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HABITAT SUITABILITY INDEX MODELS: MOTTLED DUCK

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HABITAT SUITABILITY INDEX MODELS: MOTTLED DUCK

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PREFACE

The habitat suitability index (HSI) model in this report on the mottled duck is intended for use in impact assessment and habitat management. The model was developed from a review and synthesis of existing information and is scaled to produce an index of habitat suitability between 0 (unsuitable habitat) and 1 (optimally suitable habitat). Assumptions involved in developing the HSI model and guidelines for model applications, including methods for measuring model variables, are described.

This model is a hypothesis of species-habitat relationships, not a statement of proven cause and effect relationships. The model has not been field-tested. For this reason, the U.S. Fish and Wildlife Service encourages model users to convey comments and suggestions that may help increase the utility and effectiveness of this habitat-based approach to fish and wildlife management. Please send any comments or suggestions you may have on the HSI model to:

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MOTTLED DUCK (*Anas fulvigula maculosa*)

INTRODUCTION

The mottled duck is a mallard-like resident species of the Gulf of Mexico coast, from the marshes of Pearl River on the Louisiana-Mississippi border to the Alvarado Lagoon near Veracruz, Mexico (Bellrose 1976). The highest densities of nesting mottled ducks are found in brackish to fresh coastal marshes (H. Bateman, Louisiana Department of Wildlife and Fisheries, Baton Rouge; pers. comm.). Mottled ducks also inhabit prairie land near prairie potholes in Texas and flooded rice fields in Texas (Engeling 1950) and Louisiana (Linscombe 1972).

Life History Overview

Mottled ducks nest from the first week in February to late August (Engeling 1950; Weeks 1969; Allen 1981). Peak nesting occurs during March, April, and May (Stutzenbaker 1979).

The number of eggs per mottled duck clutch averages between 8 and 10 (Bellrose 1976). A high percentage of the eggs hatch, but the percentage of successful nests is low. Only 30 of 108 nests observed by Singleton (1953) were successful. A number of direct causal factors, such as predation, nest desertion, and flooding, are important in bringing about this low nesting success.

Mottled ducks that lose their first nest frequently renest. Engeling (1950) reported a hen constructing five nests before bringing off a brood. This persistence to renest partially offsets the effects of detrimental environmental factors, but subsequent clutches are smaller than preceding clutches.

Eggs are incubated for 24-28 days (averaging 26 days) (Stutzenbaker 1979). Mottled duck broods appear as early as March and as late as August. Young fledge at 8-10 weeks, so brood-rearing occurs from March into October.

Engeling (1950) recorded the number of ducklings in 69 broods, ranging in age from less than 2 to 8 weeks. Broods less than 2 weeks of age averaged 9.4 ducklings, while 8-week-old broods averaged 6.1 birds, a reduction of 35%. Using a larger sample size, Allen (1981) estimated brood mortality from 1 to 5 weeks of age as 22.5%. Bellrose (1976) reported brood mortality at 36%.

Unpaired males begin to increase in numbers with the onset of nesting in February, and numbers of unpaired birds increase into midsummer, when young birds are fledging and most of the drakes have deserted their mates. By the end of July, fewer than 10% of all mottled ducks are still paired (Bellrose 1976), and large numbers of adults are undergoing the postnuptial molt. Pair

bonding between adults begins once again in August, and by October most of the birds are paired (S. Paulus, Rockefeller Refuge, Louisiana; pers. comm.). Weeks (1969) and Paulus (pers. comm.) noted courting adults as early as August, but Engeling (1950) did not observe courtship until February.

Mottled ducks become gregarious in late summer. Flocks up to 40,000 have been reported along the gulf coast from late July to early November (Singleton 1953; Stutzenbaker 1979). Also, during this period, large numbers of birds fly inland to newly harvested and second-growth rice fields, where they sometimes become pests (Linscombe 1972).

SPECIFIC HABITAT REQUIREMENTS

Food

Adult mottled ducks are primarily vegetarians, but consume considerable animal matter at times (Singleton 1953). During molting, mottled ducks in Texas predominantly eat the seeds of gulfcoast spikerush (*Eleocharis cellulosa*), bulrush (*Scirpus validus*),[1] widgeongrass (*Ruppia maritima*); the leafy portions of widgeongrass and dwarf spikerush (*Eleocharis parvula*); and snails (Stutzenbaker 1979). From late July through August, mottled ducks often congregate and feed in stands of sea purslane (*Sesuvium portulacastrum*) in southwestern Louisiana (Weeks 1969). Many birds also feed on waste grain in flooded rice stubble after the first crop is harvested in late summer (Engeling 1950).

Mottled ducks exhibit highly varied diets in the fall and winter. In a large sample of hunter-killed ducks in Texas, Stutzenbaker (1979) found mostly vegetation in mottled duck gizzards; however, a significant portion of the late winter diet at Rockefeller Refuge, Louisiana, consists of animal foods (Paulus, pers. comm.).

Mottled ducks feed in shallow water areas. White and James (1978) stated that water depth was an important variable for characterizing autumn habitat. During their October to December study, they never observed mottled ducks feeding in water deeper than 30 cm (11.8 inches). In addition, water depth greater than 30 cm renders food unavailable to young broods (White 1975).

Invertebrates are especially important for young ducklings (Singleton 1953; LaHart and Cornwell 1970; Stutzenbaker 1979; Swanson et al. 1979). From hatching to 3 weeks of age at Murphree Management Area, Texas, 80% of the diet of broods consisted of insects, insect larvae, small fish, snails, and amphipods (Stutzenbaker 1979). Older ducklings began a transition to plant foods in their fourth week. The most important foods at Murphree for ducklings 3 - 9 weeks of age were bulrush, widgeongrass, naiads (*Najas* spp.), two species of

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[1]In this report, scientific names of plants conform to Soil Conservation Service (1982). When scientific names used by references differ from Soil Conservation Service (1982), the names originally used by the reference are given in parenthesis.

spikerush, and two species of pondweed (Potamogeton spp.). Food intake at this time reflects food availability (Stutzenbaker 1979). These results, however, were derived from gizzard content analysis, which may underrate the importance of invertebrates (Swanson et al. 1979).

The concensus of researchers is that food does not limit duck populations (Lack 1954). Chabreck et al. (1974) found no correlation between numbers of ducks and their foods, and concluded that other factors were more important in governing the distribution of ducks. White and James (1978) characterized the habitat selected by mottled duck during autumn and winter using environmental factors that did not consider food directly.

Cover

Nesting. In coastal marshes, preferred nesting habitat of mottled ducks are areas characterized by tall, dense stands of grass located on elevated sites, well above high tide and usually within 150 m (492 ft) of water (Engeling 1950; Stutzenbaker 1979). Few mottled ducks nest in saline marshes. In Texas, ducks nest in ungrazed or lightly grazed prairie near potholes (Engeling 1950). In rice production areas, nests were found by Engeling (1950) and Singleton (1953) on levees, road sites, and in fallow rice fields where grazing pressure was light or absent.

