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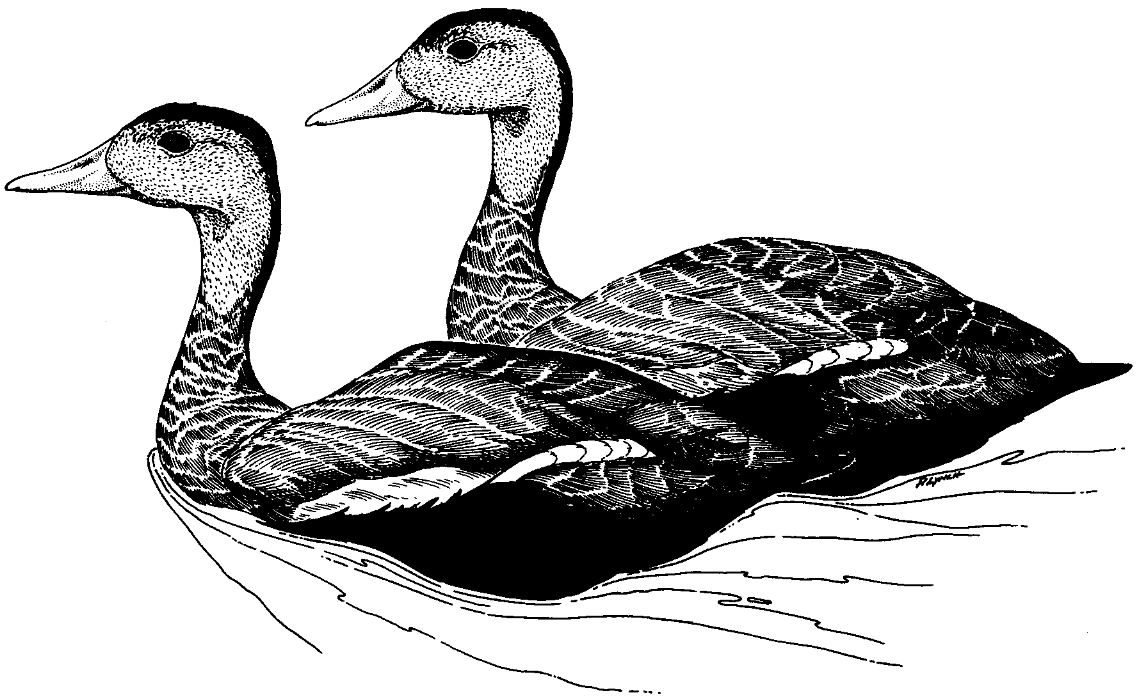

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HABITAT SUITABILITY INDEX MODELS: BLACK-BELLIED WHISTLING-DUCK (BREEDING)

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PREFACE

The habitat suitability index (HSI) model in this report on the black-bellied whistling-duck is intended for use in the U.S. Fish and Wildlife Service's (1980) habitat evaluation procedures for 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 used to develop the 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. 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 to the following address.

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Evaluations of model structure and functional relationships were provided by personnel of the U.S. Fish and Wildlife Service's (FWS) National Wetlands Research Center. Model and supportive narrative reviews also were provided by FWS Ecological Services biologists in Houston, Texas.

BLACK-BELLIED WHISTLING-DUCK (Dendrocygna autumnalis)

INTRODUCTION

Distribution

The whistling-ducks (family Anatidae, subfamily Anserinae, tribe Dendrocygnini) consist of eight species found mainly in the Southern Hemisphere (Bellrose 1976); two of these species, the black-bellied whistling-duck (Dendrocygna autumnalis) and the fulvous whistling-duck (D. bicolor), are found in the southern United States. The long legs, long necks, and erect stance of whistling-ducks give them gooselike affinities (Bellrose 1976). Delacour and Mayr (1945) believed that whistling-ducks are more closely related to geese and swans than are other tribes in the family. Black-bellied whistling-ducks molt only once a year, as do geese and swans (Bellrose 1976).

