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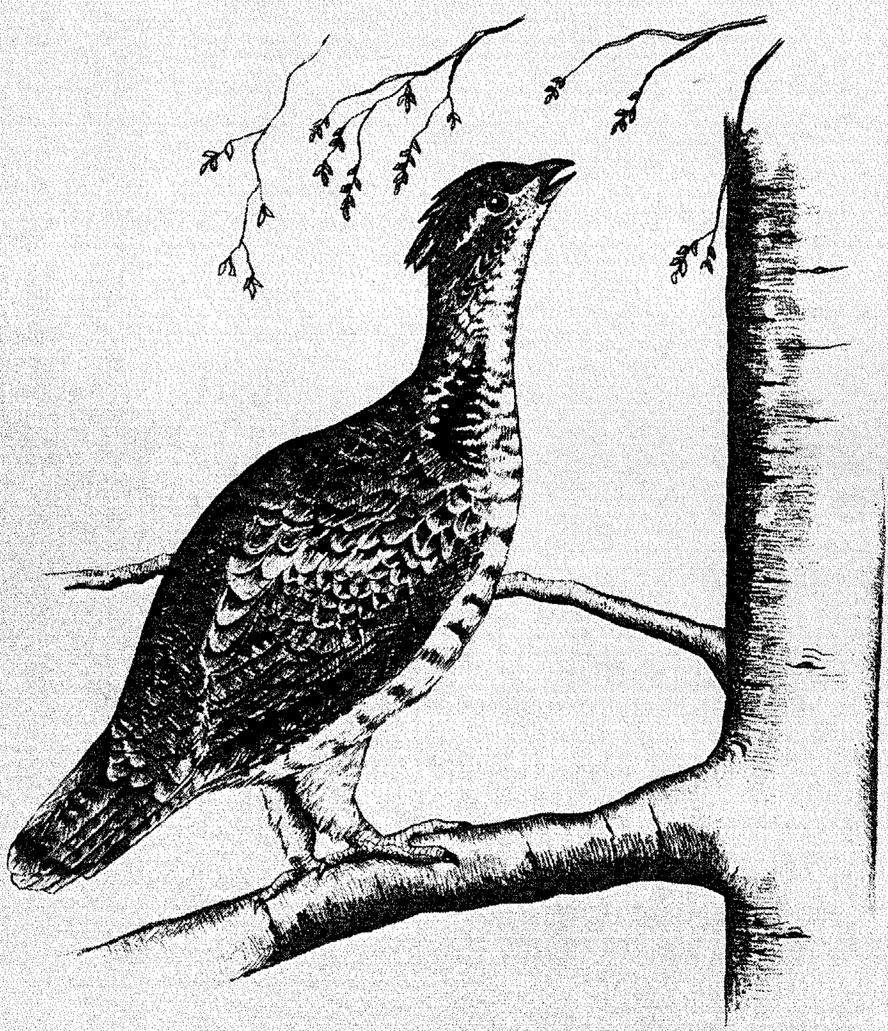
HABITAT SUITABILITY INDEX MODELS: RUFFED GROUSE



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HABITAT SUITABILITY INDEX MODELS: RUFFED GROUSE

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PREFACE

This document is part of the Habitat Suitability Index (HSI) Model Series [Biol. Rep. 82 (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 HSI models that follow. In addition, this same information may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

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

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

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CONTENTS

ACKNOWLEDGMENTS

We gratefully acknowledge Gordon W. Gullion for reviewing and assisting in development of this model, providing habitat use and ruffed grouse population data from the Cloquet Forestry Center, and aiding in interpretation of the data. Gretchen Mehmel and Peter Sanda measured characteristics of ruffed grouse habitat at Cloquet. Janet Schreur tabulated habitat data provided by Gullion and mapped cover types sampled at Cloquet.

We also thank David A. Boag, Robert E. Chambers, Ralph W. Dimmick, Daniel M. Keppie, John F. Kubisiak, Keith R. McCaffery, and Robert J. Stoll, Jr. for their critical reviews of this habitat model. The cover of this document was illustrated by Jennifer Shoemaker. Word processing was done by Carolyn Gulzow and Dora Ibarra.

RUFFED GROUSE (*Bonasa umbellus*)

HABITAT USE INFORMATION

General

The ruffed grouse (*Bonasa umbellus*) is the most widely distributed species of the Tetraoninae in North America, occurring in forested habitats from central Alaska to northern California; through the central Rocky Mountains of Idaho, Montana, western Wyoming, and north-central Utah; isolated in western South Dakota; from British Columbia east across Canada to southern Labrador; and from Minnesota, Michigan, Wisconsin, northeastern Iowa, Illinois, Missouri, and northern Arkansas east through Indiana, Ohio, New York, New England, and the southern Appalachian Mountains from Pennsylvania to northern Georgia (Aldrich 1963). Ruffed grouse have been successfully introduced outside their original range into Newfoundland and northeastern Nevada (Johnsgard 1973). It is the most widely hunted grouse in North America, providing recreational sport hunting in 43 States and Provinces.

Food

Ruffed grouse feed on a variety of plant foods, with regional and seasonal variations occurring in their diet (Korschgen 1966). Animal foods, primarily insects, are consumed in small quantities (4 to 5% of diet) by adults during summer (Edminster 1954) and in large quantities (50 to 75%) by chicks during their first few weeks of life (Bump et al. 1947; Edminster 1954). Insects decrease in importance in the diet of chicks throughout summer, and by August their diet is similar to adults, consisting primarily of plant foods (Stewart 1956). Kimmel and Samuel (1984) studied the foraging behavior of ruffed grouse chicks imprinted on humans. The diet of chicks up to 3 weeks of age was > 90% invertebrates; plant parts were not predominant until chicks were 8 weeks old.

In regions where snow cover is continuous throughout winter (e.g., northern New England and New York, Great Lakes States, Canada, Alaska, and the Rocky Mountains), the winter diet of ruffed grouse is comprised of buds and catkins of hardwood shrubs and trees (Bump et al. 1947; Gullion and Svoboda 1972; Johnsgard 1973). The staminate flower buds of aspens (*Populus* spp.), especially quaking aspen (*P. tremuloides*), are the critical winter food resource in Minnesota (Svoboda and Gullion 1972). A single mature male quaking aspen in Minnesota provides 8 to 9 days of food for one grouse. Aspens are an important winter food throughout much of the range of ruffed grouse (Brown 1946; Phillips 1967; Schemnitz 1970; Doerr et al. 1974; Gullion 1977, 1981; Kubisiak et al. 1980; Stoll et al. 1980; Schulz et al. 1983).

Other hardwood species also are used, especially when aspens are not predominant. Willow (Salix spp.) and aspen were 29 and 35%, respectively, of the total winter food volume consumed by ruffed grouse in Alberta (Doerr et al. 1974). Willow buds and twigs were 34% and aspen buds and twigs were 55% of the dry weight of food in crops of ruffed grouse collected in interior Alaska during winter (McGowan 1973). Ruffed grouse in central New York preferred buds of black cherry (Prunus serotina) and apple (Malus pumila) to those of aspen (Woehr and Chambers 1975). Winter foods of ruffed grouse in northeastern Ohio included buds of black cherry, hawthorn (Crataegus spp.), and hophornbeam (Ostrya virginiana), as well as aspen (Stoll et al. 1980). Buds and catkins of trees continue to provide food for ruffed grouse into the spring breeding season (Edminster 1954; Gullion and Svoboda 1972).

In regions where snow cover during winter is minimal or of short duration (e.g., Pacific coast, southern Ohio, Indiana, Illinois, southern Appalachians), the winter diet of ruffed grouse is more variable, including buds, fruits, and leaves from a variety of understory shrubs and herbaceous plants, as well as buds and fruits from trees (Korschgen 1966; Johnsgard 1973). Ruffed grouse in western Washington fed on buds and catkins of black cottonwoods (Populus trichocarpa) and leaves of buttercups (Ranunculus spp.) during winter (Brewer 1980). Acorns (Quercus spp.) and hophornbeam catkins were principal winter foods of ruffed grouse in Missouri (Korschgen 1966). Fruits of sumac (Rhus spp.), bittersweet (Celastrus scandens), poison ivy (Toxicodendron radicans), greenbrier (Smilax spp.), and dogwood (Cornus spp.), in addition to buds of hawthorn, aspen, and hophornbeam, were used by ruffed grouse in central and southern Ohio (Stoll et al. 1980). Gilfillan and Bezdek (1944) also noted the importance of understory species as winter food for ruffed grouse in Ohio. Greenbrier, mountain laurel (Kalmia latifolia), Christmas fern (Polystichum acrostichoides), Japanese honeysuckle (Lonicera japonica), and dogwood were important winter food items in eastern Tennessee and western North Carolina (Stafford and Dimmick 1979). Soft and hard fruits from a variety of shrubs and trees were eaten by ruffed grouse in southwestern Virginia (Norman and Kirkpatrick 1984).