Mottled ducks use a variety of plant species for nesting cover, but these species tend to form structurally similar vegetative communities. Stutzenbaker (1979) found that mottled ducks in all habitat types showed an almost inseparable affinity for tall-grass nesting areas. J.R. Singleton (Ducks Unlimited, Houston, Texas; pers. comm.) believed that 35.0-45.0 cm (13.8-17.7 inches) is an optimal height for nesting cover. In the coastal marshes, the birds frequently nest in clumps of cordgrass (Spartina patens), which normally grows to a height of 0.6-1.0 m or 2.0-3.3 ft (Engeling 1950). However, T. Joanen (Rockefeller Refuge, Louisiana; pers. comm.) reported that mottled ducks occasionally nest in saltgrass (Distichlis spicata), a species that generally grows in mats only 0.15-0.30 m (0.49-0.98 ft) tall. Where grasses are short or sparse, mottled ducks use false indigo (Baptisia sphaerocarpa) and other shrubs as nesting cover. However, areas thick with woody species, such as groundsel-tree (Baccharis spp.), are avoided (Stutzenbaker 1979). An abundance of rushes (Juncus spp.), bulrushes, and/or cattails (Typha spp.) indicate very wet soil conditions, which detract from nesting habitat quality (C. Stutzenbaker, Murphree Management Area, Texas; pers. comm.).

Vegetation at the nest site must be dense enough to conceal a hen and her nest from predators and sunlight (Stutzenbaker 1979). Nests are typically located in the most robust stands of grass available. Sparse, overgrazed, or burned nesting cover is only used when no better cover is available (Stutzenbaker 1979). Heavy grazing may also initiate succession to brush fields, which are unsuitable as nesting sites. This is especially true of some prairie and pastureland in Texas.

Marshland and pastures are frequently burned to improve forage production and, periodically, natural fires occur. Nest losses are very high in marshes where fires occur while nests are active. Periodic fires are beneficial in Texas brushland because they favor the invasion of grasses and actually improve the habitat for mottled ducks.

The history of fire in an area influences the quality of nesting cover. Stutzenbaker (1979) stated that the greater length of time fire had been excluded, the better protection (as nesting cover) the rank growth of cordgrass offered. Poor cover, however, may only partially explain low densities of nesting birds in regularly burned areas. Nests are constructed of dead grass and vegetation from previous seasons that the hen harvests while sitting at the nest site (Engeling 1950) or while in the immediate vicinity (O. Baker, Louisiana State University, Baton Rouge; pers. comm.). Areas burned or mowed regularly may lack sufficient nesting material.

Brood. Optimal habitat conditions for hens with newly hatched ducklings are characterized by a high water-to-land ratio. Emergent and shoreline vegetation are used for escape cover by hens with broods (Stutzenbaker 1979). In the coastal marshes of Texas, Engeling (1950) found that the best brood-rearing sites were bordered by a lush growth of cordgrass, saltgrass, and/or hardstem bulrush (*Scirpus californicus*). Stands of emergent vegetation were often present in the interior of these bodies of water and provided excellent escape cover for young birds. Stutzenbaker (1979) found that gulf coast spikerush was important cover at Murphree Management Area, Texas.

Broods may be reared on the edges of large lakes, ponds, potholes, or irrigation ditches (Stutzenbaker 1979), but water over 30.0 cm (11.8 inches) deep supports few broods. Paulus (pers. comm.) believed that very shallow water (2.5-7.5 cm or 1.0-3.0 inches) is optimal for ducklings 1-3 weeks of age, and 10.0-20.0 cm (3.9-7.9 inches) is optimal for fledglings.

Prairies, pastures, and ponds surrounded by coffee bean (*Cassia occidentalis*) support the highest densities of young ducklings in Texas inland areas (Engeling 1950). Rushes, smartweeds (*Polygonum* spp.), and willow primrose (*Lugwigia* sp.) also provide escape cover in prairie potholes. Ponds in heavily grazed pastures frequently have little escape cover and are not favored as brood-rearing sites (Stutzenbaker 1979).

In dry years, small ponds and potholes may be scarce, resulting in high densities of young ducks on whatever surface water remains (Allen 1981). These conditions are conducive to disease, parasite transmittal (Keith 1961), and increased competition for resources. In addition, aquatic predators are likely to occur in high densities in remaining ponds. Cover may become inaccessible as the shoreline retreats. These conditions are likely to lead to high brood mortality (Stutzenbaker 1979; Allen 1981).

Flooded rice fields are used as brood-rearing sites, but the quality of this habitat is disputed. Engeling (1950) and Joanen (pers. comm.) considered flooded rice fields excellent rearing areas. Stutzenbaker (pers. comm.) judged this habitat to be poor and believed its use may vary depending upon the availablity and proximity of better habitat.

Adult. Postbreeding adult birds frequent large permanent bodies of water with stands of submergent aquatic plants and bordered by good escape cover where they spend their flightless, monthlong, postnuptial molting period. During dry years, birds may be forced to fly relatively long distances (usually towards coastal marshes) to find sufficient water to meet these requirements (Engeling 1950; Stutzenbaker 1979). In years with good rainfall and sufficient surface water, molting ducks often use muskrat (*Ondatra zibethicus*)

and goose eat-out areas (hollow flooded areas relatively free of vegetation) near their nesting sites (Stutzenbaker 1979).

Towards the end of November, mottled ducks are dispersed in pairs predominantly in isolated ponds within the coastal marshes. White and James (1978) found that adult mottled ducks fed in areas averaging 51% emergent vegetation from October to December; however, White (1975) did not find the percentage of floating and submerged vegetation an important indicator of feeding habitat quality.

Lagoons bordered by thickets of huisache (Acacia spp.) and catclaw (Mimosa spp.) are a favorite wintering habitat for mottled ducks in Mexico (Saunders and Saunders 1981).

Reproduction

Broods are led to water within 24 hours of hatching. Brood mortality of mallard (Anas platyrhynchos) ducklings has been shown to correlate with the distance between nests and water (Dzubin and Gollop 1972). Therefore, proximity of the nesting site to water is important to the quality of nesting habitat (Engeling 1950; Singleton 1953; Stutzenbaker 1979). Information from a number of sources on average and extreme distances from mottled duck nest sites to water is reproduced in Table 1. These researchers merely recorded the distances from nests to the nearest body of water. Average values reported may, or may not, represent optimal distances to water.

Table 1. Average and extreme distances of mottled duck nests from water.

Source	Average distance	Extreme distance
Engeling (1950)	62 m (203 ft)	0-183.0 m (0-600.4 ft)
Singleton (1953)		1.5-305.0 m (4.9-1000.7 ft)
Bellrose (1976)	within 150 m (492 ft)	1.6 km (1.0 mi)
Stutzenbaker (1979)	119 m (390 ft)	0-1.6 km (0-1.0 mi)
J. Dunks (pers. comm.)		3.2 km (2.0 mi)

The benefits of nesting very near water are offset by increased predation (Keith 1961) and a high susceptibility to flooding. Severe storms, fairly routine throughout the nesting season, can have a considerably negative impact on nesting success, especially in poorly drained lowland areas. Engeling (1950) estimated that at least 50% of the active nests were flooded during a 3-day storm in Texas that dropped 10.6 cm (4.2 inches) of rain. Overbank river flooding and unusually high tides destroy some nests as well. Therefore, there is an intermediate distance from water where costs and benefits are balanced and nest success is maximized.

