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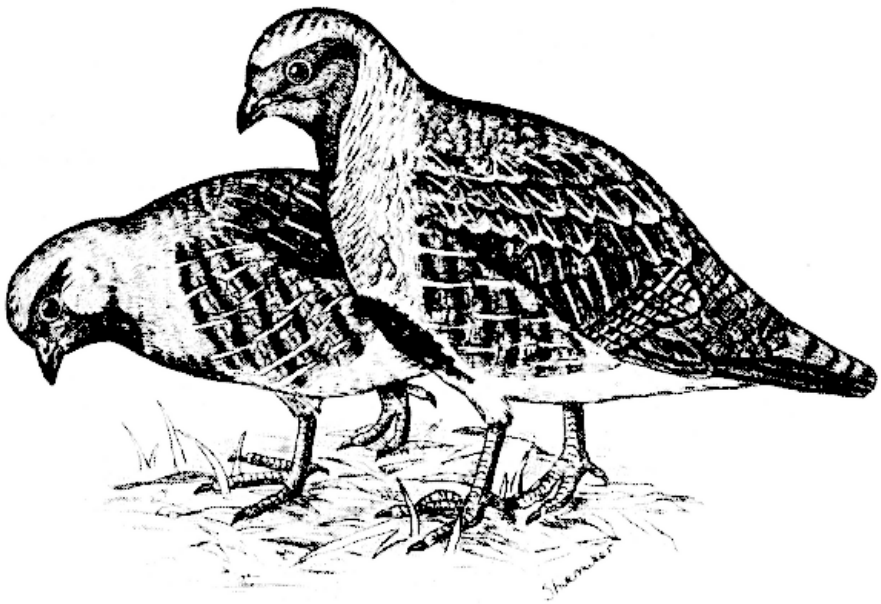
HABITAT SUITABILITY INDEX MODELS: GRAY PARTRIDGE



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HABITAT SUITABILITY INDEX MODELS: GRAY PARTRIDGE

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PREFACE

This document is part of the Habitat Suitability Index (HSI) Model Series [Biol. Rep. 82(10) (formerly 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 the HSI model that follows. 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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GRAY PARTRIDGE (Perdix perdix)

HABITAT USE INFORMATION

General

The gray, or Hungarian partridge (Perdix perdix) is able to survive and reproduce on "leftover" habitat associated with intensive agricultural land use patterns (Upgren and Kobriger 1977). Because they use edges, gray partridge probably have more potential than any other game bird to cope with modern agricultural techniques.

Gray partridge occur in three major geographic regions in North America (Stiehl 1984). The Western population inhabits portions of Washington, Oregon, Idaho, Nevada, and Utah. The Central population occur in Alberta, Saskatchewan, Manitoba, Montana, Wyoming, South Dakota, North Dakota, Minnesota, and Iowa. The Great Lakes population inhabits portions of Wisconsin, New York, and Ontario. The general habitat requirements of gray partridge in the three regions are similar, although relatively minor differences in nesting cover use between populations are evident and food preferences reflect crop availability in the respective geographic regions.

Food

Cultivated grains, plant seeds, and green leafy material are the major food items for gray partridge (Edminster 1954). Although the type of food used is related to major regional crop production, small grains are the preferred food of the species throughout its North American range (Stiehl 1984). The seeds of native vegetation are of secondary importance throughout the range of the species. Winter wheat (Triticum aestivum) is the favored grain in the Western population and throughout much of range of the Central population. Corn (Zea mays) becomes an increasingly important component of the diet of the Central and Great Lakes populations as the composition of primary agricultural crops changes. Winter wheat typically comprised the largest proportion of grain in the diet of partridge in North Dakota (Kobriger 1970, 1977) and Montana (Weigand 1980). The following items accounted for 92.1%, by volume, of all foods eaten on an annual basis by gray partridge in North Dakota: wheat, 35.3%; green plant material (primarily small grain and grass), 12.7%; barley (Hordeum vulgare), 12.5%; oats (Avena sativa), 12.4%; flax (Linum usitatissimum), 4.1%; wild buckwheat (Polygonum convolvulus), 3.3%; wild oats (Avena fatua), 3.2%; green foxtail (Setaria viridis), 2.7%; snowberry (Symphoricarpos occidentalis), 2.0%; knotweed (Polygonum aviculare), 1.7%; yellow foxtail (S. lutescens), 1.0%; and grasshoppers, (Locustidae) 1.2% (Kobriger 1977). The annual diet included 142 different items. Wheat, oats,

barley, and flax accounted for nearly two-thirds of the annual diet of adult partridge. Summer was the only season in Montana during which grain consumption accounted for less than 90% of the diet; forbs were the major food consumed in the summer (Weigand 1980).

Insects form an important part of the juvenile diet (Potts 1971; Kobriger 1977; Weigand 1980). Major insect foods of juvenile partridge in Montana were grasshoppers, ants (Formicidae), and ant eggs (Weigand 1980). Cultivated grains comprised 50% of the juvenile partridge diet in North Dakota, compared to 65% for adult birds (Kobriger 1977). More than twice the amount of weed seeds were consumed by juveniles as were eaten by adult partridge. The diet of juvenile partridge is similar to that of adult birds by the time they are approximately 6 weeks of age (Kobriger 1977).

Water

The availability of water is not an essential element of gray partridge habitat (Yeatter 1934, cited by Trippensee 1948). Surface water is not required if succulent vegetation, dew, or insects are available (McCrow 1982). Gray partridge attained their highest densities in Wisconsin in areas of minimum wetland acreage (Gates 1973). Increased density of natural wetland basins in North Dakota had a negative influence on gray partridge density (Samson 1982). Wetland habitats were not believed to be utilized to any extent by gray partridge in North Dakota and were totally absent from seven of eight home ranges monitored (Schulz 1980). Mendel and Peterson (1983) stated that available water may not be a necessary component of partridge habitat, but that gray partridge in their Idaho study were more abundant in areas where water was available. Gray partridge concentrated along permanent water sources in the late summer and fall, and large concentrations of gray partridge were attracted to available water during drought conditions.

Cover

Gray partridge habitat generally can be described as croplands, particularly small grains and corn, in association with native grasses, weedy herbaceous cover, and hayfields (Johnsgard 1973). Extensive wooded habitats are avoided, although brushy edges may be used for winter shelter, summer shading, and nesting. Shelterbelts generally are believed to be the primary source of winter cover for gray partridge and are a significant component of nesting habitat for some populations (Stiehl 1984). Hunt (1974) described prime gray partridge habitat in Saskatchewan as grain fields (wheat or barley) transected by extensive caragana (Caragana arborescens) hedgerows. Preferred gray partridge habitat in eastern Washington was wheat and alfalfa (Medicago sativa) fields, bordered by bunchgrass (Agropyron spp. and Festuca spp.) and interspersed with brushy draws (Swanson and Yocom 1958).

