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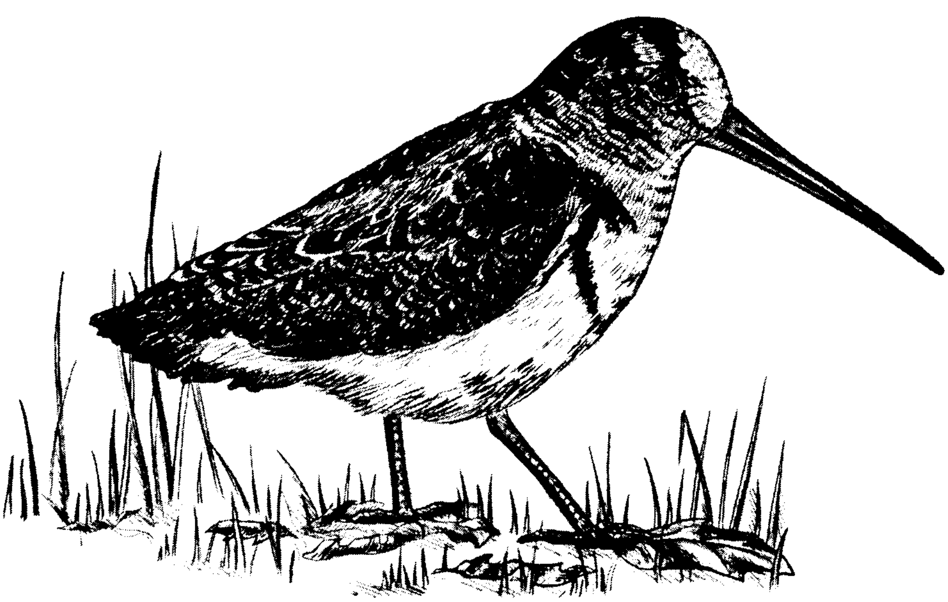
HABITAT SUITABILITY INDEX MODELS: AMERICAN WOODCOCK (WINTERING)



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HABITAT SUITABILITY INDEX MODELS: AMERICAN WOODCOCK (WINTERING)

by

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PREFACE

This document is part of the Habitat Suitability Index (HSI) Model Series [Biological Report 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. This information provides the foundation for the HSI model and may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

The HSI Model Section documents the habitat model and includes 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 HSI Model Section includes information about the geographic range and seasonal application of the model, its current verification status, and a list of the model variables with recommended measurement techniques for each variable.

The model is a formalized synthesis of biological and habitat information published in the scientific literature and may include unpublished information reflecting the opinions of identified experts. Habitat information about wildlife species frequently is represented by scattered data sets collected during different seasons and years and from different sites throughout the range of a species. The model presents this broad data base in a formal, logical, and simplified manner. The assumptions necessary for organizing and synthesizing the species-habitat information into the model are discussed. The model should be regarded as a hypothesis of species-habitat relationships and not as a statement of proven cause and effect relationships. The model may have merit in planning wildlife habitat research studies about a species, as well as in providing an estimate of the relative suitability of habitat for that species. User feedback concerning model improvements and other suggestions that may increase the utility and effectiveness of this habitat-based approach to fish and wildlife planning are encouraged. Please send suggestions to:

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CONTENTS

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AMERICAN WOODCOCK (*Scolopax minor*)

HABITAT USE INFORMATION

General

The breeding range of the American woodcock (*Scolopax minor*) extends "... from southern Manitoba, northern Minnesota, south-central and southern Ontario, southern Quebec, northern New Brunswick, Prince Edward Island, Nova Scotia, and Newfoundland, south throughout eastern North America to southeastern Minnesota, central Iowa, eastern Kansas (probably also the eastern Dakotas and eastern Nebraska), eastern Oklahoma, east-central Texas, and south to the Gulf States and southern Florida (American Ornithologists' Union 1983:206). Woodcock winter in the southern portion of their breeding range from eastern Oklahoma and Texas across Louisiana, Alabama, and Georgia to southern Florida, extending as far north as southern Missouri, Tennessee, and Virginia. Although taxonomically classified as a shorebird (Charadriiformes), the American woodcock inhabits upland and lowland forests, as well as open areas (Edminster 1954; Liscinsky 1972).

Two populations of woodcock with different migration corridors are recognized (Martin et al. 1969; Coon et al. 1977; Krohn and Clark 1977). The Eastern population breeds in New England and the Maritime Provinces of Canada and winters in the South Atlantic States (Krohn and Clark 1977). The Central population breeds in the Great Lakes States and Canadian Provinces and winters in the Gulf States. Some mixing of populations occurs. Three-fourths of woodcock on Louisiana winter grounds were produced on breeding grounds west of the Appalachian Mountains, principally in Michigan and Wisconsin, and the rest were produced east of the Appalachian Mountains (Martin et al. 1969). Woodcock breeding in eastern Maine winter in a broad area from southern Virginia to northern Florida, but a few winter as far west as Louisiana and eastern Texas (Krohn and Clark 1977). A more extensive analysis by Coon et al. (1977) confirmed results of the previous studies.

The model presented in this report (see pp. 9-19) is intended for application on the winter range of woodcock. Because there are similarities in foods and habitats used by woodcock on breeding and winter range, habitat use information is presented for their entire range.

Food

The annual diet of woodcock is comprised of 90 to 94% animal material and 6 to 10% plant seeds (Edminster 1954). Earthworms (Lumbricidae) obtained by probing in moist soils are the primary animal food (Pettingill 1936, 1939; Edminster 1954; Sheldon 1961; Krohn 1970; Liscinsky 1972; Krohn et al. 1977; Reynolds 1977; Miller and Causey 1985; Stribling and Doerr 1985), constituting 30 (Sheldon 1961) to 100% (Stribling and Doerr 1985) of the total food volume. Other animal foods consumed include beetle (Coleoptera), fly (Diptera), and butterfly and moth (Lepidoptera) larvae (Edminster 1954; Sheldon 1961; Krohn 1970). The diurnal diet of woodcock wintering in Alabama was comprised of 63% earthworms, 16% centipedes (Chilopoda), 8% beetles, 6% fly larvae, 4% unknown insect parts, and 3% miscellaneous animal material, based on total volume of stomach contents (Miller and Causey 1985). Nocturnal foraging in agricultural fields in North Carolina was exclusively for earthworms, 99% of which were *Aporrectodea* spp. and *Diplocardia* spp. (Stribling and Doerr 1985). The food consumed by juveniles does not differ from that consumed by adults although insects occurring in the litter layer may be important to juveniles during the first 3 weeks after hatching (Wenstrom 1973). Woodcock probably ingest most plant seeds accidentally while feeding on animal foods or as an item occurring in the digestive tract of earthworms (Pettingill 1939).

Stomachs collected from woodcock in Maine contained four species of earthworms: *Aporrectodea tuberculata*, *Dendrobaena octaedra*, *Lumbricus rubellus*, and *Dendrodrilus rubidus* (Reynolds 1977). Together, these species constituted 45% of all earthworms available (Formalin extraction sampling) in diurnal feeding habitats (Reynolds et al. 1977). Night crawlers (*Lumbricus terrestris*) were 38% of the earthworms present in diurnal feeding habitats (Reynolds et al. 1977), but were not available to foraging woodcock because they remained deep in their burrows during the day (Reynolds 1977). Diurnal feeding habitats heavily used by woodcock contained a mean (±1 standard error) of 56 (±4) earthworms/m^2 with a biomass of 18.2 (±1.6) g/m^2, commonly used habitats averaged 48 (±4) earthworms/m^2 with a biomass of 15.4 (±1.6) g/m^2, and habitats rarely used averaged 24 (±4) earthworms/m^2 with a biomass of 7.8 (±1.2) g/m^2 (Reynolds et al. 1977). Diurnal habitats with the greatest abundance of earthworms and greatest use by woodcock were young second-growth hardwoods, whereas habitats with few earthworms and little use by woodcock were coniferous or mixed forests.

