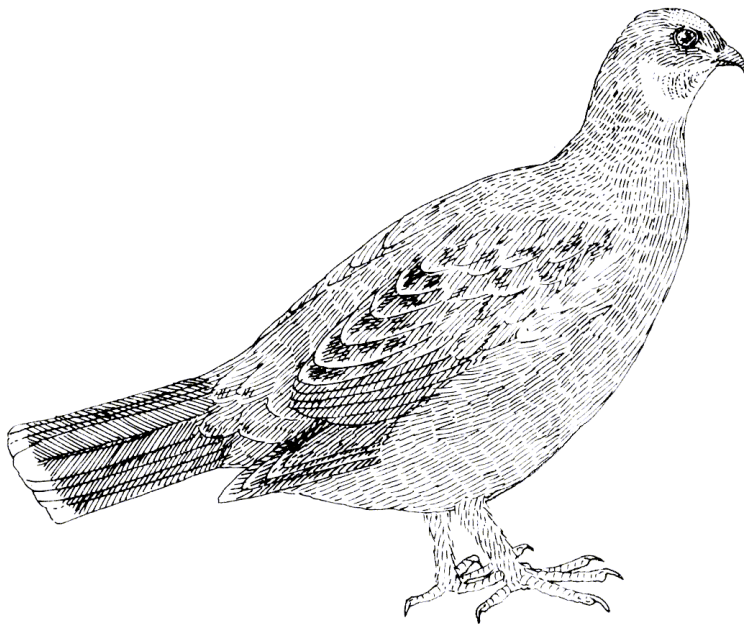


**California Wildlife Habitat Relationships Program  
California Department of Fish and Game**

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**HABITAT SUITABILITY MODELS FOR USE WITH ARC/INFO:  
BLUE GROUSE**



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CWHR Technical Report No. 1  
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HABITAT SUITABILITY MODELS FOR USE WITH ARC/INFO:  
BLUE GROUSE

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## PREFACE

This document is part of the California Wildlife Habitat Relationships (CWHR) System operated and maintained by the California Department of Fish and Game (CDFG) in cooperation with the California Interagency Wildlife Task Group (CIWTG). This information will be useful for environmental assessments and wildlife habitat management.

The structure and style of this series is basically consistent with the "Habitat Suitability Index Models" or "Bluebook" series produced by the USDI, Fish and Wildlife Service (FWS) since 1981. Moreover, models previously published by the FWS form the basis of the current models for all species for which a "Bluebook" is available. As is the case for the "Bluebook" series, this CWHR series is not copyrighted because it is intended that the information should be as freely available as possible. In fact, it is expected that these products will evolve rapidly over the next decade.

This document consists of two major sections. The Habitat Use Information functions as an up-to-date review of our current understanding regarding the basic habitat requirements of the species. This section typically builds on prior publications, including the FWS "Bluebook" series. However, the Habitat Suitability Index (HSI) Model section is quite different from previously published models. All models in this CWHR series are designed as macros (AML computer programs) for use with ARC/INFO geographic information system (GIS) software running on a UNIX platform. As such, they represent a step up in model realism in that spatial issues can be dealt with explicitly. They are "Level II" models in contrast to the "Level I" (matrix) models initially available in the CWHR System. For example, issues such as habitat fragmentation and distance to habitat elements may be dealt with in spatially explicit "Level II" models. Unfortunately, a major constraint remains the unavailability of mapped habitat information most useful in defining a given species' habitat. For example, there are no readily available maps of snag density. Consequently, the models in this series are compromises between the need for more accurate models and the cost of mapping essential habitat characteristics. It is hoped that such constraints will diminish in time.

While "Level II" models incorporate spatial issues, they build on "Level I", nonspatial models maintained in the CWHR System. As the matrix models are field tested, and occasionally modified, these changes will be expressed in the spatial models as well. In other words, the continually evolving "Level I" models are an integral component of the GIS-based, spatial models. To use these "Level II" models one must have (1) UNIX-based ARC/INFO with GRID module, (2) digitized coverages of CWHR habitat types for the area under study and habitat element maps as required for a given species, (3) the AML presented in this document, and (4) a copy of the CWHR database. Digital copies of AMLs are available from the CWHR Coordinator at the CDFG.

Unlike many HSI models produced for the FWS, this series produces maps of habitat suitability with four classes of habitat quality: (1) None; (2) Low; (3) Medium; and (4) High. These maps must be considered hypotheses in need of testing rather than proven cause and effect relationships, and proper use of the CWHR System requires that field testing be done. The maps are only an initial "best guess" which professional wildlife biologists can use to optimize their field sampling. Reliance on the maps without field testing is risky even if the habitat information is accurate.

The CDFG and CIWTG strongly encourage feedback from users of this model and other CWHR components concerning improvements and other suggestions that may increase the utility and effectiveness of this habitat-based approach to wildlife management planning.

## ACKNOWLEDGMENTS

The primary credit for this document must go to the field biologists and naturalists that have published the body of literature on the ecology and natural history of this species. They are listed in the References section. Ecological information of this sort is generally very expensive and time-consuming to obtain. Yet this basic ecological understanding is exactly what is needed most if the goal of accurately predicting changes in distribution and abundance of a particular species is ever to be achieved. The CWHR System is designed to facilitate the use of existing information by practicing wildlife biologists. We hope it will also stimulate funding for basic ecological research. Funding for producing this model was provided by the California Department of Forestry and Fire Protection and the University of California Agricultural Experiment Station.