The black-bellied whistling-duck has been described as a "tropical lowland duck" (Palmer 1976), inhabiting arid (Palmer 1976) and semi-arid (Bolen 1967a) areas in a wide range of habitats. Its range includes both the tropical and subtropical regions of North and South America (Bolen 1979; Table 1).

Black-bellied whistling-ducks have been observed perched on trees, on strands of wire fence, on loops of Spanish moss (Tillandsia usneoides), and even on utility wires (Rylander and Bolen 1970). This dexterity and facility for perching have been attributed to feet that are anatomically adapted to arboreal habitats (Rylander and Bolen 1970).

The northern black-bellied whistling-duck breeds from southern Arizona and south-central and southeastern Texas through Mexico and Central America. A southern race breeds from Panama to southern Brazil and northern Argentina (Bellrose 1976; AOU 1983).

The black-bellied whistling-duck is nonmigratory throughout much of its range (Bent 1951), although birds at the extreme northern and southern limits do migrate (Bolen 1967a). Saunders et al. (1950) and Leopold (1959) indicated that there was movement of this species during the winter months in Mexico and Guatemala. Some congregating has been noted on the wintering grounds in Mexico and Central America. Phillips (1922) reported flock sizes of up to 2,000 ducks in Mexico. Leopold (1959) reported "flocks of thousands" along the southern coast of Chiapas, Mexico. Flocks containing 13,800, 5,060, 4,170, 2,425, and 2,185 birds were reported in Mexico during January 1965 surveys (Bellrose 1976). According to Palmer (1976), flocks were sufficiently large to "occur almost literally in clouds" during the dry season in Costa Rica. Saunders and Saunders (1981) reported that black-bellied

Table 1. Habitats of black-bellied whistling-ducks in North and South America.

Habitat	Source
Tropical coasts and temperate uplands	Leopold 1959
Mangrove swamps	Leopold 1959
Brackish coastal lagoons and marshes	Saunders and Saunders 1981
Freshwater marshes	American Ornithologists Union (AOU) 1983
Borders of ponds and streams	AOU 1983
Brushlands and coastal prairies	Delnicki and Bolen 1976
Flooded timber and small lakes	Bolen 1967a
Savannas	Meanley and Meanley 1958 Bolen 1967a Delnicki and Bolen 1975
Cultivated cropland	Leopold 1959 Bolen and Forsyth 1967 Bourne and Osbourne 1978 Bourne 1981 Bolen and Rylander 1983 Bruzual and Bruzual 1983

whistling-ducks were formerly more numerous in the interior of Mexico during the winter than they are at present.

Although the 1983 edition of the American Ornithologists' Union Check-List described the black-bellied whistling-duck as a resident of southern Texas, Bolen et al. (1964), Bolen (1967a), and Bellrose (1976) considered the Texas population migratory. Bolen (1967a) indicated that the birds in Texas left their breeding grounds by November; Palmer (1976) listed October and November as departure months. Saunders and Saunders (1981) reported that more black-bellied whistling-ducks were observed farther south in Mexico during January surveys than during earlier inventories.

Bolen and Rylander (1983) found no evidence to indicate a further northward expansion of the breeding range in Texas. However, recent sightings do suggest a northward expansion into eastern Texas and southwestern Louisiana. Adult black-bellied whistling-ducks with broods have been observed near Port Arthur, Texas (Charles Stutzenbaker, Texas Parks and Wildlife Department, Port Arthur; pers. comm.), and College Station, Texas. Additionally, 7 black-bellied whistling-ducks were observed in southwestern Louisiana on the Sabine National Wildlife Refuge during the Christmas Bird Count of 15 December 1984 (Newman 1985); and during the 1984-85 hunting season, 13 were shot by hunters at the Florence Hunting Club (Wallace Ashire, Florence Hunting Club, Gueydan, Louisiana; pers. comm.). Cain (1973) believed that northward expansion of the black-bellied whistling-duck was limited because lower temperatures increased the amount of energy required for successful reproduction.