Idle agricultural areas appear to be preferred, concentrated use areas by gray partridge (Hunt 1974; Weigand 1980; Smith et al. 1982). Weigand (1980) characterized idle agricultural areas as farm/ranch sites, shelterbelts, and other units of ungrazed, uncultivated land. Idle areas ≥ 0.4 ha (1.0 acre) were used more by gray partridge than were smaller areas. Gray partridge in Idaho preferred permanent cover that consisted of isolated clumps of woody

cover, intermixed with uncut grasses and forbs (Mendel and Peterson 1983). Although large areas of dense brush were seldom used, isolated clumps and narrow bands of woody cover were used throughout the year. Use of these permanent cover types declined in late October to early November when the birds began using plowed stubble fields as cover.

McCrow (1982) reported that strip cover (vegetation associated with roadside ditches, fencelines, and field edges) was selected by gray partridge throughout the year and that the proportion of partridge observations in these cover types significantly exceeded their proportional availability. Within the strip cover habitat class, 78% of the partridge observations in Montana were associated with irrigation ditches, more than with any other land use type in all seasons except winter (Weigand 1980). The greatest frequency of observations in idle areas on an annual basis occurred on farm/ranch sites. Idle agricultural areas were believed to be an important winter habitat component for gray partridge in intensively farmed areas of North Dakota (Schulz 1980). Ninety-one percent of the gray partridge groups observed during the winter were associated with farmsteads.

Shelterbelts associated with farmsteads were extensively used as roosting sites by partridge (Schulz 1980). The use of multi-row shelterbelts was high because of the relatively low availability of other protective cover during winter. Mendel and Peterson (1983) often observed gray partridge feeding or obtaining grit under woody vegetation where the snow depth was less than on the surrounding unsheltered area. Gray partridge occasionally concentrated under shrubs when snow depths were reduced, particularly when the snow had an icy crust. Swanson and Yocom (1958) concluded that brushy draws were important winter cover for gray partridge in eastern Washington. Ninety-five percent of all partridge observed in Montana in all seasons were within 899 m (982 yds) of some kind of woody cover (Weigand 1980).

Overwinter cropland management practices can have a significant effect on gray partridge, particularly when habitat use is influenced by weather. Untilled grain fields, where stubble and waste grain are present, provide ideal food and cover for gray partridge during relatively mild winter weather (Schulz pers. comm.). However, untilled fields tend to catch snow and crust over during heavy snow periods, becoming unsuitable for partridge use. Although they initially may contain less available food than do untilled fields, tilled fields tend to blow free of snow during severe winter weather, providing useable cover and food for partridge. Tilled grain fields were preferred gray partridge winter habitat in Idaho and often supported birds for several consecutive weeks at a time (Mendel and Peterson 1983). The preference for tilled fields was attributed to the hiding and thermal cover provided by furrows, clumps of soil, and stubble and the food provided by waste grain. Fields worked in the fall by chisel plowing were believed to provide the desirable microhabitat characteristics described above more so than fields worked with moldboard plows or off-set discs. Discing was believed to result in a more thorough inversion of the soil, with less stubble and waste grain left, and less suitable cover conditions. Weigand (1980) attributed the reduced availability of grain, poorer protective cover, and virtual elimination of nesting cover for the following spring to fall tillage of grain fields in Montana.

McCrow (1982) reported that gray partridge used plowed fields in the winter in Iowa. Corn stubble fields also received relatively high use by partridge during winter; however, they were of little use when they became snow covered during severe winter weather. Church (pers. comm.) considers the availability of corn to be extremely important to the Great Lakes population of gray partridge during the winter. Standing corn, even in relatively small amounts, can support large numbers of gray partridge when snow depth prevents access to grain in stubble and tilled fields.

Gray partridge used row crops for shelter during the winter in South Dakota (Smith et al. 1982). Pastures were used for cover during periods of deep snow; however, they were not believed to be preferred winter habitat. Winter wheat fields may provide a source of food when waste grain is unavailable to gray partridge (Peterson pers. comm.). Winter wheat fields in Idaho were used as temporary feeding sites during winter; however, the fields were seldom used by partridge when they were covered by crusted snow or snow > 8 cm (3 inches) in depth (Mendel and Peterson 1983).

Increased farm size and acreage of cultivated land has generally resulted in decreased gray partridge populations (Dumke 1977; Weigand 1980; Mendel and Peterson 1983). Land use patterns that reduce fencelines, field edges, and shelterbelts and force partridge to inhabit and nest in marginal habitat result in increased mortality and decreased recruitment (Samson 1982). Jenkins (1961) reported that summer mortality of juvenile gray partridge was highest in poor quality habitat where vegetative cover was sparse. Mendel and Peterson (1983) concluded that the quantity and quality of permanent cover, particularly nesting cover, was the limiting factor for gray partridge populations in the Palouse prairie region in Idaho. An estimated 90% reduction in gray partridge populations from 1940 to 1954 in Washington was attributed to the virtual elimination of stubble fields, alfalfa, and brushy draws that provided winter cover (Swanson and Yocom 1958). Weigand (1980) concluded that the most significant factor limiting gray partridge populations in his Montana study area was the quantity and quality of protective cover in spring.

Reproduction

The amount, quality, and distribution of nesting cover are the primary determinants of gray partridge population levels (Potts 1984). The most common site for gray partridge nest establishment in Utah was in native grasses, interspersed among brush and shrubs (Porter 1955). The majority of partridge nests located in an Iowa study were in roadside ditches and vegetation associated with fencelines (McCrow 1982). Relatively wide strip cover (e.g., drainage ditch banks, grass waterways, and railroad rights-of-way) were believed to be less preferred nesting habitat than that provided by much narrower roadside ditches and fenceline cover. Vegetation associated with roadsides, field edges, and idle cover types accounted for 52% of the partridge nest sites located in North Dakota (Lokemoen and Kruse 1977). The majority of the nest sites were located in residual vegetation from the previous growing season. Abundant residual vegetation characterized 90% of the gray partridge nest sites located in a Montana study (Weigand 1980). Winter grazing by livestock on residual hay, idle agricultural areas, and grain stubble, and cultivation of the previous summer's stubble reduced the availability of residual and protective cover, thereby diminishing nesting potential.

Preferred gray partridge nest sites in Wisconsin were in vegetation associated with idle upland cover (Church 1984). Although vegetation associated with active farmsteads provides suitable winter cover, particularly in the West, active farmsteads probably have minimum, if any, potential as reproductive habitat due to disturbance and predation by pets (Church pers. comm.). Fenceline and roadside vegetation and hayfields contained 43% of the gray partridge nests located in Wisconsin (Gates 1973). Fewer nests were recorded in alfalfa hayfields, compared to grass-dominated strip cover in Iowa (Bishop et al. 1977), Minnesota (Ordal 1952), and Montana (Weigand 1977). Although not preferred, winter wheat is used by gray partridge for nest cover and may support relatively high nesting success (Mendel pers. comm.).

