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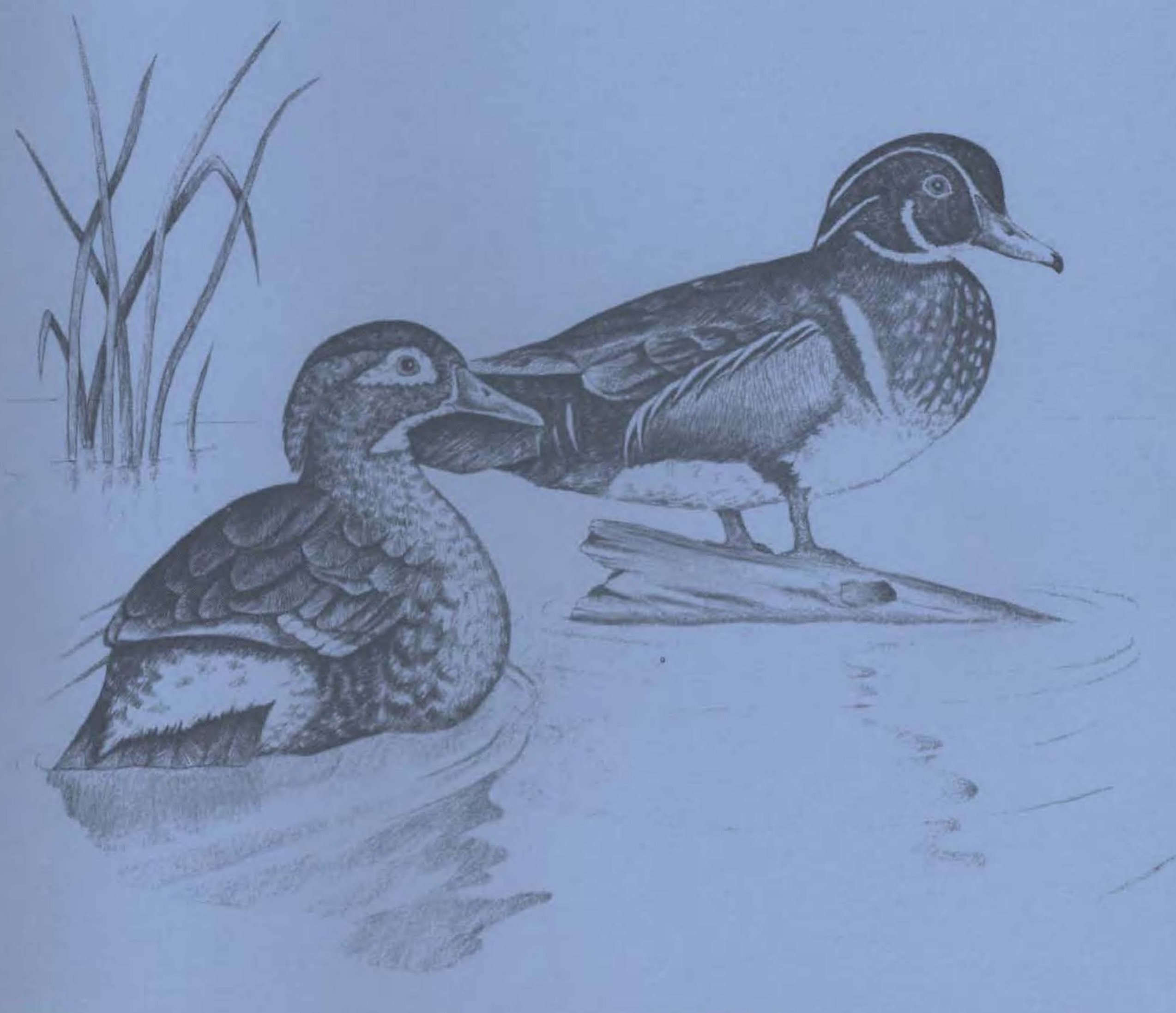
HABITAT SUITABILITY INDEX MODELS: WOOD DUCK



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This model is designed to be used by the Division of Ecological Services in conjunction with the Habitat Evaluation Procedures.

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HABITAT SUITABILITY INDEX MODELS: WOOD DUCK

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PREFACE

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

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

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

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CONTENTS

ACKNOWLEDGMENTS

Earlier versions of an HSI model for the wood duck were reviewed by Drs. Leigh Fredrickson, Frank Bellrose, and Frank McGilvrey. Dr. Fredrickson commented on two earlier drafts and his comments were very valuable in helping to describe the relationships between wood ducks and their habitat. The comments and suggestions of all three reviewers have added considerably to the quality and value of this model, and their input is very gratefully acknowledged.

The development of this HSI model was partially funded by the U.S. Army Corps of Engineers through their Waterways Experiment Station in Vicksburg, Mississippi. The participating work unit is Testing of Habitat Evaluation Methods within the Environmental Impact Research Program.

Word processing of this document was provided by Carolyn Gulzow and Dora Ibarra. The cover illustration was drawn by Jennifer Shoemaker.

WOOD DUCK (*Aix sponsa*)

HABITAT USE INFORMATION

General

Wood ducks (*Aix sponsa*) inhabit creeks, rivers, floodplain lakes, swamps, and beaver ponds (Bellrose 1976). The major breeding range of the wood duck is in the eastern United States, from Florida and east Texas north to Maine and North Dakota, and north into the eastern Canadian provinces. A Pacific population breeds from British Columbia south to California and east to Montana. The major wintering range occurs south of Maryland in the Atlantic and Gulf coast States, as well as Arkansas and Tennessee. The majority of the Pacific population winters in the Sacramento Valley. Wood ducks are permanent residents in the southern half of their breeding range.

Food

Wood ducks have been referred to as primarily herbivorous (Landers et al. 1977) although recent studies have indicated that invertebrates make up a significant part of the annual diet (Drobney and Fredrickson 1979). Wood ducks forage on the ground or in water at depths up to 46 cm (18 inches) (McGilvrey 1968). In Missouri, they foraged primarily in flooded timber during spring and fall (Drobney and Fredrickson 1979). The daily foraging radius in the southeastern United States may be as much as 40 to 48 km (25 to 30 mi) (U.S. Forest Service 1971). Food items include mast and fruits, aquatic plants and seeds, insects, and aquatic invertebrates. Acorns and other mast are important fall and winter foods (Landers et al. 1977). When acorns are lacking, other important foods include the seeds of baldcypress (*Taxodium distichum*), hickories (*Carya* spp.), buttonbush (*Cephalanthus occidentalis*), arrowarum (*Peltandra virginica*), and burreed (*Sparganium* spp.) (Bellrose 1976). In South Carolina, McGilvrey (1966) found that greater than 98% of the stomach contents of 108 wood ducks shot by hunters were fruits and seeds of water oak (*Quercus nigra*), pin oak (*Q. palustris*), baldcypress, sweetgum (*Liquidambar styraciflua*), water hickory (*C. aquatica*), and corn (*Zea mays*). Important fall foods of wood ducks in Maine were pondweeds (*Potamogeton* spp.), burreeds, water bulrush (*Scirpus subterminalis*), oaks, and wild rice (*Zizania aquatica*) (Coulter 1957). Wood ducks prefer to forage for mast in areas of shallow water, although they may also forage on the forest floor (Brakhage 1966; Bellrose 1976) and even on tree limbs before the mast has fallen (Brakhage 1966). Important foods during the breeding season include persistent overwintering fruits; corn and other domestic grain; seeds and fruits from bottomland hardwood trees, shrubs, and aquatic herbaceous plants; early spring plants; and invertebrates (McGilvrey 1968).

Female wood ducks have high protein and calcium requirements in the spring and feed heavily on aquatic invertebrates (Landers et al. 1977). They satisfy their protein requirements for egg laying through their diet rather than through internal stores (Drobney 1980). Invertebrates made up about 82% by volume of the diet of wood duck hens in Missouri during the laying period (Drobney 1980). During incubation, when protein requirements were reduced, 58.5% of the diet of the hens was plant foods. Drakes did not exhibit the same pattern of invertebrate use, indicating that hens fed selectively on invertebrates during the egg laying period. The abundance and availability of macroinvertebrates to wood duck hens during the pre-breeding period is critical to successful reproduction (Fredrickson, pers. comm.). Invertebrates made up about one-third of the fall diet of drakes and hens, and the spring diet of drakes (Drobney and Fredrickson 1979).

Ducklings less than 1 week old are dependent on animal foods (primarily insects) and forage in areas where both food and some protective cover are present (Hocutt and Dimmick 1971). The diet of ducklings is similar to that of adults by 6 weeks of age.