Summer foods include numerous fruits, berries, green vegetation, and insects (Bump et al. 1947; Edminster 1954; Korschgen 1966). Ruffed grouse feed on a great variety of berries, herbaceous vegetation, and leaves, buds, and fruits of hardwood trees and shrubs during fall when potential food items are most abundant (Gullion 1966). Hungerford (1957) reported extensive use of insects and limited use of western redcedar (Thuja plicata) leaves during fall in northern Idaho.

Water

Most grouse foods contain considerable moisture (Johnsgard 1973), and it is unlikely that ruffed grouse require free water for drinking. When grouse are found near water, it is because they prefer the food or cover associated with mesic habitats and not because of a dependence on free water (Edminster 1954).

Cover/Reproduction

Cover suitable for drumming grouse during spring is suitable fall and winter cover (Berner and Gysel 1969; Gullion 1977), and suitable fall to spring cover for males also is suitable for females (Gullion 1967, cited by Moulton 1968). Females with broods prefer habitats similar to those preferred by drumming males (Berner and Gysel 1969; Porath and Vohs 1972; Kubisiak 1978).

The seasonal requirements of ruffed grouse are met by a combination of different cover types or age classes of forest (Bump et al. 1947; Gullion and Svoboda 1972; Gullion 1977). Ruffed grouse are associated principally with deciduous hardwood forests (Bump et al. 1947; Edminster 1954; Johnsgard 1973), especially those with aspen as a dominant species (Gullion and Svoboda 1972). However, hardwood trees are absent from some regions inhabited by ruffed grouse, e.g., northern Idaho (Hungerford 1951), and conifers are used for winter and escape cover in many regions (Bump et al. 1947; Edminster 1947; Lewis et al. 1968; Woehr 1974; Stoll et al. 1977).

Although the relationship between ruffed grouse and the distribution of aspens is not obligatory, ruffed grouse achieve their greatest abundance in northern regions where aspens, especially quaking aspen, are a dominant component of the forest (Gullion and Svoboda 1972; Gullion 1977, 1984a). Optimal aspen cover supports 20 to 40 drumming males/100 ha during peak populations. Maximum densities are usually lower, ranging from 2 to 8 males/100 ha, in the peripheral range of ruffed grouse, where aspen often is unavailable (Table 1).

Ruffed grouse males typically drum from a fallen log although other objects also are used (Bump et al. 1947; Sousa 1978). An acceptable drumming log provides sufficient height to allow a view of the surroundings and a relatively level stage (Boag and Sumanik 1969). Throughout their range, ruffed grouse prefer drumming sites that are surrounded by a moderate density of woody stems (Table 2), especially in the tall shrub or sapling layers (Palmer 1963; Boag and Sumanik 1969; Gullion 1970; Woehr 1974; Titus 1976; Salo 1978; Kelly and Major 1979, cited by Backs 1984; Stoll et al. 1979; Brewer 1980; Kubisiak et al. 1980; Stauffer 1983; Hunyadi 1984). The importance of stem density to habitat suitability for drumming grouse was confirmed by an experimental removal of woody stems < 5 cm dbh from a 0.005-ha circle surrounding each of 32 primary drumming logs in southwestern Alberta (Boag 1976a). Occupancy rates and recruitment of males were lower at treatment sites than at 32 control logs, and occupancy of secondary drumming logs was greater in activity centers associated with treatment than with control logs. No preference for high stem densities was observed in northern Georgia (Hale et al. 1982) and Vermont (Sousa 1978), however, and ruffed grouse in central Alberta preferred drumming sites with lower densities of stems < 10.2 cm dbh and greater densities of stems > 10.2 cm dbh (Rusch and Keith 1971).

Suitable drumming cover at the Cloquet Forestry Center in Minnesota occurs when 8 to 12-year old aspen stands have thinned to < 19,800 stems/ha (Gullion and Svoboda 1972). Cover suitability increases with natural thinning

Table 1. Densities of breeding male ruffed grouse throughout their range (values converted to males/100 ha).

Breeding males/100 ha[a] Max	Min	Location	Period	General habitat[b]	Reference
41.7	20.5	Minnesota: Cloquet Forestry Center	1959-77	10-25 year aspen	Gullion (1977)
35.7	10.7	Wisconsin: Sandhill Wildlife Area	1968-77	Aspen-alder	Kubisiak et al. (1980)
22.2	12.3	Central Alberta	1966-68	Aspen	Rusch and Keith (1971)
15.8	5.6	New York: Connecticut Hill	1930-42	Allegheny and northern hardwoods with conifers	Bump et al. (1947)
14.7	5.7	Ontario: Algonquin Park	1971-82	Mixed conifer-aspen, sugar maple-hemlock	Theberge and Gauthier (1982)
14.0	2.5	Minnesota: Cloquet Forestry Center	1959-82	Aspen, northern hardwoods, with some conifers	Gullion and Alm (1983)
10.4	1.0	Michigan: Rifle River Area	1950-58	Mixed conifer, northern hardwoods, aspen, alder	Palmer and Bennett (1963)
10.1	2.7	Wisconsin: Sandhill Wildlife Area	1968-77	Aspen and oak	Kubisiak et al. (1980)
10.1	4.6	Southwestern Alberta	1965-75	Aspen, balsam poplar, white spruce	Boag (1976a)
7.8	0.0	Minnesota: Cloquet Forestry Center	1959-82	Pine, spruce-fir, with some aspen	Gullion and Alm (1983)
7.2	2.7	Indiana: Maumee Grouse Study Area	1969-73, 1975-83	Oak	Backs (1984)
6.9	--	Northeastern Iowa	1967	Maple-basswood, oak-hickory, aspen	Porath and Vohs (1972)

Table 1. (concluded).

Breeding males/100 ha[a] Max	Min	Location	Period	General habitat[b]	Reference
6.2	5.5	Western Washington	1977-79	Black cottonwood, red alder, western hemlock	Brewer (1980)
6.2	2.8	Southeastern Ohio	5 years	Oak-hickory, beech-maple, pine	Stoll et al. (1973)
6.1	3.2	New York: Adirondack area	1932-38	Mixed conifers, northern hardwoods	Bump et al. (1947)
4.6	1.8	Missouri: Ashland Area and Daniel Boone Forest	1963-83	Oak-hickory, sugar maple, hophornbeam	Hunyadi (1984)
4.4	1.2	Wisconsin: Stone Lake Experimental Area	1968-77	Balsam fir, aspen	Kubisiak et al. (1980)
3.9	--	Southeastern Idaho: Wasatch Mountains	1979-82	Aspen, mixed conifer	Stauffer (1983)
2.6	1.8	Northern Georgia	1976-79	Oak-hickory, yellow poplar, pine	Hale et al. (1982)
2.6	--	Vermont: Grafton	1975	Maple, beech, yellow birch, mixed conifers	Sousa (1978)

[a] All estimates based on counts of drumming males except Stauffer (1983) which was a subjective estimate.

[b] Common and scientific names of plants not mentioned in text: balsam poplar (*Populus balsamifera*); basswood (*Tilia americana*); beech (*Fagus grandifolia*); hemlock (*Tsuga canadensis*); hickory (*Carya* spp.); red alder (*Alnus rubra*); sugar maple (*Acer saccharum*); western hemlock (*Tsuga heterophylla*); yellow birch (*Betula alleghaniensis*); and yellow poplar (*Liriodendron tulipifera*).

Table 2. Stem densities at ruffed grouse drumming sites (values converted to stems/ha).