Leopold (1959) reported that the species was heavily hunted in tropical Mexico and that the meat was considered a delicacy. Saunders and Saunders (1981) reported that the high palatability of this bird made it a favorite with market hunters in Mexico who supplied the meat to restaurants and tourist hotels.

Life History Overview

Bent (1925) stated that black-bellied whistling-ducks arrived in Texas in April, while Delacour (1954) reported their arrival in April and May. An average arrival date of 17 April (1949-56) was listed by Palmer (1976) for the lower Rio Grande Valley of Texas. Bolen (1967a) recorded an average arrival date of 25 March over a 10-year period (1955-65) at the Santa Ana National Wildlife Refuge, near McAllen, Texas. Males and females return to their breeding grounds with equal fidelity; Bolen (1971) examined 31 banded adults that had returned a second year to the area of banding and found that 58% were females and 42% were males.

Black-bellied whistling-ducks apparently breed during their first year (Bellrose 1976). Birds that nest in southern Texas appear to pair on the wintering grounds (Bolen 1967a).

Bolen (1971), after conducting a banding study on nesting black-bellied whistling-ducks, concluded that this species mates for life. He observed a year-to-year mate retention involving six pairs and noted that in three cases the same mates remained paired for a second nesting attempt after the first nest was deliberately destroyed. McCamant and Bolen (1977) reaffirmed the lifelong pair-bond tendencies of the species by demonstrating that when the pair bond is broken by the loss or removal of a mate, the nest is immediately abandoned.

Courtship of this species has been described as "a simple, swanlike ritual involving similar mannerisms by each participant regardless of sex; it includes neck-stretching, head-dipping, and communal diving as basic displays" (Bolen et al. 1964). Johnsgard (1979) asserted that copulation for this species occurs in shallow water or on the shore, and is preceded by movements closely resembling normal drinking behavior. Regarding postcopulatory behavior, Bolen et al. (1964) reported that "the birds, standing side-by-side in shallow water, rapidly tread and splash while puffing their breasts and sharply curving their necks in a deep "S." The outside wing, away from the adjacent partner, is raised but remains folded; occasionally the birds face one another instead of assuming the side-by-side position."

Black-bellied whistling-ducks begin nesting an average of 56 days after arriving in southern Texas (Bolen 1967a), and exhibit a long nesting season (Cottam and Glazener 1959; Bolen and Rylander 1983). Both male and female black-bellied whistling-ducks participate in the selection of a nest site (Bolen 1962, 1967a). Inspection of suitable nesting cavities often involves as many as five pairs (Bolen 1962). This gregarious nesting behavior has resulted in the communal laying of several hens in a single cavity (designated dump-nesting or compound clutches) (Bolen 1962, 1967a; Bolen et al. 1964; Palmer 1976). Bent (1925) recorded egg laying dates for Texas between 3 May and 18 October (16 nests), with eight of these in the period 20 June to 14 July. Bolen (1967a) recorded an early nesting date of 25 April and late date of 25 August within a 3-year period in southern Texas; most frequent nesting attempts were between mid-May and mid-June. Renesting has been recorded in Texas by Delnicki and Bolen (1976), and in Arizona by Johnson and Barlow (1971).

A black-bellied whistling-duck's clutch averages 13.4 eggs (range 9-18) (Bolen 1967a). Calculating the mean clutch size for this species is complicated by the laying of compound clutches or dump nests (Bolen and Rylander 1983). This communal laying (Bolen 1962; Palmer 1976) has resulted in as many as 101 eggs in one nest box (Delnicki and Cottam 1976), 38 eggs in a natural cavity (Bolen 1962), and dozens of records of dump nests containing over 30 eggs (Eric Bolen, Texas Tech University, Lubbock; pers. comm.).

The average incubation period is 28 days (Bolen 1979; Bolen and Rylander 1983). Delacour (1954) and Johnstone (1957) listed the incubation period for the species in captivity as 27 and 26 days, respectively. Bolen (1967a, 1971) and Bolen and Smith (1979) reported that both sexes of this species share incubation duties; incubation patches on both males and females confirmed these observations (Rylander et al. 1980). Many of the compound clutches are successfully incubated by a single pair of whistling-ducks (Bolen and Rylander 1983), while others are never incubated (Bolen et al. 1964).