Grass-dominated vegetation has been identified as the dominant site for gray partridge nest establishment in Montana (Weigand 1980), North Dakota (Stewart 1975; Lokemoen and Kruse 1977; Samson 1982), South Dakota (Hupp et al. 1980), Minnesota (Ordal 1952), Wisconsin (McCabe and Hawkins 1946; Gates 1973; Church 1984), and Iowa (Bishop et al. 1977; McCrow 1982). Although forb-dominated vegetation provides spring cover when other vegetative cover is minimal, it is not preferred nesting cover (Weigand 1980). Gray partridge avoided nesting in roadside vegetation dominated by alfalfa (Medicago sativa) and sweetclover (Melilotus spp.) in South Dakota (Hupp et al. 1980). The majority of gray partridge nest sites in Iowa were located in mixed grass/forb cover that was relatively short and of low density (McCrow 1982). Preferred nest cover in Wisconsin was fairly sparse, open vegetation (Gates 1973). Smooth brome (Bromus inermis) and alfalfa were the dominant plant species at 64% of the gray partridge nest sites in North Dakota (Schulz 1980). Crested wheatgrass (Agropyron cristatum) and quackgrass (A. repens) dominated the vegetative cover at 12% of the nest sites. Roadside vegetation, consisting of bluegrass (Poa spp.), smooth brome, and quackgrass dominated 79.3% of the partridge nest sites located in Iowa (Bishop et al. 1977).

McCabe and Hawkins (1946) believed that gray partridge preferred to nest in vegetation at least 45.7 cm (18 inches) tall. The average height of vegetation at gray partridge nest sites in North Dakota was 44.1 cm (17.4 inches) (Lokemoen and Kruse 1977).

Gray partridge tend to establish their first nests in permanent cover (hedgerows, meadows, or strip cover), while renesting attempts often are made in more temporary cover (grain, alfalfa, or hayfields) (Porter 1955; Jenkins 1956; Hunt 1974). However, renesting efforts by gray partridge are relatively low and, therefore, annual production is highly dependent on the success of the first nesting attempts (McCrow 1982). The primary factor that influenced nesting success in Iowa was the availability of stable, protected nest cover. Regardless of nest density, gray partridge nesting success in alfalfa and hayfields is low, due to harvest activities (Gates 1973; Bishop et al. 1977; Church 1984). Nest success has probably decreased in recent years due to the trend toward a greater number of cuttings and earlier harvest dates. The peak period of nesting initiation throughout the range of the gray partridge occurs in early to mid-May (McCrow 1982), while the peak hatching period is in late June to early July (Gates 1973; Hunt 1974; Bishop et al. 1977; Weigand 1977; Church 1984).

Interspersion and Movements

Gray partridge that inhabit areas with a high degree of interspersion among cover types tend to have smaller activity ranges, resulting in greater partridge densities and larger populations (McCrow 1982). The species occupies areas with a broad spectrum of habitat conditions. Optimum habitat in Montana was described as 34 to 76% grain/fallow land, 4 to 28% hayland, 15 to 29% rangeland, and 5 to 26% idle land (Weigand 1980). Samson (1982) recorded higher than expected frequencies of gray partridge in North Dakota where 37 to 75% of the land was in crop production and 12 to 49% was pastureland. Lower than expected partridge observations were recorded where cropland accounted for 0 to 11% and 90 to 100% of the land use. Gray partridge in Saskatchewan inhabited an area composed of 90% intensively farmed land and 10% miscellaneous, or idle, land (Hunt 1974). In New York gray partridge had high population density where 65 to 82% of the area was in active agricultural production (Murtha 1967). Habitat was classified as marginal where ≤ 60% of the land was involved in agricultural use. Blank (1960, cited by McCrow 1982) recorded the greatest gray partridge densities in Great Britain where cropland accounted for 75% of the land use, with the balance in grassland. Dumke (1977) described the best partridge range in Wisconsin as areas dominated by small farm units with a high percentage of the land under cultivation and a relatively small proportion of the area dominated by woodlands or wetlands.

Gray partridge typically are associated with the edges between cover types (Jenkins 1961; McCrow 1982; Samson 1982; Mendel and Peterson 1983). Ninety-five percent of the partridge observations in a Montana study were within 35 m (38 yds) of a land use class different from the one in which they were observed (Weigand 1977). McCrow (1982) recorded 59% of 1,960 partridge observations in Iowa within 32 m (35 yds) of field edges. Eighty-nine percent of the observed gray partridge groups located in Idaho's Palouse prairie were detected within 70 m (77 yds) of a cover type edge (Mendel and Peterson 1983). The maximum observed distance from a field edge was 200 m (219 yds).

Gray partridge in Wisconsin did not exhibit major shifts in distribution between winter and summer ranges (Gates 1973). Weigand (1980) reported gray partridge winter home range sizes in Montana as ranging from 0.1 to 5.6 ha (0.25 to 13.8 acres) with a mean winter home range size of 1.4 ha (3.4 acres). Ninety-five percent of the partridge groups remained within 914 m (1000 yds) of their winter range throughout the year. Eighty-six percent of the marked birds spent their entire lives within 604 m (660 yds) of the sites where they were trapped (Weigand 1977). The mean winter home range for gray partridge in North Dakota was 16.6 ha (41.0 acres) and varied in size from 4.9 to 34.0 ha (12.1 to 84.0 acres) (Schulz 1980). Farris (1966) recorded a mean winter range for 19 partridge coveys in Illinois of 6.3 ha (15.6 acres). McCrow (1982) recorded an overall activity range of 1.93 km^2 (0.74 mi^2) for mated partridge in Iowa. The average radius of gray partridge mobility in Wisconsin was reported as 0.8 km (0.5 mi) (McCabe and Hawkins 1946).

Special Considerations

Several reviewers of this model stressed the unknown, but potentially significant, influence of insecticides and herbicides on gray partridge habitat

potential. Potts (1971) believed that insect abundance varies inversely with herbicide use. Increased use of herbicides in Great Britain resulted in reduced availability of forb seeds and insects and was thought to be the primary determinant of gray partridge chick mortality (Potts 1970a,b). Stiehl (1984) concluded that increased use and toxicity of insecticides and increasing application rates of herbicides probably affects chick food availability and also may significantly decrease the cover quality of field edges and residual cover and may ultimately decrease overall gray partridge productivity.

Gray partridge habitat management activities should be orientated towards improvement of the quantity and quality of linear cover (Church 1984). McCrow (1982) suggested the following management activities to increase gray partridge habitat potential: (1) grass/legume or native grass cover should be encouraged, particularly in roadsides and fencelines; (2) mowing should be delayed until the second week of July to ensure maximum nesting success; and (3) burning, grazing, and widespread spraying of herbicides on roadside and fenceline vegetation should be avoided.