Woodcock in Pennsylvania made greatest use of aspen (*Populus* spp.) and alder (*Alnus* spp.) stands with highest densities of earthworms (Liscinsky 1972). Average earthworm densities (potassium permanganate extraction sampling) in alder were 71.6/m^2 in heavily used, 40.8/m^2 in moderately used, and 6.8/m^2 in lightly used stands. Average earthworm densities in aspen were 24.8/m^2 in heavily used, 6.0/m^2 in moderately used, 3.2/m^2 in lightly used, and 0.0/m^2 in unused stands. Radio-marked female woodcock in northeastern Minnesota preferred areas within occupied stands that had greater ($P < 0.05$ for 7 of 10 comparisons) biomass of earthworms (Formalin extraction sampling) (Morgenweck 1977). High-use areas within seven stands had mean earthworm biomasses ranging from 7.8 to 23.0 g/m^2, whereas means for the stands ranged from 2.2 to 11.2 g/m^2. Means for high-use areas within three stands that did not differ from means for the stands ranged from 4.4 to 9.3 g/m^2.

Woodcock feed primarily during the day (Sheldon 1967; Krohn 1970; Dunford and Owen 1973; Dyer 1976; Boggus and Whiting 1982), but also feed at night during migration (Krohn et al. 1977; Connors and Doerr 1982) and on wintering grounds (Ensminger 1954; Glasgow 1958; Britt 1971; Stribling and Doerr 1985). Large damp fields with sparse ground cover and some overhead shrub cover were used by woodcock for nocturnal feeding on wintering grounds in Louisiana (Glasgow 1958; Britt 1971). Ensminger (1954) found that earthworms were equally abundant in fields used and avoided by woodcock in Louisiana. Dyer (1976), Boggus and Whiting (1982), and Johnson and Causey (1982) suggest that vegetative cover may be more important than food availability in determining diurnal habitat use on wintering grounds.

Woodcock used agricultural fields in North Carolina for nocturnal feeding during migration (Connors and Doerr 1982) and during winter (Stribling and Doerr 1985). Soybean (Glycine max) fields were preferred feeding areas during winter, but there was no difference ($P > 0.05$) among wet weight earthworm biomasses (sampled by digging and sorting) in soybean fields (2.56 g/m^2 x 0.075 m depth), disked corn (Zea mays) fields (2.72 g/m^2 x 0.075 m depth) and winter wheat (Triticum spp.) fields (1.12 g/m^2 x 0.075 m depth). Woodcock wintering in Alabama fed on earthworms (75% dry weight in esophagus and proventriculus) in proportion to their occurrence at feeding sites (74% dry weight) in diurnal habitats (sampled by digging and sorting) (Miller and Causey 1985). Food items ranked from most to least preferred were scarab beetle larvae (Scarabeidae), diplurans (Diplura), scolopendrid centipedes (Scolopendromorpha), elaterid beetle larvae (Elateridae), earthworms, lithobid centipedes (Lithobiomorpha), geophilid centipedes (Geophilomorpha), ants (Formicidae), fly larvae, and miscellaneous beetle larvae. All orders were significantly more preferred (Waller-Duncan K - ratio t test, K = 100) than the miscellaneous beetle larvae. Scarab beetle larvae, diplurans, and scolopendrid centipedes were significantly more preferred than lithobid centipedes, earthworms, geophilid centipedes, ants, and fly larvae.

Earthworm abundance is dependent on suitable soil conditions and vegetative food (Edwards and Lofty 1977; Reynolds et al. 1977). Soil moisture and temperature are two of the most critical soil properties affecting earthworm abundance (Reynolds and Jordan 1975). Earthworms require a moist soil environment for maximum growth, activity, and reproduction (Edwards and Lofty 1977). They exhibit a greater tolerance for low than high temperatures and high than low moisture. Soils with temperatures of 10 to 18°C and moisture of 15 to 80% were considered optimal for earthworm activity in woodcock breeding habitats in Maine, containing 85% of the sampled biomass of active earthworms (Reynolds et al. 1977). At other study areas in Maine, Galbraith (1984) found 92% of the sampled biomass of earthworms occurred in soils within the optimal temperature and moisture ranges defined by Reynolds et al. (1977).

When soil moisture or temperature temporarily becomes unsuitable, earthworms either estivate in a mucous cocoon or migrate deeper into the soil profile where more suitable soil conditions exist (Edwards and Lofty 1977). Either action effectively makes them unavailable to foraging woodcock (Reynolds et al. 1977; Rabe, Prince, and Goodman 1983; Galbraith 1984). The distribution of woodcock among habitats will change in response to changes in earthworm availability (Britt 1971; Wenstrom 1973; Boggus and Whiting 1982). Rabe, Prince, and Goodman (1983) developed a bioenergetics model using soil moisture and temperature to successfully predict (maximum 6% deviation of predicted from observed biomasses) earthworm availability in aspen stands occupied by breeding woodcock. Earthworm biomass increased from a low in April to a maximum during May through June, decreased from June to August, and increased again during September; maximum biomass (108 g/m²) of available earthworms during May through June coincided with maximum energetic requirements of woodcock during brood rearing. A laboratory experiment conducted by Rabe, Prince, and Beaver (1983) suggests that dark soil color may be the proximal cue used by woodcock to locate moist soils where availability of earthworms is greatest.

Suitable soil moisture conditions for earthworms are likely to be maintained in loam rather than sand, silt, or clay textured soils (Guild 1948 cited by Edwards and Lofty 1977; Liscinsky 1972; Reynolds and Jordan 1975; Galbraith 1984). Loam soils have an optimal mix of coarse sand and fine silt and clay particles that provide suitable soil moisture tension for transport of water molecules across earthworm membranes (Reynolds and Jordan 1975). Clay soils have higher moisture tension, requiring a high percentage of moisture to facilitate water transport for earthworms. Sandy soils have lower moisture tension, requiring lower percent moisture than clay soils to facilitate water transport for earthworms but having poor moisture holding capacities compared to loams. Guild (1948 cited by Edwards and Lofty 1977) ranked various soils in Scotland according to earthworm biomasses: light loams > medium loams = clay = alluvium > gravelly sand. Soils in Maine ranked from highest to lowest earthworm biomass were moderately well drained loam to fine sandy loam (39.1 g/m²), excessively well drained fine sandy loam to sandy loam (27.3 g/m²), and poorly drained silt loam to loam (16.0 g/m²) (Galbraith 1984). Moderately well drained loams and fine sandy loams maintained greater biomasses of earthworms throughout the summer than did other soil types.

Palatability of vegetative food available to earthworms also affects their abundance (Liscinsky 1972; Reynolds and Jordan 1975; Reynolds et al. 1977; Galbraith 1984). Leaf palatability for earthworms in Maine was ranked as alder = aspen > birch (*Betula* spp.) = maple (*Acer* spp.) = cherry (*Prunus* spp.) = elm (*Ulmus* spp.) > conifers (*Abies* and *Pinus* spp.) (Reynolds *et al.* 1977). On the northern breeding range of woodcock, highest biomasses of earthworms were observed in alder and aspen habitats and lowest biomasses in coniferous habitats (Liscinsky 1972; Morgenweck and Marshall 1982; Galbraith 1984). Although Galbraith (1984) observed lowest biomasses of earthworms in conifer forests, he noted that conifer forests in areas previously farmed contained earthworm biomasses (20.1 g/m²) comparable to those observed by Reynolds et al. (1977) in deciduous habitats classified as commonly used by woodcock. Furthermore, conifer forests and pine plantations were used by foraging woodcock on winter range (Boggus and Whiting 1982; Johnson and Causey 1982). A palatability ranking of plant species has not been documented for earthworms occurring in soils in southeastern states, but some species of shallow-working earthworms apparently thrive under pine forests (Fayle 1961).

The ability of woodcock to forage effectively for earthworms is limited by density of ground cover. Sparse ground cover facilitates mobility and bill probing by woodcock (Ensminger 1954; Liscinsky 1972; Godfrey 1974; Boggus and

Whiting 1982; Johnson and Causey 1982). Unvegetated ground surface area in diurnal habitats averaged 56% in Maine (Dunford and Owen 1973), ranged from 35 to 67% in Michigan (Rabe 1977), ranged from 31 to 60% in Alabama (Horton and Causey 1979), and averaged 87 ± 11% in good diurnal habitats in southwestern Quebec (Wishart and Bider 1976).