Nesting habitat may also flood during extended periods of light to moderate rainfall. However, nesting hens respond to slowly rising water by

adding material to their nests, thereby elevating them above flood waters. Bellrose (1976) reported that mottled ducks built nests up to a height of nearly 0.5 m (1.6 ft).

Mottled ducks nest in lowland areas and basins in dry years. These areas hold the last remaining pools and potholes. They are also the first areas to flood, resulting in high nest loss. Lynch (1967), however, noted that marsh levees with staggered borrow pits provided flood-proof nest sites and drought-proof brood sites.

Water

The physiological water requirements of mottled ducks are assumed to be met in areas of adequate cover.

Special Considerations

Mottled ducks are territorial. Home ranges were observed to vary from 42.5-132.0 ha or 105.0-326.2 acres (Weeks 1969). The nest site of a pair may or may not be within the territory they defend (Engeling 1950). Stutzenbaker (1979) found active nests were never less than 18 m (59 ft) apart. The distance between active nests was typically 61 to 91 m (200 to 300 ft). Weeks (1969) calculated the territorial size of six nesting pairs and found it to vary from 10 to 36 ha (25 to 90 acres).

Water quality can influence mottled duck use of water bodies (H. Chabreck, Louisiana State University, Baton Rouge; pers. comm.). Water contaminated by oil or chemical spills or characterized by strong odors arising from rotting vegetation is unsuitable for rearing broods.

Mottled ducks prefer nest sites with minimal human disturbance. Activities involving loud noises or frequent use by people, cattle, or dogs increase the rate of nest desertion and decrease the percentage of successful nests and the density of nests (Engeling 1950; Singleton 1953; Stutzenbaker 1979). Through continual exposure, birds appear to be able to acclimate to regular disturbances (Busnell 1977).

Predators have been implicated in a number of nest failures (Singleton 1953; Weeks 1969; Stutzenbaker 1979). Engeling (1950) suggested that predation also plays a major role in brood mortality. He observed predation by dogs and believed turtles were responsible for missing extremities on some ducklings he examined. The actual effect of predation on mottled duck production is poorly understood. In addition, the literature includes conflicting reports on the importance of various predators. Stutzenbaker (1979) believed that the single most important factor in nest loss is predation by the raccoon (*Procyon lotor*). But Singleton (1953) attributed the loss of only 1 nest out of 108 to raccoons. In his study, the total effect of native predators was insignificant. Nevertheless, Singleton (1953) did find that predation by domestic dogs was important, especially in the vicinity of farms and dwellings. He attributed the loss of 26 of 108 nests to dogs.

Adult and fledgling birds in the postbreeding period die from numerous reasons including predation, disease, lead poisoning, and accidents. Mortality as a result of these factors is probably insignificant in comparison to

losses from sport hunting. In Texas, over 50% of the population is estimated to be harvested in some years (Stutzenbaker 1979). Mottled ducks are readily attracted to decoys during teal (Anas spp.) season in September, and some are shot at this time. Nevertheless, Stutzenbaker (1979) believed that the number of illegally taken mottled ducks is relatively small and remains well within the acceptable wildlife management limits.

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area. The model encompasses the known range of the species. This area includes the gulf coast of Louisiana, Texas, and Mexico.

Season. The HSI model provides an index to the suitability of the habitat from the initiation of nesting until broods are fledged. Sampling should be conducted during the spring and summer because some of the model variables pertain to environmental conditions that occur only during these seasons. If the model is applied during other seasons, variables that are seasonally programmed must be adjusted.

Cover types. The mottled duck inhabits fresh, brackish, and saline coastal marshes; coastal prairies and pasturelands; and cultivated and fallow rice fields. See Appendix A for habitat descriptions. These wetland types correspond to the palustrine emergent (PEM), palustrine scrub-shrub (PSS), estuarine intertidal emergent (E2EM), and estuarine intertidal scrub-shrub (E2SS) types of Cowardin et al. (1979). The model evaluates the suitability of all cover types. The literature contains conflicting values for rice fields as habitat for nesting hens and hens with broods. Both fallow and flooded rice fields are assigned an HSI of 0.5, a value midpoint between the conflicting viewpoints.

Minimum habitat area. Minimum habitat area is defined as the minimum amount of contiguous habitat required before an area will be occupied by a species. Water bodies of any size may be used by mottled ducks if other habitat requirements are met. Maximum land areas needed for nesting are not recorded in the literature. Because mottled ducks are territorial, areas that do not provide at least a 10.0-m (32.8-ft) wide buffer on all sides of the nest site appear unsuitable, resulting in a minimum habitat area of approximately 314 m^2 (3,380 ft^2).

Verification level. The model was critiqued by waterfowl biologists and wildlife managers of the Texas and Louisiana gulf coast. Three of these individuals (O. Baker, Louisiana State University, Baton Rouge; S. Paulus, Rockefeller Refuge, Louisiana; and C. Stutzenbaker, Murphree Management Area, Texas) are actively involved in mottled duck research. The model was reviewed by Dr. R. Chabreck (Louisiana State University) and T. Joanen (Rockefeller Refuge). The reviewers' comments have been incorporated into the current model.

Model Description

Overview. This model is developed for the two life stages of the mottled duck during the reproductive season: nesting hens and hens with broods. After the broods fledge and until the next nesting season, adult mottled ducks are highly mobile and less habitat-specific. Areas suitable for nesting hens and hens with broods are assumed to be suitable for mottled ducks during the remainder of the year.

Flooding is a significant cause of nest loss, and droughts are detrimental to both nesting hens and hens with broods. The frequency at which droughts and floods occur depends upon rainfall over the mottled duck range. The annual amount of precipitation is an environmental factor and not a component of the habitat and, as such, is not addressed in the model.

The specific habitat requirements section identifies a number of environmental factors that determine habitat quality for mottled ducks. Individual suitability indices (SI) for these factors are combined to generate HSI values for the area of concern. The relationship of habitat variables and life requisites to the HSI is illustrated in Figure 1.

The following sections document the logic and assumptions (Table 2) used to interpret the known habitat information for the mottled duck and to explain the relationships among variables and equations used in the HSI model. A limiting relationship among three life requisites - reproductive cover, food availability, and other (freedom from disturbance) - is assumed when determining the HSI for mottled ducks during the reproductive season.

Reproductive cover. Suitable nesting habitat for mottled ducks is assumed to be those areas within 3.0 km (1.9 mi) of fresh- to brackish water where the substrate is not submerged in the spring and where woody vegetation canopy cover is less than 30%. Nesting cover suitability in this HSI model is influenced by the following three variables: percentage cover of rushes, bulrushes, or cattails (V_1); percentage canopy cover of trees and shrubs (V_2); and the structure (height and density) of herbaceous, emergent vegetation (V_3). Areas with an abundance of rushes, bulrushes, or cattails are prone to flooding, rendering them less suitable as nesting sites. The quality of nesting cover is reduced if trees and shrubs are present. Vegetation that provides 10%-15% overhead cover is considered of fair value for nesting. Good nesting cover is sufficiently dense to provide 16%-79% overhead cover. Excellent nesting cover would provide 80%-100% overhead cover and would be so thick that a human would normally walk on top of the grass, instead of through it.