We thank Barry Garrison, Karyn Sernka, and Sandie Martinez of the California Department of Fish and Game for their assistance in typing, editing, and producing this report.

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## BLUE GROUSE (*Dendragapus obscurus*)

### HABITAT USE INFORMATION

#### General

Blue grouse (*Dendragapus obscurus*) inhabit coniferous forests in western North America (American Ornithologists' Union 1983). In California, they are uncommon to common permanent residents at middle to high elevations. Blue grouse inhabit open, medium to mature-aged stands of fir (*Abies* spp.), Douglas-fir (*Pseudotsuga menziesii*), and other conifers (Zeiner et al. 1990). In the breeding season, they tend to prefer aspen groves (*Populus tremuloides*) and the edges of coniferous forest. In the winter, they prefer coniferous forests (Aldrich 1963). In California, blue grouse inhabit the North Coast, Klamath, and Sierra Nevada ranges and portions of the Warner, White and Tehachapi mountains (Zeiner et al. 1990). Blue grouse populations consist of the sooty grouse group, which is found along the Pacific coast, and the dusky grouse group, which is found in the Great Basin and Rocky Mountains (American Ornithologists' Union 1983). This model is applicable for blue grouse in California. However, due to the small amount of data available for this area, information about blue grouse in other areas has been incorporated into the model.

#### Food

The food habits of the blue grouse vary from a 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). The plant material was comprised of 64% needles from true firs and Douglas-fir; 17% from berries such as currants (*Ribes* spp.), serviceberries (*Amelanchier* spp.), blackberries (*Rubus* spp.), huckleberries (*Vaccinium* spp.), and bearberry (*Arctostaphylos uva-ursi*); and 17% from 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 the 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 comprised 60% of the food consumed by juveniles from 10-42 days old (King 1973). In Idaho blue grouse move from their high elevation winter range to lower elevation Douglas-fir forests during May and June, and their diet consisted primarily of the flowering parts of various plants (Marshall 1946). These grouse moved to even lower elevations along streams during July and August, and their diet shifted to the fruits and

leaves of various shrubs. Forest habitats in early stages of second growth vegetation provide important summer foods for adults and chicks (Fowle 1960).

The winter (October through April) diet 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 true 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* var. *murryana*) (39.3%), juniper (*Juniperus* spp.) (21.4%), limber pine (*P. flexilis*) (17.9%), Douglas-fir and subalpine fir (*Abies lasiocarpa*) (8.9%), and Engelmann spruce (*Picea engelmannii*) (5.4%) (Harju 1974). Hines (1987) found that blue grouse in British Columbia preferred western hemlock (*T. heterophylla*) and Douglas-fir as winter food. Zwickel and Bendell (1972) believed that winter food supplies were generally adequate for blue grouse. It appears that spring densities are related to the quality of the breeding range rather than winter food supplies (Zwickel et al. 1968). It is possible that the quality and quantity of winter habitat may be a limiting factor for blue grouse in some parts of their range.

#### Water

Blue grouse in Washington and northern Idaho were generally found near a source of moisture, either open water or succulent vegetation and berries (Beer 1943; Rogers 1968). 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 found cover under logs, stumps, and small conifers, which are similar to sites used for nesting. 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 15-31 cm (6-12 in) dbh and 6-15 m (20-50 ft) tall (Caswell 1954). In southeastern Idaho, grouse were found in a variety of habitats including sagebrush (*Artemisia* spp.), aspen, maple (*Acer* spp.), and conifers during the breeding season (Stauffer and Peterson 1985).



Winter range is provided primarily by montane forests (Bendell and Elliott 1966), and blue grouse spend most of the winter in coniferous trees until snow melt allows ground feeding (Hoffman 1956). In Colorado, most blue grouse observed in the winter were found in conifers, with Douglas-fir being preferred (Cade and Hoffman 1990). 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, but blue grouse tended to be found in the largest conifers available within all occupied stands. Conifer stands that were not suitable for wintering blue grouse included low density (less than 70 trees/ha [28/ac]) stands of small conifers and high density (more than 1,200 trees/ha [486/ac]) stands of mature trees. In southeastern Idaho, winter use was concentrated in high elevation, open conifer stands (Stauffer and Peterson 1985). On Hardwicke Island, British Columbia, blue grouse also wintered in conifer forests (Hines 1987). In this study, birds were found in many stages of western hemlock. However, mature forest was the preferred winter habitat. Pekins et al. (1991) found that blue grouse in Utah selectively roosted in the largest Douglas-fir trees during the day and subalpine fir trees at night. Diurnal and nocturnal roosts were typically adjacent to tree trunks in the lower two-thirds of trees.

## Reproduction

Blue grouse in British Columbia preferred open habitats over dense habitats during the breeding season (Bendell and Elliott 1966). Open habitats averaged 15% canopy cover of trees, while 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). As canopy cover deviated from this condition, habitats became less acceptable to territorial males. In general, blue grouse populations decline rapidly as canopy cover of conifers approaches 75% (Redfield et al. 1970). The density of booming 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, preferring more open areas.