The gray partridge habitat management actions suggested by Mendel and Peterson (1983) for the Palouse region of Idaho and Washington and other ecologically similar areas (e.g., Idaho's Rathdrum and Camas prairies) include:

(1) Maintain and develop roadsides, field edges, and hillside vegetation that are dominated by grass/forb cover;

(2) Encourage the establishment of scattered shrubs;

(3) Emphasize open grassland vegetation through the use of light grazing;

(4) Reduce or eliminate the burning of roadsides, waterways, and other areas of permanent (idle) cover;

(5) Encourage rough plowing of stubble fields in winter, or leave stubble standing;

(6) Increase cover density and edge by encouraging the use of strip cropping; and

(7) Create permanent cover strips > 5 m (5.5 yd) wide that are well interspersed within croplands. Permanent cover should ideally comprise 10 to 20% of each 2.59 km^2 (1.0 mi^2).

Church and Porter (1984) provided guidance and techniques applicable to the introduction of gray partridge populations.

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area. This HSI model has been developed for application throughout the range of the gray partridge in North America. Figure 1 illustrates the approximate geographic range of the gray partridge within the contiguous United States.

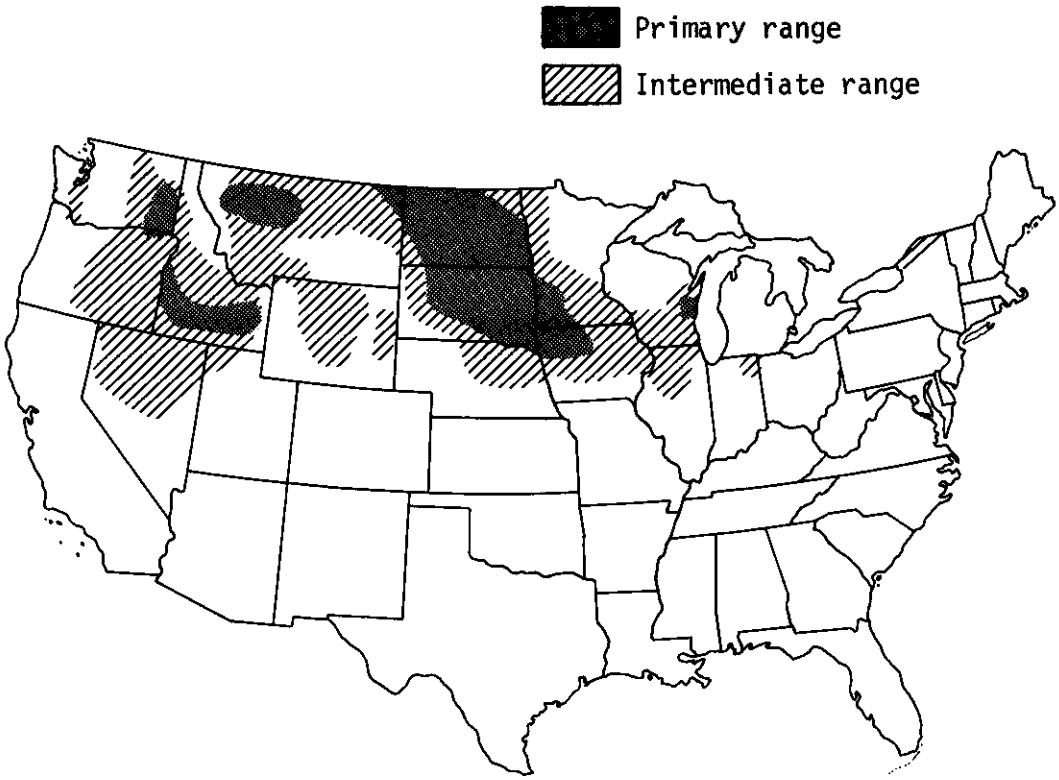


Figure 1. Approximate current distribution of the gray partridge in the contiguous United States (modified from Dumke et al. 1984:177).

Season. This model has been developed to evaluate year-round habitat potential for the gray partridge.

Cover types. This model was developed for application in the following cover types (terminology follows that of U.S. Fish and Wildlife Service 1981): Cropland (C); Pasture/Hayland (P/H); Grassland (G); and Forbland (F).

Several variables in this model are based on idle cover types. Idle cover types typically are considered units of land subjected to little or no grazing pressure and are not used for crop or hay production. The literature dealing with gray partridge ecology generally describes idle cover types as road/railroad rights-of-way, idle and active farmsteads; shelterbelts; vegetation associated with fencelines, irrigation ditches, or waterways; and field edges or corners. However, any of the major cover types identified in the preceding paragraph may be idle if they are not cropped or grazed for a period in excess of 1 year.

Minimum habitat area. Minimum habitat area is defined as the minimum amount of contiguous habitat that is required before an area will be occupied by a species. Information on the minimum habitat area for the gray partridge was not located in the literature. However, the minimum area believed necessary to support a covey of partridge in North Dakota is 4 ha (10 acres) if all habitat requirements are present (Schulz pers. comm.). Based on this information, it is assumed that at least 4 ha (10 acres) are required to meet the year-round habitat requirements of a gray partridge covey. If less than 4 ha (10 acres) of suitable habitat are present, the HSI is assumed to be 0.0.

Verification level. This HSI model provides habitat information useful for impact assessment and habitat management. The model is a hypothesis of species-habitat relationships and does not reflect proven cause and effect relationships.

Earlier drafts of this model were reviewed by Mr. Kevin S. Church, College of Environmental Science and Forestry, State University of New York, Syracuse; Mr. Glen W. Mendel, Moscow, ID; Mr. Steven R. Peterson, Alaska Department of Fish and Game, Juneau; Mr. John W. Schulz, North Dakota Game and Fish Department, Rugby; and Dr. Richard B. Stiehl, Southeast Missouri State University, Cape Girardeau. Improvements and modifications suggested by these individuals have been incorporated into this model.

Model Description

Overview. The gray partridge is unique among gamebirds in that it thrives in areas where intensive agriculture is the dominant land use. Studies throughout the species' range typically indicate that increased partridge populations correspond with increased agricultural production, particularly grain crops. The availability of an adequate source of winter food and suitable nesting habitat appear to define an area's potential to support gray partridge. The primary food of gray partridge, especially during the winter, is waste grain. Insects, forbs, and seeds supplement the spring, summer, and fall diets. Appropriate nesting cover is a key component of gray partridge habitat. The highest nesting success typically is associated with grass-dominated vegetation in uncropped, ungrazed areas. Although gray partridge do nest in pastures, hayland, and alfalfa, nesting success within areas devoted to these uses is low.

The following discussion documents the logic and assumptions used to translate information on gray partridge habitat use to the variables and equations used in the HSI model. Specifically, these sections cover: (1) identification of important habitat variables; (2) definition and justification of the suitability levels of each variable; and (3) descriptions of the assumed relationships between variables.

The juxtaposition of cover types that provide food and reproduction resources for the gray partridge has a major influence in defining the potential quality of an evaluation area for the species.