Water

No information on dietary water needs of the wood duck was found in the literature. However, water needs are likely satisfied in wetland habitats used by the wood duck. The remainder of this section describes those water characteristics that influence habitat use by wood ducks.

Water depth affects the quantity, variety, and distribution of cover and food, and wood duck needs are generally met between the shoreline and a water depth of 1.8 m (6 ft) (McGilvrey 1968). However, even when wood ducks feed in deeper water, the actual feeding depth is generally restricted to the top 30 cm (12 inches) of water (Fredrickson, pers. comm.). Water is critical in wood duck breeding and brood-rearing habitat from mid-January to late September in the southern United States and from mid-April to late September in the northern portions of the range. Water in most of the breeding habitat should be from 7.5 to 45 cm (3 to 18 inches) deep, still or slow-moving, and sheltered from the wind. Areas with water less than 30 cm (12 inches) deep are especially important in providing invertebrate foods for breeding wood ducks (Drobney and Fredrickson 1979). A water current of 4.8 km/hr (3 mph) has been estimated as the maximum tolerable stream flow for breeding wood ducks, although broods seldom use areas with currents greater than 1.6 km/hr (1 mph) (McGilvrey 1968).

Isolated wetlands much less than 4 ha (10 acres) in size are considered marginal brood rearing habitat (McGilvrey 1968). The more shoreline per unit area of water, the more suitable the habitat, provided the distance between opposite shores is at least 30 m (100 ft).

Cover

Suitable cover for wood ducks may be provided by trees or shrubs overhanging water, flooded woody vegetation, or a combination of these two types (McGilvrey 1968). A ratio of 50 to 75% cover to 25 to 50% open water is preferred in breeding and brood rearing habitat. Adult molting habitat is similar to brood habitat (Palmer 1976), although molting adults make greater use of herbaceous wetlands dominated by cattails and bulrushes (Bellrose, pers. comm.).

An abundance of downed timber provides suitable year-round cover (Webster and McGilvrey 1966). Young trees and mature shrubs with low overhead and lateral growth provide optimal cover for breeding adults (McGilvrey 1968). Ideal shrub cover is provided by shrubs that form a dense canopy about 0.6 m (2 ft) above the water surface. The deciduous forested types used by breeding wood ducks vary throughout their range, although wooded areas that are flooded in early spring are the most suitable nesting habitat. McGilvrey (1968) lists the following as the most important habitats for nesting wood ducks: Southern floodplain forests; red maple (Acer rubrum) swamps; Central floodplain forests; temporarily flooded oak-hickory forests; and Northern bottomland hardwoods. Buttonbush is an important source of cover for wood ducks throughout much of their range (Webster and McGilvrey 1966; McGilvrey 1968).

Winter-persistent emergents that have a life form similar to shrubs, such as cattail (Typha spp.), soft rush (Juncus effusus), bulrush (Scirpus spp.), burreed, purple loosestrife (Lythrum salicaria), and phragmites (Phragmites communis), may satisfy cover requirements where more desirable shrubs and trees are not available (McGilvrey 1968).

Wood duck brood cover is provided by a combination of downfall and woody and herbaceous emergent plants, well interspersed with small, open water channels (Webster and McGilvrey 1966; Palmer 1976). In the Mississippi Alluvial Valley, broods less than 2 weeks old typically use flooded lowland forests in order to satisfy their requirements for invertebrate foods (Fredrickson, pers. comm.). Wood ducks older than 2 weeks of age use habitats dominated by buttonbush. Wood duck broods in Massachusetts preferred areas with dense cover interspersed with small open pools, clumps of buttonbush, and muskrat houses (Grice and Rogers 1965). Buttonbush clumps and muskrat houses provided loafing sites out of the water. Optimal composition in brood habitat consists of 30 to 50% shrubs, 40 to 70% herbaceous emergents, 0 to 10% trees, and 25% open water (McGilvrey 1968). Eight wood duck broods in Florida concentrated their activities in a shrub wetland community with shrub cover greater than 76%, dominated by mature Carolina willow (Salix caroliniana) (Wenner and Marion 1981). Shrubs and/or clumped herbaceous vegetation may provide cover in areas where downed timber is not available (Webster and McGilvrey 1966). South Carolina beaver ponds that provided both shrubby and herbaceous cover received greater use by wood duck broods than ponds dominated by either shrubs or herbaceous vegetation (Hepp and Hair 1977). Shrubs provide cover, security, and loafing sites, while herbaceous vegetation provides cover and habitat for invertebrates that make up a major portion of the diet of ducklings. Emergent herbaceous vegetation that does not provide any early spring cover, especially in pure stands, does not provide much suitable brood cover (Webster and McGilvrey 1966). An abundance of downed trees in shallow water [up to 0.9 m (3 ft) deep] provides excellent brood rearing cover and "...is particularly important for early broods hatching before leaves appear on trees and shrubs and before the appearance of emergent plants" (McGilvrey 1968:11).

Emergent plants used for brood cover vary with latitude but include smartweeds (Polygonum spp.), American lotus (Nelumbo lutea), pickerelweed (Pontederia cordata), bluejoint (Calamagrostis canadensis), arrowheads (Sagittaria spp.), soft rush, spatterdock (Nuphar luteum), arrowarum, and clump sedges (Carex spp.) (McGilvrey 1968). Other important herbaceous plants are water primrose (Jussiaea spp.), reed canarygrass (Phalaris arundinacea), cattail, burreed, swamp loosestrife, and grasses.

Wood duck broods and breeding pairs require loafing sites scattered throughout their habitat for preening and sunning (McGilvrey 1968). The best loafing sites are surrounded by water, have good visibility, and are near escape cover. Loafing sites should be at least 45 by 45 cm (18 by 18 inches) in size and 5 to 15 cm (2 to 6 inches) above water. Optimal habitat contains 10 to 20 loafing sites (muskrat mounds, stumps, logs, small islands, and tussocks) per 0.4 ha (1 acre). Shorelines and points of land that are relatively bare of vegetation are marginal substitutes for more optimal loafing sites. The lack of suitable loafing sites may be a limiting factor in brood use (Beard 1964).

Wood duck broods in South Carolina used small ponds (0.03 to 0.50 ha; 0.07 to 1.2 acres) significantly more often than larger ponds (1.51 to 3.80 ha; 3.7 to 9.4 acres) (Hepp and Hair 1977).

Shrub swamps dominated by buttonbush were preferred as fall roost sites in southern Illinois over flooded forested habitats and open water (Parr et al. 1979). One such roost of 200 ha (494 acres) consisted of 60% buttonbush cover and 40% open water. Another fall roost site was dominated by American lotus, and another one was dominated by water willow (Decodon verticillatus).

Ideal winter habitat consists of a complex of wetlands centered on a permanent wetland (Fredrickson, pers. comm.). Optimum winter habitat includes scrub/shrub wetlands, emergent wetlands, dead timber, and flooded forests.

Reproduction

The distribution of breeding populations of wood ducks is closely related to "... bottomland hardwood forest with trees of sufficient size to contain usable nest cavities and water areas that satisfy food and cover requirements" (McGilvrey 1968:3). Important limiting factors include the availability of suitable nesting cavities (McGilvrey 1968), and the availability of protein foods for pre-breeding females (Fredrickson, pers. comm). Hens are most easily able to satisfy their protein requirements in flooded lowland forests, where flooding dynamics create a highly productive invertebrate food base. In the Mississippi Alluvial Valley, 1 ha (2.47 acres) of properly flooded forest can provide enough protein foods to support 800 wood ducks for 1 day (Fredrickson, pers. comm.). If it is assumed that a hen will use a flooded forest habitat for 60 days during the pre-breeding and nesting periods, then 1 ha (2.47 acres) of properly flooded forest can support about 13 hens (or 5 hens/0.4 ha [1.0 acre]) during the 60-day use period. A ratio of 8 ha (20 acres) of nesting habitat to every 0.4 ha (1 acre) of brood habitat is recommended for maximum production in areas where natural cavities provide the only potential nest sites (McGilvrey 1968). However, this ratio is based on: (1) the presence of at least 1 suitable cavity/2 ha (5 acres); and (2) the carrying capacity of each 0.4 ha (1.0 acre) of brood habitat being sufficient to accommodate broods produced by four nest cavities.