The variables are aggregated into a measure of nesting hen cover in a manner that allows compensations for low values of any variable by high values of the other variables. If any variable, however, is unsuitable (SI=0), then the nesting hen cover will also be unsuitable.

It is assumed that the primary habitat for hens and broods is characterized by a submerged substrate. The quality of cover for broods and hens is influenced by the percentage areal cover of woody or herbaceous emergent vegetation (V_4), and the structure (height and density) of woody or herbaceous emergent vegetation (V_5). Emergent vegetation consists primarily of grasses, rushes, and sedges, but may include woody vegetation that typically grows in

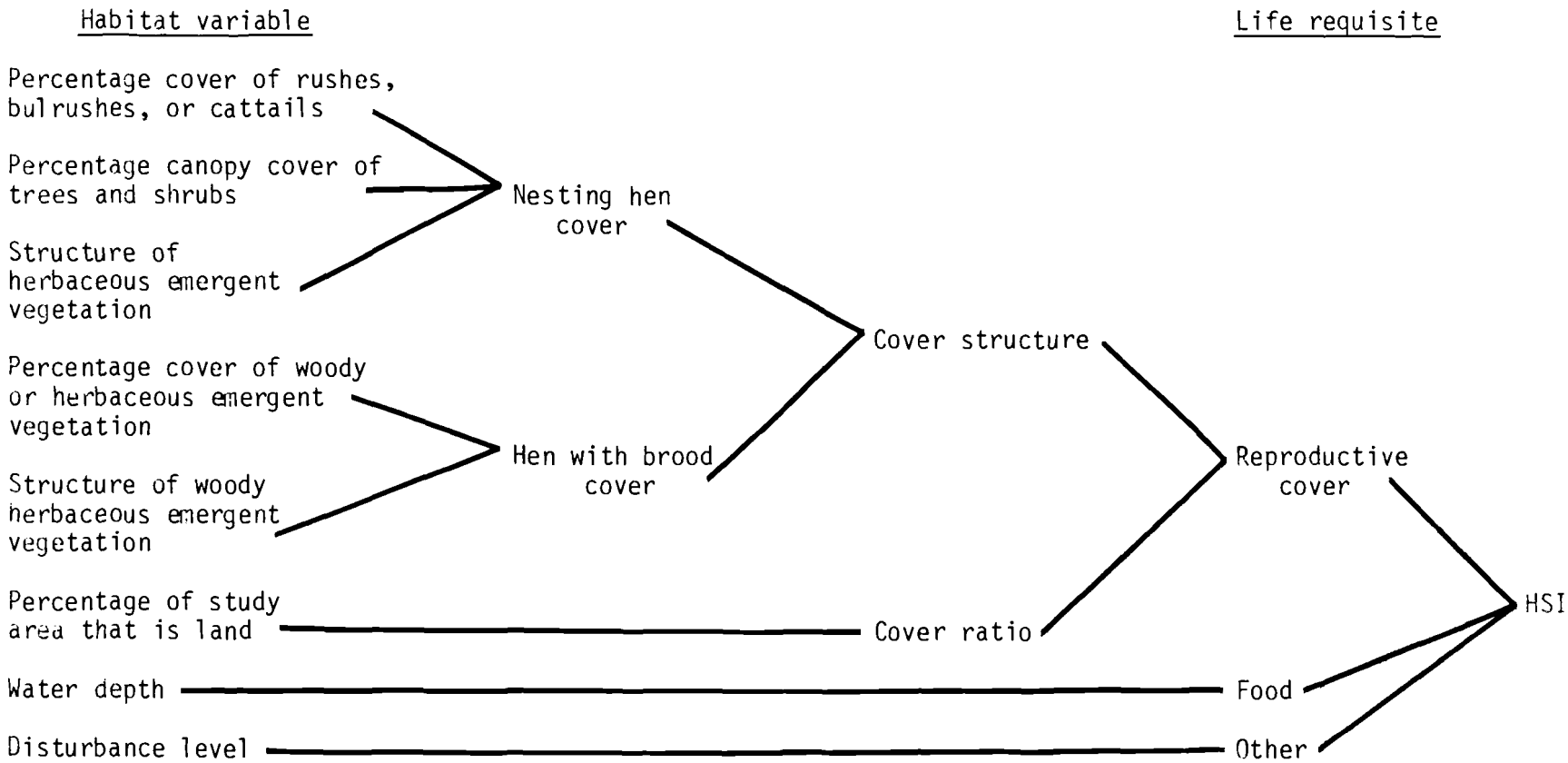


Figure 1. Relationship of habitat variables and life requisites to the habitat suitability index (HSI) for nesting mottled duck hens and mottled duck hens and broods.

Table 2. Data sources and assumptions for mottled duck suitability indices.

Variable and source		Assumption
V_1	Engeling 1950 Stutzenbaker 1979	Optimal nesting habitat is dominated by grasses and similarly structured vegetation. Presence of bulrushes, rushes, or cattails is assumed to reflect conditions too moist for optimum nesting habitat.
V_2	Stutzenbaker 1979	Quality of nesting habitat decreases with increasing cover of woody vegetation; habitat with 30% woody vegetation canopy cover is unsuitable.
V_3	Engeling 1950 Stutzenbaker 1979	Nesting habitat quality is related to height and density of grasses and similarly structured vegetation excluding bulrushes, rushes, and cattails.
V_4	Engeling 1950 Stutzenbaker 1979	Optimal brood-rearing habitat is a submersed substrate supporting growth of emergent vegetation over 50% of its area.
V_5	Engeling 1950 Stutzenbaker 1979	Quality of emergent vegetation as escape cover is related to its height and density.
V_6	Weeks 1969	Optimal reproductive habitat for mottled ducks consists of equal amounts of nesting and brood-rearing habitats.
V_7	Engeling 1950 Paulus, pers. comm.	Depth of water is related to feeding efficiency of mottled duck hens and broods.
V_8	Engeling 1950 Singleton 1953 Stutzenbaker 1979	Irregular disturbance is detrimental to nesting mottled duck hens and hens with broods.

shallow water. Because hens and broods use open water as well as vegetation for escape cover, an approximate 1:1 ratio of these habitat types is considered optimal for V_4. Quality of emergent or woody vegetation is related to height and density. Examples of minimal escape cover include mats of saltgrass or short, sparse stands of spikerush. Herbaceous vegetation from 0.3 to 1.0 m (1.0 to 3.3 ft) in height, such as cordgrass or rank gulf coast spikerush, would provide fair escape cover. Optimal escape cover would be sufficiently dense and tall as to be impenetrable to a predator. However, when emergent vegetation is so dense that it forms an impenetrable stand with no channels, passages, or hiding places for ducklings, it becomes unsuitable as escape cover.

The assumed interaction between V_4 and V_5 allows compensation for a low value of one variable by a high value of the other. But, if either or both variables are measured to be a zero on the suitability index, brood cover is unsuitable.