In Colorado, blue grouse breed throughout their range 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 vegetation appears to be more important than floristics 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). Lewis (1981) studied persistent and transient territorial sites of male blue grouse and was unable to determine any significant physical difference between the two types of sites.

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 British Columbia (Donaldson and Bergerud 1974). Even-aged, closed canopy forests had the lowest grouse densities in this study area. Three habitat components that may be important to males when 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 and shrub layers increases 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 (F. C. Zwickel, pers. comm.). In central-southeast Alaska, singing males were located 45 times more often in older forest than in adjacent clearcuts (Doerr et al. 1984).

Blue grouse territories in Montana contained small thickets of conifers used for nesting and escape cover (Martinka 1972). Territories contained an average of 0.08 ha (0.2 ac) 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 ac) in size with 85 m (278 ft) of edge, which was significantly smaller than thickets occurring within territories. Males preferred younger thickets, generally 20-40 years in age, with an average tree dbh of 12 cm (5 in). Thickets in territories contained an average of 105 trees greater than 20 cm (8 in) dbh/0.4 ha (1.0 ac), while nonterritory thickets contained an average of 248 such trees/0.4 ha (1.0 ac). Douglas-fir thickets tended to provide better protection than thickets of ponderosa pine (*Pinus ponderosa*). When thicket size, amount of edge, and average thicket tree dbh were used in a discriminant function analysis, a high degree of discrimination between territories and nonterritories was evident.

Areas used by blue grouse during the spring in Wyoming were frequently in or near aspen or lodgepole pine stands with adjacent openings (Harju 1974). Trees in grouse use areas averaged 11 m (35 ft) tall and 18 cm (7 in) dbh, compared to averages of 15 m (50 ft) and 29 cm (11 in) 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 40-70% cover of tall shrubs and trees (Stauffer 1983). Breeding areas with about 50% tree cover had more grouse than areas with fewer 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 and were lined with twigs and feathers, and almost all nests were located near the territories of male blue grouse (Weber 1975). Broods were most often found in mule ears (*Wyethia amplexicaulis*), sagebrush 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 concealing cover that was 31-38 cm (12-15 in) tall.

In Montana, blue grouse females with broods used grass-forb areas in early summer and, as vegetation dried out by late-July, increased their use of deciduous thickets (Mussehl 1960). In British Columbia, females with broods were most often 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 Idaho occupied areas with greater than 50% cover of herbaceous vegetation that was greater than 50 cm (20 in) 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 seldom used (Mussehl 1963). Herbaceous cover is very important to chicks in their first six 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 18-20 cm (7-8 in) in height and had an average canopy cover of 57% in a drought year and 72% in years of normal precipitation. The herbaceous cover contained both grasses and forbs, with grasses slightly more abundant. Bare ground (8-20%) provided travel lanes for broods. Large areas of herbaceous vegetation may not be needed by broods, as 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.

In Wyoming, brood habitat for dusky blue grouse averaged 60% 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 botanical 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, there was little variation in population parameters

such as death rates, clutch size, and late-summer brood size. Although populations were generally lower in habitats containing dense or very dense conifer cover compared to those with open conifer cover, the differences in breeding densities could not be explained by the vegetative structure or plant succession on the different sites. Populations of grouse were declining in some areas that appeared to be structurally identical to areas that supported very high densities. Habitat features apparently were important primarily in setting broad limits of tolerance in areas within which blue grouse are found. Actual densities of grouse at a particular time may be related to other factors.

### Interspersion and Composition

Blue grouse generally winter on high elevation, 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 include 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 mi) (Weber et al. 1974), while movements in a British Columbia study ranged from 1.6-16.1 km (1-10 mi), with an average of 5.8 km (3.6 mi) (Bendell and Elliott 1967). Autumn migrations up to 50 km (31 mi) were recorded in Washington, although most migrations were less than 16 km (10 mi) (Zwickel et al. 1968). A female grouse in Washington moved 63 km (39 mi) to winter range, although most grouse movements were less than 16 km (10 mi) (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 and Hoffman 1990). From July through September, most broods in Montana moved 0.8 km (0.5 mi) or less but later dispersed over a very large winter range (Mussehl 1960).

The density of blue grouse on two 14.6 ha (36 ac) study areas in British Columbia was 1.09 birds/ha (0.44 bird/ac) (Bendell and Elliott 1967). Average male territory size was 0.4-0.8 ha (1-2 ac) in Utah (Weber et al. 1974). Territory size in densely populated areas in British Columbia was 0.4-0.8 ha (1-2 ac), while maximum male territory size was 3.2 ha (8 ac) (Bendell and Elliott 1967). Territories of males in Alberta averaged 0.6 ha (1.5 ac) and did not overlap (Boag 1966).

The home range of adult females was found to average 17.4 ha (43 ac) (Boag 1966). These ranges overlapped the ranges of other males and females. Adult females in British Columbia constricted their home ranges from 6-2 ha (15-5 ac) and yearlings from 20-2 ha (49-5 ac) 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 ac) (Cade and Hoffman 1993). Summer home ranges of broods in Montana averaged 51 ha (126 ac), and varied from 12.5-115 ha (31-283 ac) (Mussehl 1960). 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 strongly modify the structure and species composition of herbaceous vegetation during the brood-rearing season. Mussehl (1963) found ungrazed areas provided better brood cover.