Winter food component. The proportion of the evaluation area in cropland is a key component of food quality for the gray partridge. However, not all croplands provide a potential winter food source for the species. Croplands devoted to the production of row crops, other than corn, may provide summer foods, yet have no value as a winter food source. The largest portion of the partridge diet is comprised of grains, and agricultural lands devoted entirely to grain production are assumed to have the greatest potential for providing winter food for the species. The seeds of grasses and forbs also provide a potential winter food source for gray partridge. However, areas where grain crops are not produced are assumed to have a minimum value in terms of providing an adequate source of winter food for the species. Overwinter cropland management practices can have a significant influence on the availability of waste grain. Grain fields subjected to fall tillage generally have a reduced food potential, compared to fields where crop residues and stubble remain. Gray partridge may obtain food from other sources, such as waste grain in and around livestock feeding areas, grain storage areas, and livestock manure. These food sources typically are used during periods of severe winter weather and are not addressed as variables in this habitat model. However, the user of this model may wish to consider the general availability of these sites when assigning a final winter food value for an evaluation area.

The life requisite value for winter food for the gray partridge is assumed to be a function of: (1) the percent of the area in cropland; (2) the percent of the cropland consisting of corn or other grain crops; and (3) the percent of cropland subjected to fall/winter tillage. Figure 2a illustrates the assumed relationship between the percent of the area in cropland and a suitability index for this variable. Figures 2b and 2c present the assumed relationships between the percent of the evaluation area in grain production and overwinter crop management practices, respectively, and suitability indices for these variables for the gray partridge.

Optimum conditions for gray partridge winter food are assumed to exist when 50 to 90% of the evaluation area is dominated by cropland (Fig. 2a) and when $\geq$ 80% of the cropland is devoted to corn and/or other grain production (Fig. 2b). Areas with less than 50% cropland are assumed to have less ability to provide suitable winter food resources for the species. Areas lacking grain production, or sites where cropland is absent, may provide a marginal source of winter food for the gray partridge if grass and forb seeds are present. Therefore, an area devoid of cropland is assumed to provide a winter food source of minimum potential. Habitat quality is assumed to increase as the proportion of cropland devoted to grain production increases.

Although the proportion of available habitat in cropland and grain production may represent assumed optimum conditions, the management of grain fields can have a significant influence on the winter food resources. Fields in which stubble remains throughout the winter provide optimum availability of waste grain as a food source for partridge. However, stubble fields tend to catch and hold snow during periods of heavy or extended snowfall. Deep and/or crusted snow eliminates stubble fields as foraging areas for gray partridge. Grain fields subjected to fall tillage generally blow free of snow during heavy snowfall periods. However, crop residues are typically reduced or completely eliminated from the ground surface in tilled fields, resulting in

Fig. 2a

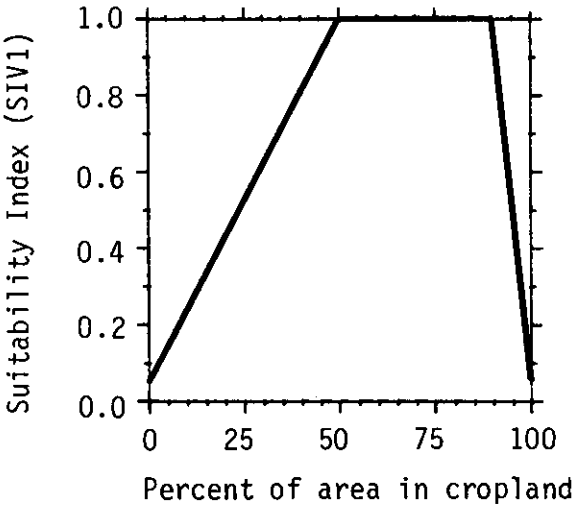


Fig. 2b

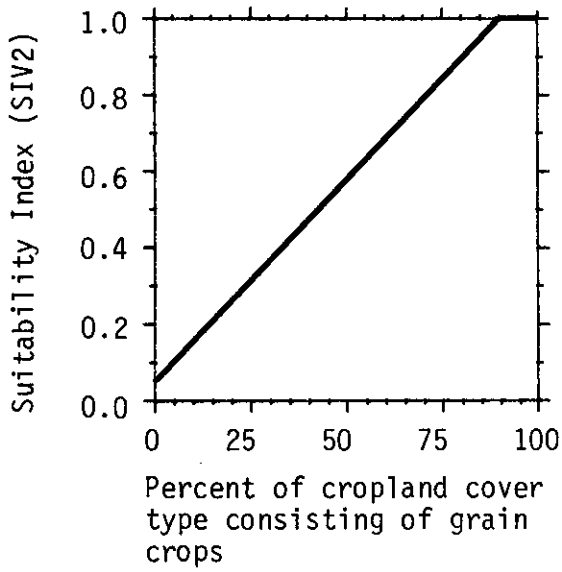


Fig. 2c

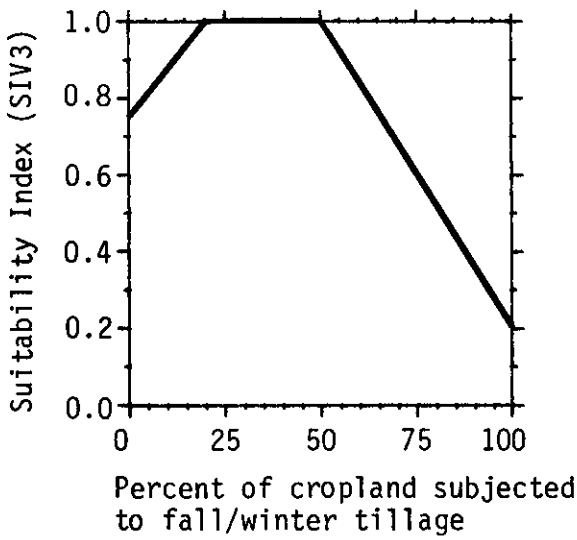


Figure 2. The relationships between habitat variables used to evaluate winter food and suitability indices for the gray partridge.

reduced food potential compared to that of stubble fields. The precise effect of specific tillage techniques is difficult to quantify because it is dependent on soil conditions and the thoroughness of the management action. While ideal winter food availability is assumed to be provided by stubble fields, excluding the influence of weather, less suitable conditions are present when the upper soil layer is tilled with some crop residue remaining on and intermixed with the soil. Fall plowing with chisel plows generally leaves more crop residues, while the use of moldboard and disk plows greatly reduces or completely eliminates crop residues on the ground surface.