Location	Size category	Stems/ha	Comments	Reference
Minnesota: Cloquet Forestry Center	Aspen > 0.6 m tall	4,900-14,800	Optimal 13-25 year aspen	Gullion (1970, 1977)
Wisconsin: Sandhill Wildlife Area	> 1.8 m tall	4,400-14,800	Optimal 6-25 year aspen	Kubisiak (pers. comm.)
Central Alberta	Shrubs > 0.9 m tall	8,545^{ns}	Means for 67 drumming sites compared with 163 random stations	Rusch and Keith (1971)
	Trees < 10.2 cm dbh	3,815^{a***}		
	Trees > 10.2 cm dbh	850^{b***}		
New York: Tug Hill Plateau	< 30 cm tall	975^{a***}	Means for drumming sites compared with available habitat	Woehr (1974)
	> 30 cm tall to 1.25 cm dbh	17,575^{ns}		
	2.5 cm dbh	7,712^{b***}		
	5.0 cm dbh	912^{ns}		
	7.5 cm dbh	350^{a**}		
	> 10.0 cm dbh	480^{ns}		
Ontario: Algonquin Park	< 10 cm dbh	2,872 and 3,980^{ns}	Means for 2 areas with different grouse densities	Theberge and Gauthier (1982)
Michigan: Rifle River Area	< 0.6 m tall	31,849^{a**}	Means for habitat within 10.1 m radius of 40 drumming logs compared with habitat 10.1 to 20.1 m distant	Palmer (1963)
	0.6-1.5 m tall	13,289^{ns}		
	1.5-2.4 m tall	4,776^{ns}		
	> 2.4 m tall to 7.6 cm dbh	8,401^{b***}		
	7.6-15.2 cm dbh	1,181^{b**}		
	15.2-22.9 cm dbh	138^{b**}		
	> 22.9 cm dbh	109		
Southwestern Alberta	< 1.0 m tall	2,120^{b}	Means for 80 drumming logs compared with 98 unused logs	Boag and Sumanik (1969)
	> 1.0 m tall to 5 cm dbh	4,720^{b}		
	5-10 cm dbh	2,720^{b}		
	10-20 cm dbh	620^{a}		
	> 20 cm dbh	140^{b}		
Indiana	< 13 cm dbh	35,000^{b***}	Means for 64 drumming logs compared with unused logs	Kelly and Major (1979, cited by Backs 1984)

Table 2. (concluded).

Location	Size category	Stems/ha	Comments	Reference
Western Washington	> 0.2 m tall	21,592[b**]	Means for 25 drumming logs compared with 26 unused logs	Brewer (1980)
Southeastern Ohio	< 1.0 m tall	80,060[ns]	Means for 30 perennial logs compared with 27 transient centers	Stoll et al. (1979)
	> 1.0 m tall to 2.5 cm dbh	16,803[b***]		
	2.6-5.1 cm dbh	1,977[b***]		
	5.2-10.2 cm dbh	988[ns]		
Missouri: Monkey Mt. and Anderson Wildlife Areas, Boone Forest	> 1.0 m tall	15,296[b] 13,412[b] 11,760[b]	Means for drumming logs at 3 areas compared with available habitat	Hunyadi (1984)
Southeastern Idaho	< 7 cm dbh	8,509[b*]	Means for 19 drumming logs compared with 19 unused logs	Stauffer (1983)
	7-15 cm dbh	494[ns]		
	15-23 cm dbh	174[ns]		
	> 23 cm dbh	100[ns]		
Northern Georgia	< 0.5 m tall	120,000[ns]	Means for 14 drumming logs compared with 14 unused logs	Hale et al. (1982)
	> 0.5 m tall to 10 cm dbh	14,000[ns]		
	> 10 cm dbh	556[ns]		
Vermont: Grafton	< 2.5 cm dbh	941-5,651[ns]	Densities for 5 drumming logs compared with available habitat in stands	Sousa (1978)
	2.5-12.7 cm dbh	2,063-6,098[ns]		
	> 12.7 cm dbh	494-941[ns]		

[a]Mean less than mean for available habitat or unused logs.

[b]Mean greater than mean for available habitat or unused log.

[ns]$\underline{P} > 0.10$

[*]$\underline{P} < 0.10$

[**]$\underline{P} < 0.05$

[***]$\underline{P} < 0.01$

and increasing height of stems associated with maturation of a stand (Gullion and Svoboda 1972; Gullion 1977). Optimal drumming cover occurs in 13 to 25-year old aspen stands with a stem density of 4,900 to 14,800/ha (Gullion 1970:Fig. 3) and a closed canopy about 10 m overhead (Gullion and Svoboda 1972; Gullion 1977). The habitat has "gone-by" and rather abruptly ceases to support drumming grouse when stem densities decrease to < 4,900/ha (Gullion and Svoboda 1972; Gullion 1977). Aspen in central Wisconsin initially are occupied when stands are < 5 years of age and have maximum stem densities of 19,800/ha (Kubisiak et al. 1980; Kubisiak 1985; Kubisiak pers. comm.). Optimal drumming cover is provided by 6 to 25 year old aspen stands having densities of woody stems > 1.8 m tall from 4,400 to 14,800/ha and a canopy height ≥ 4.6 m (Kubisiak pers. comm.).

The age when a tree stand initially provides suitable habitat for ruffed grouse and length of time that it remains suitable habitat will be affected by growth rates of plants providing cover, and this varies among species and growing site environments (Gullion 1984b). Mature hardwood tree stands that have thinned below suitable tree densities continue to provide suitable cover if there is sufficient density and height of woody shrubs in the understory (Kubisiak et al. 1980; Gullion 1984a). Shrubs > 0.9 m in height provide suitable cover when there are 80 to 200 stems within a 3.0 to 3.7 m radius of the drumming stage (Gullion 1972, cited by Boag 1976a), equivalent to densities of 19,000 to 68,700/ha. However, shrubs need to be > 1.5 m tall to provide suitable overhead cover (Kubisiak 1985; Gullion pers. comm.). Forty-three of 112 drumming sites located by Salo (1978) in western Washington were in dense thickets (300,000 stems > 2.5 m tall/ha) of salmonberry (*Rubus spectabilis*) in the understory of mature, open canopy forests.

Optimal drumming habitat provides cover for ruffed grouse and even stem spacing which allows them to maintain effective surveillance for predators (Gullion and Svoboda 1972; Gullion 1977). This is referred to as vertical cover. Preferred habitats provide optimal cover across the major portion of an activity center and not just immediately surrounding the drumming log (Gullion and Marshall 1968; Gullion 1984b). Grouse territories that include several suitable alternate drumming sites are more likely to be occupied for extended periods (perennial use) than territories without suitable alternate drumming sites (Boag 1976b). Mid-seral aspen stands provide optimal vertical cover during fall through spring and suitable snow conditions for snow-burrow roosting during winter (Gullion and Svoboda 1972).

Conifers can be detrimental to survival of ruffed grouse in drumming habitats (Gullion and Marshall 1968; Gullion 1970; Rusch and Keith 1971), because low-growing conifers provide concealment for mammalian predators, and the "high pine" conifers provide concealment and excellent opportunities for raptors to ambush grouse. Gullion and Marshall (1968) attributed 86% of ruffed grouse kills at Cloquet, Minnesota to raptor predation. Maximum grouse densities during peak populations at Cloquet (Table 1) were twice as high in a predominantly hardwood tract compared to a predominantly coniferous tract of forest (Gullion and Alm 1983). Mean longevity and survival of ruffed grouse also were greater in the predominantly hardwood forest tract. Maximum densities of drumming males (7.5/100 ha) in balsam fir (*Abies balsamea*) habitats at Stone Lake, Wisconsin were only 20% of maximum densities (35.7/100 ha) in optimal aspen-alder (Alnus spp.) habitat at Sandhill, Wisconsin (Kubisiak et al. 1980). The presence of conifers around drumming sites in central Ontario was not considered detrimental to ruffed grouse populations because avian predators were scarce (Theberge and Gauthier 1982).

Conifers provide the only suitable drumming or winter cover in some regions, but densities of ruffed grouse are lower in these habitats than in optimal aspen habitats (Table 1). Young white spruce (Picea glauca) < 10 cm dbh provided drumming cover in mixed deciduous/coniferous forests in southwestern Alberta (Boag and Sumanik 1969), and young balsam fir in the understory of mature aspen forests provided cover for drumming grouse at Stone Lake, Wisconsin (Kubisiak et al. 1980). Conifers were considered important winter cover in New York (Bump et al. 1947; Edminster 1947; Woehr 1974), Ohio (Stoll et al. 1977), Indiana (Muehrcke and Kirkpatrick 1969), Missouri (Lewis et al. 1968), and Idaho (Hungerford 1951). Ruffed grouse in north-central Minnesota preferred jack pine (Pinus banksiana) forests for cover during winter, a habitat type also used by spruce grouse (Dendragapus canadensis) (Pietz and Tester 1982). Ruffed grouse inhabiting the boreal forest region of New Brunswick used spruce-fir and jack pine forests throughout the year (Keppie pers. comm.). Conifers, especially fir and spruce with branches growing low to the ground, provide important thermal cover for grouse in regions where snow depths or snow conditions during winter limit snow-burrow roosting (Woehr 1974; Chambers pers. comm.; Keppie pers. comm.). More than 90% of winter roosts in central New York were located in conifers during two winters when snow-burrow roosting was prohibited by wet or crusted snow on all but five nights (Woehr 1974).