Blue grouse densities are low in mature coastal forests, but populations generally increase quickly following logging or burning (Redfield et al. 1970). This population increase is followed by 10-25 years of stability and then by 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 do 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.*

The California Wildlife Habitat Relationships (CWHR) System (Airola 1988; Mayer and Laudenslayer; 1988, Zeiner et al. 1990) contains habitat ratings for each habitat type predicted to be occupied by blue grouse in California.

#### *Season.*

This model is designed to predict the suitability of habitat for blue grouse throughout the year. Model predictions, however, may be more accurate for breeding habitat.

#### *Cover types.*

This model can be used anywhere in California for which an ARC/INFO map of CWHR habitat types exists. The CWHR System contains suitability ratings for reproduction, cover, and feeding for all habitats blue grouse are predicted to occupy. These ratings can be used in

conjunction with the ARC/INFO habitat map to model wildlife habitat suitability.

#### *Minimum habitat area.*

Minimum habitat area is defined as the minimum amount of contiguous habitat required before a species will occupy an area. Specific information on minimum areas required for blue grouse throughout the year was not found in the literature. This model assumes two home ranges is the minimum area required to support a blue grouse population during the breeding season.

#### *Verification level.*

The spatial model presented here has not been verified in the field. The CWHR suitability values used are based on a combination of literature searches and expert opinion. We strongly encourage field testing of both the CWHR database and this spatial model.

### **Model Description**

#### *Overview.*

This model uses CWHR habitat type as the main factor determining suitability of an area for this species. In addition, distance to water is used to adjust the suitability of the area.

A CWHR habitat type map must be constructed in ARC/INFO GRID format as a basis for the model. The GRID module of ARC/INFO was used because of its superior functionality for spatial modeling. Only crude spatial modeling is possible in the vector portion of the ARC/INFO program, and much of the modeling done here would have been impossible without the abilities of the GRID module. In addition to more sophisticated modeling, the GRID module's execution speed is very rapid, allowing a complex model to run in less than 30 minutes.

The following sections document the logic and assumptions used to interpret habitat suitability for the blue grouse.

#### *Cover component.*

A CWHR habitat map must be constructed. The mapped data (coverage) must be in ARC/INFO GRID format. A grid is a GIS coverage composed of a matrix of information. When the grid coverage is created, the size of the grid cell should be determined based on the resolution of the habitat data and the home range size of the species with the smallest home range in the study. You must be able to map the home range of the smallest species with reasonable accuracy. However, if the cell size becomes too small, data processing time can increase considerably. We recommend a grid cell size of 30 m (98 ft). Each grid cell can be

assigned attributes. The initial map must have an attribute identifying the CWHR habitat type of each grid cell. A CWHR suitability value is assigned to each grid cell in the coverage based on its habitat type. Each CWHR habitat is rated as high, medium, low or of no value for each of three life requisites: reproduction; feeding; and cover. The geometric mean value of the three suitability values was used to determine the base value of each grid cell for this analysis.

#### *Distance to water.*

Blue grouse require free water, particularly during the breeding season. This model downgrades all grid cells one suitability level if they are further than 700 m (2,297 ft) from a lake or permanent stream.

#### *Species' distribution.*

The study area must be manually compared to the range maps in the CWHR Species Notes (Zeiner et al. 1990) to ensure that it is within the species' range. All grid cells outside the species' range have a suitability of zero.

#### *Spatial analysis.*

Ideally, a spatial model of distribution should operate on coverages containing habitat element information of primary importance to a species. For example, in the case of woodpeckers, the size and density of snags as well as the vegetation type would be of great importance. For many small rodents, the amount and size of dead and down woody material would be important. Unfortunately, the large cost involved in collecting microhabitat (habitat element) information and keeping it current makes it likely that geographic information system (GIS) coverages showing such information will be unavailable for extensive areas into the foreseeable future.

The model described here makes use of readily available information such as CWHR habitat type, elevation, slope, aspect, roads, rivers, streams and lakes. The goal of the model is to eliminate areas that are unlikely to be utilized by the species and lessen the value of marginally suitable areas. It does not attempt to address all the microhabitat issues discussed above, nor does it account for other environmental factors such as toxins, competitors, or predators. If and when such information becomes available, this model could be modified to make use of it.

Although blue grouse are known to prefer edge conditions, the resolution and accuracy of our data did not allow us to explicitly analyze the effect of edge. This issue is addressed indirectly in the CWHR database and by using the geometric mean rather than the arithmetic mean when extracting habitat suitability ratings from the CWHR database. Open areas containing a shrub understory are rated higher than more dense types that would lack a shrub understory.

In conclusion, field surveys will likely discover that the species is not as widespread or abundant as predictions by this model suggest. The model predicts potentially available habitat. There are a variety of reasons why the habitat may not be utilized.

*Definitions.*

**Home Range:** the area regularly used for all life activities by an individual during the season(s) for which this model is applicable.

**Dispersal Distance:** the distance an individual will disperse to establish a new home range. In this model it is used to determine if Potential Colony Habitat will be utilized.