The closer the nest cavity to water, particularly to suitable brood habitat, the better (McGilvrey 1968). Cavities in trees in or near the water are preferred. Most wood duck nests in tree cavities in Massachusetts were located within 183 m (200 yds) of water (Grice and Rogers 1965). Wood ducks nesting in tree cavities in Minnesota selected cavities that were significantly closer to water and to canopy openings than were randomly sampled trees (Gilmer et al. 1978). Nest trees ranged from 0 to 350 m (0 to 383 yds) from water and averaged 80 m (87.5 yds). Twenty-one of 31 nest trees selected by radio-marked hens were within 0.5 km (0.31 mi) of permanent water, while eight nests were farther than 1.0 km (0.62 mi) from permanent water. Artificial nest sites in wooded areas are best located within 0.4 km (0.25 mi) of water, but nest boxes located up to 1.6 km (1 mi) from water may also receive use (Bellrose 1976). Nest boxes placed within 1.4 km (0.86 mi) of brood habitat in a Florida study area received significantly greater use than those placed further away (Wenner and Marion 1981).

Wood ducks generally nest in tree species that have a mature size of at least 35 to 40 cm (14 to 16 inches) dbh and a long life expectancy (Hansen 1966). The minimum-sized tree used for nesting in Minnesota was 28 cm (11 inches) dbh (Gilmer et al. 1978). Overmature and decadent trees usually contain the largest number of suitable cavities (McGilvrey 1968). Conifers (Hansen 1966) and dead trees, other than cypress, rarely provide suitable cavities (McGilvrey 1968). The most suitable cavity trees range from 60 to 90 cm (24 to 36 inches) dbh. Natural cavities used for nesting by wood ducks in Massachusetts ranged from 33.0 to 91.4 cm (13 to 36 inches) dbh, with a mean dbh of 68.6 cm (27 inches) (Grice and Rogers 1965).

Acceptable nest cavities in trees are at least 2 m (6 ft) above ground, have an entrance size of 9 to 30.5 cm (3.5 to 12 inches) in diameter, and a depth of 15 to 120 cm (6 to 48 inches) (McGilvrey 1968). Bellrose (pers. comm.) considered the minimum entrance dimensions to be 7.6 by 10.0 cm (3.0 by 4.0 inches); smaller entrances restrict many wood ducks. Optimal tree cavities, according to McGilvrey (1968) have an entrance size of 10 cm (4 inches) in diameter, a diameter at the bottom of 25 to 27.5 cm (10 to 11 inches), a cavity depth of 60 cm (24 inches), and are 6 to 15 m (20 to 50 ft) above ground. Fredrickson (pers. comm.) suggested that the optimum cavity height of 6 to 15 m, as defined by McGilvrey (1968), is simply where most suitable cavities form in trees rather than an expressed preference by nesting wood ducks. However, Bellrose et al. (1964) found an increasing index of use (i.e., use compared to availability) with increasing cavity height. A suitable cavity must drain well and preferably has its entrance protected from the weather (McGilvrey 1968). Cavity trees in southeastern Missouri were defined as all trees at least 24.1 cm (9.5 inches) dbh that contained at least one cavity with an entrance size of at least 6.4 by 8.9 cm (2.5 by 3.5 inches) (Weier 1966). Suitable cavities were those of adequate dimensions that did not have adverse features, such as water or excessive debris in the cavity or open tops above the cavity. A total of 109 cavity trees were found in three cover types, and 17 were judged to contain suitable cavities for wood ducks, a ratio of 1 suitable cavity to 6.4 cavity trees. A suitable cavity on two study areas in Massachusetts was defined as having a minimum entrance size of 6.4 by 8.9 cm (2.5 by 3.5 inches) and being within 0.8 km (0.5 mi) of water (Grice and Rogers 1965). Results were 1 suitable cavity/5.3 cavity trees (13 suitable out of 69 cavities) on one study area and 1 suitable cavity/4 cavity trees (9 suitable out of 36 cavities) on the second area.

The density of suitable cavities on two Massachusetts study areas was 2.5/2.59 km^2 (1 mi^2) and 0.6/2.59 km^2 (1 mi^2), although the estimates were based on total study area size rather than on timbered area only (Grice and Rogers 1965). The density of suitable cavities in timbered bottomland in Iowa was 1/9.7 ha (24 acres) (Dreis and Hendrickson 1952, cited by Grice and Rogers 1965). In Illinois, suitable cavities were defined as those with an entrance diameter of at least 8.9 cm (3.5 inches) and that were free of water or debris (Bellrose et al. 1964). One suitable cavity/5.3 ha (13 acres) was found in bottomland forests, and 1 suitable cavity/2.0 ha (5 acres) was found in upland woodlots. The density of suitable cavities (defined above) in three timber types in Missouri ranged from 1/1.4 ha (3.4 acres) to 1/4.2 ha (10.3 acres), and averaged 1/2.1 ha (5.2 acres) of forested habitat (Weier 1966). The highest reported density of suitable cavities [defined by an entrance diameter of at least 10 cm (3.9 inches)] was 4/ha (1.6/acre) in mature northern hardwood and mature aspen forests in Minnesota (Gilmer et al. 1978).

<u>Interspersion</u>

The best wood duck habitat is characterized by nest sites in close proximity to brood habitat (McGilvrey 1968). However, wood duck broods in North Carolina moved 2.4 km (1.5 mi) from a nesting pond to a shrub thicket marsh for brood rearing (Hardister et al. 1962). Although most of the movement was along a water course, overland travel of 0.16 km (0.1 mi) was required from the nesting pond to the river used for the major part of the movement. Wood duck hens and broods in Minnesota travelled overland up to 3.9 km (2.4 mi) from nest site to brood habitat (Ball 1973, cited by Gilmer et al. 1978). Wood duck broods in eastcentral Texas moved up to 11.7 km (7.7 mi) to brood habitat from nest sites located in areas without brood habitat, although overall brood survival was only 8% (Ridlehuber 1980). Management of forests for wood duck nesting cavities greater than 0.8 km (0.5 mi) from brood habitat is generally not recommended (McGilvrey 1968). Ball et al. (1975:778) found "... a significant negative linear correlation ... between distance of overland moves completed prior to 2 weeks of age and number of surviving ducklings in broods of radio-marked hens" (21 wood duck hens, 8 mallard [Anas platyrhyncos] hens). Broods that moved less than 0.8 km (0.5 mi) averaged 8.5 ducklings compared to an average of 6.8 ducklings in broods that moved greater distances. The maximum reported brood density is 17 broods on a 5.7 ha (14 acres) impoundment in Maryland (McGilvrey n.d., cited by McGilvrey 1968). In North Carolina, a 16.2 ha (40 acres) brood-rearing area supported a minimum of 27 wood duck broods in 1966 and 17 broods in 1967 (Vance 1968). Also in North Carolina, duckling density averaged about 2.0/0.4 ha (1.0 acre) of suitable brood rearing habitat and ranged from 1.6 to 2.3 ducklings/0.4 ha (1.0 acre) (Baines 1971).

McGilvrey (1969) reported a survival rate of hatched ducklings to flight stage of 53% (9.8 ducklings/brood at hatch; 5.2 ducklings/brood reaching flight stage). Ball et al. (1975) accounted for the loss of total broods, and concluded that wood duck hens successfully raised 41% of the total ducklings hatched.

Wood ducks do not maintain stable home ranges, and both the size and shape of their home ranges are flexible (Bellrose 1976). The total home range utilized by broods in South Carolina varied from 0.77 to 29.6 ha (1.9 to 73.1 acres) (Hepp and Hair 1977). Movements from fall roosts in Illinois ranged up to 10 km (6.2 mi), although most movements were within 2.2 km (1.4 mi) of the roosts (Parr et al. 1979). Areas of activity during the fall ranged from 23.9 to 186.2 ha (59 to 460 acres) and averaged 90.6 ha (224 acres). Most activity of nesting hens in Minnesota was within 1.0 km (0.6 mi) of the nest site, suggesting that a pair may use an area of approximately 3.0 km^2 (1.6 mi^2) (Gilmer et al. 1978).

Special Considerations

In areas where natural cavities are lacking or limiting, artificial nest boxes can be used to increase breeding populations (Bellrose et al. 1964). The most important factors limiting wood duck breeding populations are availability of and competition for suitable cavities, predators (McGilvrey 1968), and food (Fredrickson, pers. comm.). A nest box program that provides predator-proof nesting cavities can minimize the effects of the first two of these factors. In Massachusetts, Grice and Rogers (1965) found strong evidence that natural nest cavities were in short supply and concluded that (p. 87) "... wood ducks can be maintained at a higher level of abundance with [nest boxes] than without them". Other studies have also reported increases in breeding populations due to the use of nest boxes (Bellrose et al. 1964; Jones and Leopold 1967; Strange et al. 1971; Alexander 1977). However, some evidence exists to suggest that an excessive number of nest boxes may be detrimental to wood duck production. In California, a breeding population of wood ducks increased faster than the number of available nest sites (Jones and Leopold 1967). Over the course of the 9-year study, nest sites were gradually increased from 3 to 16 on a 11.3 ha (28 acres) marsh; an increase of breeding pairs from 3 to 35-40 occurred during the same period. At the higher levels of pair density, the population became essentially self-limiting due to intraspecific competition for nest cavities, an increase in nest desertion and dump nesting (i.e., instances in which several hens lay eggs in the same nest site), and a resultant decrease in the production of young per pair. Nest interference is also common on sites with extensive habitat where food is abundant and nest sites are limited (Fredrickson, pers. comm.). However, several researchers have reported that dump-nesting resulted in a greater production of young (Morse and Wight 1969; Clawson et al. 1979; Heusmann et al. 1980). Strader et al. (1978) cautioned that crowded nesting conditions could be detrimental to wood duck production; they observed a wood duck hen call a brood from an adjacent nest box mounted on the same support pole and abandon incubation of her own clutch.

