ample insect and herbaceous foods.

Habitats with herbaceous height and/or densities present at levels lower than optimum (as described above) will not have maximum suitability. In such habitats, it is assumed that suitability will increase as either the herbaceous height or density suitability values approach optimum levels; however, the

lower of the two values will have the greatest influence on the final herbaceous component value. The suitability value for herbaceous diversity directly influences the value given to herbaceous vegetation. Habitats with a given suitability value for herbaceous height and density will have lower overall suitabilities as herbaceous diversity decreases from optimal to low levels. However, habitats with low diversity may have moderate suitability, if herbaceous height and density are adequate, because it is assumed that even areas with a single plant species will be used by blue grouse. This relationship can be expressed mathematically by the following equation:

$$\text{Food/cover component (herbaceous portion)} = (SIV_4 \times SIV_5)^{1/2} \times SIV_6$$

Interspersion component. Maximum blue grouse densities occur in areas where trees are well interspersed with more open habitats. It is assumed that optimal conditions are provided when the distance from herbaceous or shrub cover types to forest or tree savanna cover types is 0.4 km (0.25 mile) or less. Suitability will decrease to zero as this distance approaches 3.2 km (2.0 miles). This relationship is presented graphically in Figure 4.

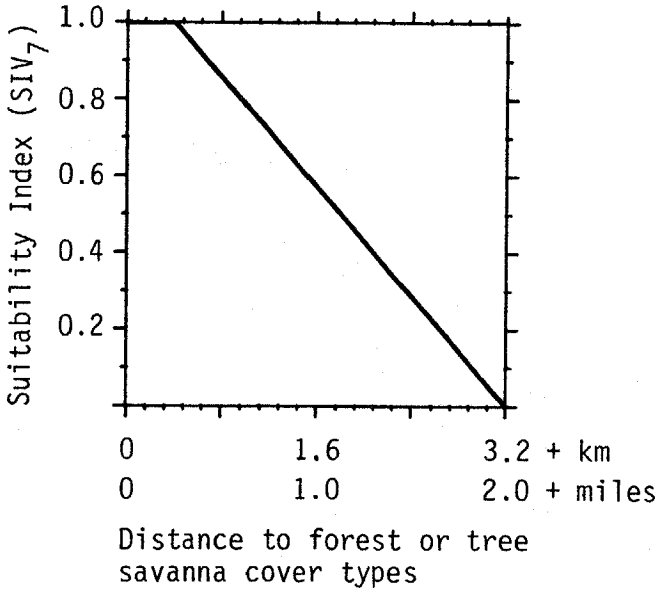

Figure 4. The relationship between the distance from herbaceous or shrub cover types to forest or tree savanna cover types and a suitability index for the blue grouse.

Model Relationships

HSI determination. The overall value for a habitat for blue grouse is a function of the quality of the herbaceous and shrubby vegetation in all cover types, the interspersion of herbaceous and shrub dominated cover types with forest or tree savanna cover types, and the total canopy cover of trees on the area. It is assumed that any of these may act as a limiting factor in determining the HSI.

It is assumed that the lowest value for either herbaceous or shrub growth, modified by the interspersion value, will determine the value of the herbaceous/shrub portion of a cover type for blue grouse. Overall habitat suitability is assumed to be the lower of either the value for percent tree coverage on the entire area or the total value obtained for the herbaceous/shrub portion in all cover types. These assumptions are based on the following logic: (1) All cover types should contain adequate quality of both herbaceous and shrub vegetation. Cover types with either poor herbaceous or poor shrub conditions will provide poor food and cover; (2) The value of the herbaceous and shrub vegetation in cover types without trees (ES,DS,ESS,DSS,G,F,P/H) will be affected by the interspersion of cover types providing trees (EF,DF,ETS,DTS). Interspersion of trees is considered to be adequate in cover types providing trees; and (3) Habitats with too few or too many trees over the entire area will be poor quality, regardless of the condition of the herbaceous and shrub growth.