Even though the type of tillage applied to cropland may have a significant influence on the availability of waste grain to gray partridge, this model does not attempt to evaluate the influence of specific tillage techniques. Although stubble fields are assumed to provide optimum winter food availability for the species, areas that are entirely comprised of stubble fields may provide unsuitable habitat during severe winter weather. Conversely, areas where all grain fields are fall-tilled are assumed to have minimal winter food availability, regardless of weather conditions. Therefore, it is assumed, in this model, that areas with both stubble and tilled fields present represent optimum habitat conditions for gray partridge winter food availability. Theoretically, a mixture of stubble and tilled cropland permits gray partridge to utilize stubble fields during relatively mild winter weather and to shift habitat use to tilled fields during harsher winter weather. Figure 2c represents the assumed relationships between the percentage of cropland subjected to fall tillage and suitability indices for the gray partridge. Areas where grain fields are totally untilled during fall and winter are assumed to have moderate winter food habitat potential. Croplands totally subjected to fall tillage are assumed to have minimum value in terms of providing adequate amounts of winter food for the species. Optimum conditions are assumed to exist when 20 to 50% of the cropland is subjected to fall tillage.

Determination of the winter food component is a function of the suitability indices for the percent of the evaluation area in cropland (SIV1), the percent of the cropland types devoted to corn/grain production (SIV2), and the percent of cropland subjected to fall/winter tillage (SIV3). The percent of the area in cropland and percent of cropland devoted to corn/grain production are assumed to have equal value in defining the winter food potential for gray partridge. The suitability index calculated for the percent of cropland subjected to fall/winter tillage (SIV3), is used to modify the combined value obtained for SIV1 and SIV2. The indices calculated using the curves presented in Figure 2 are combined in Equation 1 to determine the winter food index (WFI) for the gray partridge:

$$WFI = (SIV1 \times SIV2)^{1/2} \times SIV3 \qquad (1)$$

Evaluation areas in which cropland is completely absent are assumed to have a winter food value of 0.1.

Reproduction component. The proportion of the evaluation area in idle cover types (Fig. 3a) and distribution of idle cover (Fig. 3b) are the key components that define the reproduction habitat potential for the gray partridge. However, vegetation composition and abundance within these areas also influence the quality of reproductive habitat. Ungrazed and uncropped units of land that support moderately dense vegetation, dominated by grasses, are assumed to characterize ideal gray partridge nesting habitat. Although pasture and hayfields are used as nesting habitat, nesting success is relatively low in these land use types.

The reproductive life requisite value for the gray partridge is assumed to be a function of: (1) the percent of the evaluation area in idle land; (2) the distribution of idle land; (3) the percent herbaceous canopy cover in idle land; (4) the proportion of the herbaceous canopy composed of grass in idle land; and (5) the percent of the evaluation area in pasture/hayland.

Optimum reproductive habitat conditions for gray partridge are assumed to exist when 10 to 20% of the evaluation area is composed of idle cover types (Fig. 3a), and the idle cover types are well interspersed within cropland cover types (Fig. 3b). Canopy cover of herbaceous vegetation within idle cover types that ranges from 40 to 75% (Fig. 3c), with a relative composition of 40 to 80% grass (Fig. 3d), is assumed to characterize ideal reproductive habitat conditions. The presence of a relatively small proportion of an area in pastures and haylands may serve to improve reproductive habitat conditions by increasing cover type diversity and edge. However, pasture sites generally have poor nesting success if they are subjected to heavy grazing pressure. Although vegetative cover within haylands may represent assumed optimum conditions, gray partridge nesting success in haylands is low due to nest disturbance, nest destruction, and fatalities resulting from hay harvest activities. It is assumed, in this model, that $\leq$ 20% of an area devoted to these land uses represents optimum reproductive habitat because of increased habitat diversity (Fig. 3e). However, the complete absence of pasture/hayland does not detract from overall habitat quality if suitable amounts of idle land and cropland are present. As the percentage of an area devoted to pasture, particularly hayland, increases, reproductive habitat potential for the species is assumed to decrease. Areas devoted entirely to pasture/hayland have minimum reproductive habitat potential for the gray partridge.

Less than 10% of an area composed of idle cover types is assumed to represent less suitable reproductive habitat quality, due to the scarcity of potentially suitable nesting habitat. However, gray partridge will establish nests in grain fields and pasture/hayland. Therefore, the complete absence of idle cover is assumed to reflect reproductive habitat conditions of minimum potential, rather than totally unsuitable conditions. As the proportion of idle cover types increases above 20%, reproductive habitat is assumed to decrease due to the relative loss of cover type edge. Areas completely dominated by idle cover types are assumed to have minimum value as reproductive habitat.