Ruffed grouse nests typically are located at the base of trees in open hardwood stands although other sites are used, such as the base of stumps, under slash, bushes, or brush piles (Bump et al. 1947; Edminster 1947). Aspen stands in Minnesota with stem densities < 4,900/ha provide preferred nesting cover (Gullion 1977), and nesting females feed extensively on emerging aspen leaves and prefer to locate their nests close to mature aspens (Gullion and Svoboda 1972; Gullion 1977; Maxson 1978). Nearby undergrowth is usually sparse (Bump et al. 1947; Gullion 1977).

Brood cover occurs in transition zones between lowland and upland forests or forest edges and openings with a well-developed herbaceous and shrub understory (Bump et al. 1947; Edminster 1947; Sharp 1963; Porath and Vohs 1972; Stauffer 1983). Optimal brood habitat in Minnesota occurs in regenerating aspen stands with 12,400 to 29,000+ stems/ha (Gullion 1970, 1977). Most upland aspen stands in Wisconsin can provide suitable brood habitat, but optimal habitat occurs in 6 to 25 year old stands or where alder or other equivalent cover exists (Kubisiak 1978).

Interspersion and Composition

Ruffed grouse are not migratory, but they will move short distances among different seasonal habitats (Johnsgard 1973). Optimal interspersion of cover types occurs when all seasonal habitat requirements are contained within 4 ha

(Gullion and Svoboda 1972). In Minnesota, these seasonal requirements are met by an interspersion of seedling (1 to 12 years old), sapling (13 to 25 years old), and mature (> 25 years old) aspen stands (Gullion and Svoboda 1972). Mature male aspen within 91 m of adequate fall to spring cover provide the essential winter food source (Gullion 1977). Kubisiak et al. (1980) found 98% of drumming sites in Wisconsin within 40 m of a mature aspen food source. However, only 53% of drumming logs in southern Ohio were within 100 m of mature aspen (Stoll et al. 1979).

Male ruffed grouse in Minnesota occupied an average of 8.9 ha from March to June but occupied a reduced area of 6.7 ha during the drumming season (Archibald 1975). Females occupied areas of 16.5 ha, moving from lowland-upland edge in early spring to upland sites for nesting. Females gradually reduce their movements from prelaying through incubation (Maxson 1978). Occupied areas averaged 12.1 ha during prelaying, 8.4 ha during laying, and 0.9 ha during incubation. Females can move their broods up to 5.8 km to suitable cover (Schladweiler 1965). The cruising radius of most broods, however, is < 0.4 km (Chambers and Sharp 1958). Juveniles are more mobile than adults during fall (Hale and Dorney 1963), and juvenile females disperse farther than males (Godfrey and Marshall 1969).

Special Considerations

Ruffed grouse are associated with disturbed forest habitats (Gullion 1977). However, elimination of forest cover over an area > 4 ha results in reduced breeding densities (Gullion 1970). Extensive areas of a single cover type are not as valuable to ruffed grouse as the close interspersion of several smaller cover types. Aspen regeneration 1 to 12 years old provides optimal brood cover in Minnesota, aspen saplings 13 to 25 years old provide optimal fall to spring (drumming) cover, and aspens > 25 years old provide an essential winter food source and nesting habitat (Gullion and Svoboda 1972; Gullion 1977).

Small clearcuts (Edminster 1947; Stauffer 1983; Gullion 1984a) and burning (Sharp 1970) can improve grouse habitat by maintaining an interspersion of young through mature successional stages of forest. Grazing by livestock can adversely affect brood habitat (Robertson 1976; Stauffer 1983), extensive timber harvesting reduces breeding densities, and lack of timber management results in large tracts of mature forest that are unsuitable for ruffed grouse (Gullion 1977).

Ruffed grouse occur sympatrically with spruce and/or blue grouse (Dendragapus obscurus) throughout portions of their range (Aldrich 1963). Ruffed and spruce grouse use the same winter habitats in north-central Minnesota (Pietz and Tester 1982), and these two species use similar habitats throughout much of the boreal forest (Keppie pers. comm.). Ruffed and blue grouse in Idaho rarely use the same habitats even though they occupy the same areas (Marshall 1946; Stauffer 1983); ruffed grouse occur in more mesic sites with greater canopy cover. There is no evidence of competition between ruffed and blue or spruce grouse (Pietz and Tester 1982; Stauffer 1983).

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographical area. This model is intended for application within the region where aspen is a predominant component of the forest ecosystem. With modifications, discussed under Application of the Model, it may be applicable throughout the range of ruffed grouse.

Season. This model was developed to evaluate the year-round habitat of the ruffed grouse.

Cover types. This model was developed to evaluate habitat suitability in Deciduous and Evergreen Forest (DF, EF), Tree Savanna (DTS, ETS), and Shrubland (DS, ES) cover types (U.S. Fish and Wildlife Service 1981). Further subdivision of these cover types is possible and is discussed on page 20 under Application of the Model.

Minimum habitat area. Minimum habitat area is defined as the minimum amount of contiguous suitable habitat that is required before an area will be occupied by a particular species. This information was not found in the literature for ruffed grouse. An activity center for an individual drumming male can be as small as 2.4 ha (Gullion 1977), but a pair of grouse/4 ha is about the highest density grouse population that can be expected under most conditions (Gullion and Svoboda 1972). Therefore, this model should not be applied on an area < 4 ha. Both Stoll (pers. comm.) and Chambers (pers. comm.) recommended a minimum habitat area of 20 ha for isolated blocks of forest surrounded by unsuitable grouse habitat, e.g., a farm woodlot surrounded by cropland.

Verification level. This model was developed with the assistance of Gordon W. Gullion, Project Leader of the University of Minnesota's Forest Wildlife Project at the Cloquet Forestry Center, near Cloquet, Minnesota. The variables in this model are based on Mr. Gullion's experience and long-term data collected on the Cloquet Forest. In 1981, the U.S. Fish and Wildlife Service contracted Mr. Gullion to provide habitat and grouse use data from 20 drumming logs, 20 4-ha activity centers surrounding the logs, and five blocks of forested habitat ranging from 18.1 to 27.5 ha. These data (Cade 1984) were used to refine variable relationships and suitability levels from earlier drafts of the model.

Previous drafts of this model were also reviewed by:

David A. Boag, Professor, Department of Zoology, University of Alberta, Edmonton, Alberta

Robert E. Chambers, Professor, Department of Environmental and Forest Biology, State University of New York, Syracuse, NY

Ralph W. Dimmick, Professor, Department of Forestry, Wildlife, and Fisheries, University of Tennessee, Knoxville, TN

Daniel M. Keppie, Professor, Department of Forest Resources, University of New Brunswick, Fredericton, New Brunswick

John F. Kubisiak, Project Leader, Forest Wildlife Research Group, Wisconsin Department of Natural Resources, Babcock, WI

Keith R. McCaffery, Project Leader, Forest Wildlife Research Group, Wisconsin Department of Natural Resources, Rhinelander, WI

Robert J. Stoll, Jr., Wildlife Biologist, Ohio Department of Natural Resources, New Marshfield, OH

Specific comments from each reviewer were incorporated into the current model. Boag (pers. comm.), Chambers (pers. comm.), Dimmick (pers. comm.), and Stoll (pers. comm.) questioned whether it was possible to develop a single habitat suitability model that would be applicable throughout the range of ruffed grouse. Modifications of this model that may increase its usefulness in various regions are discussed under Application of the Model.

Model Description

Overview. Optimal habitat for ruffed grouse is provided by the interspersion of several forest age classes. The ruffed grouse is considered in this model to be a multicover type species, using different age classes of forests. Winter Food and Fall to Spring Cover are the life requisites considered in this model and are assumed to be the same for both male and female grouse. It is assumed that water is not a limiting factor for ruffed grouse populations. Nesting and brood-rearing habitat are assumed to never be more limiting than winter food and fall to spring cover requirements.