Water

It is likely that most of the metabolic water requirements of woodcock are provided by their food (Mendall and Aldous 1943), but captive birds have been observed to drink by sucking water with their bills (Sheldon 1967).

Cover

The diurnal cover requirements of woodcock are met by a variety of plant associations depending on geographic location. Second-growth hardwood forests, especially those with aspen or alder, or mixed hardwood and conifer forests provide suitable cover on northern breeding grounds (Liscinsky 1972; Dunford and Owen 1973; Wenstrom 1973; Godfrey 1974; Wishart and Bider 1976; Rabe 1977). Diurnal cover on southern wintering grounds occurs in bottomland hardwood forests (Dyer 1976; Horton and Causey 1979), hardwood thickets (Glasgow 1958), upland forests of mixed hardwoods and pine (Kroll and Whiting 1977; Horton and Causey 1979; Boggus and Whiting 1982), and upland longleaf pine (*Pinus palustris*) plantations (Johnson and Causey 1982).

Diurnal cover preferred by woodcock on breeding (Wenstrom 1973; Morgenweck 1977; Rabe 1977) and winter range (Kroll and Whiting 1977; Horton and Causey 1979) includes a wide range of structural types, with very open or very dense habitats least preferred or unused. Rabe (1977) speculated that very dense habitats may inhibit woodcock flight or increase predation potential, and very open habitats may not provide adequate concealment for woodcock. Shrub and tree overstories affect the density of ground cover and soil characteristics determining abundance of earthworms, e.g., soil moisture, soil texture, vegetation palatability (Reynolds et al. 1977; Galbraith 1984). Shrub and tree cover, thus, indirectly influence the availability of earthworms to woodcock foraging in diurnal habitats. Suitability of food and diurnal cover are closely interrelated.

Forest habitats in northeastern Minnesota with the greatest frequency of use by radio-marked female woodcock had tree (> 10.0 cm dbh) densities ranging from 123 to 617 stems/ha, sapling (2.5 to 10.0 cm dbh) densities with a range similar to tree densities, and shrub (< 2.5 cm dbh) densities ranging from 12,597 to 86,450/ha (Wenstrom 1973). Working at the same area as Wenstrom (1973), Morgenweck (1977) found radio-marked female woodcock preferred to use areas within occupied stands that had greater ($P < 0.05$ for 8 of 10 comparisons) stem densities of shrubs (> 46 cm height and < 5.0 cm dbh). Mean densities of shrubs at high-use areas within eight stands ranged from 95,000 to 271,000/ha, whereas mean densities for the stands ranged from 40,000 to 103,000/ha. A structural analysis of diurnal habitat in northern Michigan indicated that woodcock preferred an intermediate range of understory densities, including sapling, shrub, and ground cover (Rabe 1977). Mean sapling (2.5 to 7.6 cm dbh) densities ranged from 1,850 to 12,280 stems/ha, mean shrub (> 45 cm height and < 2.5 cm dbh) densities ranged from 7,432 to 13,799/ha, and mean percent ground cover ranged from 33 to 65%. Mean tree densities ranged from 50 to 890/ha.

Bottomland hardwood and mixed hardwood-pine forests were preferred diurnal habitats for woodcock wintering in central Alabama; hardwood sapling and 21 to 23-year-old pine plantations were least preferred (Horton and Causey 1979). Total stem densities in bottomland hardwood (6,422/ha) and mixed hardwood-pine (8,440/ha) forests were intermediate in value compared to total stem densities for hardwood saplings (13,511/ha) and 21 to 23-year-old pine plantations (2,915/ha), suggesting that woodcock least preferred extremely dense or open diurnal habitats. Mean tree (≥ 10.0 cm dbh) densities were 741/ha in both bottomland hardwood and mixed hardwood-pine forests; mean sapling (2.5 to 10.0 cm dbh) densities were 1,976 and 2,463 stems/ha for bottomland hardwoods and mixed hardwood-pine, respectively; and mean shrub (> 61.0 cm height and < 2.5 cm dbh) densities were 3,705 and 5,236/ha for bottomland hardwoods and mixed hardwood-pines, respectively. The two least preferred habitats, hardwood saplings and 21 to 23-year-old pine plantations, had mean tree densities of 247 and 741/ha, mean sapling densities of 3,384 and 988/ha, and mean shrub densities of 9,880 and 1,186/ha.

Diurnal habitats occupied by woodcock wintering in east Texas included a 2-year-old clearcut planted with loblolly (P. taeda) and shortleaf (P. echinata) pines (2.5 woodcock/ha), a pole size mixed pine-hardwood stand (1.7 woodcock/ha), and a saw timber size mixed pine-hardwood stand (0.6 woodcock/ha) (Kroll and Whiting 1977). A discriminant function analysis indicated that the habitats occupied by woodcock, considered collectively, differed from similar unoccupied habitats by having greater basal area of pines, closer openings, less dense mid- and understory vegetation, sandy soils, greater percentage of soil organic material, and higher concentrations of potassium and zinc in the soils. Basal area of pines made the greatest contribution to the discriminant function and averaged 9.5 m^2/ha in the occupied pole and saw timber stands and 4.6 m^2/ha in the unoccupied stands.

Nocturnal habitats used by woodcock on northern breeding grounds included open pastures, abandoned agricultural fields, clearcut hardwood stands, and Christmas tree plantations (Sheldon 1967; Dunford and Owen 1973; Godfrey 1974; Owen and Morgan 1975; Hale and Gregg 1976; Wishart and Bider 1976, 1977). Openings used as nocturnal cover in Quebec averaged 0.4 ha and had 4 to 30% canopy coverage of woody vegetation ≥ 0.9 m in height but ≤ 8% canopy coverage of woody vegetation ≥ 4.6 m in height (Wishart and Bider 1976). Little feeding occurred in open nocturnal habitats on northern breeding grounds (Krohn 1970; Dunford and Owen 1973; Owen and Morgan 1975; Wishart and Bider 1977), and some woodcock remained in forests (diurnal cover) during the night (Wishart and Bider 1977). On wintering grounds in central Alabama, 44% of nocturnal locations for radio-marked woodcock were in open areas (nocturnal habitat) and 56% were in forested habitats (diurnal habitat) (Horton and Causey 1979). Woodcock roosted and performed courtship displays in nocturnal habitats on breeding grounds (Dunford and Owen 1973) but also foraged in nocturnal habitats on wintering grounds (Ensminger 1954; Glasgow 1958; Britt 1971; Stribling and Doerr 1985). Woodcock wintering in North Carolina preferred cutover soybean fields for nocturnal foraging (Connors and Doerr 1982; Stribling and Doerr 1985). The ridge/furrow complex associated with cutover soybean fields provided greater protective cover from wind than disked corn or winter wheat fields.

Reproduction

Male courtship displays occur on "singing grounds" which are open areas in early successional stages of plant development (Sheldon 1967; Liscinsky 1972; Kinsley et al. 1982). Openings used as singing sites in Quebec averaged 0.4 ha (Wishart and Bider 1976), but areas as small as 9.2 m^2 (Sheldon 1967) or as large as 40.5 ha (Owen et al. 1977) are used. "Singing grounds" are used as nocturnal roosting sites during summer (Dunford and Owen 1973).

Canopy coverage of woody plants on singing grounds in Massachusetts ranged from 10 to 90% (Maxfield 1961). Singing sites in Pennsylvania with the greatest frequency of use by woodcock had lower height of vegetation at edges of openings, higher densities of shrubs, and smaller openings than singing sites with little use (Gutzwiller and Wakely 1982). Sixteen of 42 structural characteristics measured at singing grounds did not differ significantly between two areas in Pennsylvania, including median small tree densities of 240/ha, median tree densities of 250/ha, and median shrub densities of 4,320/ha (Gutzwiller et al. 1983). Occupied singing grounds in Pennsylvania were in young stands averaging 11 years of age with a mean canopy height of 3.4 m and mean tree densities of 1,334/ha (Kinsley et al. 1982).

Characteristics of singing grounds in southern States are poorly documented. Woodcock in east Texas displayed in grassy and brush openings in 1 to 7-year-old pine plantations (Whiting and Boggus 1982). Singing sites preferred by woodcock in north-central Oklahoma were sparsely vegetated, on moderate slopes, and close to water and diurnal cover (Lambert and Barclay 1975).