**Day to Day Distance:** the distance an individual is willing to travel on a daily or semi-daily basis to utilize a distant resource (Potential Day to Day Habitat). The distance used in the model is the home range radius. This is determined by calculating the radius of a circle with an area of one home range.

**Core Habitat:** a contiguous area of habitat of medium or high quality that has an area greater than two home ranges in size. This habitat is in continuous use by the species. The species is successful enough in this habitat to produce offspring that may disperse from this area to the Colony Habitat and Other Habitat.

**Potential Colony Habitat:** a contiguous area of habitat of medium or high quality that has an area between one and two home ranges in size. It is not necessarily used continuously by the species. The distance from a core area will affect how often Potential Colony Habitat is utilized.

**Colony Habitat:** Potential Colony Habitat that is within the dispersal distance of the species. These areas receive their full original value unless they are further than three home range radii from a core area. These distant areas receive a value of low since there is a low probability that they will be utilized regularly.

**Potential Day to Day Habitat:** an area of high or medium quality habitat less than one home range, or habitat of low quality of any size. This piece of habitat alone is too small or of inadequate quality to be Core Habitat.

**Day to Day Habitat:** Potential Day to Day Habitat that is close enough to Core or Colony Habitat can be utilized by individuals moving out from those areas on a day to day basis. The grid cell must be within Day to Day Distance of Core or Colony Habitat.



**Other Habitat:** contiguous areas of low value habitat larger than two home ranges in size, including small areas of high and medium quality habitat that may be imbedded in them, are included as usable habitat by the species. Such areas may act as “sinks” because long-term reproduction may not match mortality.

The table below indicates the specific distances and areas assumed by this model.

Distance variables:	Meters	Feet
Dispersal Distance	9,670	31,725
Day to Day Distance/Home Range radius	403	1,322
Distance to water	700	2,296

Area variables:	Hectares	M <sup>2</sup>	Acres	Ft <sup>2</sup>
Home Range	51	510,000	126	5,488,560
Core Habitat	≥ 102	≥ 1,020,000	≥ 252	≥ 10,977,120

### Application of the Model

A copy of the ARC/INFO AML can be found in Appendix 1. The steps carried out by the macro are as follows:

1. **Downgrade areas too far from water:** the first step is to downgrade areas too far from water. If the grid cell is more than 700 m (2,297 ft) from water, it loses one level of suitability.
2. **Determine Core Habitat:** this is done by first converting all medium quality habitat to high quality habitat and removing all low value habitat. Contiguous areas of habitat are then grouped into regions. The area of each of the regions is determined. Those large enough (≥ two home ranges) are maintained in the Core Habitat coverage. If no Core Habitat is identified then the model will indicate no suitable habitat in the study area.
3. **Identify Potential Colony Habitat:** using the coverage from Step 2, determine which regions are one to two home ranges in size. These are Potential Colonies.

4. **Identify Potential Day to Day Habitat:** using the coverage derived in Step 2, determine which areas qualify as Potential Day to Day Habitat.
  
5. **Calculate the Cost Grid:** since it is presumed to be more difficult for animals to travel through unsuitable habitat than suitable habitat, we use a cost grid to limit travel based on habitat suitability. The cost to travel is one for high or medium quality habitat. This means that to travel 1 m through this habitat costs 1 m of Dispersal Distance. The cost to travel through low quality habitat is two and unsuitable habitat costs four. This means that to travel 1 m through unsuitable habitat costs the species 4 m of Dispersal Distance.
  
6. **Calculate the Cost Distance Grid:** a cost distance grid containing the minimum cost to travel from each grid cell to the closest Core Habitat is then calculated using the Cost Grid (Step 5) and the Core Habitat (Step 2).
  
7. **Identify Colony Habitat:** based on the Cost Distance Grid (Step 6), only Potential Colony Habitat within the Dispersal Distance of the species to Core Habitat is retained. Colonies are close enough if **any** cell in the Colony is within the Dispersal Distance from Core Habitat. The suitability of any Colony located further than three home range radii from a Core Habitat is changed to low since it is unlikely it will be utilized regularly.
  
8. **Create the Core + Colony Grid:** combine the Core Habitat (Step 2) and the Colony Habitat (Step 7) and calculate the cost to travel from any cell to Core or Colony Habitat. This is used to determine which Potential Day to Day Habitat could be utilized.
  
9. **Identify Day to Day Habitat:** grid cells of Day to Day Habitat are only accessible to the species if they are within Day to Day Distance from the edge of the nearest Core or Colony Habitat. Add these areas to the Core + Colony Grid (Step 8).
  
10. **Add Other Habitat:** large areas ( $\geq$  two home ranges in size) of low value habitat, possibly with small areas of high and medium habitat imbedded in them may be utilized, although marginally. Add these areas back into the Core + Colony + Day to Day Grid (Step 9), if any exist, to create the grid showing areas that will potentially be utilized by the species. Each grid cell contains a one if it is utilized and a zero if it is not.
  
11. **Restore Values:** all areas that have been retained as having positive habitat value receive their original geometric mean value from the original geometric value grid (see *Cover component* section) with the exception of distant colonies. Distant colonies (colonies more than three home range radii distant) have their value reduced to low because of the low likelihood of utilization.