The following sections identify important habitat variables used in the model, describe suitability levels of the variables, and describe the relationships among variables.

Winter food component. Optimal winter food for ruffed grouse is provided by the flower buds of mature male aspens (Svoboda and Gullion 1972; Gullion 1984a). Other plants also provide a winter food source, but they will be of lower value and support fewer grouse than will mature male aspen. Svoboda and Gullion (1972) estimated that one average mature male aspen would provide a grouse with 8 to 9 days of food. Based on a 180 day winter (November-April), one grouse would require 20 mature male aspen during winter (Kubisiak et al. 1980). Suitability of winter food will be determined by the interspersion of mature male aspen and fall to spring cover. Optimal winter food is assumed to exist when ≥ 20 mature male aspen are within 91 m of fall to spring cover (Gullion 1977). Suitability of winter food is assumed to decrease as the distance between 20 mature male aspen and fall to spring cover increases from 91 to 183 m. If there are < 20 mature male aspen within 183 m of fall to spring cover, it is assumed that other deciduous shrubs and trees will provide winter food but at a lower level of suitability. Because mature male aspens can be clustered in clones or scattered throughout a stand, winter food suitability is measured as the average radius of circles encompassing 20 mature male aspen (Fig. 1), i.e., the distance to the 20th mature male aspen from a sampling point. This distance relationship is used whether suitable winter food and fall to spring cover occur in the same or different cover types (stands).

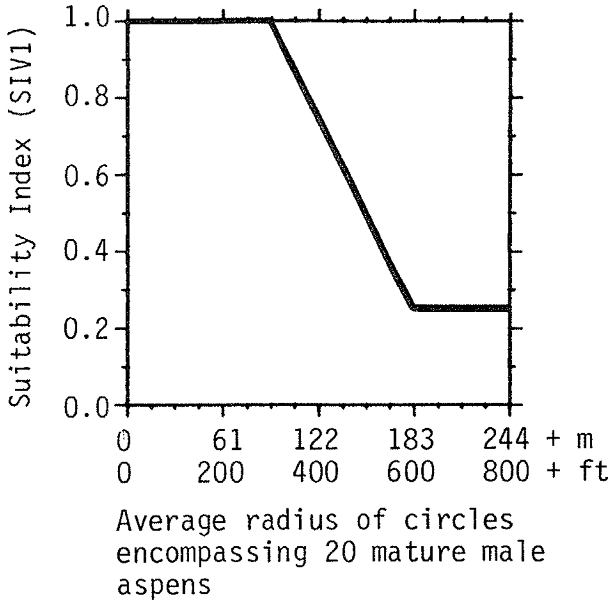

Figure 1. The relationship between the average radius of circles encompassing 20 mature male aspen and suitability indices for winter food.

Fall to spring cover component. Fall to spring cover is a function of the degree of obstruction provided by woody vegetation and is dependent upon density, height, and growth form of woody stems. Dense hardwood stems (trees or shrubs) provide physical obstruction to predators as well as a high level of visibility for the grouse (vertical cover). Coniferous stems also provide physical obstruction to predators but may restrict visibility for ruffed grouse. Overhead cover is provided by suitable density and height of plant growth forms providing vertical cover.

Vertical cover may be provided by deciduous shrubs, deciduous trees, coniferous trees, or by a mixture of these forms. Trees are defined in this model as woody plants having a single, erect stem originating from a single base at the ground, and shrubs are defined as woody plants having multiple, erect stems originating from a single base at the ground. The difference between deciduous trees and deciduous shrubs is even spacing versus clumping of erect stems. This differs from the practice of using stem height to differentiate trees and shrubs, as defined by the U.S. Fish and Wildlife Service (1981) for other HSI models. It is assumed that a certain amount of physical obstruction (vertical cover) is necessary to provide optimal fall to spring cover for ruffed grouse. Cover provided by deciduous trees (especially aspens) has been most thoroughly studied and forms the basis for comparing cover provided by woody vegetation of various growth forms.

Stem densities of deciduous trees ranging from 4,900 to 14,800 stems/ha are considered to be optimum (Gullion 1970). Stem densities of deciduous trees ≤ 4,400 stems/ha are considered too sparse to provide vertical cover, and densities ≥ 21,000 stems/ha are considered too dense to provide suitable vertical cover because mobility and visibility for ruffed grouse will be restricted. Because the growth form of deciduous trees differs considerably from that of deciduous shrubs and conifers, it is necessary to convert shrub and conifer stem densities to an equivalent stem density value in order to compare various growth forms. Equivalent stem density is defined as the number of stems of deciduous shrubs or conifers that will provide the equivalent amount of cover provided by one deciduous tree.

The typical growth form of deciduous shrubs [e.g., beaked hazel (Corylus cornuta)] is that of a woody plant with multiple, clumped, narrow stems (< 2.5 cm dbh). It is assumed in this model that, on the average, four typical deciduous shrub stems ≥ 0.9 m in height will occupy the space and provide equivalent density of vertical cover as one deciduous tree (Gullion pers. comm.). The equivalent stem density coefficient for deciduous shrubs ≥ 0.9 m in height, therefore, is 0.25. Shrubs < 0.9 m in height are assumed to be too short to provide any vertical cover.

The growth form of conifers is that of a woody plant with a dense, wide crown. Because of this growth form, it is assumed that one typical conifer with a low crown height (height to the lowest live branch) between 0.0 and 0.9 m above ground provides the same amount of vertical cover (i.e., physical obstruction) as provided by four deciduous trees. As the low crown height of conifers increases from 0.9 to 4.6 m, the equivalent cover provided by conifers decreases from four times the cover provided by one deciduous tree to a value equal to the cover provided by one deciduous tree. Vertical cover will be provided only by the trunk and not the branches of conifers when lowest branch heights are ≥ 4.6 m. This relationship is shown in Figure 2a.

Fig. 2a

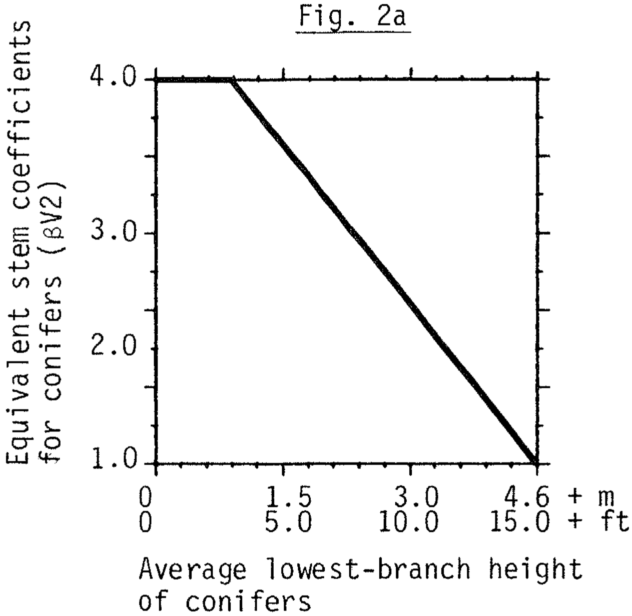

Fig. 2b

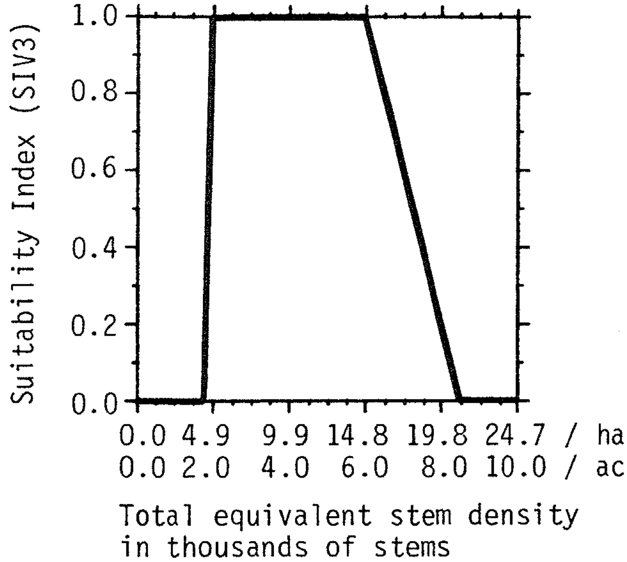

Figure 2. The relationship between lowest-branch height of conifers and equivalent stem density coefficients for conifers (2a) and between total equivalent stem density and suitability indices for vertical cover (2b).