Woodcock nest on the ground (Sheldon 1967; Liscinsky 1972) in a wide variety of cover types (Roboski and Causey 1981; Coon et al. 1982). Nests in Pennsylvania were usually located near edges, trees, or shrubs, but little preference relative to available habitat was apparent (Coon et al. 1982). Brushy edges of poorly stocked pole timber stands were preferred nesting cover in Wisconsin; 29 of 32 nests located were in aspen, the others in northern hardwoods (Gregg and Hale 1977). Nests located in Alabama were in open-grown, intermediate aged pole timber or maturing saw timber; 61% were in mixed pine/hardwoods, 17% in hardwoods, 13% in pines, and 9% in openings (Roboski and Causey 1981). Second-growth forest stands on dry, well drained sites were used for nesting in northern lower Michigan (Bourgeois 1977). Broods used denser forests with wetter soils. Broods in northeastern Minnesota shifted from upland to lowland sites coincident with a decline in soil moisture on the uplands (Wenstrom 1973).

Interspersion and Movements

Woodcock migrate between northern breeding and southern wintering grounds (Glasgow 1958; Sheldon 1967). They arrive on northern breeding grounds from mid-March to April (Sheldon 1967; Marshall 1982). The fall migration from breeding grounds in Canada begins in late September and continues until mid-December when woodcock arrive on southern wintering grounds (Owen et al. 1977). Most woodcock leave Minnesota by early November (Marshall 1982); they leave Pennsylvania between 30 November and 8 December (Coon et al. 1976). Woodcock arrive on wintering grounds in Louisiana as early as late October, with maximum numbers arriving in December (Glasgow 1958; Martin et al. 1969). Louisiana wintering grounds are occupied by woodcock from November through February (Martin et al. 1969).

Areas occupied by woodcock on the breeding range were composed of several small activity centers connected by flight paths and averaged 6.0 ha (Godfrey 1974). Diel (24-hour) centers averaged 0.25 ha, diurnal centers averaged 0.10 ha, and nocturnal centers were < 0.01 ha. Woodcock wintering in Alabama occupied diurnal areas ranging from 1.1 to 22.5 ha, total diurnal and nocturnal areas from 6.5 to 24.3 ha, and had activity centers (67% of all locations) of 0.4 to 5.7 ha (Horton and Causey 1979). Broods in Minnesota occupied areas of 6.1 to 6.7 ha with greatest use concentrated in only 2.2 ha (Wenstrom 1973).

Distances between diurnal cover and singing grounds averaged 92 m in Pennsylvania (Kinsley et al. 1982) and ranged from 0 to 182 m in Massachusetts (Maxfield 1961). Juvenile woodcock in Maine traveled a mean distance of 332 ± 78 m between diurnal and nocturnal cover (Dunford and Owen 1973). Woodcock broods will fly 1 to 3 km from nesting cover to openings used for nocturnal cover. Adult woodcock traveled a mean distance of 170 ± 17 m between diurnal and nocturnal cover in Maine (Owen and Morgan 1975). Distances from the mid-point of diurnal activity centers to the nearest known opening (nocturnal habitat) ranged from 30 to 121 m ($\bar{x}$ = 65 m) on winter range in Alabama (Horton and Causey 1979).

<u>Special Considerations</u>

Some forestry and agricultural practices can have a beneficial effect on woodcock habitat. Cutover aspen areas in Wisconsin with exposed mineral soil are used as roosting and feeding areas (Hale and Gregg 1976). Prescribed burning in longleaf pine stands creates suitable habitat for woodcock by reducing vegetative ground cover (Johnson and Causey 1982). Openings for singing grounds can be created by cutting small blocks of forest (Sepik et al. 1977). However, drainage of wetlands may lower the water table in otherwise suitable habitat, adversely reducing the earthworm food source for woodcock (Sheldon 1967). Woodcock are susceptible to pesticide contamination, because earthworms concentrate residues from pesticides such as DDT and heptachlor (Stickel et al. 1965). A diet of earthworms containing 3 ppm heptachlor residues is fatal to woodcock.

The American woodcock is included on the list of National Species of Special Emphasis (U.S. Fish and Wildlife Service 1982). Species of special emphasis are: "Those fish, wildlife, and plant species of special biological, legal, or public interest, upon which U.S. Fish and Wildlife Service effort and attention is focussed."

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographical area. This model was developed for application on woodcock winter range within the southern United States, including Virginia, North and South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, Arkansas, Tennessee, eastern Texas, and eastern Oklahoma.

Season. This model is designed to evaluate the diurnal habitat requirements of woodcock during winter (November through February). It also may be applicable for evaluating diurnal habitat on breeding range. However, the interspersion of suitable nocturnal (courtship) and diurnal habitat may be limiting for woodcock on their breeding range (Owen pers. comm.), and this relationship is not addressed with this model.

Cover types. This model was developed to evaluate habitat suitability in the following deciduous and coniferous cover types (terminology follows U.S. Fish and Wildlife Service 1981): Forest (F); Shrubland (S); Tree Savanna (TS); Shrub Savanna (SS); Forested Wetland (FW); and Scrub/Shrub Wetland (SW).

Minimum habitat area. Minimum habitat area is defined as the minimum amount of contiguous suitable habitat required before an area will be occupied by a particular species. This information was not found in the literature for woodcock. However, the smallest diurnal home range for woodcock in Alabama was 1.1 ha (Horton and Causey 1979). Therefore, this model should not be applied on an area < 1.0 ha.

Verification level. Most of the model variables and relationships used in the woodcock HSI model were developed at a workshop conducted by P. J. Sousa (Habitat Evaluation Procedures Group, U.S. Fish and Wildl. Serv., Fort Collins, CO) in Georgetown, South Carolina on 20 and 21 October 1983. The following individuals provided assistance at the workshop and reviewed earlier drafts of the model:

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Specific comments from reviewers are incorporated in the current model and referenced as personal communications.

Model Description

Overview. Woodcock occupy nocturnal and diurnal habitats on wintering grounds. Open areas used for nocturnal roosting also are used for feeding. However, all woodcock do not use open areas at night (Wishart and Bider 1977; Horton and Causey 1979). Causey (pers. comm.), Marshall (pers. comm.), Morgenweck (pers. comm.), Owen (pers. comm.), Prince (pers. comm.), Whiting (pers. comm.), and Wood (pers. comm.) suggest that diurnal habitat typically is more limiting than open nocturnal habitat. However, male woodcock begin courtship activities on winter range in January or February, using open nocturnal habitats for courtship displays (Whiting pers. comm.). The importance of "singing grounds" on winter range has not been determined for woodcock populations. This model assumes that suitable open areas for nocturnal habitat are not limiting for woodcock during winter. Suitability of diurnal habitat is determined by vegetative structure and soil characteristics as they relate to food availability (Causey pers. comm.; Krohn pers. comm.; Marshall pers. comm.; Morgenweck pers. comm.; Owen pers. comm.; Prince pers. comm.; Whiting pers. comm.). The life requisites included in this model, Food and Cover, are assumed to be the same for male and female woodcock.

Food component. Although woodcock feed on a variety of invertebrates, earthworms are their principal food (Miller and Causey 1985). Suitability of food within a cover type is a function of earthworm availability. Vegetative cover characteristics (discussed under cover component, p. 13) indirectly affect food availability by influencing abundance of earthworms and density of ground cover that may inhibit foraging by woodcock (Reynolds et al. 1977; Galbraith 1984; Causey pers. comm.; Krohn pers. comm.). This model assumes habitats that provide suitable availability of earthworms also provide suitable availability of other soil invertebrates.

Earthworm availability is dependent on the abundance of active (non-estivating) earthworms in the upper soil layer. It is assumed that inactive (estivating) earthworms and those occurring > 10 cm deep are unavailable to foraging woodcock (Reynolds et al. 1977; Rabe, Prince, and Goodman 1983; Galbraith 1984). Availability of earthworms to woodcock can be predicted from soil texture and drainage classes (Galbraith 1984; Owen pers. comm.; Morgenweck pers. comm.; Whiting pers. comm.), because soil moisture and texture are primary determinants of soil moisture tension which affects abundance of active earthworms (Reynolds and Jordan 1975). Increasing proportions of small soil particles and increasing percent moisture increases soil moisture tension.