## **Problems with the Approach**

### *Cost.*

The cost to travel across low suitability and unsuitable habitat is not known. It is likely that it is quite different for different species. This model incorporates a reasonable guess for the cost of movement. A small bird will cross unsuitable habitat much more easily than a small mammal. To some extent differences in vagility between species is accounted for by different estimates of dispersal distances.

### *Dispersal distance.*

The distance animals are willing to disperse from their nest or den site is not well understood. We have used distances from studies of the species or similar species when possible, otherwise first approximations are used. More research is urgently needed on wildlife dispersal.

### *Day to day distance.*

The distance animals are willing to travel on a day to day basis to use resources has not been quantified for most species. This issue is less of a concern than dispersal distance since the possible distances are much more limited, especially with small mammals, reptiles, and amphibians. Home range size is assumed to be correlated with this coefficient.

## **SOURCES OF OTHER MODELS**

Schroeder (1984) developed a quantitative HSI model for blue grouse using measures of canopy cover of evergreen and aspen trees, percent shrub cover, average shrub height, various measures of herbaceous cover, and distance to forest edge. 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 within areas expected to have blue grouse populations.



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## APPENDIX 1: Blue Grouse Macro

```
/*      BLUE GROUSE

/* bgrmodel.aml - This macro creates an HSI coverage for the
/*      Blue Grouse.

/* Version: Arc/Info 6.1 (Unix), GRID-based model.

/* Authors: Irene Timossi, Sarah Miller, Wilde Legard,
/*      and Reginald H. Barrett
/*      Department of Forestry & Resource Management
/*      University of California, Berkeley

/* Revision: 2/10/95

/* -----
/* convert .ID to uppercase for info manipulations
&setvar .ID [translate %.ID%]

/* Start Grid

grid

/*

&type (1) Initializing Constants...

/* Homerange: the size of the species' homerange.

/* DayPay: The amount the species is willing to pay traveling on
/* a day-to-day basis. Used to determine the area utilized on a
/* day-to-day basis.

/* DispersePay: Distance traveled when dispersing. The amount
/* the animal is willing to pay when dispersing from a core area.

/* Waterdist: Home range diameter added to nest distance to water. Is
/* the maximum distance from water that a species can be for reproduction.

/* High: The value in the WHR grid which indicates high quality habitat.

/* Medium: The value in the WHR grid which indicates medium quality habitat.

/* Low: The value in the WHR grid which indicates low quality habitat.

/* None: The value in the WHR grid which indicates habitat of no value.

/* SpecCode: The WHR code for the species

/* AcreCalc: The number needed to convert square units
/*      (feet or meters) to acres.
```

```

&setvar SpecCode = B134

&if %.Measure% = Meters &then
&do
&setvar Homerange    = 509922
&setvar DayPay       = 403
&setvar DispersePay  = 9670
&setvar WaterDist    = 700
&setvar AcreCalc     = 4047
&end
&else
&if %.Measure% = Feet &then
&do
&setvar Homerange    = 5488560
&setvar DayPay       = 1322
&setvar DispersePay  = 31725
&setvar WaterDist    = 2297
&setvar AcreCalc     = 43560
&end
&else
&do
&type Measurement type incorrect, check spelling.
&type Only Meters and Feet are correct.
&goto &BADEND
&end

&setvar High        = 3
&setvar Medium      = 2
&setvar Low         = 1
&setvar None        = 0

/* The following global variables are declared in the menu:

/* .WHRgrid (WHR grid name): the name of the grid containing all
/* the WHR information.

/* .Bound (Boundary grid name): the grid containing only the
/* boundary of the coverage. All cells inside the boundary
/* have a value of 1. All cells outside the boundary must
/* have a value < 1.

/* .ID (Identifier): a 1 to 4 character code used to identify
/* the files produced by this program. You may prefer
/* to use an abbreviation of the species' common name
/* (e.g. use `fis1` for fisher).

/* .SizeOfCell (Cell size): the size (width) of the cells
/* used in the coverage grids. All grids used in the
/* analysis must have the same cell size.

/* .Measure: the units the coverage is measured in (feet or meters).

```

&type (2) Creating working grid of geometric means...

```
/* Create a Geometric Means grid (Geom) for the species by
/* copying these values from the WHR grid if they are close enough
/* to water.
```

```
if (((%.Stream% <= %WaterDist%) or (%.Lake% <= %WaterDist%)) or (%.WHRgrid%.%SpecCode%_G ==
0))
  Geom = %.WHRgrid%.%SpecCode%_G
else
  Geom = %.WHRgrid%.%SpecCode%_G - 1
endif
```

```
/*
```

&type (3) Changing %Medium% value cells to %High% value for Merge grid...

```
/* Create a grid (Merge) merging Medium and High
/* value cells from the Geometric mean grid (Geom),
/* while leaving the value of other cells (Low and None) unchanged.
/* Merge by changing the value of all medium cells to High.
```

```
Merge = con(Geom == %Medium%, %High%, Geom)
```

```
/*
```

&type (4) Converting Merge grid zones into a Region grid...

```
/* Convert the zones of the merge grid (Merge) into
/* unique regions (Region). These will be used later
/* to create core, colony, and day-to-day areas.
```

```
Region = regiongroup(Merge, #, EIGHT)
```

```
/*
```