McGilvrey (1968) recommended that nest boxes be placed in clusters of 5 to 10 spaced 15 to 30 m (50 to 100 ft) apart within clusters. Bellrose (1976) recommended that nest boxes be placed in groups of 2 to 4/0.4 ha (1.0 acre). Bellrose et al. (1964) recommended a nest box density of 2 to 3/0.4 ha (1.0 acre) in "high-quality habitat", although criteria to determine high-quality habitat were not presented. This level of nest boxes was recommended for woodlots where nesting in natural cavities was 1 pair/4.0 ha (10 acres). Additional guidelines for nest box placement are available in Bellrose et al. (1964), Bellrose (1976), and McGilvrey (1968). None of these references, however, contain information on a possible saturation level of nest boxes beyond which production would either remain constant or decrease. All of the above references note that nest boxes are effective only if they are predator-proof and regularly maintained.

Clearing of bottomland hardwoods has adversely affected wood duck populations because bottomland hardwood sites provide habitat for nesting, brood rearing, and wintering (Bellrose 1976).

HABITAT SUITABILITY INDEX (HSI) MODELS

Model Applicability

Geographic area. The two HSI models contained here have been developed for application within the breeding and wintering range of the wood duck (Fig. 1).

Season. These HSI models may be used to evaluate breeding (spring and summer) habitat and/or winter (fall and winter) habitat, depending on the residency status of the wood duck in the area to be evaluated.

Cover types. These models may be used to evaluate habitat in the following cover types (terminology follows that of U.S. Fish and Wildlife Service 1981): Deciduous Forest (DF); Deciduous Forested Wetland (DFW); Deciduous Scrub-Shrub Wetland (DSW); Herbaceous Wetland (HW); and Riverine (R). Use of unflooded deciduous forests is restricted to the breeding season model and should not be included when using the winter habitat model; however, flooded lowland deciduous forests should be included as winter habitat. Evaluation of wetlands should be restricted to those with water present during either the nesting/brood-rearing period or during the winter period, depending on the model(s) being used.

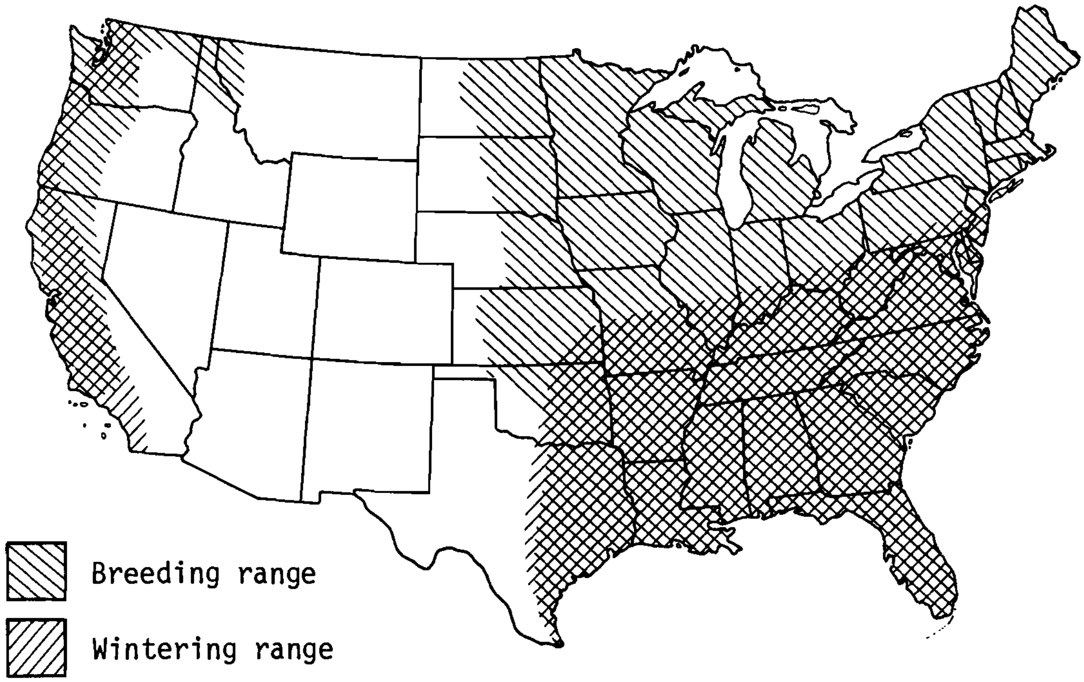


Figure 1. Geographic applicability of the wood duck HSI models within the United States (ranges from Bellrose 1976).

Minimum habitat area. Minimum habitat area is defined as the minimum amount of contiguous habitat that is required before an area will be occupied by a species. The minimum habitat area for broods is estimated to be 4 ha (10 acres) of any of the wetland cover types listed above. Potential brood habitat may exist either as an isolated wetland of at least 4 ha or as smaller wetlands separated by less than 46 m (50 yds) of land where the total area of potential brood habitat equals at least 4 ha. In stream or riverine habitat, small brood units should be within 0.4 km (0.25 mi) of each other. Minimum habitat area for habitat components other than brood habitat is unknown.

Verification level. These models have not been tested against habitats of known quality. Earlier drafts were reviewed by Drs. Leigh Fredrickson, Frank Bellrose, and Frank McGilvrey. Their review comments have been incorporated into the models.

Model Description - Breeding

Overview. The breeding season HSI model for the wood duck considers nesting and brood-rearing needs as critical components of breeding habitat. An HSI value for the breeding season considers the quality, composition, and juxtaposition of nesting and brood rearing resources. Food (vegetable and invertebrate) is considered to be correlated with vegetative cover, and the variable used to evaluate brood cover in this model is assumed to serve as a surrogate measure of food suitability. Factors other than vegetative cover (e.g., water quality, current, depth, permanence) may affect food suitability for wood ducks, but are not included in this model due to the difficulty of establishing relationships between the variables and a measure of food suitability. This is particularly difficult for highly dynamic variables, such as flooding periodicity. The assumption that food suitability can be estimated by considering vegetative cover only is the major limitation of this model.

The following sections identify important habitat variables, describe suitability levels of the variables, and describe the relationships between variables. The relationship between habitat variables, life requisites, and cover types used in this model and an HSI value for the wood duck during the breeding season is shown in Figure 2.

Nesting component. The quality of nesting habitat is a function of the availability of nesting sites. Potential nesting sites may be either naturally occurring tree cavities or artificial nest sites in the form of nest boxes. However, the presence of natural (including those in live trees and snags) and/or artificial nest cavities does not guarantee an equivalent number of successful nests. The proportion of observed potential nesting sites that are actually suitable for wood duck nesting and the proportion of suitable nesting sites that can be expected to support successful nests are important criteria determining the number of ducklings produced in a specified area.

Grice and Rogers (1965) tallied all cavities on two study areas but defined as suitable those cavities with minimum entrance dimensions of 6.4 by 8.9 cm (2.5 by 3.5 inches) and that were located within 0.8 km (0.5 mi) of water. Only 22 of 105 cavities (20.9%) met the minimum criteria. Weier (1966) tallied all cavities within 0.8 km (0.5 mi) of water that had a minimum entrance dimension of 6.4 by 8.9 cm (2.5 by 3.5 inches), a nesting platform of at least 12.7 by 17.8 cm (5 by 7 inches), and that were located in trees with a minimum dbh of 24 cm (9.5 inches). Suitable cavities met those criteria, did not contain water or debris, and were not open-topped. Seventeen of 109 cavities (15.6%) meeting minimum criteria were classed as suitable. In order to most easily evaluate natural cavities with this model, it is assumed that a cavity is potentially useful if it has a minimum entrance size of 7.6 by 10.0 cm (3.0 by 4.0 inches) (Bellrose, pers. comm.). Based on the information presented above, it is also assumed that only 18% of observed cavities meeting this minimum criterion will actually be suitable for wood duck use. All artificial nest sites are assumed to be suitable if they are predator-proof and cleaned and repaired annually.