Well drained loam soils have optimal soil moisture tension for earthworms (Reynolds and Jordan 1975), providing the greatest abundance of earthworms (Guild 1948 cited by Edwards and Lofty 1977; Liscinsky 1972; Galbraith 1984) and optimal suitability for earthworm availability to woodcock (Fig. 1). Sand and clay soils have poor soil moisture tension for earthworms (Reynolds and Jordan 1975), providing few earthworms and unsuitable earthworm availability to woodcock. Well drained loamy sand, silt, sandy clay, and silty clay soils are assumed to have suboptimal suitability. Lower moisture levels associated with excessively drained soils reduce suitability to a greater extent than the higher moisture levels associated with poorly drained soils, because earthworms have greater tolerance for high than low moisture levels (Edwards and Lofty 1977). Furthermore, poorly drained loamy sand, silt, sandy clay, and silty clay soils have greater suitability than their well drained counterparts, because the higher moisture levels partially compensate for the suboptimal texture.

Availability of earthworms to foraging woodcock also is determined by density of ground cover, including stems and leaves of live vegetation and woody downfall. Dense ground cover limits woodcock mobility and restricts their ability to probe for worms. Optimal foraging conditions are assumed to exist when canopy coverage of vegetation and downfall ≤ 30 cm above ground is ≤ 50% (Causey pers. comm.; Owen pers. comm.; Prince pers. comm.; Whiting pers. comm.). Suitability declines as percent canopy coverage increases to > 50%, and when canopy coverage is ≥ 80%, earthworms are assumed to be unavailable to woodcock (Fig. 2).

Unsuitable (i.e., an index of 0.0) soil conditions for earthworms (SIV1; Fig. 1) or percent canopy coverage of ground cover (SIV2; Fig. 2) will result in an unsuitable food suitability index (FSI) value, and any suitability value for soil conditions should be lowered by suboptimal (i.e., an index < 1.0) values for ground cover. This relationship is the same for all cover types and can be depicted by equation 1:

$$FSI = SIV1 \times SIV2 \tag{1}$$

DRAINAGE CLASS	Sand	Loamy sand	Sandy loam	Loam	Silty loam	Silt	Sandy clay loam	Clay loam	Silty clay loam	Sandy clay	Silty clay	Clay
Excessively drained (dry)	0.0	0.2	0.6	0.6	0.6	0.0	0.6	0.6	0.6	0.2	0.0	0.0
Well drained (moist)	0.0	0.4	1.0	1.0	1.0	0.2	1.0	1.0	1.0	0.4	0.2	0.0
Poorly drained (wet)	0.0	0.6	0.8	0.8	0.8	0.4	0.8	0.8	0.8	0.6	0.4	0.0

TEXTURE CLASS

Figure 1. Relationship between suitability indices for earthworm availability and soil drainage and textural classes.

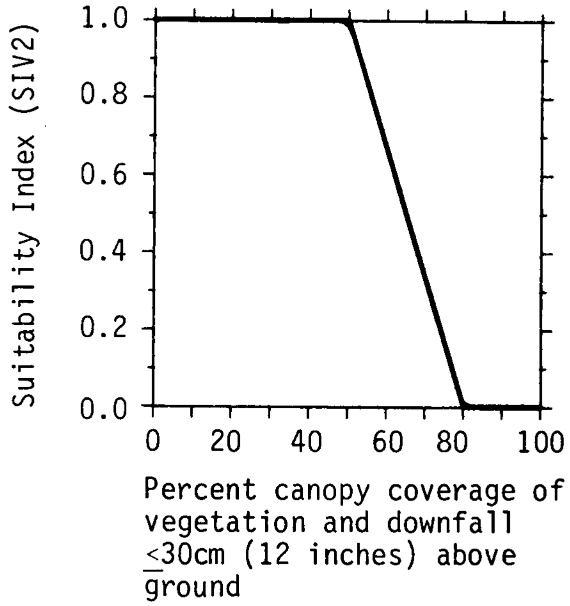

Figure 2. Relationship between suitability indices for earthworm availability and canopy coverage of vegetation and downfall.

Cover component. Suitability of diurnal cover in forested cover types is a function of the structural cover provided by the understory of tall grasses, forbs, and shrubs (woody stems < 5.0 m in height) and the overstory of trees (woody stems ≥ 5.0 m in height). Understory and overstory cover have compensatory relationships that are described below. When tree densities are ≥ 2,000/ha, a minimum of 25% herbaceous and shrub canopy cover is required to provide an optimal diurnal cover suitability index (CSI). Maximum suitability of cover contributed by trees (0.5) is assumed to be only one-half (Fig.3a) the maximum suitability contributed by understory vegetation (Fig. 3b), because tree stems provide less low cover than the stems, leaves, and branches of shrubs and herbs. When tree densities decrease from 2,000 to 500/ha, the minimum canopy coverage of herbs and shrubs required to provide optimal cover suitability increases from 25 to 50%. When tree densities are ≤ 500/ha, canopy coverage of herbs and shrubs required to provide optimal cover suitability is ≥ 50%; cover suitability is dependent only on understory vegetation and decreases from optimal to unsuitable when herbaceous and shrub canopy coverage decreases from 50 to 0%. These relationships apply only to forested cover types (F, FW, and TS) and can be depicted by equation 2:

$$CSI = SIV3 + SIV4 \text{ (to a maximum value of 1.0)} \qquad (2)$$

Suitability of diurnal cover in shrubland cover types is a function of the suitability of herbaceous and shrub crown cover (SIV3) and suitability of average height of the shrub canopy (SIV5). Shrub canopy height is an important component of cover value in shrubland cover types where overhead cover is not provided by trees. Shrub canopy heights ≥ 3.0 m are assumed to be optimal and shrub canopy heights ≤ 0.5 m provide no cover value (Fig. 3c). Suboptimal suitability for herbaceous and shrub crown cover (SIV3) or canopy height of shrubs (SIV5) in a shrubland cover type results in suboptimal cover value, and cover value is unsuitable if either variable is unsuitable. It is assumed that cover value in shrubland cover types increases as suitability of either crown cover or canopy height approaches optimal suitability. However, an additional assumption is that the lower of the two suitability values has greater impact on the final shrubland cover value. When suitability of crown cover and canopy height of shrubs are equivalent, it is assumed that the cover value also will be equal to that level of suitability. These relationships are applicable to shrubland cover types (S, SW, and SS) and can be expressed by equation 3:

$$CSI = (SIV3 \times SIV5)^{1/2} \qquad (3)$$

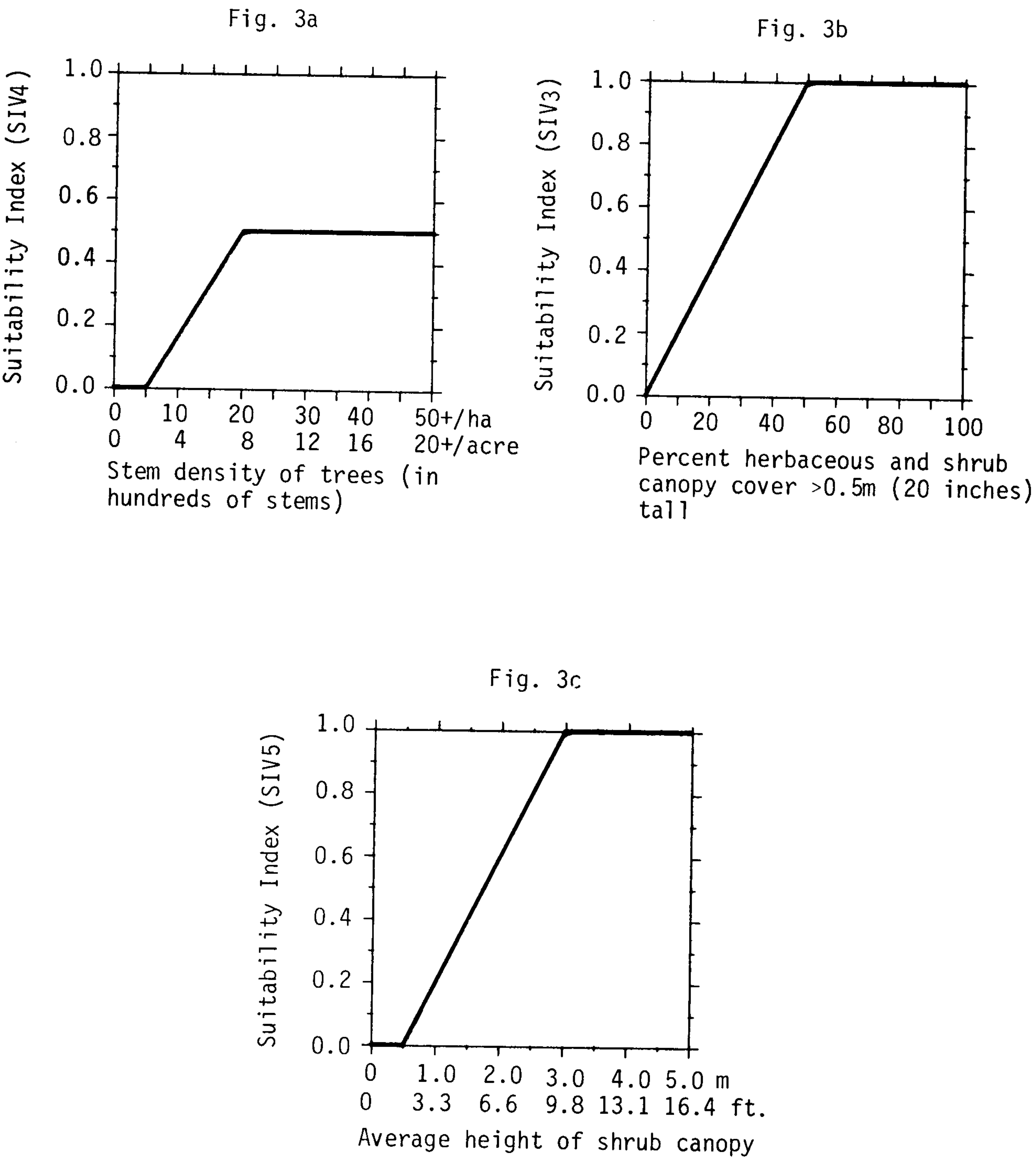

Figure 3. Relationships of cover suitability indices to habitat variables used to evaluate cover suitability for woodcock.

HSI determination. An HSI for any given cover type is assumed to be the lower of the values determined for Food (FSI) and Cover (CSI) in the cover type. Several steps and calculations are necessary to determine an area-wide HSI score for cover types used by woodcock. They are as follows:

1. Compute Food and Cover Suitability Index values for each cover type by collecting field data for habitat variables, entering these data into the proper suitability curve, and using the resulting indices in the appropriate life requisite equations.

2. The HSI value in each cover type equals the lower value of Food or Cover Suitability Index. This relationship allows either Food or Cover value to limit habitat suitability within a cover type.

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 woodcock in the study area.

Application of the Model

Summary of model variables. Two habitat variables are used to evaluate food value for woodcock, and three variables are used to evaluate cover value (Fig. 4). Definitions of habitat variables and suggested field measurement techniques for sampling vegetation and soil texture and drainage classes are provided in Figure 5. In order to obtain an HSI value for woodcock using this model, habitat conditions (existing or future) must be estimated for each cover type, and mean habitat characteristics must be entered into the appropriate suitability curves. Stratifying samples by the most homogeneous units possible will provide the greatest accuracy and precision for habitat and HSI estimates. Therefore, subdividing forested cover types (DF, EF, DFW, EFW, DTS, ETS) according to species composition and age classes is recommended.

Model assumptions. The major assumptions in this model are:

1. Diurnal habitat is the limiting life requisite for woodcock wintering in the southeastern U.S.

2. Suitable diurnal habitat must provide both suitable food and suitable cover.

3. Food suitability is determined by availability of earthworms to woodcock.

4. Cover suitability is correlated with density of herbaceous, shrub, and tree cover.

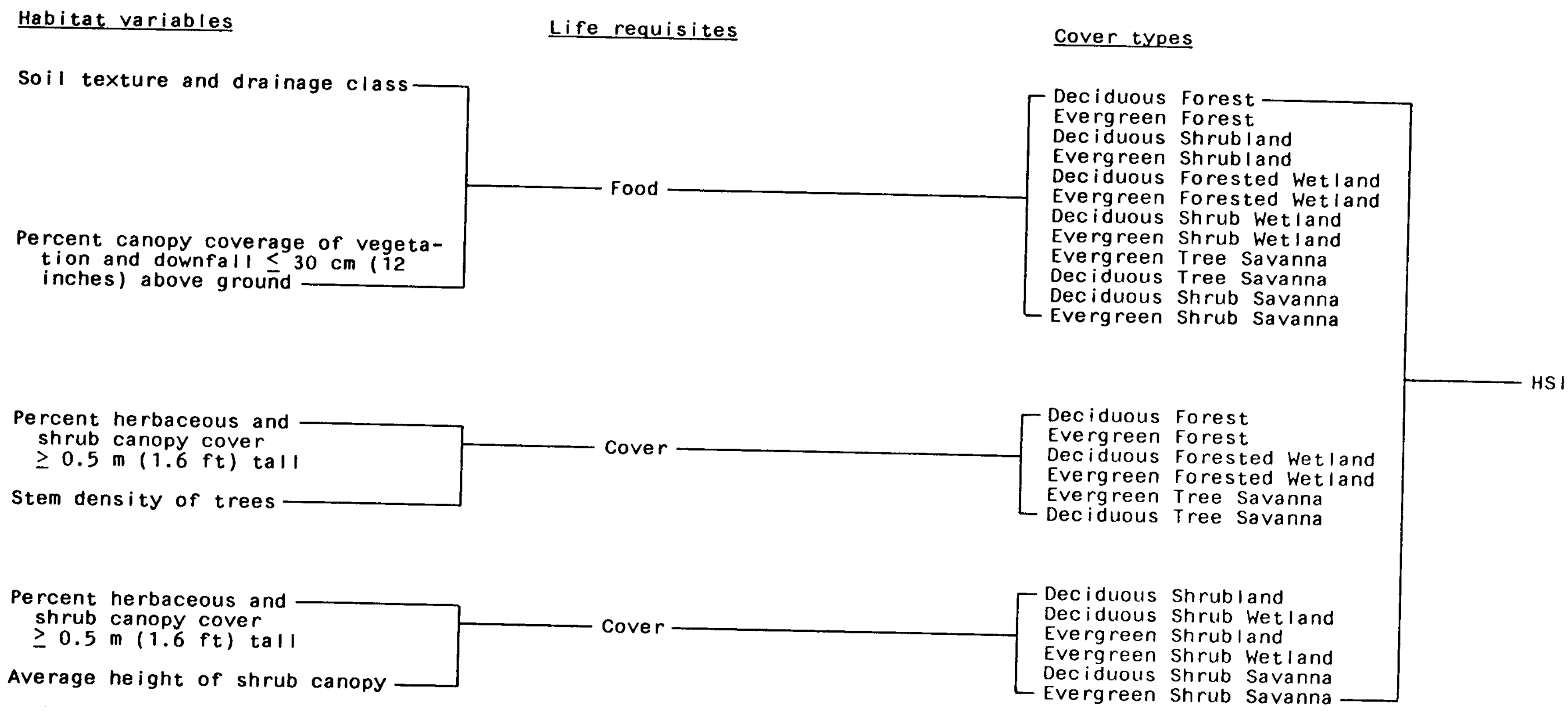

Figure 4. Relationship of habitat variables, life requisites, and cover types to the Habitat Suitability Index (HSI) for the American woodcock.