&type (5) Calculating the area of Region grid zones...

```
/* Calculate the area of the zones (ZoneArea) on the region
/* grid (Region).
```

```
ZoneArea = zonalarea(Region)
```

```
/*
```

&type (6) Creating a Core Area grid...

```
/* Extract areas from the zonal area grid (ZoneArea)
/* suitable for core areas (Core). Core areas are defined
/* as the Medium+High zones in the merge grid (Merge)
/* with an area of at least two home ranges (%Homerange%).
/* Set their value = 1.
```

```
if (Merge == %High% and ZoneArea >= %Homerange% * 2)
  Core = 1
```

```

endif

&if not [exists Core -vat] &then
  &goto END

/*

&type (7) Creating a Colony grid...

/* Extract areas from the zonal area grid (zoneArea)
/* possibly suitable for colonization (ColTemp).
/* Colony areas are defined as Low or Medium+High zones
/* in the Merge grid (Merge) with an area of between one
/* and two home ranges (%Homerange%). Set their value = 1.

/* Then set all nodata values in the grid to zero (Colony).

docell
  if (Merge == %High%)
    if (ZoneArea > %Homerange% and ZoneArea < %Homerange% * 2)
      ColTemp = 1
    endif
  endif
endif
end

Colony = con(isnull(ColTemp),0,ColTemp)

/*

&type (8) Creating a Day-to-Day Use grid...

/* Create a grid based on the values in the zonal
/* area grid (ZoneArea) and merge grid (Merge)
/* suitable for day-to-day use (DayToDay). Day-to-day use
/* areas are defined as Low if the area is less than two
/* homeranges in size or Medium+High zones in the
/* merge grid (Merge) with an area of less than one home
/* range (%Homerange%). Set their value = 1.

if ((Merge > %Low% and ZoneArea <= %Homerange%) or ~
  (Merge == %Low% and ZoneArea < %Homerange% * 2))
  DayToDay = 1
else
  DayToDay = 0
endif

/*

&type (9) Creating a Cost Grid based on habitat value...

/* Using the merge grid (Merge), create a cost grid (Cost)
/* based on the habitat-value. Cost represents the relative
/* resistance a species has to moving across different quality
/* habitat: Habitat-value Cost
/*      None      4

```

```

/*          Low          2
/*          Medium+High  1

if (Merge == %None%)
  Cost = 4
else if (Merge == %Low%)
  Cost = 2
else if (merge == %High%)
  Cost = 1
endif

/*

&type (10) Calculating cost to travel from Core Areas...

/* Calculate the cost to travel the distance (CostDist)
/* from the nearest core area source (Core) using the cost
/* grid (Cost).
/*
CostDist = CostDistance(Core,Cost)

/*

&type (11) Calculating which Colony areas are Cost Effective...

/* If Colony Areas exist...
/* Find the areas in the Colony grid (Colony) that could
/* be colonized from the core areas:

/* Assign costs to all cells in the Colony areas (Colony)
/* from the Cost grid (CostDist). Zero surrounding NODATA areas.

/* Make each colony a separate zone (ZoneReg) using
/* the regiongroup command.

/* Use zonalmin to find the minimum cost to arrive at each
/* colony (ZoneMin).

/* Set all NODATA cells to zero in ZoneMin to produce
/* ColZer1.

/* To find out which of the potential colonies can be utilized,
/* determine which have a cost that is equal to or less than
/* DispersePay. If the cost to get to a colony is less than
/* or equal to DispersePay, keep it in grid Col.

/* Fill the null value areas in Col with zeros to create ColZer2

&if not [exists ColTemp -vat] &then
  &goto SkipColony

ColDist = con(Colony > 0, CostDist, 0)
ZoneReg = regiongroup(Colony, #, EIGHT)

```

```

ZoneMin = zonalmin(ZoneReg,ColDist)
ColZer1 = con(isnull(ZoneMin),0,ZoneMin)

if (ColZer1 <= %DispersePay% and ColZer1 > 0)
  Col = Colony
else
  Col = Core
endif

ColZer2 = con(isnull(Col),0,Col)

/*

&type (12) Creating Core + Colony grid...

/* If colonies exist....
/* Create a grid (ColCore) that combines the core
/* (Core) and colony (Colony) grids.
/* This grid will be used to analyze day-to-day use.

if (Colony == 1)
  ColCore = 1
else
  ColCore = Core
endif

&label SkipColony

&type (13) Calculate cost to travel from Core and Colony Areas...

/* If colonies exist...
/* Calculate the cost to travel the distance (CostDis2)
/* from the nearest core or colony area source (ColCore).
/* Otherwise just copy the CostDist grid to use for Day-to-Day
/* analysis.

&if not [exists ColTemp -vat] &then
  CostDis2 = CostDist
&else CostDis2 = CostDistance(ColCore,Cost)

/*

&type (14) Calculating which Day-to-Day areas are Cost Effective...

/* This step adds the utilized Day-to-Day cells to the
/* Core + Colony Area grid (ColZer2) to produce the
/* Day1 grid.

/* Use the Core + Colony Cost grid (CostDis2)to find out
/* what can actually be used day-to-day (any cell with
/* a cost of DayPay or less).

/* Retain any cell in the Day-to-Day grid (DayToDay) with