Fig. 3a

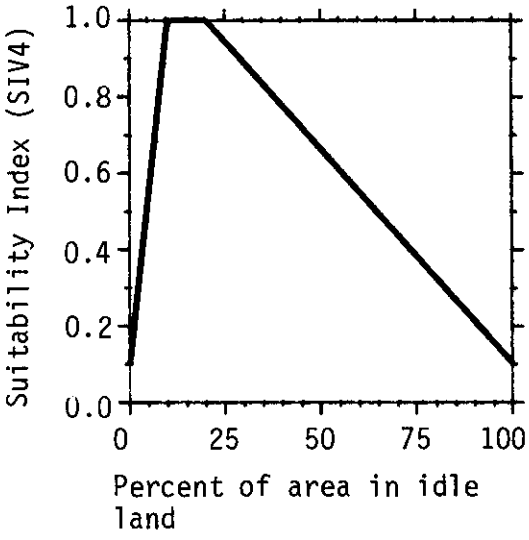


Fig. 3b

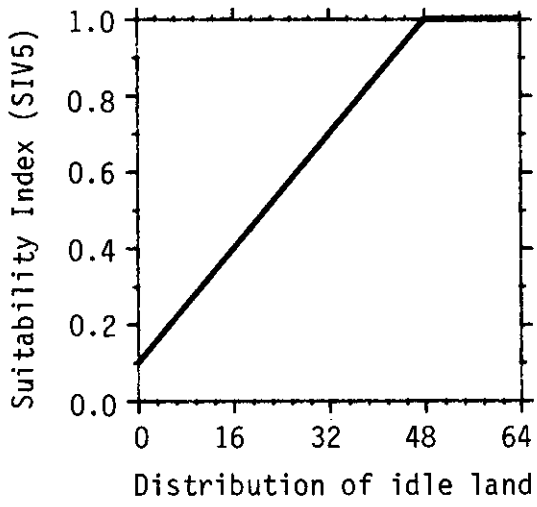


Fig. 3c

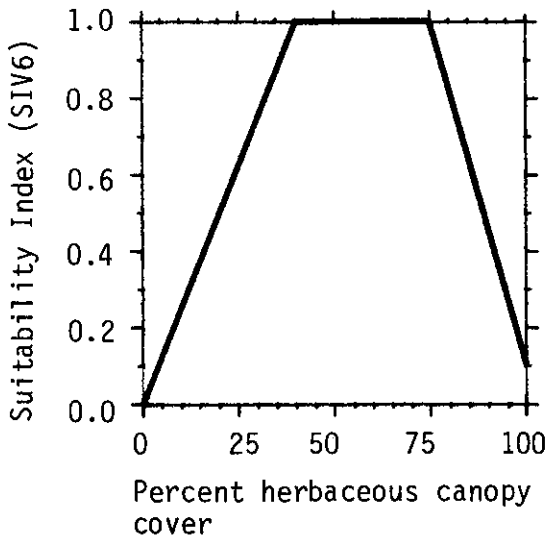
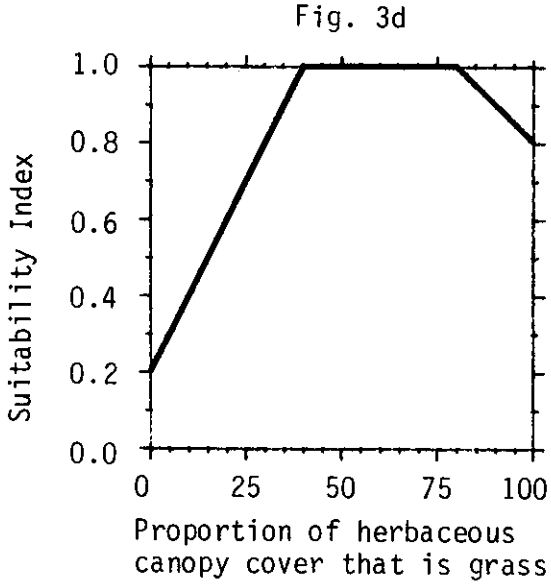


Figure 3. The relationships between habitat variables used to evaluate reproductive habitat and suitability indices for the gray partridge.



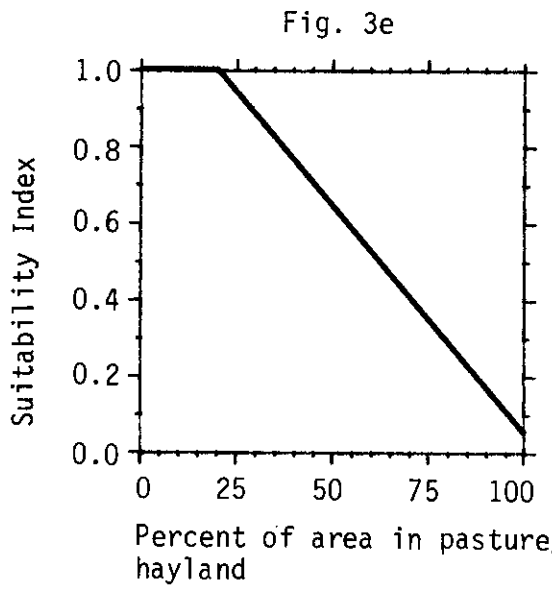


Figure 3. (concluded).

The distribution of idle cover types in the evaluation area has a major influence on the reproductive habitat potential for the gray partridge. Areas composed of cropland well interspersed with idle cover types are of more value to the species than are areas where idle cover is concentrated in large homogeneous units or in a few isolated sites. The distribution of idle cover is evaluated by determining the number of 4.0 ha (10 acres) cells that contain, or border, suitable idle cover types on a 2.56 km^2 (1.0 mi^2) basis (see Application of Model section for detailed instructions on the determination of this value). Figure 3b illustrates the relationship between the number of cells containing suitable cover and the suitability index. Areas composed totally of cropland, or lacking suitable idle cover, will have a cover distribution index of 0.1, while areas containing idle cover in ≥ 48 cells (75%) will have an index of 1.0. A minimum value of 0.1 has been assigned to areas totally composed of cropland, or lacking suitable idle cover, to allow for the potential nesting of gray partridge in cropland (e.g., winter wheat).

Idle cover areas are assumed to represent relatively poor reproductive habitat when herbaceous canopy coverage is less than 40% (Fig. 3c), and less than 40% of the herbaceous vegetation is grass (Fig. 3d). Extremely dense herbaceous vegetation, > 75% canopy cover, is assumed to be less suitable nesting habitat because gray partridge prefer fairly light to moderately dense nesting cover. However, even extremely dense stands of herbaceous vegetation are assumed to have minimum value as nesting habitat. The majority of the literature describing the nest sites of gray partridge identify grass-dominated vegetation as preferred for the establishment of nests. While optimum vegetative nesting conditions are assumed to range from 40 to 80% grass composition,

herbaceous vegetation comprised entirely of forbs is assumed to have some value. Sites supporting vegetation consisting entirely of grass are assumed to have relatively high reproductive potential for the species. The complete absence of pasture/hayland is assumed not to limit an area's habitat potential for gray partridge, particularly if idle cover types are present. However, due to the disturbance and reduction of vegetative quality due to haying and grazing, reproductive habitat potential is assumed to decrease as the proportion of the study area in these cover types increases above 20%. Areas consisting entirely of pasture/hayland are assumed to represent habitat with minimum reproductive potential.

Determination of a reproductive life requisite value for gray partridge is a function of the suitability indices for the percent of the area in idle land (SIV4), the distribution of idle land (SIV5), the percent herbaceous canopy cover (SIV6), the proportion of herbaceous canopy cover in idle cover types that is grass (SIV7), and the percent of the area in pasture/hayland (SIV8). The reproductive life requisite component is derived from the values obtained for idle lands and pasture/hayland cover types. The potential value of idle cover types as partridge reproductive habitat is assumed to be twice as important as that of pasture/haylands. The quality of herbaceous vegetation in idle cover types, as measured by density (SIV6), and grass composition (SIV7), is directly influenced by the abundance of these types of vegetation in the study area. The final reproductive potential of idle cover types as reproductive habitat is governed by the distribution of idle cover types (SIV5) throughout the evaluation area. The indices calculated using the curves presented in Figure 3 are combined in Equation 2 to determine the reproductive index (RI) for gray partridge:

$$RI = \frac{2\{[SIV4 \times (SIV6 \times SIV7)^{1/2}] \times SIV5\} + SIV8}{3} \qquad (2)$$

Model Relationships

HSI determination. The calculation of a Habitat Suitability Index for the gray partridge considers the life requisite values obtained for winter food and reproduction. The HSI is equal to the lowest value determined for either winter food (Equation 1) or reproduction (Equation 2).

Summary of model variables. Eight habitat variables are used in this model to evaluate winter food and reproduction values for the gray partridge. The relationships between habitat variables, cover types, life requisites, and the HSI are summarized in Figure 4.

Figure 5 provides variable definitions and suggested measurement techniques (Hays et al. 1981).