Total equivalent stem density can be determined by Equation 1:

$$\text{Total equivalent stem density} = d + 0.25s + \beta V2c \qquad (1)$$

where d = number of deciduous trees/ha

s = number of deciduous shrub stems/ha

c = number of coniferous trees/ha

$\beta V2$ = equivalent stem density coefficient for conifers

The relationship between habitat suitability and total equivalent stem density is the same as that previously described for deciduous trees and is depicted in Figure 2b.

The suitability of vertical cover for ruffed grouse is determined by total equivalent stem density and height of woody stems providing cover. Woody stems ≥ 4.6 m in height provide optimal suitability for overhead cover (Kubisiak pers. comm.). Suitability decreases when woody stems are < 4.6 m in height, and woody stems ≤ 1.5 m in height do not provide suitable overhead cover (Gullion pers. comm.; Kubisiak pers. comm.) (Fig. 3). The relationship between stem height and suitability is assumed to be the same for all three woody growth forms that may provide vertical cover.

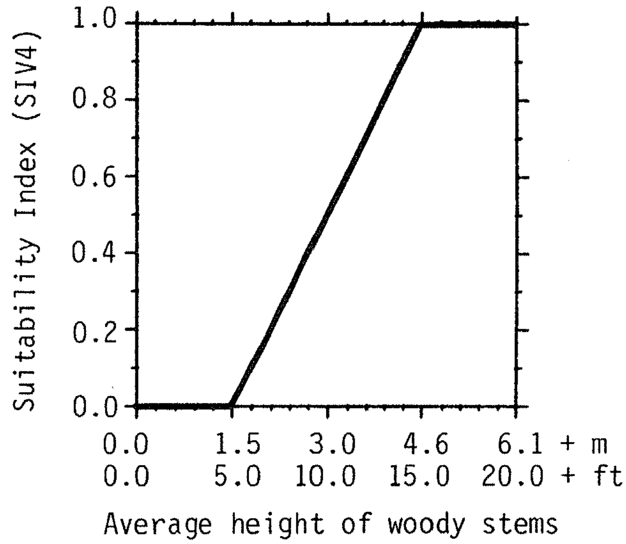

Figure 3. The relationship between woody stem heights and suitability indices for height of vertical cover.

During secondary succession of deciduous forests, suitability of vertical cover for ruffed grouse will increase as total equivalent stem density decreases from 21,000 to 14,800 stems/ha and stem heights increase to ≥ 4.6 m. Most aspen stems will have grown to optimal heights (≥ 4.6 m) when an aspen stand has matured and thinned to optimal total equivalent stem densities (4,900 to 14,800 stems/ha) (Kubisiak pers. comm.). As an aspen stand continues to mature and thins to ≤ 4,400 tree stems/ha, habitat suitability will also depend upon the density and height of understory woody shrubs or conifers (Kubisiak et al. 1980; Gullion 1984a).

Suitability of vertical cover height is assumed to be optimum if there are a minimum of 4,900 equivalent stems/ha at optimal heights (i.e., ≥ 4.6 m). When this minimum height/density relationship is met, additional stems at either suboptimal or optimal heights will not alter the suitability of vertical cover height. Therefore, suitability of vertical cover height is evaluated for the 4,900 equivalent stems/ha having highest suitability for stem height (SIV4) and may include any single or combination of woody growth forms. If total equivalent stem density is > 4,900/ha, then a weighted SIV4 is determined by considering equivalent stems by growth form beginning with the most suitable growth form (i.e., having highest SIV4) and continuing until exactly 4,900 equivalent stems/ha are included in Equation 2:

$$\text{Weighted SIV4} = \sum_{i=1}^{3}\left[\text{SIV4}_i \times \frac{(\text{equivalent stems/ha})_i}{4{,}900/\text{ha}}\right] \qquad (2)$$

where i = 1, 2, and 3 are different woody growth forms (i.e., deciduous shrubs, deciduous trees, or coniferous trees) such that

$$\text{SIV4}_1 \geq \text{SIV4}_2 \geq \text{SIV4}_3, \text{ and } \sum_{i=1}^{3} (\text{equivalent stems/ha})_i = 4{,}900/\text{ha}$$

If the growth form with the highest SIV4 ($SIV4_1$) has > 4,900 equivalent stems/ha, then the weighted SIV4 equals $SIV4_1$. If growth form 1 has < 4,900 equivalent stems/ha, then the maximum number of equivalent stems/ha that can be entered for growth form 2 equals 4,900 minus the number of stems for growth form 1. If the sum of equivalent stems/ha for growth forms 1 and 2 is < 4,900 stems/ha, then the maximum number of equivalent stems/ha that can be entered for growth form 3 equals 4,900 minus the sum of equivalent stems/ha for growth forms 1 and 2. For example: A cover type has 800 deciduous trees/ha with an average height of 10.0 m (SIV4 = 1.0), 20,000 deciduous shrubs/ha with an average height of 2.4 m (SIV4 = 0.3), and 200 conifers/ha with an average height of 3.0 m (SIV4 = 0.5) and average low-branch height of 0.5 m (βV2 = 4.0). There are 800 equivalent stems of deciduous trees, 5,000 equivalent stems of deciduous shrubs, and 800 equivalent stems for conifers. Therefore, the weighted SIV4 = [(1.0 x 800) + (0.5 x 800) + (0.3 x 3,300)]/ 4,900 = 0.447. Note that 3,300, rather than 5,000, equivalent shrub stems are entered in the weighted SIV4 making the sum of the equivalent stems (800 + 800 + 3,300) equal to 4,900/ha.

If total equivalent stem density is ≤ 4,900 stems/ha, the weighted SIV4 can be determined using equation 2, but without any restrictions on the order that growth forms are entered or that their equivalent stem densities sum to 4,900/ha.

Tall conifers provide concealment for raptors which prey upon ruffed grouse, and conifers with low branches provide concealment for mammalian predators. Maximum densities and survival of ruffed grouse are lower in forests where conifers are the predominant trees (Gullion and Marshall 1968; Kubisiak et al. 1980; Gullion and Alm 1983). An area that provides optimal equivalent stem density and height of vertical cover for ruffed grouse but has only conifers in the tree strata is assumed to provide only 25% of the optimal fall to spring cover value. Similarly, the presence of any conifers in an otherwise suitable habitat will reduce suitability of fall to spring cover because of the additional concealment for predators provided by conifers. The recommended relationship is presented in Equation 3:

$$\text{conifer penalty} = \left[\left(3 \times \frac{c}{c + d}\right) + 1\right]^{-1} \qquad (3)$$

where c = number of coniferous trees/ha

d = number of deciduous trees/ha

This equation represents a curvilinear relationship (Fig. 4) that reduces suitability at a more rapid rate with a low percentage of conifers and at a less rapid rate with higher percentages of conifers. Cover suitability is assumed to decline quickly with a small percentage of conifers which can conceal raptors. However, cover suitability decreases at a lower rate with increasing percentage of conifers, because it is unlikely that there will be a proportional increase in predation opportunities with increasing percentage of conifers.

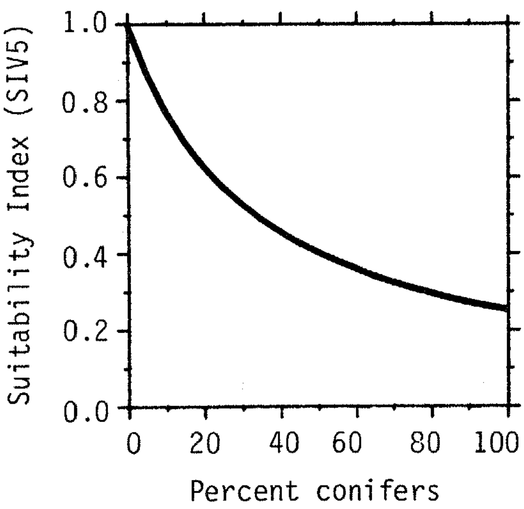

Figure 4. The relationship between percent coniferous trees and the suitability index for the conifer penalty.

Fall to spring cover can be summarized as follows:

1. Vertical cover can be provided by deciduous trees, coniferous trees, deciduous shrubs, or any combination of these growth forms.

2. A certain amount of physical obstruction (stem density) is necessary to provide suitable vertical cover. The equivalent of one deciduous tree is assumed to be four deciduous shrub stems and 0.25 to one coniferous tree, depending on the low crown height. Total equivalent stem density is determined based on these assumed relationships.