Bolen and Smith (1979) found that a nest of a black-bellied whistling-duck was unattended only 16% of the time. Johnstone (1957) studied five species of captive whistling-ducks and indicated that the nests of black-bellied whistling-ducks were never unattended once incubation had begun. Johnsgard (1961) believed that the lack of down in the nest was due to continual attentiveness. He claimed that down was not necessary for nest insulation when male waterfowl shared in the incubation duties.

McCamant and Bolen (1979) examined nest and hatching success for black-bellied whistling-ducks over a 12-year period in southern Texas. Incubated nests exhibited hatching success of 48.2% and nest success of 75.3%. However, dump nesting and abandonment without incubation reduced the hatching and nest success to only 19.5% and 28.2%, respectively. Hatching success for compound clutches is often low (Bolen et al. 1964). Bolen and Rylander (1983) indicated that the percentage of eggs that hatched decreased as the size of the clutch increased.

Common predators of black-bellied whistling-duck eggs at the nest site include rat snakes (*Elaphe obsoleta*), raccoons (*Procyon lotor*), and opossums (*Didelphis virginiana*) (McDaniel et al. 1962; Bolen et al. 1964). McDaniel et al. (1962) partially attributed a low hatching rate of 13.6% to these predators, while Bolen et al. (1964) calculated that 13% of eggs at nests were lost, apparently to the same predators. Delnicki and Bolen (1975) postulated that "an abundance of otherwise suitable tree cavities would not necessarily permit significant increases in the black-bellied whistling-duck population" because of an abundance of raccoons and opossums near nesting cavities.

The mortality of black-bellied whistling-duck ducklings is reported greater earlier in life than later; duckling mortality at the nest has been estimated at 10% (Bolen 1967a). Heins (1984) calculated that on the average, 45% of whistling duck broods were lost from the time the ducklings arrived on their brood-rearing areas until they fledged. Bolen (1967a) and Delnicki and Bolen (1975) hypothesized that the number of ducklings lost en route to water may be proportional to the distance traveled. Brood and juvenile mortality has been attributed to trampling, exposure, abandonment, and fire ants (*Solenopsis xyloni*) (Bolen 1967a). Other potential sources include avian, reptilian, and aquatic predators; accidents; endoparasites; and inclement weather (Bolen 1967a; Heins 1984).

Black-bellied whistling-ducks exhibit swanlike and gooselike traits in their family life. Ducklings climb on the back of a parent, a feature characteristic of swans, and parents have exhibited the gooselike mannerism of placing the young between them when swimming (Bolen et al. 1964).

Cain (1970) discussed the growth, plumage, and development of juvenile black-bellied whistling-ducks. He found that flight was attained between 56 and 63 days, juvenile plumage was complete in 10 to 13 weeks, and the first adult plumage was acquired by the 34th or 35th week.

Bolen (1970) found that the sex ratios of black-bellied whistling-ducks at fertilization, hatching, and among juveniles and adults, did not statistically differ from a 50:50 distribution. Bolen and McCamant (1977) examined band recoveries and the year-to-year return to nesting adults to estimate an annual mortality rate of 50%.

SPECIFIC HABITAT REQUIREMENTS

Food and Foraging Habitat

Rylander and Bolen (1974) examined structural and behavioral differences in the feeding adaptations of four species of whistling-ducks and concluded that the black-bellied whistling-duck is evolutionarily adapted to grazing. The duck is able to feed in upland situations, a trait typical of many species of geese.