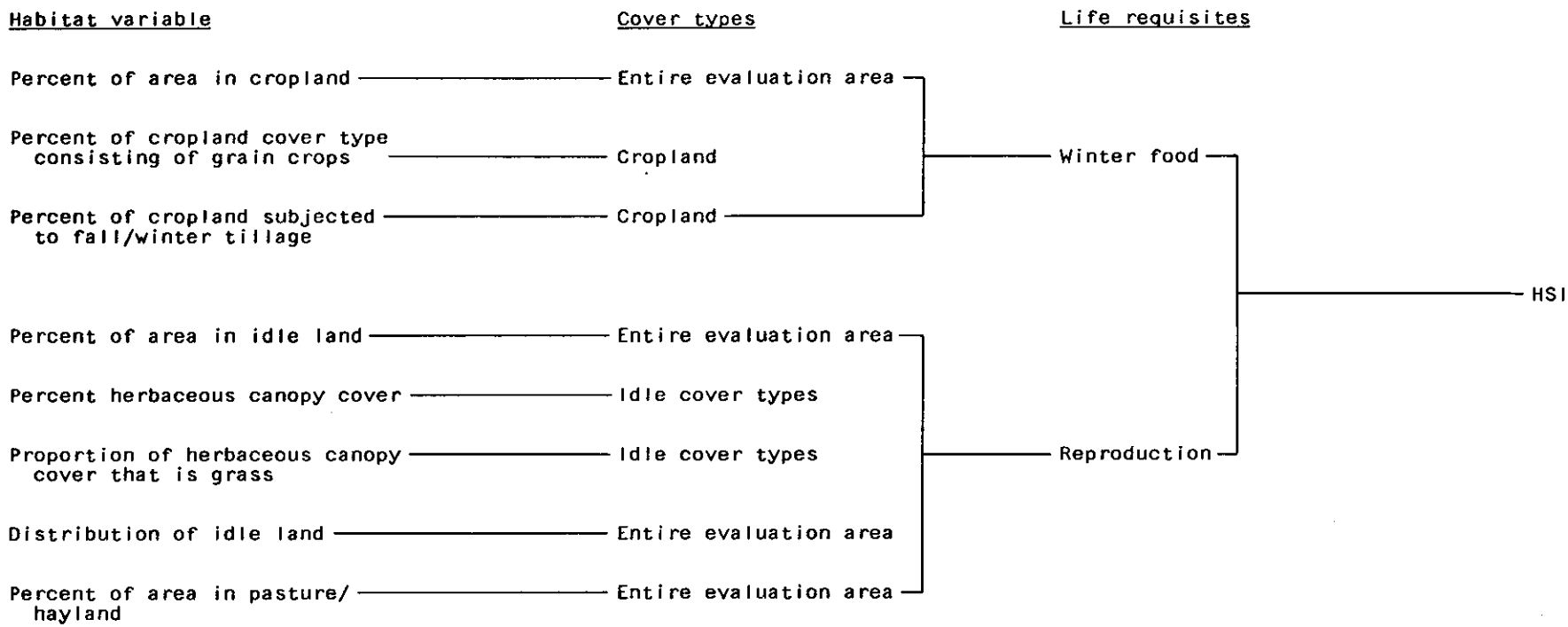


Figure 4. Relationships of habitat variables, cover types, and life requisites in the gray partridge HSI model.

Variable (definition)		Cover types	Suggested technique
V1	Percent of area in cropland (the proportion of the entire evaluation area that is comprised of land in agricultural production other than pasture or hayland).	Entire evaluation area	Remote sensing, cover type map
V2	Percent of cropland cover type consisting of grain crops (the proportion of the croplands devoted to the production of corn, wheat, barley, oats, milo, etc.).	C	Remote sensing, on-site inspection
V3	Percent of cropland subjected to fall/winter tillage (the proportion of cropland, other than pasture or hayland, in which stubble and crop residues are reduced or eliminated due to plowing after crop harvest).	C	Remote sensing, on-site inspection
V4	Percent of area in idle land [the proportion of the entire evaluation area that is comprised of ungrazed, uncropped land (e.g., shelterbelts, road/railroad rights-of-way, fencelines, and irrigation ditches)].	Entire evaluation area	Remote sensing, cover type map
V5	Distribution of idle land [a summation of the number of 4 ha (10 acres) grids on an overlay representing 2.56 km^2 (1 mi^2) that contain, or border, idle land cover types]. See Application of the Model section for detailed instructions for the calculation of this value.	Entire evaluation area	Remote sensing, cover type map, overlay

Figure 5. Definitions of variables and suggested measurement techniques.

Variable (definition)		Cover types	Suggested technique
V6	Percent herbaceous canopy cover [the percent of the ground surface that is shaded by a vertical projection of all nonwoody vegetation (grass, forbs, sedge, etc.)].	IDLE	Line intercept, quadrat
V7	Proportion of herbaceous canopy cover that is grass (the relative percent of all herbaceous cover that is comprised of grasses).	IDLE	Line intercept, quadrat
V8	Percent of area in pasture/ hayland (the proportion of the entire evaluation area devoted to grazing and hay production).	Entire evaluation area	Remote sensing, cover type map, on-site inspection

Figure 5. (concluded)

Application of the Model

Determination of an HSI value requires that the distribution of idle cover types be evaluated. Several steps are necessary in order to calculate an index for the distribution of idle cover (SIV5):

1. The study area must be evaluated on a 2.56 km^2 (1.0 mi^2) basis. An estimate of the distribution of land or cover types comprising idle cover is accomplished by the use of an overlay divided into 64 equal grid squares. Each grid represents a 4 ha (10 acres) area with an index value of 0.0156 (i.e., each grid represents 1.56% of the area of the section).

2. Determine the distribution of idle cover types by placing the overlay grid over the cover type map of the evaluation area. Each grid that contains, or borders, one or more idle land types is assigned a value of 0.0156. Grids that do not contain, or do not touch, land types considered to be idle receive no value. The gray partridge does not use forested cover types. However, the edges of wooded areas may be used. Therefore, cells that are partially composed of, or border, wooded cover types should be assigned a value of 0.0156. Cells that are totally within forested cover types should not be considered as gray partridge habitat and have a 0.0 value.

3. Each grid that borders or contains an idle cover type(s) is assigned a maximum value of 0.0156. Grids should not be double counted. For example, a grid in the corner of a section may border a road right-of-way and contain a shelterbelt. Even though more than one idle cover type is present within the grid, its value remains 0.0156.

4. The total number of grids containing or bordering land classified as idle multiplied by 0.0156, yields the suitability index for distribution of idle land. For the purposes of this model values ≥ 0.75 (i.e., $\geq$ 48 cells/mi^2 containing or bordering idle land) is assumed to represent optimum conditions.

SOURCES OF OTHER MODELS

Church and Viola (1984) developed a pattern recognition (PATREC) model for evaluation of gray partridge winter habitat quality that is applicable to regions supporting cereal-hay-corn agriculture in the Great Lakes portion of the species' range.

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16. Abstract (Limit: 200 words)

This report is part of the Habitat Suitability Index model series which provides habitat information useful for impact assessment and habitat management. 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 the HSI model that follows. In addition, this same information may be useful in the development of other models more appropriate to specific assessment or evaluation needs for the gray partridge (Perdix perdix).

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).

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