The structural component of reproductive cover is determined in this model by the value of either nesting hen cover, calculated from V_1, V_2 and V_3, or hen and brood cover, calculated from V_4 and V_5, whichever is lower. As described previously, nesting hens require a high land-to-water ratio, but a high water-to-land ratio is optimal after broods hatch. Because resolution of these opposing needs is impossible, approximately equal parts water (submerged substrate) and land (substrate not submerged and not supporting growth of rushes, bulrushes or cattails), or a study area that is 40%-60% land (V_6), is assumed to be optimal in an area that supports both nesting hens and hens with broods. If the study area is considered small and is composed of mainly land or water, it may be more reasonable to evaluate the area for only nesting hens or hens with broods. For these situations, V_{6a} or V_{6b}, depending on the life stage being evaluated, should be substituted for V_6 as the appropriate measure of cover ratio suitability.

The value of the reproductive cover life requisite is determined by the interaction between the suitability of cover structure and cover ratio. Although a favorable cover ratio can partially compensate for poor cover structure, the greater influence of structure on overall suitability is indicated by a weighting factor on cover structure during calculation of the reproductive cover life requisite value.

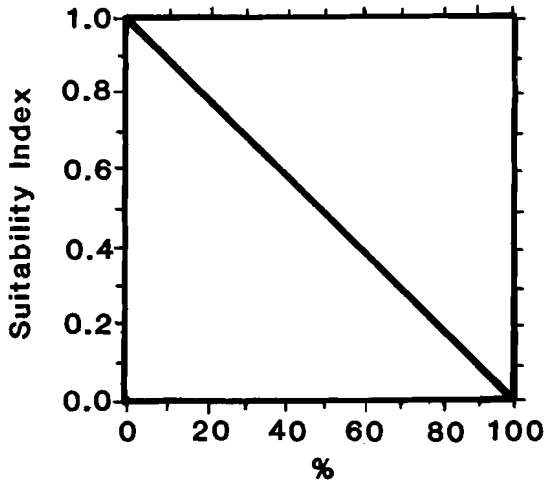
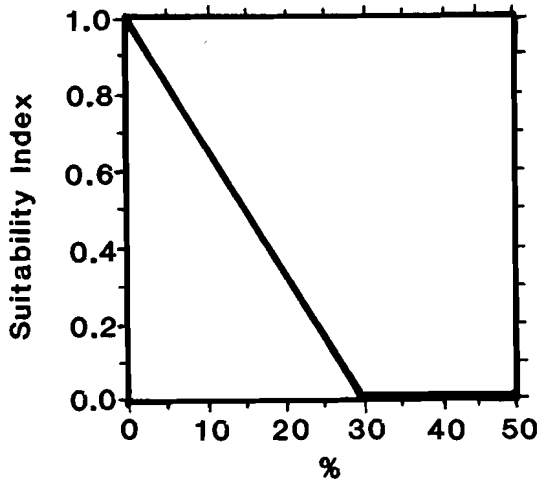
Food. The quantity and quality of food were assumed to be nonlimiting for mottled ducks. However, food availability is included in the model through a measure of the amount of water that is of a suitable depth for feeding (V_7).

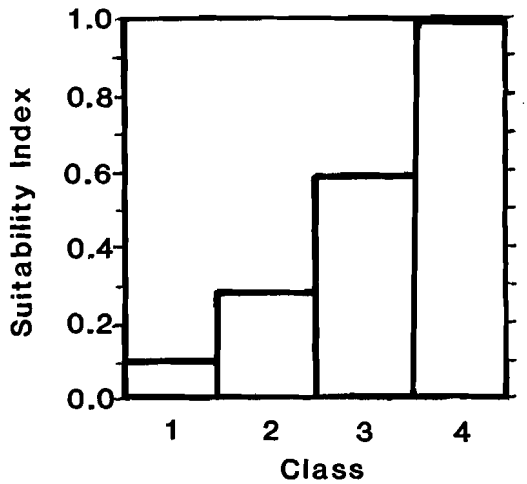
Other. The level of disturbance (V_8) influences the quality of the habitat. Hens exposed to irregular, infrequent disturbances may desert nests. The effects of irregular disturbances on hens and broods are not reported in the literature. Nevertheless, disturbances that affect nesting success would also influence brood-rearing because broods are reared near the nest site.

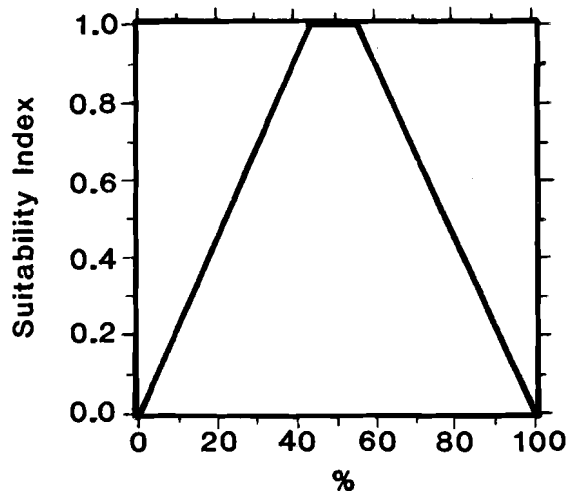
Suitability Index (SI) Graphs for Model Variables

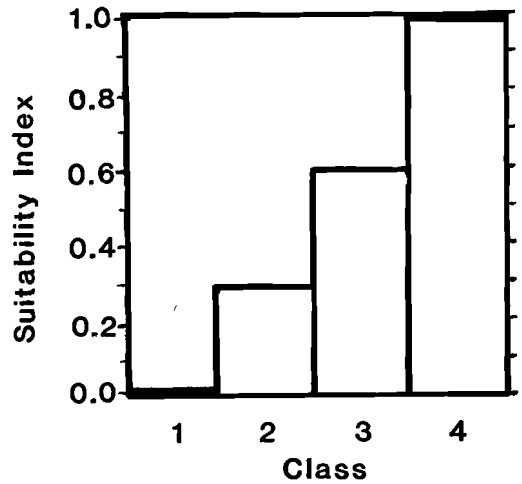
This section provides graphic representations of the relationships between values of habitat variables and habitat suitability for mottled duck

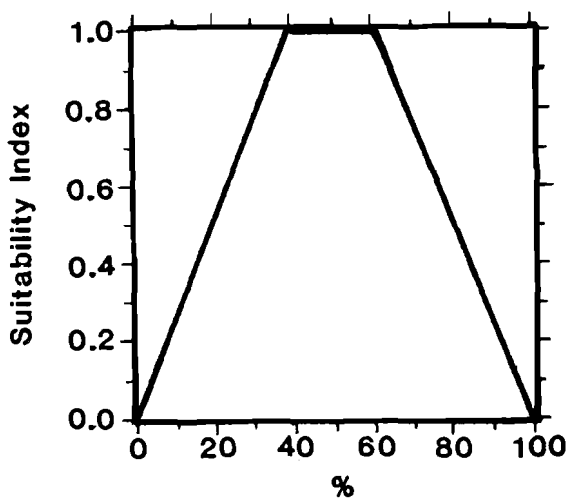
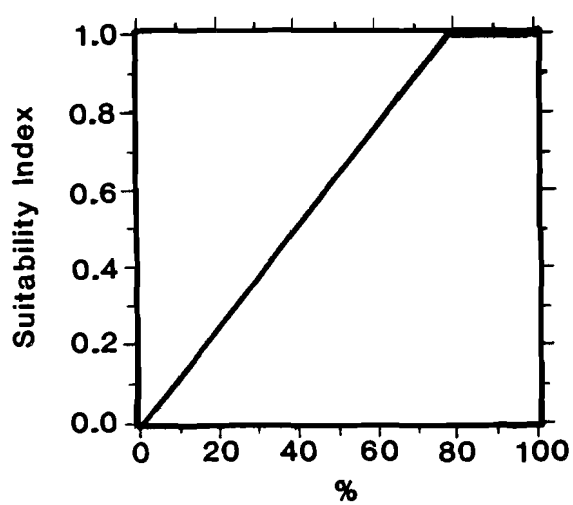
nesting hens and hens with broods in estuarine (E) and coastal palustrine (P) habitats. The SI values are read directly from the graph (1.0 = optimum suitability, 0.0 = unsuitable) for any variable. Although there are interdependencies and correlations between many habitat variables, each variable is assumed to operate independently over the range of other variables under consideration.