Variable (definition)		Cover types	Suggested techniques
V1	Soil texture and drainage class [the relative proportion of sand, silt, and clay particles in the soil, and frequency and duration of periods when the soil is not saturated (Brady 1974)]	DF,EF,DS,ES, DFW,EFW,DSW, ESW,ETS,DTS, ESS,DSS	As mapped in U.S. Soil Cons. Serv. Soil Survey Rep., or by obtaining random soil samples and determining texture by feel (Hays et al. 1981) and soil moisture by compressing soil between fingers (dry - soil crumbles when compressed, moist - soil forms a cast when compressed, wet - soil drips water when compressed)]
V2	Percent canopy coverage of vegetation and down fall ≤ 30 cm (12 inches) above ground [proportion of the area ≤ 30 cm (≤ 12 inches) in height above the ground surface that is covered by vegetation and downed woody material (e.g., limbs, branches)].	DF,EF,DS,ES, DFW,EFW,DSW, ESW,ETS,DTS, ESS,DSS	Line intercept (Hays et al. 1981)
V3	Percent herbaceous and shrub canopy cover > 0.5 m (20 inches) high [percent of the ground surface that is shaded by a vertical projection of herbaceous and shrub vegetation > 0.5 m (20 inches) and < 5.0 m tall (16.4 ft), including climbing vines.]	DF,EF,DS,ES, DFW,EFW,DSW, ESW,ETS,DTS, ESS,DSS	Line intercept (Hays et al. 1981)
V4	Stem density of trees [the number of woody stems ≥ 5.0 m (16.4 ft) tall/ha (2.471 acres)].	DF,EF,DFW, EFW,ETS,DTS	Quadrat count (Hays et al. 1981)

Figure 5. Definitions of habitat variables and suggested measuring techniques.

Variable (definition)		Cover types	Suggested techniques
V5	Average height of shrub canopy [the average vertical distance from the ground to the highest point of the tallest woody plants < 5.0 m (16.4 ft) tall].	DS,ES,DSW, ESW,ESS,DSS	Graduated rod (Hays et al. 1981)

Figure 5. (concluded)

The primary model assumption identifies diurnal habitat as the limiting factor for wintering populations of woodcock. A corollary to this assumption is that nocturnal habitat will never be more limiting than diurnal habitat. If conditions in the potential application area differ from those assumed to be limiting in this model, then use of this model for habitat assessment will be inappropriate. If the user feels that the primary assumption is valid for an identified application, then the other three major assumptions must be addressed. Modification of these major assumptions and individual assumptions described under each component can be made if the user believes that such modifications 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.

Woodcock feed extensively on soil invertebrates other than earthworms at certain times during winter (Miller and Causey 1985). This model assumes that suitable soil texture and drainage characteristics (Fig. 1) for earthworms also are suitable for other soil invertebrates that may be utilized by woodcock. Many soil invertebrates respond to soil moisture gradients similar to earthworms (Wallwork 1976). Temporal fluctuations in soil moisture and temperature, both seasonally and annually, affect earthworm availability and, hence, habitat suitability for woodcock. Soil texture and drainage classes are assumed to represent long-term average conditions affecting soil suitability for earthworms (Galbraith pers. comm.; Owen pers. comm.). Most cover types on woodcock winter range that provide suitable diurnal cover and soil moisture are likely to have abundant earthworms and other invertebrate food items (Causey pers. comm.). However, farming history (Galbraith 1984) and overstory species composition (Liscinsky 1972; Reynolds et al. 1977; Galbraith 1984) also affect earthworm abundance on the northern breeding range of woodcock.

A more accurate estimate of earthworm availability may be achieved by directly sampling abundance of non-estivating earthworms in the upper 10 cm of the soil, provided that temporal variation in earthworm abundance is incorporated in the sampling design. A Formalin extraction technique (Reynolds et al. 1977) or digging and sorting (Edwards and Lofty 1977) should be used at randomly located 0.25-m^2 plots with replications at least every two weeks from

November through February. Suitability levels for mean earthworm densities, extrapolated from Reynolds et al. (1977), are optimal (1.0) when $\geq$ 56 worms/m^2 are available, decreasing to unsuitable (0.0) when $\leq$ 16 worms/m^2 are available. This relationship is based on studies done on breeding range in Maine, and its applicability to winter range is unknown.

SOURCES OF OTHER MODELS

A linear discriminant function model based on vegetation and soil characteristics classified habitats in east Texas as suitable or unsuitable winter habitat for woodcock (Kroll and Whiting 1977). No attempt was made to discriminate among different levels of suitability for occupied habitats.

REFERENCES

American Ornithologists' Union. 1983. Check-list of North American birds, 6th edition. Am. Ornithol. Union. 877 pp.

Boggus, T. G., and R. M. Whiting, Jr. 1982. Effects of habitat variables on foraging of American woodcock wintering in east Texas. Pages 148-153 in T. J. Dwyer and G. L. Storm, tech. coords. Woodcock ecology and management. U.S. Fish Wildl. Serv. Wildl. Res. Rep. 14.

Bourgeois, A. 1977. Quantitative analysis of American woodcock nest and brood habitat. Proc. Woodcock Symp. 6:109-118.

Brady, N. C. 1974. The nature and properties of soils. 8th edition. MacMillan Publishing Co., Inc. New York, NY. 639 pp.

Britt, T. L. 1971. Studies of woodcock on the Louisiana wintering grounds. M.S. Thesis, Louisiana State Univ., Baton Rouge. 105 pp.

Connors, J. I., and P. D. Doerr. 1982. Woodcock use of agricultural fields in coastal North Carolina. Pages 139-147 in T. J. Dwyer and G. L. Storm, tech. coords. Woodcock ecology and management. U.S. Fish Wildl. Serv. Wildl. Res. Rep. 14.

Coon, R. A., P. D. Caldwell, and G. L. Storm. 1976. Some characteristics of fall migration of female woodcock. J. Wildl. Manage. 40(1):91-95.

Coon, R. A., T. J. Dwyer, and J. W. Artmann. 1977. Identification of potential harvest units in the United States for the American woodcock. Proc. Woodcock Symp. 6:147-153.

Coon, R. A., B. K. Williams, and J. L. George. 1982. Examination of woodcock nest sites in central Pennsylvania. Pages 55-62 in T. J. Dwyer and G. L. Storm, tech. coords. Woodcock ecology and management. U.S. Fish Wildl. Serv. Wildl. Res. Rep. 14.

Dunford, R. D., and R. B. Owen, Jr.. 1973. Summer behavior of immature radio-equipped woodcock in central Maine. J. Wildl. Manage. 37(4):462-469.

Dyer, J. M. 1976. An evaluation of diurnal habitat requirements for the American woodcock (Philohela minor) in southern Louisiana. Ph.D. Diss., Louisiana State Univ., Baton Rouge. 228 pp.

Edwards, C. A., and J. R. Lofty. 1977. Biology of earthworms. John Wiley and Sons, New York, NY. 333 pp.

Edminster, F. C. 1954. American game birds of field and forest. Charles Scribner's Sons, New York, NY. 490 pp.

Ensminger, A. B. 1954. Earthworm populations on wintering areas of the American woodcock in the vicinity of Baton Rouge, Louisiana. M.S. Thesis, Louisiana State Univ., Baton Rouge. 97 pp.

Fayle, D. C. F. 1961. Who needlessly sets foot upon a worm? For. Chron. 37(1):10-15.

Galbraith, W. J. 1984. Earthworm biomass available to woodcock in relation to forest, soil, and land-use in Maine. M.S. Thesis, Univ. Maine, Orono. 44 pp.

Glasgow, L. L. 1958. Contributions to the knowledge of the ecology of the American woodcock, Philohela minor (Gmelin), on the wintering range in Louisiana. Ph.D. Diss., Texas A&M Coll., College Station. 158 pp.

Godfrey, G. A. 1974. Behavior and ecology of American woodcock on the breeding range in Minnesota. Ph.D. Diss., Univ. Minnesota, Minneapolis. 346 pp.

Gregg, L. E., and J. B. Hale. 1977. Woodcock nesting habitat in northern Wisconsin. Auk 94(3):489-493.

Guild, W. J. McL. 1948. Effect of soil type on populations. Ann. Appl. Biol. 35(2):181-192. Cited by Edwards and Lofty 1977.

Gutzwiller, K. J., and J. S. Wakely. 1982. Differential use of woodcock singing grounds in relation to habitat characteristics. Pages 51-54 in T. J. Dwyer and G. L. Storm, tech. coords. Woodcock ecology and management. U.S. Fish Wildl. Serv. Wildl. Res. Rep. 14.