3. Suitability of vertical cover also depends upon the height of woody stems providing vertical cover density. However, not all stems need to have suitable heights for vertical cover height to be optimum.

4. As the percentage of cover provided by coniferous trees increases, the suitability of the habitat for ruffed grouse decreases due to increased concealment for predators. If conifers provide the only tree cover, then the maximum value for fall to spring cover will be 0.25, or 25% of the potential of sites with only deciduous trees.

Fall to spring cover value is a function of the suitability of total equivalent stem density (SIV3, Fig. 2b) modified by the weighted suitability of the heights of woody stems (Fig. 3, Equation 2), and further modified by the suitability of the percentage of trees that are conifers (SIV5, Fig. 4). This model evaluates cover for ruffed grouse based on vertical cover suitability modified by predator concealment suitability. Equation 4 is recommended for determining the suitability of Fall to Spring Cover (FSCOV):

$$FSCOV = SIV3 \times \text{Weighted } SIV4 \times SIV5 \qquad (4)$$

This equation allows either unsuitable (SI = 0.0) total equivalent stem density or unsuitable height of woody stems to produce unsuitable Fall to Spring Cover. Because none of the variables are considered compensatory and each directly modifies the suitability of the others, suboptimal suitabilities for two or three variables yield a suitability index for Fall to Spring Cover that is lower than the lowest individual suitability index for the variables.

HSI determinations. Calculation of an HSI for a multicover type species involves consideration of both the suitability and the interspersion of life requisites. However, the interspersion of life requisites is incorporated in the Winter Food variable (SIV1, Fig. 1) in this model. Several steps and calculations are necessary to determine an overall HSI for a study area:

1. Compute life requisite values for each cover type by collecting field data for each variable, entering this data into the proper equation, coefficient curve, or suitability curve, and using the resulting index values in the appropriate life requisite equations.

2. The HSI for a cover type equals the lower of the values for Fall to Spring Cover and Winter Food.

3. Determine the weighted HSI score for each cover type by multiplying the area of each cover type by its corresponding HSI value (from 2 above).

4. The overall HSI for a study area is equal to the sum of the weighted HSI scores (from 3 above) divided by the total area of all cover types potentially used by ruffed grouse in the study area.

Application of the Model

Summary of model variables. Seven habitat variables must be sampled to evaluate Fall to Spring Cover for ruffed grouse; one habitat variable is used to evaluate Winter Food (Fig. 5). Definitions of habitat variables and suggested field measurement techniques (Hays et al. 1981) are provided in Figure 6. In order to obtain an HSI for the ruffed grouse using this model, field data for habitat conditions (existing or future) must be measured or estimated and mean habitat characteristics entered into the appropriate equations or suitability curves.

Fall to Spring Cover and Winter Food variables should be measured at the same sampling points. Sampling points should be stratified by cover types or individual timber stands. Stratifying samples by the most homogeneous units possible will provide the greatest accuracy and precision for habitat and HSI estimates. Individual timber stands are likely to be more homogeneous than broad cover types, such as defined by the U.S. Fish and Wildlife Service (1981). If U.S. Fish and Wildlife Service (1981) cover types are used, Forest and Tree Savanna cover types can be subdivided into seedling (stems $\leq$ 2.5 cm dbh), sapling (stems > 2.5 cm to 15.2 cm dbh), and pole/mature (stems > 15.2 cm dbh) classes to create more homogeneous groups. Failure to stratify samples may result in a suitable Fall to Spring Cover rating for unsuitable grouse habitat if structural characteristics of early and late successional forest stands (both unsuitable Fall to Spring Cover) are averaged together, falsely indicating the presence of suitable mid-seral conditions. This can occur because the SI curve for total equivalent stem density (SIV3) is a non-linear response function.

Model assumptions and modifications. The major assumptions in this model are:

1. Winter food and fall to spring cover are the limiting requirements for ruffed grouse populations.

2. Optimal winter food for ruffed grouse is provided by mature male aspens.

3. Vertical cover for ruffed grouse is dependent on growth form, density and height of woody stems.

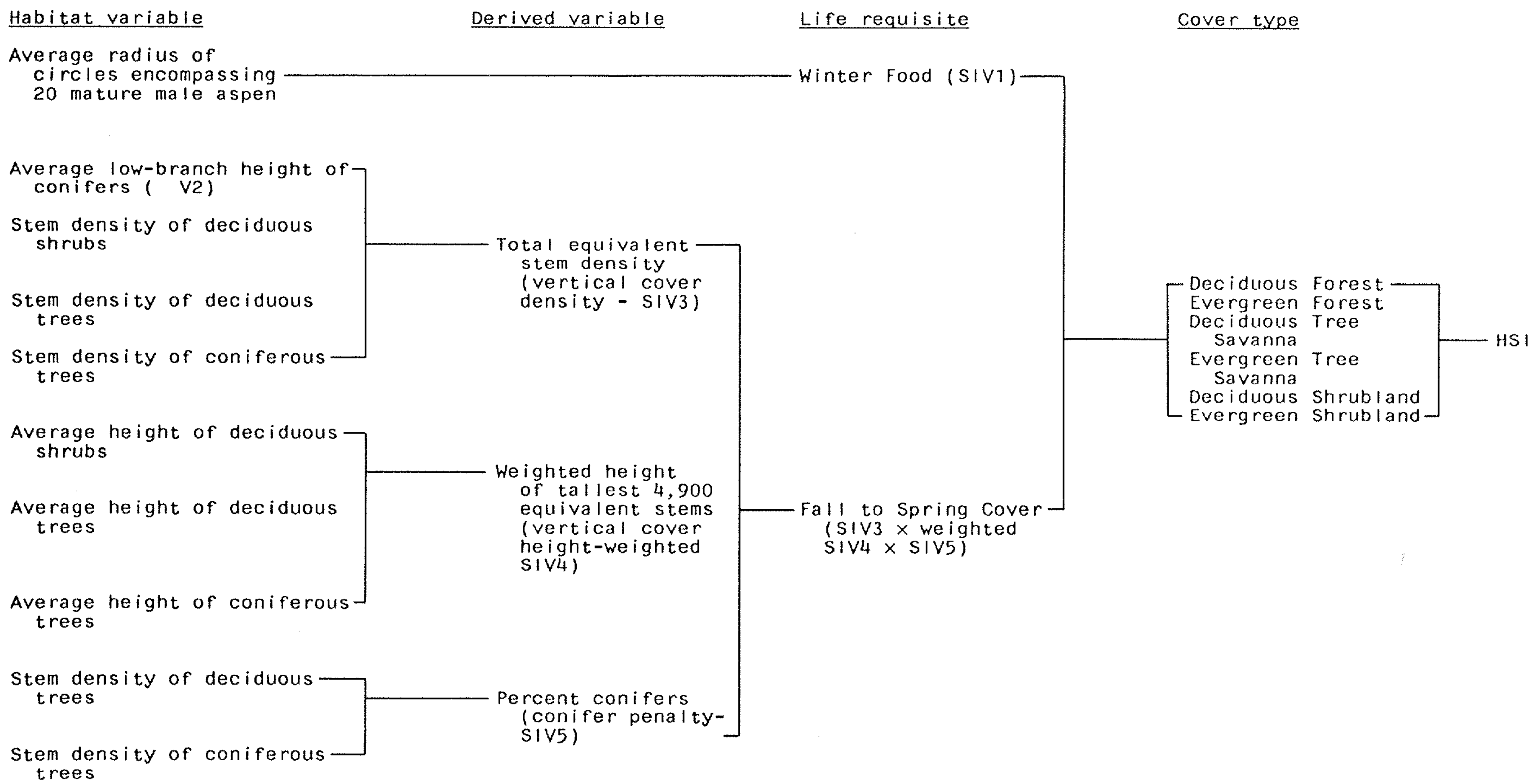

Figure 5. Relationships of habitat variables, derived variables, life requisites, and cover types to the habitat suitability index (HSI) for the ruffed grouse.