The second major criterion determining the number of successful nests on a given area is the proportion of suitable cavities that can be expected to produce successful nests. Bellrose et al. (1964) found that of 631 natural cavities available and structurally suitable (i.e., minimum entrance dimensions as described above and free of water or debris), 235 (37%) were used by wood ducks. Data from numerous studies summarized by Bellrose (1976) indicate that the average use of artificial nest sites is 41% (46,761 house years; 19,108 nests). However, these data for both natural and artificial sites do not take into account whether factors other than the availability of nest sites were limiting the nesting population; for example, poor quality brood-rearing

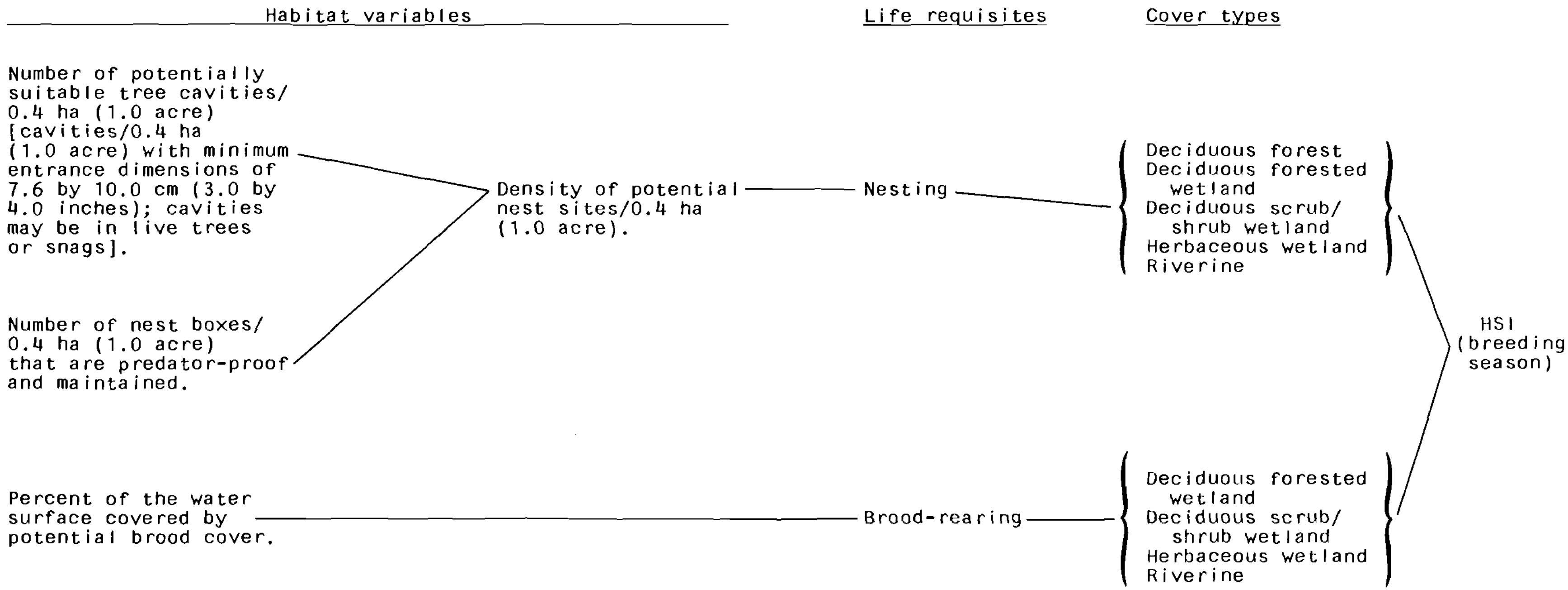


Figure 2. The relationship of habitat variables, life requisites, and cover types to an HSI value for the wood duck during the breeding season.

habitat may have limited recruitment of hens into the breeding population, or poor pre-breeding habitat may have limited the number of hens able to successfully nest. For the purposes of this model, it is assumed that all potential nest sites meeting the minimum criteria defined above may potentially be used.

If it is assumed that all suitable natural and artificial nest sites may potentially be used, then the success rate of the initiated clutches will determine the overall production of young from nest sites. The success rate of nests in natural cavities in Illinois was 49.1% (118 nests, 58 successful) from 1939-1940 and 39.9% (158 nests, 68 successful) from 1958-1961, with the lower success rate due to an increase in predation (Bellrose et al. 1964). However, the highest success rate in natural cavities reported in the literature is 52% (Prince 1965, cited by Bellrose 1976). It is assumed in this model that 52% is the best success rate that can be expected for wood ducks nesting in natural cavities.

Bellrose (1976) summarized the results of a number of studies of artificial nest sites for wood ducks. The average success rate, with individual success rates weighted by the number of nests, was 71.6%. However, the two highest reported success rates for wood ducks nesting in artificial cavities are 95%, based on 341 nests in Arkansas (Brown 1973, cited by Bellrose 1976), and 94%, based on 281 nests in Iowa (Leopold 1966, cited by Bellrose 1976). Based on this information, it is assumed in this model that 95% is the best success rate that can be expected for wood ducks nesting in nest boxes.

Based on the preceding discussion, the number of successful nests that can be expected on a given area can be determined by the following equation:

$$\text{\# of potentially successful nests} = (NT \times P1_T \times P2_T) + (NB \times P1_B \times P2_B) \quad (1)$$

where: NT = the number of tree cavities with a minimum entrance size of 7.6 by 10.0 cm

$P1_T$ = the proportion of observed tree cavities that can be expected to be suitable for nesting by wood ducks

$P2_T$ = the proportion of suitable cavities that can be expected to produce successful nests

NB = the number of available nest boxes

$P1_B$ = the proportion of nest boxes that are actually suitable for nesting by wood ducks

$P2_B$ = the proportion of suitable nest boxes that can be expected to produce successful nests

Substituting the values determined previously for $P1_T$, $P2_T$, $P1_B$, and $P2_B$ yields the following equation:

$$\# \text{ of potential successful nests} = (NT \times .18 \times .52) + (NB \times 1.0 \times .95)$$
$$= (NT \times .09) + (NB \times .95) \quad (2)$$

The maximum reported density of successful nests appears to be about 5 successful nests/0.4 ha (1.0 acre) on a North Carolina study area (Hester n.d., cited by McGilvrey 1968). Although this may not represent a stable maximum density (Bellrose, pers. comm.), it is assumed in this model that 5 successful nests/0.4 ha (1.0 acre) represents the maximum density of successful nests and therefore determines the maximum production of ducklings. Based on equation (2), this maximum density can be achieved with either 55.6 natural cavities/0.4 ha (1.0 acre) or 5.3 nest boxes/0.4 ha (1.0 acre), or by a combination of the two types of nest sites. However, this nest site density does not necessarily need to exist across an entire study area in order to have optimal habitat. The relationship between optimal nesting habitat and optimal brood-rearing habitat is discussed under the Interspersion Component section. Although some evidence exists to suggest that wood duck nesting populations can be so dense that overall production is adversely affected (Jones and Leopold 1967; Strader et al. 1978), such a relationship has not been documented to the point that a decrease in habitat suitability beyond a certain density of nesting sites can be predicted.

Brood-rearing component. The quality of brood-rearing habitat is influenced by cover, water permanence, and wetland characteristics.

Cover for wood duck broods consists of dense cover in shallow wetlands with water present throughout the period of brood occupancy. Cover can be provided by emergent herbaceous vegetation, emergent shrubs and trees with crowns within 1 m (3.3 ft) of the water surface, or woody downfall. Dense cover that is well interspersed with small open water channels provides optimal brood habitat. Optimal brood cover within a wetland is assumed to occur when the proportion of total cover in the wetland ranges from 50 to 75 %. Other factors that influence the suitability of brood habitat include water depth, quality, current, and permanence. All of these factors influence the amount of cover and the macroinvertebrate food base to a certain extent and may be highly dynamic within a wetland. It is assumed in this model that cover conditions are the reflection of the combined influence of these variables. It is assumed, therefore, that the quality of wood duck brood habitat can be evaluated solely on the basis of the amount of cover available in the wetland. A major implication of this assumption is that the abundance and quality of vegetative and invertebrate foods is indicated by the cover conditions described above. This assumed relationship may not be valid in all conditions, especially in flooded lowland forests, where an abundant detrital-based food source may be present in the absence of low, dense cover.