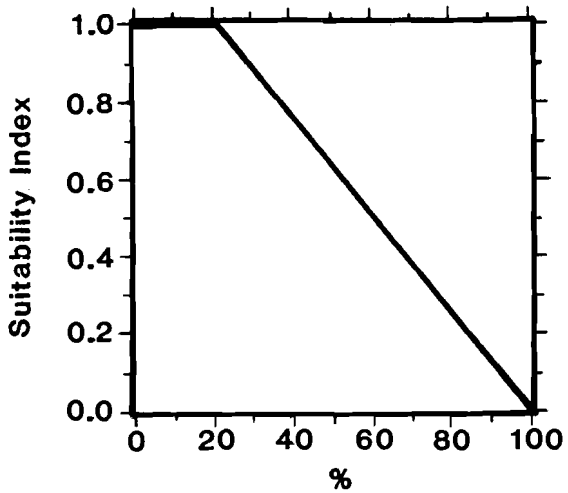
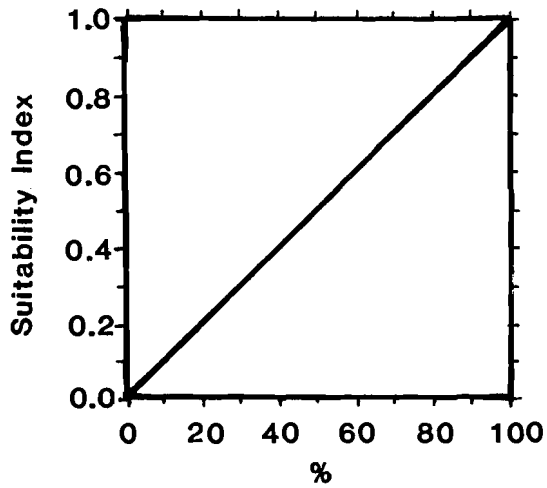
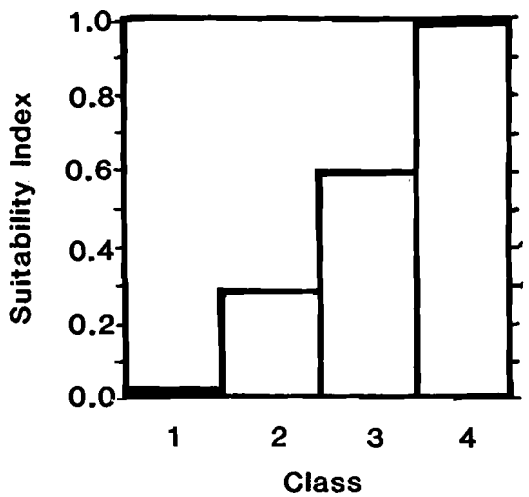
Habitat	Variable		Suitability Graph
E, P	V_1	Percentage of unsubmerged substrate covered by rushes, bulrushes, or cattails.	
E, P	V_2	Percentage canopy cover of trees and shrubs on unsubmerged substrate.	

Habitat	Variable		Suitability Graph
E, P	V_3	Structure of herbaceous vegetation (excluding rushes, bulrushes, and cattails) on unsubmerged substrate. 1) Not growing in clumps. 2) Growing in clumps; 0.25 to 0.50 m (0.82 to 1.64 ft) tall and/or providing overhead cover of 1% to 15%. 3) Growing in clumps; 0.50 to 0.75 m tall (1.64 to 2.46 ft) and/or providing overhead cover of 16% to 79%. 4) Growing in clumps with overlapping tops; > 0.75 m (2.46 ft) tall and/or providing > 80% overhead cover. Note: Calculate the percentage of total unsubmerged substrate area in each structure class (1, 2, 3, and 4). This percentage, expressed as a decimal, becomes the weighting factor (W) for each class. Calculate SI_{V_3} as follows: $SI_{V_3} = 0.1W_1 + 0.3W_2 + 0.6W_3 + 1.0W_4$.	

Habitat	Variable		Suitability Graph
E, P	V_4	Percentage of continually submerged substrate covered by woody or herbaceous emergent vegetation.	

E, P	V_5	Structure of woody or herbaceous emergent vegetation growing in continually submerged substrate. 1) < 0.3 m (< 1.0 ft) tall or too dense to allow passage of ducklings. 2) ≥ 0.3 m (≥ 1.0 ft) growing in mats or in sparse stands. 3) 0.3 to 1.0 m (1.0 to 3.3 ft) tall and sufficiently dense to make passage difficult for a large predator (e.g., raccoon). 4) >1.0 m (> 3.3 ft) tall and sufficiently dense to be almost impenetrable to a large predator but with openings and passageways for escape of ducklings.	

Habitat	Variable		Suitability Graph
E, P	V_5 (Cont'd)	Note: Calculate the percentage of total submerged substrate area in each structure class (1, 2, 3, 4). This percentage, expressed as a decimal, becomes the weighting factor (W) for each class. Calculate SI_{V_5} as follows: $SI_{V_5} = 0.0W_1 + 0.3W_2 + 0.6W_3 + 1.0W_4$.	
E, P	V_6	Percentage of study area that is land (substrate not submerged and not supporting growth of rushes, bulrushes, or cattails). Note: The following alterations of V_6 (V_{6a} and V_{6b}) are applicable when small areas are being evaluated for only nesting hens or hens and broods (see explanation in section on Model Use).	
E, P	V_{6a}	Percentage of study area that is land. (Nesting hens.)	

Habitat	Variable		Suitability Graph
E, P	V_{6b}	Percentage of study area that is land. (Hens with broods.)	
E, P	V_7	Percentage of continually submerged substrates with water depth less than 30.0 cm (11.8 inches) at low mean tide.	
E, P	V_8	Disturbance level (see Appendix B for level definitions). 1) Extreme. 2) Moderate. 3) Minimal. 4) None.	

HSI Determination

The following steps and calculations are necessary to properly determine an HSI score:

1. Review the section on model applicability for validity of the model for the intended population.

2. The HSI for rice fields is set at 0.5.

3. Compute the suitability index values for each variable after collecting field data for each variable and entering these data in the proper suitability curve.