Black-bellied whistling-ducks commonly feed at night (Leopold 1959; Johnsgard 1975; Womack et al. 1977). Birds such as owls (Tytonidae and Strigidae) and goatsuckers (Caprimulgidae) are able to see at night because they have more rods than cones in their retinas (Welty 1982). Rods are photosensitive receptors responsive to dim light, while cones function in color vision. Womack et al. (1977) found no significant differences in the number or proportion of rods among four species of whistling-ducks (including black-bellied). Other studies, however, have shown that the number of rods per unit area, as well as the percentage of rods (as compared to cones), was larger in the black-bellied whistling-duck than in the mallard (Anas platyrhynchos) (Hersloff et al. 1974; Wells et al. 1975). Some researchers have cautiously concluded that the higher number and proportion of rods in whistling-ducks (including black-bellied) enable them to see better at night than other ducks (Bolen and Rylander 1983).

Black-bellied whistling-ducks are primarily vegetarians. Bolen and Forsyth (1967) examined items from 22 stomachs and 11 crops and found that 92% of the contents by volume was plant material. Major food species included cultivated grain sorghum (Sorghum vulgare) and Bermuda grass (Cynodon dactylon). Native food plants of some importance included smartweeds (Polygonum spp.), millets (Echinochola spp.), and water stargrass (Heteranthera liebmanni). Animal foods constituted 8% by volume and included insects, mollusks, and the snail Physa anatina.

Samples (n = 30, n = 5) of adult black-bellied whistling-ducks' stomachs from Guyana, South America, taken in 1973 and 1974, contained 97% and 90% plant material, respectively (Bourne 1981). Rice (Oryza sativa) accounted for 86% and 74% of the diets, respectively. In the 1973 sample, 3% of the birds' diet consisted of animal foods, including aquatic insects and snails, and two stomachs contained small tadpoles of the giant toad (Bufo marinus) (Bourne 1981). Bruzual and Bruzual (1983), who examined the stomach contents of 13 ducks in Venezuela, found that plant material contributed 99% by volume to the ducks' diet. Important species included domestic rice, jungle rice (Echinochola colonum), bird's eye (Caperonia palustris), and nut grass (Cyperus rotundus). Bent (1925) reported corn (Zea mays) as a major component of the diet of black-bellied whistling-ducks in Mexico. Along the Gulf of Mexico, gizzard (n = 13) contents of black-bellied whistling-ducks consisted of 98.1% plant food and 1.9% animal food, and gullets (n = 5) contained 98% plant food and 2% animal food (Saunders and Saunders 1981).

Ducklings during the brood stage take a variety of animal foods. One-day-old birds (n = 20) consumed insects, spiders, snails (Physa anatina), and in one instance, a bivalve (Sphaerium securis) (Bolen and Beecham 1970). Animal matter consumed by 35-day-old ducklings included insects, snails, oligochaetes, and single occurrences of an unidentified tick and a freshwater shrimp.

About 10% animal matter was taken by juvenile black-bellied whistling-ducks in Guyana, South America (Bourne 1981), where young apple snails (Pomacea spp.) were the major animal food identified. However, Bolen and Beecham (1970) indicated that black-bellied whistling-duck ducklings apparently rely less heavily on animal foods than some other waterfowl species. Two black-bellied whistling-ducks ducklings consumed 54% animal foods and 46% plant foods (Bourne 1981); the main plant foods consisted of seeds of a millet (Echinochloa sp.) and Paspalum sp., while the bulk of the animal foods was unidentified terrestrial spiders.

Some seasonal variations in the feeding habits of black-bellied whistling-ducks have been noted in Texas. Bolen and Forsyth (1967) indicated that the food habits of the species change with the onset of the growing season. Upon reaching the breeding grounds in spring, the birds feed on waste grains around stockyards. They eat the seeds of Bermuda grass in May and aquatic plant seeds throughout the summer. Flights to sorghum fields begin in June and continue through early autumn.

Unlike the fulvous whistling-duck, which swims or dives for its food, the adult black-bellied whistling-duck prefers to forage while standing in shallow water (Johnsgard 1975). Bolen et al. (1964) reported that the birds are rarely seen in water deeper than the length of their legs. In Guyana, black-bellied whistling-ducks prefer a water depth of 2.5 to 11.7 cm (Bourne and Osbourne 1978). Heins (1984) found that 80% of black-bellied whistling-ducks' broods fed in open water, where the ducklings foraged mostly by diving or dabbling.