Interspersion component. Nesting and brood-rearing needs can be met by different cover types, and a consideration of the juxtaposition and composition of cover types providing the life requisites is necessary in order to evaluate breeding habitat suitability.

Habitat suitability is influenced by the juxtaposition of nesting and brood-rearing habitat. Optimal juxtaposition of nesting and brood-rearing resources is assumed to exist when cover types providing these life requisites are located within 0.8 km (0.5 mi) of each other. When potential nesting and brood-rearing habitats are separated by more than 3.2 km (2 mi) of upland habitats with no aquatic "travel lanes", it is assumed that the cover types are too far apart to be used by wood ducks or that mortality of ducklings travelling from the nest to brood-rearing habitat will equal 100%.

Habitat suitability is also influenced by the proportion of habitat (composition) providing nesting and brood-rearing resources. In order to determine the optimal composition of nesting and brood-rearing habitat, it is necessary to determine the number of young capable of reaching flight stage per unit area of optimal brood-rearing habitat compared to the number of young produced per unit area of optimal nesting habitat. The maximum reported density of broods is 17 broods on a 5.7 ha (14 acres) impoundment in Maryland, equivalent to 1.2 broods/0.4 ha (1.0 acre) (McGilvrey n.d., cited by McGilvrey 1968). The observed broods on a 54.7 ha (135 acres) area, including the 5.7 ha impoundment, averaged 9.8 ducklings at hatching and 5.2 ducklings reaching flight stage, a survival rate of 53% (McGilvrey 1969). The 5.7 ha impoundment, therefore, supported about 88 ducklings (i.e., 17 broods x 5.2 ducklings/brood) to flight stage, an average of 6.2 ducklings/0.4 ha (1.0 acre) of brood-rearing habitat. This level of production is considered to be the potential of optimal brood-rearing habitat for the purposes of this model.

Optimal nesting habitat was described earlier as capable of producing 5 successful nests/0.4 ha (1.0 acre). If the average clutch size in normal nests is assumed to be 12.2 (Bellrose 1976) and all eggs are assumed to hatch successfully, then 0.4 ha (1.0 acre) of optimum nesting habitat can potentially produce 61 ducklings (i.e., 12.2 ducklings/clutch x 5 clutches/0.4 ha) leaving the nest sites. The highest survival rate of ducklings reported in the literature is 53% (McGilvrey 1969). It is assumed in this model that this is the optimal survival rate of ducklings reaching brood-rearing habitat. If it is further assumed that survival from the nest to brood-rearing habitat equals 100% (i.e., interspersion is optimal), and optimal brood-rearing habitat exists, then an average of 32.3 ducklings (0.53 x 61) will survive to flight stage from the 61 ducklings produced on 0.4 ha (1.0 acre) of optimal nesting habitat. As described above, 0.4 ha (1.0 acre) of optimum brood-rearing habitat can potentially support 6.2 ducklings to flight stage. Therefore, the ratio of optimum brood-rearing habitat to optimum nesting habitat to support maximum wood duck production is approximately 5.2:1 (i.e., 32.3/6.2 = 5.2). The maximum potential production of wood ducks per unit area will occur if optimal nesting and optimal brood-rearing conditions exist on all areas under consideration. Therefore, the optimal composition of wood duck habitat is approximately 19% optimal nesting habitat ([1/5.2] x 100 = 19%) and 100% optimal brood-rearing habitat ([5.2/5.2] x 100 = 100%).

The assumptions involved in determining optimal composition of nesting and brood-rearing resources are summarized below:

1. Optimal nesting habitat will produce 5 successful nests/0.4 ha (1.0 acre).

2. Average clutch size in normal nests (i.e., non-dump nests) is 12.2, and hatching success equals 100%.

3. Survival of ducklings from nests to brood-rearing habitat equals 100%, and survival to flight stage of ducklings reaching brood-rearing habitat equals 53%.

4. Optimal brood-rearing habitat can support 6.2 ducklings/0.4 ha (1.0 acre) to flight stage.

5. Optimal habitat conditions for wood duck production consist of nesting habitat and brood-rearing habitat provided by the same cover types (i.e., all cover types provide both nesting and brood-rearing habitat).

Model Description - Winter

Overview. This winter HSI model for the wood duck considers cover as the key life requisite determining winter habitat suitability. The measurement of vegetative cover within wetlands is assumed to serve as a surrogate measure of winter food suitability. Other factors affect food suitability, but are not included in this model. The assumption that a measure of vegetative cover can be used to evaluate food suitability is a limitation of the model. The assumption may not be valid in some situations, such as when wood ducks are feeding in flooded bottomland forests, where food may be abundant in the absence of low vegetative cover. The relationship between habitat variables, winter cover, cover types, and an HSI for winter habitat of the wood duck is shown in Figure 3.

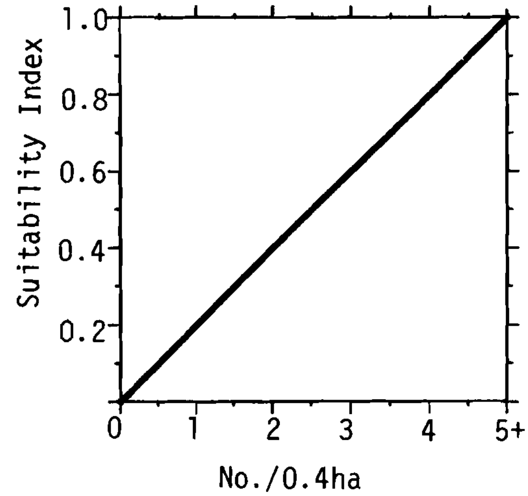
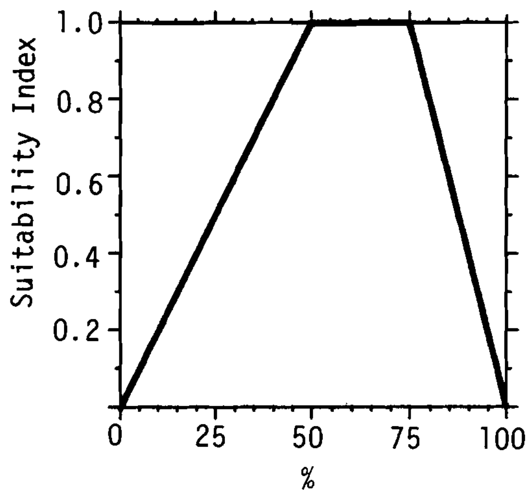
Habitat variable	Life requisites	Cover types	
Percent of the water surface covered by potential winter cover ——	Cover ——	Deciduous forested wetland Deciduous scrub/shrub wetland Herbaceous wetland Riverine	—— HSI (winter)

Figure 3. The relationship of habitat variables, life requisites, and cover types to an HSI value for the wood duck during the winter.

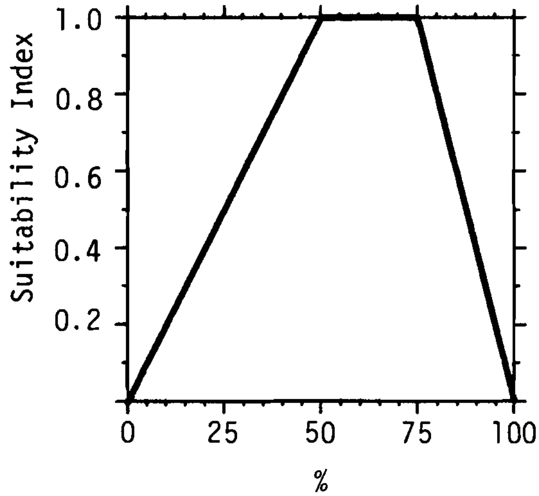
Cover component. It is assumed in this model that winter habitat needs of the wood duck are similar to habitat used during the brood-rearing period (see p. 13). Optimal conditions are assumed to be present if the amount of total cover (woody and/or herbaceous) ranges from 50-75%. Winter-persistent herbaceous plants are the only type of herbaceous vegetation considered in an evaluation of winter habitat. Water depth, quality, current, and permanence are not treated as separate habitat variables for the reasons discussed in the brood-rearing section of the breeding season model. Although acorns and other mast are an important winter food source, wood ducks will use other foods if necessary. It is assumed that food suitability will vary directly with cover suitability, and is not considered as a separate winter life requisite in this model.

Model Relationships - Breeding and Winter

Suitability Index (SI) graphs for habitat variables. This section contains suitability index graphs that illustrate the habitat relationships described earlier. Suitability index graphs for both the breeding HSI model and the winter HSI model are presented in this section.