4. Calculations

Component	Equation
Nesting Hen Cover (NHC)	$(SI_{V_1} \times SI_{V_2} \times SI_{V_3})^{1/3}$
Hen with Brood Cover (HBC)	$(SI_{V_4} \times SI_{V_5})^{1/2}$
Cover Structure (CS)	NHC or HBC, whichever is lower
Cover Ratio (CR)	SI_{V_6}
Reproductive Cover Life Requisite (C)	$(CS^2 \times CR)^{1/3}$
Food Life Requisite (F)	SI_{V_7}
Other Life Requisite (O)	SI_{V_8}

HSI = C, F, or O, whichever is lowest.

Data representing three hypothetical study areas were used to calculate sample HSI values (Table 3). Habitat suitability for both nesting hens and hens with broods on the first study area is limited by the disturbance level. The second area was evaluated as nesting hen habitat only. This area has high reproductive cover value but is again limited by disturbance. The suitability of the third study area, considered to be hen with brood habitat only because of the low percentage of land, is determined by food availability.

Table 3. Calculation of suitability indices (SI), component indices, and habitat suitability indices for three sample data sets using habitat variable (V) measurements and mottled duck HSI model equations.

Model Component	Study area I		Study area II		Study area III	
	Data	SI	Data	SI	Data	SI
V_1	50%	0.5	0%	1.0	--	--
V_2	0%	1.0	5%	0.83	--	--
V_3	40% Class 2 60% Class 3	0.48	20% Class 3 80% Class 4	0.92	--	--
V_4	45%	1.0	--	--	50%	1.0
V_5	100% Class 4	1.0	--	--	60% Class 3 40% Class 4	0.76
V_6	30%	0.75	--	--	--	--
V_{6a}	--	--	80%	1.0	--	--
V_{6b}	--	--	--	--	10%	1.0
V_7	80%	0.8	--	--	85%	0.85
V_8	Class 2	0.3	Class 3	0.6	Class 4	1.0
NHC	0.62		0.91		--	
NBC	1.0		--		0.87	
CS	0.62		0.91		0.87	
CR	0.75		1.0		1.0	
C	0.66		0.94		0.91	
F	0.8		--		0.85	
O	0.3		0.6		1.0	
HSI	0.3		0.6		0.85	

Field Use of the Model

The use of this model is not appropriate in all situations, such as when water quality has been degraded. The reduction in available habitat as a result of environmental contaminants will interfere with proper interpretation of the model.

The level of detail needed for a particular application of this model will depend on temporal, monetary, and accuracy constraints. Detailed field sampling of all variables will provide the most reliable and consistent HSI values. Any or all variables can be estimated to reduce the amount of time required to apply the model. Increased use of subjective estimates decreases consistency. Estimates should be accompanied by appropriate documentation to insure that decisionmakers understand both the method of HSI determination and the quality of the data used in the HSI model.

Visual estimates of terrestrial and emergent vegetation and water depths will greatly reduce the working hours necessary to compute the HSI. These are best estimated by an onsite inspection supplemented with aerial photographs. Investigators should be especially cautious when estimating water depths. The absence of emergent vegetation does not necessarily indicate deep water because of the negative effects of high turbidity, currents, or salinity on plant growth. Suggested field measurement techniques are given in Table 4.

The user may wish to evaluate an area solely on its value as either nesting habitat or as brood-rearing habitat. This may be desirable especially in areas known to be used heavily during a particular life stage or in areas that are considered too small to obtain an adequate representation of the land to water ratio. To evaluate an area for mottled duck nesting, V_4, V_5 and V_7 are dropped from the model and V_{6a} replaces V_6. To evaluate an area as brood-rearing habitat, V_1, V_2, and V_3 are dropped and V_{6b} replaces V_6. The HSI value is determined by using the same procedure outlined for the combined life stage model.

Interpreting Model Outputs

A mottled duck HSI, determined by field application of this model, may not reflect the population density of mottled ducks in the study area because other factors may have significant influence in determining species abundance. The model may, however, yield HSI values that have positive correlations with long-term abundance. This correlation has not been tested, other than from inferences drawn from the literature to support the model. The proper interpretation of the HSI is one of comparison. If different areas have different HSI's, then the area with the higher HSI should have the potential to support more mottled ducks than the one with the lower HSI.

Table 4. Suggested methods for field measurement of variables used in the mottled duck HSI model.

Variable	Methods
V_1, V_2	Percentage cover of emergent vegetation and percentage canopy cover of trees and shrubs can be estimated from aerial photographs supplemented by vegetation maps (Environmental Geological Atlas of the Texas Coastal Zone 1973-1976; Chabreck and Linscombe 1978) validated by ocular reconnaissance.
V_3	Height of herbaceous emergent vegetation can be measured with a meter stick. Density measurements can be made by ocular estimates. Pechanec and Pickford (1937) described a simple technique for training field technicians to estimate vegetation measurements.
V_4	Areal coverage of emergent vegetation can be estimated using the same methods used for V_1 and V_2 or by using methods described by White (1975). The White procedure must be modified to sample all emergent vegetation.
V_5	Height and density of emergent vegetation can be measured by using the same methods as V_3.
V_6	The percentage of the study area that is land can be estimated by positioning a standard dot grid over aerial photographs and comparing the number of dots in each habitat type. Dots should be uniformly spaced and scaled to 25 dots/km^2.
V_7	Water depths can be measured with a meter stick or by using methods described by Lind (1979). Depth contours for larger lakes are shown on U.S. Geological Survey topographic maps and National Oceanic and Atmospheric Administration coastal charts.
V_8	Disturbance levels can be determined by onsite inspection and by interviewing local residents and wildlife managers. Permanent disturbances can often be identified on aerial photographs.

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APPENDIX A

HABITAT DESCRIPTIONS

SALINE MARSHES

This habitat is typified by wetlands of relatively high salinity, often located adjacent to the coastline. The most common floral species of the saline marshes in Louisiana are Spartina alterniflora, Distichlis spicata, Juncus roemerianus and Spartina patens (Chabreck 1972). In Texas, Spartina alterniflora, Batisi maritima, Salicornia sp., Suaeda sp., Borrichia frutescens, and Avicennia germinans are the most abundant plants. Distichlis spicata may be common locally (Environmental Geological Atlas of the Texas Coastal Zone 1973-1976).

FRESH TO BRACKISH MARSHES

This is a zone of moderately saline to freshwater wetlands located usually within 100 km (62 mi), but occasionally adjacent to the coastline. The most common floral species of this zone in Louisiana include Spartina patens, Distichlis spicata, Sagittaria falcata, Eleocharis spp., and Panicum hemitomon. Spartina patens dominates the brackish and intermediate marshes, while Panicum hemitomon is the most abundant plant in the freshwater marshes (Chabreck 1972). In Texas, Spartina spartinae, Spartina patens, Spartina cynosuroides, Scirpus sp., Typha sp., and Juncus sp. are consistently the most common species (Environmental Geological Atlas of the Texas Coastal Zone 1973-1976).