Black-bellied whistling-ducks have adapted to agricultural areas. Their seasonal use of cultivated grains cannot be overemphasized. When available, sorghum (Bolen et al. 1964; Bolen and Forsyth 1967), corn (Leopold 1959; Bolen and Forsyth 1967), and rice (Bourne and Osborne 1978; Bruzual and Bruzual 1983) are heavily consumed. In cattle feedlots and stockyards, the birds apparently feed on scattered corn (Bolen and Forsyth 1967).

Water

No information on dietary water needs of the black-bellied whistling-duck was found in the literature. However, water needs are likely satisified in wetland habitats used by the species. The role that water plays in other life requisites is discussed under the appropriate sections.

Grit

Bolen and Forsyth (1967) analyzed the stomach contents of 22 black-bellied whistling-ducks and found that the mean weight of grit was 1.4 g, with a range from 0.8 to 2.4 g. Grit material varied in size and consisted of both opaque and translucent materials.

Cover

Nesting. Black-bellied whistling-ducks have been reported to nest in or on a wide variety of substrates including closed and open tree cavities (broken tops or limbs of trees), machinery and manufactured containers (i.e., carbide cans and an inoperative cotton gin), chimneys, pigeon lofts, nest boxes, and the ground (Haverschmidt 1947; Johnstone 1957; Meanley and Meanley 1958; Bolen 1962, 1967a,b; McDaniel et al. 1962; Bolen et al. 1964; Johnson and Barlow 1971; Delnicki and Bolen 1975; McCamant and Bolen 1979).

Black-bellied whistling-ducks will use any tree species with a suitably-sized cavity for nesting (Delnicki and Bolen 1975). The entrances to 17 active nesting cavities in southern Texas averaged 17x35 cm (width x height) (Bolen et al. 1964). Similarly, Delnicki and Bolen (1975) found that entrances of 29 cavities actually used averaged 17x31 cm; the smallest entrance for a cavity actually used was a nearly symmetrical hole 10x12 cm. Bolen et al. (1964) and Delnicki and Bolen (1975) indicated that the floor dimensions for cavities used were similar in size, and concluded that cavity size was unrelated to the number of eggs laid in a nest. The distance of the cavity entrance from the nesting platform is not considered a hindrance to ducklings (Bolen et al. 1964; Delnicki and Bolen 1975) as the birds are apparently adapted to climbing the vertical sides of a cavity (Rylander and Bolen 1970; Rylander 1975). Bolen et al. (1964) did not consider the mean height of nest entrances above either the ground or water as a harmful factor for ducklings leaving the nest.

Trees with suitable cavities had a mean diameter at breast height (dbh) of 64 cm (range 30.9-118.8 cm) (Delnicki and Bolen 1975). Structural characteristics of nest trees that influence the availability of cavities included longevity, wood density, and growth form (Delnicki and Bolen 1975). Long-lived species that remain upright long after death and have a well-defined trunk region and main branches are more likely to provide suitable cavities. Trees used in southern Texas include live oak (Quercus virginiana), ebony (Pithecellobium flexicaule), hackberry (Celtis laevigata), willow (Salix spp.), elm (Ulmus spp.), and mesquite (Prosopis glandulosa) (Bolen et al. 1964; Bolen 1967a; Delnicki and Bolen 1975). Black-bellied whistling-ducks will also nest over open water on flooded impoundments if trees with suitable cavities are available (Bolen 1967a). Trees providing cavities on Lake Mathis in southern Texas included live oak, hackberry, willow, elm, and mesquite (Bolen 1967a). However, Bolen (1967a) postulated that after 8 years only live oaks would remain to provide suitable cavities in flooded impoundments and further concluded that nesting over flooded impoundments should be regarded as atypical. In Arizona, two nests were located in Fremont's cottonwood (Populus fremonti) (Johnson and Barlow 1971). Delnicki and Bolen (1975) found that one suitable natural cavity was available in every 7.7 ha (0.13/ha) of ebony or live oak savanna habitat in south Texas. They believed this was a minimal figure because some inaccessible cavities may have been suitable, and some cavities may have been missed.