Variable (definition)	Cover types	Suggested techniques
The average radius of circles encompassing 20 mature male aspen [staminate flower producing aspen (Gullion 1984a), typically ≥ 25 years of age and 15.2 cm (6 inches) dbh].	DF,EF,DTS, ETS,DS,ES	Tape measure, optical range finder, pacing
Density of deciduous shrub stems [number/ha (2.471 acres) of deciduous woody stems ≥ 0.9 m (3.0 ft) tall growing with multiple, clumped, erect stems emanating from a common base at the ground].	DF,EF,DTS, ETS,DS,ES	Quadrat count [variable sized plots depending upon the relative density of plant growth forms (e.g., 0.004 ha for abundant growth forms and 0.04 ha for scarce growth forms)]
Density of deciduous trees [number/ha (2.471 acres) of deciduous woody stems ≥ 0.9 m (3.0 ft) tall growing with a single, erect stem from the ground].	DF,EF,DTS, ETS,DS,ES	Quadrat count [variable sized plots depending upon the relative density of plant growth forms (e.g., 0.004 ha for abundant growth forms and 0.04 ha for scarce growth forms)]
Density of coniferous trees [number/ha (2.471 acres) of coniferous woody stems ≥ 0.9 m (3.0 ft) tall growing with a single, erect stem from the ground].	DF,EF,DTS, ETS,DS,ES	Quadrat count [variable sized plots depending upon the relative density of plant growth forms (e.g., 0.004 ha for abundant growth forms and 0.04 ha for scarce growth forms)]
Average lowest-branch height above ground (measured to lowest point on bottom of branch) of conifers.	DF,EF,DTS, ETS,DS,ES	Graduated rod
Average height of woody stems (the average vertical distance from the ground to the top of woody stems, measured separately for deciduous shrubs, deciduous trees, and conifers).	DF,EF,DTS, ETS,DS,ES	Graduated rod, trigonometric hypsometry

Figure 6. Definitions of habitat variables and suggested measuring techniques.

4. Conifers provide vertical cover for ruffed grouse, but because they also provide cover for predators that prey upon grouse, the net effect of having conifers in ruffed grouse habitats is a reduction in habitat suitability.

The primary model assumption identifies winter and the spring and fall drumming periods as the limiting seasons for ruffed grouse. A corollary to this assumption is that nesting and brood rearing requirements will never be more limiting than fall to spring requirements. This assumption might be incorrect for ruffed grouse at the southern extreme of their range. Based on observed low juvenile to adult ratios (1:1) during fall, Dimmick (pers. comm.) suggests that nesting or brood rearing requirements limit fall populations of ruffed grouse in Tennessee. This hypothesis has not been substantiated, but users applying this model in the southern Appalachians should proceed with caution. Boag (pers. comm.) suggests that limiting factors change with the abundance of ruffed grouse, and density of the birds during the breeding season, through lack of space per se, is limiting for high density populations of ruffed grouse. It is important to recognize that use of this model for habitat assessment is inappropriate if conditions in the potential application area differ from those assumed limiting in this model.

If a user feels that the primary assumption is valid for an identified application, then the other three major assumptions must be addressed. Modifications of these assumptions and specific assumptions described under each component can be made if the user believes that such modification will better approximate conditions in the intended area of application. Users should be aware that output from modified models will not be directly comparable with other applications employing this model in its unmodified form. However, this has little consequence when a user desires to rank habitat suitability according to availability of habitats within a limited geographical area rather than according to availability on a continent-wide basis.

The second major assumption identifies mature male aspens as optimal winter food for ruffed grouse. The importance of aspens as winter food for ruffed grouse decreases in regions where winter snow cover is nonexistent or of short duration (Gullion and Svoboda 1972). Aspens often are unavailable to ruffed grouse in these regions. Other food items such as sumac, bittersweet, poison ivy, greenbrier, dogwood, and hophornbeam may need to be included in Variable 1 (Fig. 1) for model applications in Ohio, Indiana, and Illinois (Stoll et al. 1980; Stoll pers. comm.). Likewise, mountain laurel, Christmas fern, and honeysuckle may need to be included in Variable 1 for model applications in the southern Appalachian Mountains (Stafford and Dimmick 1979). However, the amount of these food items required to support grouse over winter has not been determined, and users will have to exercise their own discretion when incorporating other food items in the Winter Food variable. Winter food requirements of ruffed grouse in regions where winter-long snow cover does not occur are sufficiently broad that winter food may not be limiting (Gullion 1984b), and Variable 1 can appropriately be deleted from the model for some applications.

The third major assumption identifies density and height of woody stems as important components of vertical cover for ruffed grouse. However, in some ruffed grouse habitats in the southeastern states, vertical cover is provided by an understory of Japanese honeysuckle vines or a branching, evergreen canopy of mountain laurel and/or rhododendron (Rhododendron spp.) (Dimmick pers. comm.). Actual stem densities are low in pole sized timber stands and SIV3, consequently, would indicate unsuitable vertical cover. A vegetation profile board (Hays et al. 1981) may provide a better measure of cover density than stem density in habitats where vines are providing significant vertical cover. Actual calibration of the suitability curve for Variable 3 to reflect percent cover as measured by a vegetation profile board will have to be determined by individual users.

The fourth major assumption identifies conifers as having an overall negative impact on habitat suitability for ruffed grouse, because they provide concealment for predators, especially raptors. Predation on ruffed grouse is not always a significant decimating factor associated with coniferous habitats (Theberge and Gauthier 1982; Chambers pers. comm.; Dimmick pers. comm.; Keppie pers. comm.; Stoll pers. comm.). Furthermore, conifers with low-growing branches (e.g., spruce and firs) may have greater cover value for ruffed grouse than concealment value for raptors and should not be considered as detrimental as "high pine" conifers (Gullion and Marshall 1968; Boag pers. comm.; Chambers pers. comm.). Several modifications of the conifer penalty (SIV5, Fig. 4) are possible to reflect these different assumptions. A user can choose to eliminate the conifer penalty (SIV5) from the HSI equation for Fall to Spring Cover, modify the conifer penalty (Equation 3) to include only certain conifer species or growth forms (e.g., long-needled "high pines"), or modify the conifer penalty to differentially weight the detrimental impacts of conifer species or growth forms (e.g., weight spruce and fir as having 25% of the negative impact of pines).

Conifers provide important thermal cover for ruffed grouse inhabiting regions where winter snow cover is absent [e.g., Missouri (Lewis et al. 1968)] or unsuitable for snow-burrow roosting [e.g., central New York (Woehr 1974)]. Snow-burrow roosting may represent the optimal solution for thermal regulation by ruffed grouse, but wet or crusted snow conditions will prevent snow-burrow roosting (Woehr 1974), increasing winter mortality of grouse (Dorney and Kabat 1960). Roosting in conifers may be the best alternative available to ruffed grouse when snow-burrow roosting is impossible (Woehr 1974). Thus, conifers may actually have an overall positive impact on habitat suitability for ruffed grouse in regions where snow-burrow roosting is limited for extended periods, even though predation losses also are high (Chambers pers. comm.; Keppie pers. comm.). Chambers (pers. comm.) suggested that 15 to 30% conifer cover represents optimal suitability for winter cover in northeastern habitats, with suitability decreasing at either lower or higher percentages of conifers. Several clumps (0.1 to 0.2 ha in size) of conifers provide better cover than either scattered or large, contiguous stands of conifers.

SOURCES OF OTHER MODELS

A dynamic linear model developed by Steinke (1975) attempts to maximize ruffed grouse numbers per unit area by simulating optimal production of the winter food source, i.e., buds of mature male aspens. Maximum theoretical grouse populations were achieved after 40 years by clearcutting and burning hardwood forests to maintain mid-seral stages. Although cover and the interspersion of cover and food were recognized as important factors for ruffed grouse populations, they were not incorporated into Steinke's (1975) model, precluding evaluation of year-round habitat suitability for ruffed grouse.

A pattern recognition (PATREC) model developed for ruffed grouse in southeastern Idaho (Wilson 1983) uses conditional probabilities with Bayes' Theorum to relate habitat patterns to a potential for having high (7.7 grouse/100 ha) and low (0.4 grouse/100 ha) density grouse populations. Probabilities can be converted to indicate the relative number of grouse that a tract of land can potentially support. No explanation was provided as to why the selected variables might be related to habitat suitability and, thus, able to differentiate between habitats supporting high and low density grouse populations. The lack of information relating model variables to habitat requirements of the ruffed grouse will make it difficult to adapt this model for application outside of southeastern Idaho.

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A review and synthesis of existing information were used to develop a Habitat Suitability Index (HSI) model for the ruffed grouse (Bonasa umbellus). The model consolidates 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). HSI models are designed to be used with Habitat Evaluation Procedures previously developed by the U.S. Fish and Wildlife Service.

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