Cover type	Variable		
DF,DFW, DSW,HW,R	V_3	Density of potential nest sites/0.4 ha (1.0 acre). Determined by the equation: $(0.18 \times V_1) + (0.95 \times V_2)$ where V_1 = the number of potentially suitable tree cavities/0.4 ha, and V_2 = the number of nest boxes/0.4 ha (see Figure 4 for complete definition of V_1 and V_2).	
DFW,DSW, HW,R	V_4	Percent of the water surface covered by potential brood cover (see Figure 4 for definition).	

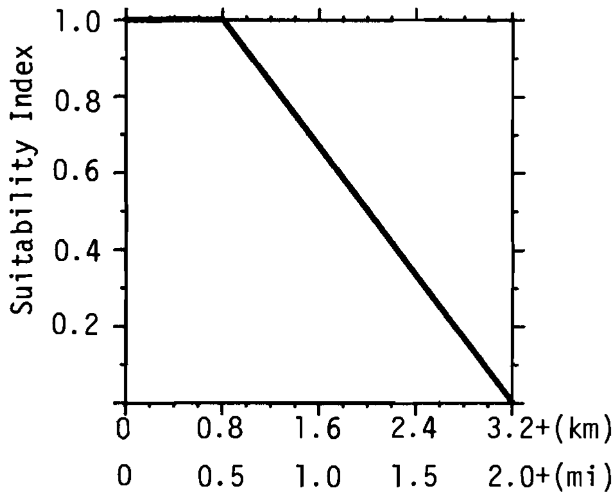
DFW,DSW, HW,R V_5 Percent of the water surface covered by potential winter cover (see Figure 4 for definition).



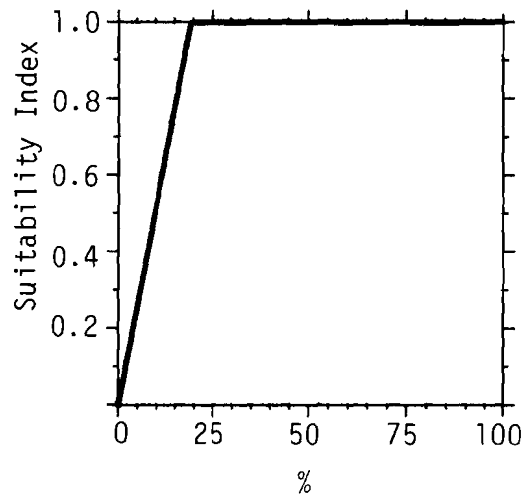
<u>Suitability Index (SI) graphs for interspersion variables</u>. This section contains suitability index graphs that illustrate the relationship between interspersion variables and breeding habitat suitability for the wood duck. The use of these graphs is explained under <u>HSI determination</u>.

<u>Variable</u>

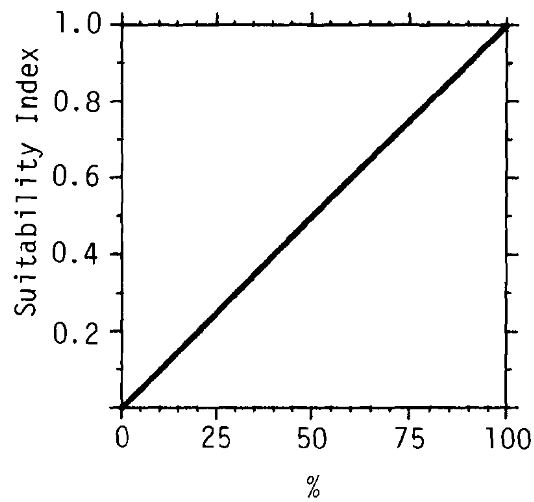
V_6 Distance between cover types.



V_7 Percent of area providing equivalent optimum nesting habitat.



V_8 Percent of area providing equivalent optimum brood-rearing habitat.



Determination of life requisite values. The determination of life requisite suitability indices by cover type with this model involves simple one-variable equations. The nesting value in all cover types equals the SI of V_3. Brood habitat suitability and winter habitat suitability in all cover types except deciduous forest, equals the SI of V_4 and V_5, respectively.

HSI determination - breeding HSI model. It is possible that some cover types will provide nesting habitat but not brood-rearing habitat, or brood habitat but not nesting habitat. In order to adequately evaluate breeding habitat, juxtaposition and composition of resources must be considered. Several steps and calculations are necessary in order to properly incorporate interspersion variables into the HSI determination. They are as follows:

1. Compute the nesting and brood-rearing values for each cover type by collecting field data for each habitat variable, entering this data into the proper suitability index curve, and using the resulting index values in the appropriate life requisite equations. If either nesting or brood-rearing equals zero in all cover types, then the HSI will equal zero and no further calculations are necessary.

2. Determine the relative area (%) of each cover type within the study area as follows:

$$\text{Relative Area (\%) for Cover Type A} = \frac{\text{Area of Cover Type A}}{\text{Total Area of All Cover Types used by the Wood Duck}} \times 100$$

   Consider only those cover types used by the wood duck in determining this percentage.

3. Determine which cover types are not providing either nesting or brood-rearing habitat. For each of these cover types, a suitability index for juxtaposition of resources must be computed using V_6.

   This is accomplished by selecting random points on a map in each cover type missing a life requisite and measuring the distance to the edge of the nearest other cover type that provides that life requisite. Enter each distance measurement into the SI graph for V_6, record the individual interspersion indices, and calculate the average interspersion index for each cover type. If both nesting and brood-rearing habitat are provided within a specific cover type, the interspersion index equals 1.0 for the cover type.

4. Modify the relative area (%) of each cover type missing a life requisite by multiplying the relative area by the average interspersion index for that cover type. This determines the useable relative area (%) of each cover type. For those cover types that provide all life requisites the useable relative area (%) is the same as the relative area (%).

5. To determine the % area in optimum condition for any life requisite, first multiply the useable area (%) for each cover type by the life requisite values for that cover type (from 1 above). Sum the products of this multiplication across all cover types for each life requisite. The sum for each life requisite is the equivalent percent area that provides that life requisite at optimal levels (this is actually an equivalent figure, i.e., 100% of the area at a 0.5 value is equal to 50% of the area at an optimal, 1.0 value).

6. To determine overall life requisite values enter the value determined in Step 5 for nesting into the SI graph for V_7, and the value

determined for brood-rearing into the SI graph for V_8. The resulting index value from V_7 is the overall nesting value, and the index value from V_8 is the overall brood-rearing value.

7. The HSI is equal to the lowest of the overall life requisite values. This single HSI value is considered to represent breeding suitability across the entire area evaluated.

HSI determination - winter HSI model. The winter HSI for the wood duck in a specified cover type equals the winter cover value (i.e., the SI for V_5) determined for that cover type.

HSI determination for year-round use areas. The HSI models presented here are designed to evaluate breeding and winter habitat separately. In those areas where the wood duck is a resident species, it may be desirable to assign one overall HSI to a study area. In order to do so, a weighted (by cover type area) average HSI for winter habitat is determined and compared to the single HSI determined for breeding habitat. Because wood ducks may move between winter habitat and breeding habitat, the HSI in areas of permanent residency should equal the highest of the values determined for breeding and winter habitat suitability.

Application of the Models

Model limitations. These models represent a relatively simple approach to evaluating wood duck habitat suitability during the breeding season and winter. The use of cover estimates as surrogate measures of food suitability is perhaps the most important limitation of this model. Other factors that affect food suitability, such as wetland dynamics, and more direct food measurements are not included in this model because of the lack of adequate literature in these areas. Fredrickson (pers. comm.) indicates that current studies have the potential to address the unknowns in these models and that it should be possible to improve these models in the next few years. However, until such information becomes available, users should be aware of the model's limitations, especially in regards to wetland dynamics. For example, flooded lowland forests potentially provide an abundant source of macroinvertebrates to hens prior to nesting, also to broods during the first few weeks after hatching, and to wintering wood ducks. The quality of this habitat may be high even in the absence of optimum cover conditions as depicted by Variables 4 and 5 in this model. However, means to accurately and directly address the impacts of wetland dynamics on a macroinvertebrate food base are not currently available. The major problem limiting the use of the winter HSI model is that the model does not include an assessment of the importance of wetland complexes to wintering wood ducks (Fredrickson, pers. comm.). Rather, each wetland type is evaluated individually, since the means of evaluating a large variety of arrangements of wetlands is not currently available. Users of this model should use the Habitat Use Information section of this model, as well as local information, to adapt this model to local conditions, if necessary.