Understory vegetation can influence the use of nest trees (Bolen et al. 1964). Delnicki and Bolen (1975) claimed that "trees without brush understories are more often used than others." Although Meanley and Meanley (1958) indicated that a "thicket of characteristic trees and shrubs was the preferred habitat," Bolen et al. (1964) reported that the understory of active nest trees usually consisted of grasses and other herbaceous vegetation. Bolen et al. (1964) also noted that when the ground vegetation of potential nest trees reverted to a "brush" understory, black-bellied whistling-ducks ceased using the nest trees. They gave several reasons why the birds no longer used the trees for nesting: ducklings become entangled in the brush upon leaving the nest, predators have increased cover and access to nest trees, and whistling ducks have a diminished view of potential cavities.

Unlike cavity nests, which usually lack a brush understory, ground nests are generally well concealed under an overstory of brush (Haverschmidt 1947; Johnstone 1957; Bolen 1962; Bolen et al. 1964; Bolen and Rylander 1983). Bolen et al. (1964) described the ground nest "as a well constructed, although shallow basket of woven grasses about 20x17 cm in size." The percentage of black-bellied whistling-ducks nesting on the ground in southern Texas is unknown (Bolen 1962, 1967a; McDaniel et al. 1962; Bolen et al. 1964). However, ground nests are apparently more common for the southern race of this species in rice-culture habitats, where natural tree cavities are not as available (Haverschmidt 1947; Bourne and Osborne 1978). In Guyana, the breeding habitat for ground-nesting black-bellied whistling-ducks was flooded rice fields with many species of plants providing good cover (Bourne and Osborne 1978). A typical nest was one in a fallow rice field with 71% graminoid, 8% forb, 5% woody, and 16% unvegetated cover. The mean vegetation cover for all breeding sites was about 43%; the average plant height, about 0.5 m (Bourne and Osbourne 1978).

Black-bellied whistling-ducks readily use nest boxes when available (Bolen 1967b). Bolen (1967b) developed predator-proof nest boxes resembling wood duck (Aix sponsa) boxes. The boxes, constructed of 1.3-cm marine plywood, were 27.9 cm^2 and 55.9 cm high in the front, tapering to 50.8 cm in the rear. Entrance holes were 12.7 cm in diameter. Strips of roughened wood or wire-window screening attached inside the box beneath the entrance aided the exit of ducklings. Mounted on 5.1-cm well pipe, the boxes were protected with conical sheetmetal guards 91.4 cm in diameter. Nests in these predator-proof boxes were 77% successful, but those in unprotected nesting boxes and natural cavities were 46% and 44% successful, respectively. The use of predator-proof nest boxes resulted in a 19% renesting success of this species in southern Texas (Delnicki and Bolen 1976).

McCamant and Bolen (1979) evaluated nest-box use by black-bellied whistling-ducks over a 12-year period in southern Texas and concluded that of the 81% of the boxes used over the interval, only 20% of 21,982 eggs laid in nest boxes actually hatched. The poor hatching was attributed to desertion of some dump nests. One dump nest contained 101 eggs, of which 38 hatched (Delnicki and Cottam 1976; McCamant and Bolen 1979). Johnsgard (1975) suggested that dump nesting is prevalent where suitable nest cavities for cavity-nesting species are limited. However, the reasons for dump nesting by black-bellied whistling-ducks remain a mystery because dump nests and ground nests are often found near unused nest boxes (McCamant and Bolen 1979). McCamant and Bolen (1979) hypothesized that dump nesting in this species is possibly triggered more by social interaction at available nest sites (i.e., tree cavities or nest boxes) than because of a shortage of cavities or other habitat limitations. Delnicki (1973) postulated that dump nesting is detrimental to the species because many eggs do not hatch, young die in the nest box, and brood mortality may be excessive when brood size exceeds the brooding capacity of the adult birds. Delnicki and Bolen (1975) indicated that the average distance from an active nest to water was about 400 m, but found active nests as far as 1,000 m from water.