Gutzwiller, K. J., K. R. Kinsley, G. L. Storm, W. M. Tsilkowski, and J. S. Wakely. 1983. Relative value of vegetation structure and species composition for identifying American woodcock breeding habitat. J. Wildl. Manage. 47(2):535-540.

Hale, J. B., and L. E. Gregg. 1976. Woodcock use of clearcut aspen areas in Wisconsin. Wildl. Soc. Bull. 4(3):111-115.

Hays, R. L., C. Summers, and W. Seitz. 1981. Estimating wildlife habitat variables. U.S. Fish Wildl. Serv. FWS/OBS-81/47. 111 pp.

Horton, G. I., and M. K. Causey. 1979. Woodcock movements and habitat utilization in central Alabama. J. Wildl. Manage. 43(2):414-420.

Johnson, R. C., and M. K. Causey. 1982. Use of longleaf pine stands by woodcock in southern Alabama following prescribed burning. Pages 120-125 in T. J. Dwyer and G. L. Storm, tech. coords. Woodcock ecology and management. U.S. Fish Wildl. Serv. Wildl. Res. Rep. 14.

Kinsley, K. R., S. A. Liscinsky, and G. L. Storm. 1982. Changes in habitat structure on woodcock singing grounds in central Pennsylvania. Pages 40-50 in T. J. Dwyer and G. L. Storm, tech. coords. Woodcock ecology and management. U.S. Fish Wildl. Serv. Wildl. Res. Rep. 14.

Krohn, W. B. 1970. Woodcock feeding habits as related to summer field usage in central Maine. J. Wildl. Manage. 34(4):769-775.

Krohn, W. B., and E. R. Clark. 1977. Band-recovery distribution of eastern Maine woodcock. Wildl. Soc. Bull. 5(3):118-122.

Krohn, W. B., J. C. Rieffenberger, and F. Ferrigno. 1977. Fall migration of woodcock at Cape May, New Jersey. J. Wildl. Manage. 41(1):104-111.

Kroll, J. C., and R. M. Whiting, Jr. 1977. Discriminant function analysis of woodcock winter habitat in east Texas. Proc. Woodcock Symp. 6:63-71.

Lambert, R. A., and J. S. Barclay. 1975. Woodcock singing grounds and diurnal habitat in north-central Oklahoma. Proc. Southeastern Assoc. Game and Fish Commissioners 29:617-630.

Liscinsky, S. A. 1972. The Pennsylvania woodcock management study. Pennsylvania Game Comm. Res. Bull. 171. 95 pp.

Marshall, W. H. 1982. Minnesota woodcock. Loon 54(4):203-211.

Martin, F. W., S. O. Williams, III, J. D. Newsom, and L. L. Glasgow. 1969. Analysis of records of Louisiana-banded woodcock. Proc. Southeastern Assoc. Game and Fish Commissioners 23:85-96.

Maxfield, H. K. 1961. A vegetational analysis of fifty woodcock singing grounds in central Massachusetts. M.S. Thesis, Univ. Massachusetts, Amherst. 31 pp.

Mendall, H. L., and C. M. Aldous. 1943. The ecology and management of the American woodcock. Maine Coop. Wildl. Res. Unit, Univ. Maine, Orono. 201 pp.

Miller, D. L., and M. K. Causey. 1985. Food preferences of American woodcock wintering in Alabama, J. Wildl. Manage. 49(2):492-496.

Morgenweck, R. O. 1977. Diurnal high use areas of hatching-year female American woodcock. Proc. Woodcock Symp. 6:155-160.

Morgenweck, R. O., and W. H. Marshall. 1982. Earthworms of two Minnesota forest areas. J. Minnesota Acad. Sci. 48(1):18-21.

Owen, R. B., Jr., and J. W. Morgan. 1975. Summer behavior of adult radio-equipped woodcock in central Maine. J. Wildl. Manage. 39(1):179-182.

Owen, R. B., Jr., J. M. Anderson, J. W. Artmann, E. R. Clark, T. G. Dilworth, L. E. Gregg, F. W. Martin, J. D. Newsom, and S. R. Pursglove. 1977. American woodcock. Pages 147-175 in G. C. Sanderson, ed. Management of migratory shore and upland game birds in North America. Int. Assoc. Fish Wildl. Agencies, Washington, DC.

Pettingill, O. S., Jr. 1936. The American woodcock *Philohela minor* (Gmelin). Mem. Boston Soc. Nat. Hist. 9(2):169-391.

__________. 1939. Additional information on the food of the American woodcock. Wilson Bull. 51(2):78-82.

Rabe, D. L. 1977. Habitat utilization by the American woodcock in northern Michigan. M.S. Thesis, Michigan State Univ., E. Lansing. 47 pp.

Rabe, D. L., H. H. Prince, and D. L. Beaver. 1983. Feeding site selection and foraging strategies of American woodcock. Auk 100(3):711-716.

Rabe, D. L., H. H. Prince, and E. D. Goodman. 1983. The effect of weather on bioenergetics of breeding American woodcock. J. Wildl. Manage. 47(3):762-771.

Reynolds, J. W. 1977. Earthworms utilized by the American woodcock. Proc. Woodcock Symp. 6:161-169.

Reynolds, J. W., and G. A. Jordan. 1975. A preliminary conceptual model of megadrile activity and abundance in the Haliburton Highlands. Megadrilogica 2(2):1-9.

Reynolds, J. W., W. B. Krohn, and G. A. Jordan. 1977. Earthworm populations as related to woodcock habitat usage in central Maine. Proc. Woodcock Symp. 6:135-146.

Roboski, J. C., and M. K. Causey. 1981. Incidence, habitat use, and chronology of woodcock nesting in Alabama. J. Wildl. Manage. 45(3):793-797.

Sepik, G. F., R. B. Owen, Jr., and M. W. Coulter. 1977. Experimental woodcock management at the Moosehorn National Wildlife Refuge. Proc. Woodcock Symp. 6:83-91.

Sheldon, W. G. 1961. Summer crepuscular flights of American woodcock in central Massachusetts. Wilson Bull. 73(2):126-139.

__________. 1967. The book of the American woodcock. Univ. Massachusetts Press, Amherst. 227 pp.

Stickel, W. H., D. W. Hayne, and L. F. Stickel. 1965. Effects of heptachlor-contaminated earthworms on woodcocks. J. Wildl. Manage. 29(1):132-146.

Stribling, H. L., and P. D. Doerr. 1985. Nocturnal use of fields by American woodcock. J. Wildl. Manage. 49(2):485-491.

U.S. Fish and Wildlife Service. 1981. Standards for the development [illegible] Habitat Suitability Index models. 103 ESM. U.S. Fish Wildl. Serv., [illegible] Ecol. Serv. n.p.

__________. 1982. Identification of national species of special em[illegible]. Fed. Reg. 47(176):39890-39891.

Wallwork, J. A. 1976. The distribution and diversity of soil fauna. A[illegible] Press, New York, NY. 355 pp.

Wenstrom, W. P. 1973. Habitat utilization and activities of female American woodcock (Philohela minor Gmelin) in northeastern Minnesota during spring and summer. Ph.D. Diss., Univ. Minnesota, Minneapolis. 203 pp.

Whiting, R. M., Jr., and T. G. Boggus. 1982. Breeding biology of American woodcock in east Texas. Pages 132-138 in T. J. Dwyer and G. L. Storm, tech. coords. Woodcock ecology and management. U.S. Fish Wildl. Serv. Wildl. Res. Rep. 14.

Wishart, R. A., and J. R. Bider. 1976. Habitat preferences of woodcock in southwestern Quebec. J. Wildl. Manage. 40(3):523-531.

__________. 1977. Aspects of woodcock nocturnal activity in southwestern Quebec. Can. Field-Nat. 91(2):141-147.

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16. Abstract (Limit: 200 words)

A review and synthesis of existing information were used to develop a Habitat Suitability Index (HSI) model for the American woodcock (Scolopax minor). The model consolidates habitat use information into a framework appropriate for field application, and is scaled to produce an index 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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