Use of model variables. Although these models provide a relatively simple means of evaluating the suitability of wood duck habitat, use of the breeding HSI model requires an estimate of the number of potential nest cavities in trees. Sampling of cavities in live trees is difficult and likely to provide an underestimate. Several options, other than intensive sampling, are available for estimating density of potential nest sites. In areas that are managed for wood ducks with a nest box program, optimum conditions may be provided by artificial sites alone. In cases where there are at least 5.3 nest boxes/0.4 ha (1.0 acre), optimum suitability levels have been reached, and a survey of potential natural nest sites is unnecessary. Alternatively, the potential for cavity production in various cover types can be estimated based on species composition and size classes of trees. McGilvrey (1968) provides a list of desirable tree species for cavity production by geographic region. The minimum dbh of a potential nest tree is 35 cm (14 inches), although the most suitable cavity trees range from 60 to 90 cm (24 to 30 inches) dbh. Intensive sampling of a limited area may provide an adequate estimate of cavity density, or an estimate may be interpolated from available literature (e.g., Dreis and Hendrickson 1952; Bellrose et al. 1964; Weier 1966; Gilmer et al. 1978) or provided by local knowledge.

Definitions of habitat variables and suggested field measurement techniques (Hays et al. 1981) are provided in Figure 4.

SOURCES OF OTHER MODELS

Several other attempts have been made to develop habitat models for the wood duck, including models developed for use with the Habitat Evaluation Procedures in Missouri (Flood et al. 1977; Hallett and Fredrickson 1980; Urich et al. 1983). The Missouri models provide a means of ranking habitat suitability based on habitat characteristics. Flood et al. (1977) includes the wood duck and hooded merganser (*Lophodytes cucullatus*) in a model for waterfowl in bottomland hardwood, upland hardwood, and riverine cover types. The model in Hallett and Fredrickson (1980) is intended for use in both bottomland and upland hardwood cover types and is a refinement of the model in Flood et al. (1977). The model in Urich et al. (1983) is intended for use in bottomland hardwoods and is a modification of the two previous Missouri models. The Missouri models evaluate habitat suitability only in bottomland and/or upland hardwood forests, and do not provide criteria for evaluating the suitability of other wetland types for wood ducks. They are most useful, therefore, where wood duck habitat is provided by upland hardwood forests and forested wetlands. A major difference between the Missouri models and the breeding season HSI model presented here is the method by which interspersion variables are treated. The Missouri models consider the distance between the cover type being evaluated and some critical resource (i.e., timbered habitat or permanent water) as a habitat variable. In our model, we use the distance between a cover type and a missing life requisite (i.e., nesting or brood-rearing habitat) to modify the available habitat area and also use life requisite composition suitability index curves to evaluate the balance of life requisites provided by a given area. A final major difference between the Missouri models and the breeding season HSI model presented here lies in the manner in

Variable (definition)		Cover types	Suggested technique
V_1	Number of potentially suitable tree cavities/ 0.4 ha (1.0 acre) [tree cavities/0.4 ha (1.0 acre) with minimum entrance dimensions of 7.6 by 10.0 cm (3.0 by 4.0 inches); cavities may be in live trees or snags].	DF,DFW,DSW, HW,R	Quadrat
V_2	Number of nest boxes/ 0.4 ha (1.0 acre) (the number of artificial wood duck nest sites/0.4 ha that are predator-proof and maintained).	DF,DFW,DSW, HW,R	Quadrat
V_3	Density of potential nest sites/0.4 ha (1.0 acre) (an estimate of the density of natural and artificial nest sites available to wood ducks. Determined by the following equation: $(0.18 \times V_1) + (0.95 \times V_2)$ where V_1 and V_2 are as defined above).	DF,DFW,DSW, HW,R	----
V_4	Percent of the water surface covered by potential brood cover [an estimate of the proportion of a wetland's water surface area that is covered by shrub cover, overhanging tree crowns within 1 m (3.3 ft) of the water surface, woody downfall, and herbaceous vegetation].	DFW,DSW, HW,R	Remote sensing, ocular estimation, line intercept

Figure 4. Definitions of variables and suggested measurement techniques.

Variable (definition)		Cover types	Suggested technique
V_5	Percent of the water surface covered by potential winter cover (same as for V_4 except that only winter persistent species should be considered in the herbaceous vegetation component).	DFW,DSW HW,R	Remote sensing, ocular estimation, line intercept

Figure 4. (concluded).

which HSI values are determined. The former models result in one HSI value for each cover type, while this model results in one HSI value for the aggregation of cover types used by the wood duck in a given area.

A simple approach to evaluating wood duck breeding habitat along streams was developed by Burbank (1972). This approach is based on tree size and subjective evaluation of general stand conditions. McGilvrey (1968) provides criteria that can be used to develop a habitat model for the wood duck for several geographic areas.

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16\. Abstract (Limit: 200 words)

A review and synthesis of existing information were used to develop models for breeding and wintering habitats for the wood duck (Aix sponsa). The models are scaled to produce indices of habitat suitability between 0 (unsuitable habitat) and 1 (optimally suitable habitat). Habitat suitability indices are designed for use with Habitat Evaluation Procedures previously developed by the U.S. Fish and Wildlife Service.

17\. Document Analysis a. Descriptors

Mathematical models
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c. COSATI Field/Group

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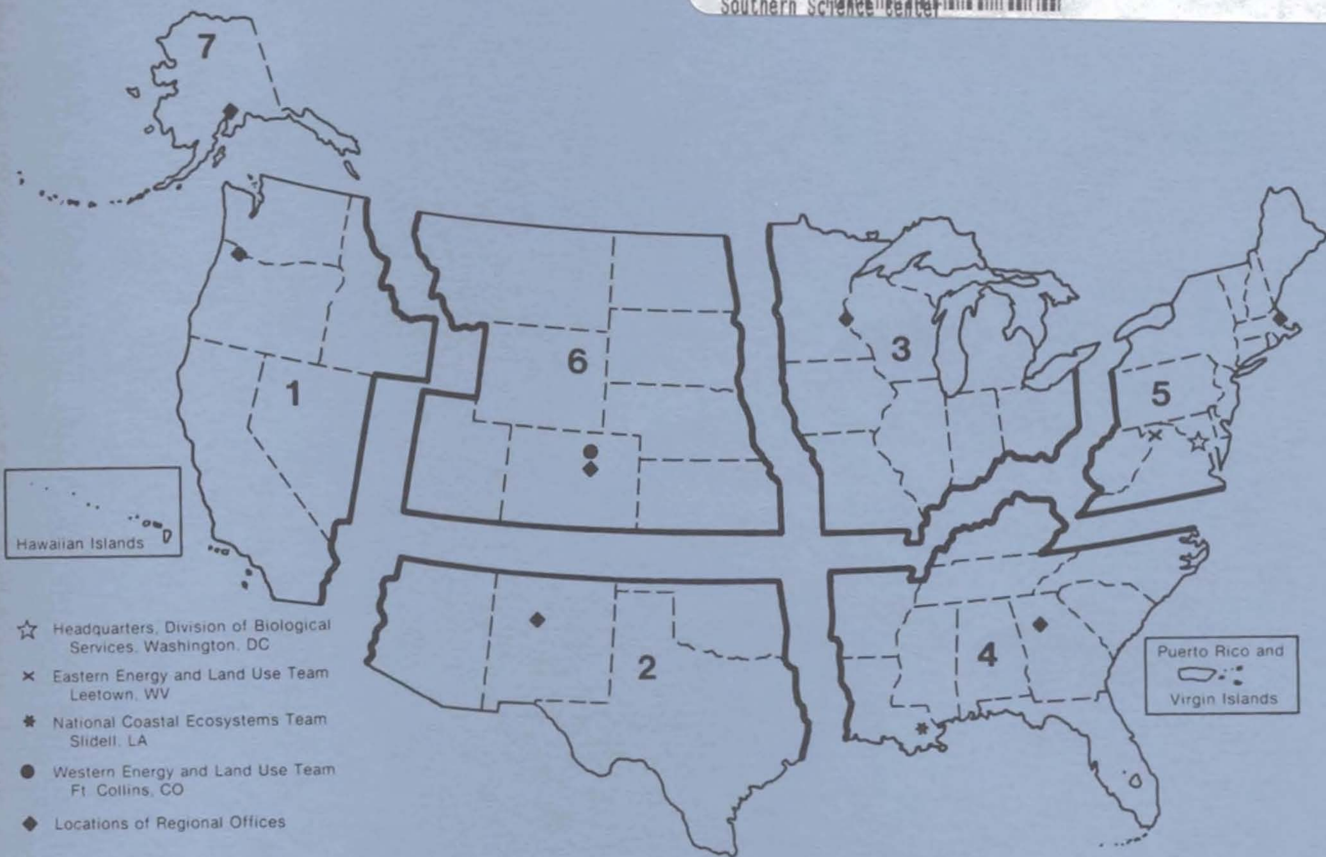

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