FALLOW RICE FIELDS, PRAIRIES AND PASTURELAND

The Texas prairie exhibits a more diverse floral assemblage than does the coastal marsh. The dominant species often vary with site characteristics. Nevertheless, much of these prairielands are dominanted by extensive stands of Andropogon sp. and Sorghastrum sp. sprinkled with patches of brushy species, such as Prosopis glandulosa, Celtis sp. and Acacia farnesiana, as well as various species of cacti on drier soils (Environmental Geological Atlas of the Texas Coastal Zone 1973-1976). Within the prairie, the areas most important to the mottled duck as nesting and brooding habitats are the wetter areas dotted with potholes and characterized by species such as Paspalum plicatulum, Andropogon sp., Rubus trivialis, Juncus sp., Aster spinosus, and/or Coreopsis tinctoria (Engeling 1950). Fallow rice fields in Wharton County, Texas, are characterized by Paspalum plicatulum, Paspalum urvillei, Rubus trivialis, Andropogon sp., Rudbeckia sp., Eleocharis sp., Cynodon dactylon, and/or Aristida oligantha.

There is very little uncultivated prairie or pastureland in Louisiana, and many of the fallow rice fields are now used for growing soybeans. Those fallow fields used for livestock grazing between rice seasons are characterized by the following plants: Polygonum spp., Cyperus albomarginatus, Digitaria sanguinalis, Krigia cepitosa (Serinea oppositifolia), Baccharis sp., Iva annala (I. ciliata), Ranunculus lindheimeri, Sisyrinchium sp., as well as Fimbristylis sp., Carex sp. and Scleria sp., (Harmon 1960; Davis 1961; Rumsey 1961).

APPENDIX B

PROCEDURES FOR COMPUTING DISTURBANCE SCORES

MINIMAL DISTURBANCE

Minimally disturbed areas are those at least 25 m (82 ft) from maintained roads or heavily used waterways, or at least 300 m (984 ft) from any place or structure regularly occupied by people or dogs, or that emit machinery-caused noise audible at 300 m. Areas of minimal disturbance should not be subject to infrequent abrupt disturbances, such as airboats and off-road vehicles. When evaluating the disturbance level to nesting birds, grazing should be light or absent from March to May.

MODERATE DISTURBANCE

Moderately disturbed areas are those within 25 m of roads, or within 300 m of light to moderate levels of disturbance, such as occupied dwellings, business, or light industry. Disturbances in the immediate vicinity should not be extreme. For instance, areas within 300 m of barking, free-ranging dogs or low-flying aircraft at the end of a runway are not areas of moderate disturbance. Infrequent, but intense disturbances (marsh-buggies and motorcycles) may occur. Grazing should be light or absent from March to May.

EXTREME DISTURBANCE

Areas with extreme disturbance may support heavy grazing or may be located within 300 m of exceedingly noisy or obtrusive industry, or other intense disturbances, such as runways. Free-ranging dogs, marsh-buggies, and motorcycles may be present.

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15. Supplementary Notes

16. Abstract (Limit: 200 words)

A review and synthesis of existing information were used to develop a habitat model for mottled duck (Anas fulvigula maculosa). The model is scaled to produce an index of habitat suitability between 0 (unsuitable habitat) and 1 (optimally suitable habitat) for coastal areas of the northern Gulf of Mexico. Habitat suitability indices are designed for use with habitat evaluation procedures previously developed by the U.S. Fish and Wildlife Service. Guidelines for mottled duck model applications and techniques for estimating model variables are described.

17. Document Analysis a. Descriptors

Mathematical models
Birds
Waterfowl

b. Identifiers/Open-Ended Terms

Habitat
Habitat Suitability Index
Mottled duck
Anas fulvigula maculosa

c. COSATI Field/Group

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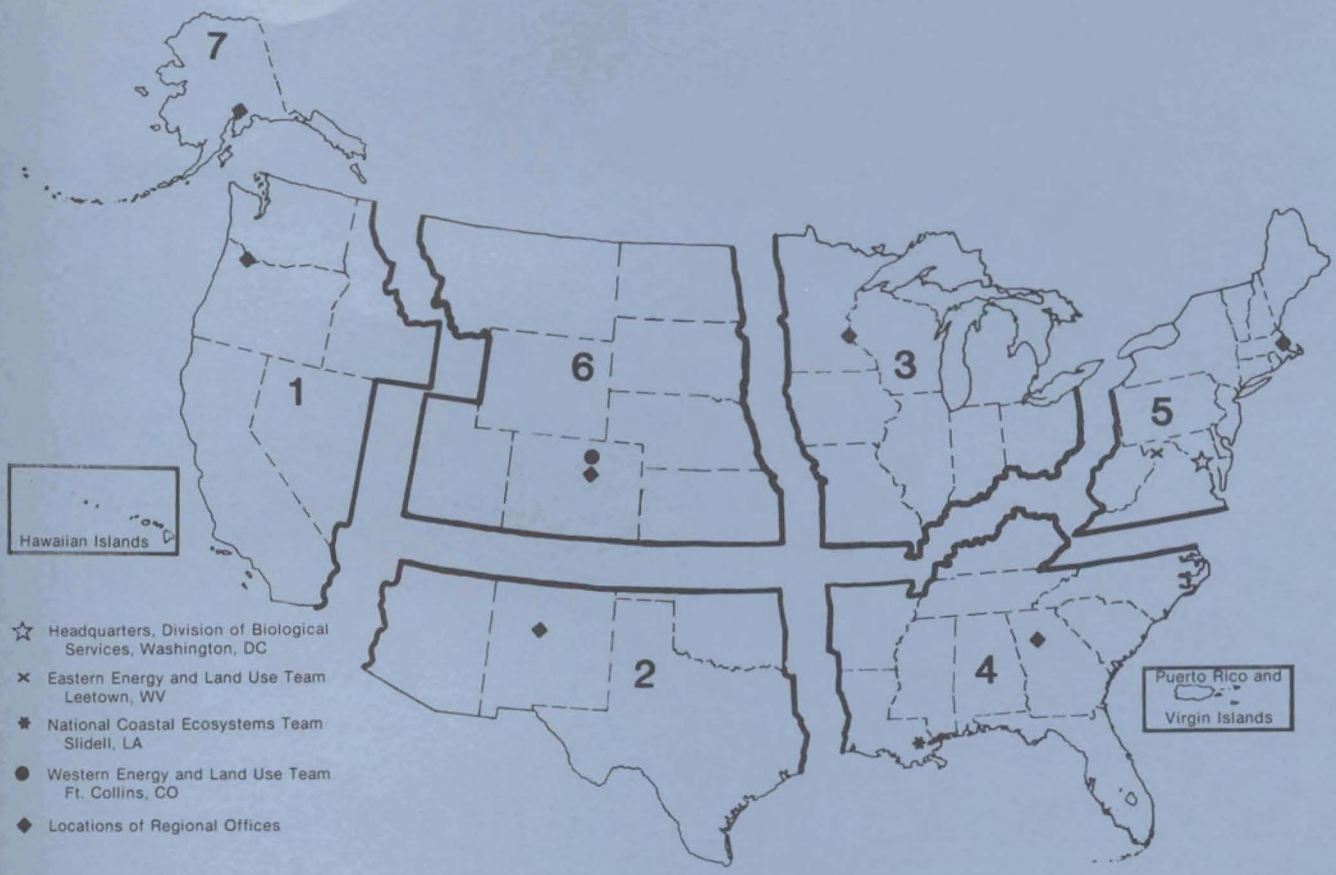

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