The HSI is calculated as follows:

1. Determine suitability index (SI) values for each variable in the appropriate cover type by entering the field data into the appropriate SI graph. [Note: For V_1 only, determine one SI value for all cover types used by the blue grouse by multiplying the percent canopy cover of evergreen and aspen trees in each cover type used by the blue grouse by the relative area (see Step 3) of each cover type, summing these products for all cover types, and dividing by 100. Enter this figure into the SI graph for V_1 to determine the SI value for V_1.]

2. Calculate food/cover values for both the shrub and herbaceous portion in each cover type by using the SI values in the appropriate equation.

3. Determine the relative area (%) of each cover type used by blue grouse within the study area, as follows:

$$\text{Relative area (\%) for cover type A} = \frac{\text{Area of cover type A}}{\text{Total area of all cover types used by the blue grouse}} \times 100$$

4. Multiply the lower of either the herbaceous or shrub food/cover value for each cover type by the relative area (%) of that cover type.

5. Sum the values determined in Step 4 for forest and tree savanna cover types (EF, DF, ETS, and DTS).

6. Multiply the values determined in Step 4 for each herbaceous and shrub cover type (ES, DS, ESS, DSS, G, F, and P/H) by the SI value for V_7 for that cover type, and sum these products.

7. Add the sums from Steps 5 and 6, and divide by 100.

8. The HSI is equal to the lower of either the SI value for V_1, or the value from Step 7.

Summary of model variables. Seven habitat variables are used in this model to determine an HSI for the blue grouse. The relationship between habitat variables, life requisites, cover types, and the HSI for the blue grouse is illustrated in Figure 5.

Application of the Model

Application of the blue grouse HSI model requires the measurement of the quality of the herbaceous and shrub vegetation in all cover types. This value is then modified by considering the interspersion of trees with herbaceous and shrub vegetation. The value for tree canopy cover is determined for the entire study area. Overall habitat suitability is limited by either the value of the herbaceous and shrub portion or the value of the tree portion of the model. Refer to the HSI Determination section for further details.

Definitions of variables and suggested measurement techniques (Hays et al. 1981) are provided in Figure 6.