```

```

/* a cost less than or equal to DayPay and greater than zero.

/* If the Distance-Cost grid (CostDis2) = 0,
/* it is part of the Core or Colony Area and
/* should get its value from Core + Colony Area
/* grid (ColZer2).

&if [exists ColTemp -vat] &then
  &do
    if (CostDis2 <= %DayPay% and CostDis2 > 0)
      Day1 = DayToDay
    else
      Day1 = ColZer2
    endif
  &end
&else
  &do
    if (CostDis2 <= %DayPay% and CostDis2 > 0)
      Day1 = DayToDay
    else
      Day1 = Core
    endif
  &end

/*

&type (15) Finding Other Areas That May Be Utilized....

/* This step picks up any large low value areas and any small
/* medium or high value polygons that are imbedded
/* in them.

/* First find any areas that are not currently in the included
/* set (Day1Z) but are in the original geometric mean coverage (geom)
/* set Other to 1 where Day1Z = 0.

/* if Other is all nodata, create the All coverage from
/* the Day1Z coverage.

/* Split all other areas into separate regions (OthReg)

/* Calculate the area of the regions (OthArea).

/* Keep any region in OthArea with an area > 2 homeranges (Util).

/* Change any null values in Util to zeros (OthZero).

/* Add these areas to the Day1 coverage to create All

Day1Z = con(isnull(Day1),0,Day1)

if ((Day1Z < 1) and (Geom > 0))
  Other = 1
endif

```

```

&if not [exists Other -vat] &then
  All = Day1Z
&else
  &do
    OthReg = regiongroup(other,#,EIGHT)

    OthArea = zonalarea(OthReg)

    if (OthArea >= %Homerange% * 2)
      Util = 1
    else
      Util = 0
    endif

    OthZero = con(isnull(Util),0,Util)

    if (OthZero == 1)
      All = OthZero
    else
      All = Day1Z
    endif
  &end
/*

&type (16) Creating a Value grid...

/* For any cell in All that has a value of 1, store the suitability
/* value from the Geometric mean grid (Geom) to the Value grid.

/* Other cells inside the boundary (%.Bound%) get a value of 0.
/*

if (All == 1)
  Value = Geom
else if (%.Bound% == 1)
  Value = 0
endif

/*

&type (17) Creating an HSI grid...

/* if Colonies exist...
/* For any cell that was part of a colony that is further than
/* 3 times the HR radius (DayPay) away from a core area, set the suitability
/* to Low. Distant colonies lose value because of their small size.
/* This step produces grid Collow.

/* Set all NODATA values in Collow to zero in ColZer3.

/* Find any day-to-day use areas (DayToDay) that are being
/* utilized (ColZer3). If they are further than four homeranges
/* from a core area (CostDist), they are utilized from a distant
/* colony and their value will be decreased to Low in Day2.

```



```

/* Then change nulls to zero in ValZero

/* Keep all data within the boundary; call this final grid HSI.

&if [exists ColTemp -vat] &then
&do
  if (ColZer1 >= %DayPay% * 3)
    ColLow = %Low%
  else
    ColLow = Value
  endif

  ColZer3 = con(isnull(ColLow),0,ColLow)

  if ((CostDist > %DayPay% * 4) and (ColZer3 > 0) and ~
    (DayToDay == 1))
    Day2 = 1
  else
    Day2 = ColZer3
  endif
&end
&else
  Day2 = Value
valzero = con(isnull(Day2),0,Day2)

if (%.Bound% == 1)
  %.ID%hsi = valzero
endif

/*

&type (18) Quitting from GRID and adding the acres field.....

/* Quit from GRID (Q), then run additem to add an acre item to
/* the HSI grid vat file (%ID%HSI.vat). Reindex on value when done.

Q
additem %.ID%hsi.vat %.ID%hsi.vat acres 10 10 i
indexitem %.ID%hsi.vat value

/*

&type (19) Calculating acres.....

/* Use INFO to calculate the acreage field: Multiply the number
/* of cells by the cell size squared and divide by the number of
/* square meters per acre (4047). Reindex on value when done.

&data arc info
arc
select %.ID%hsi.VAT
CALC ACRES = ( COUNT * %.SizeOfCell% * %.SizeOfCell% ) / %AcreCalc%
Q STOP

```

```

&END

indexitem %.ID%hsi.vat value

/*

&type (20) Killing all intermediate coverages before ending macro...

/* &goto OKEND

grid

kill Geom
kill Merge
kill Region
kill ZoneArea
kill Core
kill ColTemp
kill Colony
kill DayToDay
kill Cost
kill CostDist
kill ColDist
kill ZoneReg
kill ZoneMin
kill ColZer1
kill Col
kill ColZer2
kill ColCore
kill CostDis2
kill Day1
kill Day1Z
kill Other
kill OthReg
kill OthArea
kill Util
kill OthZero
kill All
kill Value
kill Collow
kill ColZer3
kill Day2
kill valzero

q

&goto OKEND

&label END
&type **
&type **
&type NO CORE AREAS EXIST, EXITING MACRO
&type **
&type **

```

kill Core  
kill Region  
kill ZoneArea  
kill Merge  
kill Geom

quit

&label OKEND  
&label BADEND

&type ----- All done! -----

&return