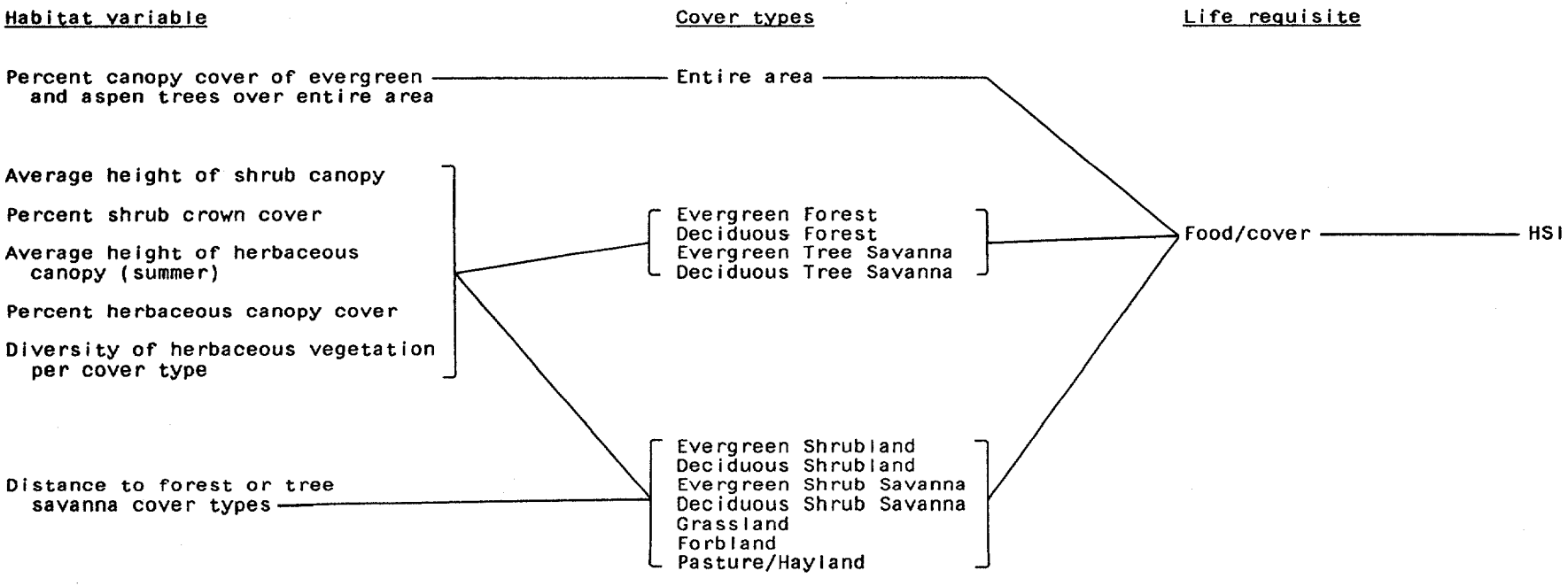

Figure 5. Relationships of habitat variables, life requisites, cover types, and the HSI in the blue grouse model.

Variable (definition)		Cover types	Suggested techniques
V_1	Percent canopy cover of evergreen and aspen trees over entire area [the percent of the ground surface that is shaded by a vertical projection of the canopies of evergreen and aspen woody vegetation taller than 5.0 m (16.4 ft) in height. Determined for the entire area by multiplying the percent canopy cover in each cover type used by the blue grouse by the relative area (see page 13 for definition) of that cover type, and summing these products for all cover types used by the blue grouse.]	Entire study area	Line intercept; remote sensing
V_2	Percent shrub crown cover [the percent of the ground surface that is shaded by a vertical projection of the canopies of woody vegetation ≤ 5.0 m (16.4 ft) tall].	EF,DF,ETS,DTS, ES,DS,ESS,DSS, G,F,P/H	Line intercept, quadrat
V_3	Average height of shrub canopy [the average vertical distance from the ground to the highest point of all woody plants ≤ 5.0 m (16.4 ft) tall].	EF,DF,ETS,DTS, ES,DS,ESS,DSS, G,F,P/H	Line intercept, graduated rod
V_4	Percent herbaceous canopy cover (the percent of the ground surface that is shaded by a vertical projection of all non-woody vegetation).	EF,DF,ETS,DTS, ES,DS,ESS,DSS, G,F,P/H	Line intercept, quadrat

Figure 6. Definitions of variables and suggested measurement techniques.

Variable (definition)		Cover types	Suggested techniques
V_5	Average height of herbaceous canopy (summer) (the average vertical distance from the ground surface to the dominant height stratum of the herbaceous vegetative canopy).	EF,DF,ETS,DTS, ES,DS,ESS,DSS, G,F,P/H	Line intercept, graduated rod
V_6	Diversity of herbaceous vegetation per cover type (the number of plant species comprising 1% or more of the total herbaceous canopy coverage per cover type).	EF,DF,ETS,DTS, ES,DS,ESS,DSS, G,F,P/H	Line intercept, quadrat
V_7	Distance to forest or tree savanna cover types (the distance from random points to the nearest edge of a forest or tree savanna cover type).	ES,DS,ESS,DSS, G,F,P/H	Remote sensing

Figure 6. (concluded)

SOURCES OF OTHER MODELS

Martinka (1972) developed discriminant function models based on vegetative structure in Montana that successfully classified areas into either breeding male territories or nonterritories. Steinhoff (1958) developed a rating scale of grouse abundance in Colorado based on factors such as soils, elevation, and vegetation. These studies classify areas as either being, or not being, blue grouse range, and do not provide quantitative values to distinguish between various quality levels of ranges that are expected to have blue grouse populations.

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A review of the literature and synthesis of available data are used to develop a habitat suitability model for the blue grouse (Dendragapus obscurus). The model consolidates habitat values into a framework suitable for field application, and is scaled to produce an index value between 0.0 (unsuitable habitat) and 1.0 (optimum habitat) for the breeding habitat of the blue grouse. Habitat Suitability Index models are designed to be used in conjunction with Habitat Evaluation Procedures previously developed by the U.S. Fish and Wildlife Service.

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