Brood-rearing. Our knowledge of the brood-rearing habitat of black-bellied whistling-duck is limited to a few generalizations of Bolen

(1967a) and field observations of Heins (1984). Bolen (1967a) found that the habitat used by black-bellied whistling-duck broods in Texas varied with each particular study area. Fluctuations of water levels on Lake Mathis prevented the establishment of permanent stands of emergent plants, and broods spent 33% of their time on open water. In contrast, at Santa Ana National Wildlife Refuge, where water levels were more stable and stands of dense vegetation dominated the surface, 78% of black-bellied whistling-duck broods frequented dense stands of cattail (Typha domingensis) and 18% frequented bulrush (Scirpus californicus).

Heins (1984) calculated means of habitat variables and compared high and low brood-use by black-bellied whistling-duck ducklings in two study areas in southern Texas. The high-use ponds were smaller ($\bar{x}$ = 22.5 ha) and shallower ($\bar{x}$ = 54.7 cm) and had a greater interspersion of emergent plants and open water (Table 2). For management, Heins (1984) recommended that (1) ponds should be between 2 and 30 ha, (2) ponds should have permanent water deep enough to provide aquatic insects and plants for food, (3) ample emergents should be present to provide cover but should not be thick enough to hinder movements, (4) there should be a good interspersion of emergents and open water, and (5) suitable loafing sites should be available.

Heins (1984) believed that other factors possibly influenced the selection of rearing ponds: (1) the physiological requirements of brood

Table 2. Means of significant habitat variables for ponds with high and low brood-use by black-bellied whistling-ducks on two study areas in southern Texas (Heins 1984).

Variable	Within-group means: High-use ponds	Within-group means: Low-use ponds	Significance between means (P)
Mean depth (cm)	54.7	64.2	<0.001
Maximum depth (cm)	109.8	128.5	<0.001
Shoreline length (km)	2.0	4.3	<0.001
Pond area (ha)	22.5	54.2	<0.001
Shore:area ratio	0.2	0.1	<0.001
Cover type[a]	3.0	1.5	<0.001
No. vegetative types	10.2	12.5	<0.001

[a]Higher cover type rating = more interspersion.

habitat (i.e., food, water, space, cover); (2) the psychological needs of parents and young (i.e., sense of security and well-being); (3) the water chemistry of ponds; (4) certain behavioral and "sociability" factors regarding both parents and ducklings (e.g., the selection of the best feeding areas by broods or the selection by adults of the same rearing ponds in which they were reared); (5) the proximity of feeding areas for adults to rearing ponds; and (6) other yet-to-be-defined habitat factors. She concluded that a much more extensive study was needed to better characterize preferred brood habitat and to correlate habitat factors with brood use by black-bellied whistling-ducks.

Special Considerations

The building of stock tanks, irrigation impoundments, and reservoirs has apparently enabled black-bellied whistling-ducks to expand their range northward in southern Texas; legal protection from hunting may have also aided the expansion (Bolen et al. 1964). This duck is currently hunted in Texas but is not considered a "sporting bird" because it is easily shot (Robert Newman, Louisiana State University, Baton Rouge; pers. comm.). Leopold (1959) believed that the species' unwariness and ease of harvest warranted giving it immediate and special consideration at the first sign of a "serious decrease in numbers." Bent (1925) suggested that excessive market hunting of this species near Brownsville, Texas, had reduced their numbers to a point where they had "entirely disappeared" from the area. Bolen (1967a) believed that the black-bellied whistling-duck could not be hunted in southern Texas without endangering its status there. Hunting pressure and harvest should be closely monitored.

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area and season. This habitat suitability index model was developed for application throughout the breeding range of the black-bellied whistling-duck in Texas (Figure 1). It is designed to evaluate breeding season (April-October) habitat quality.

Cover types. This model was developed to evaluate habitat in the following cover types (terminology follows that of Cowardin et al. 1979): lacustrine, palustrine forested, palustrine scrub-shrub, palustrine persistent emergent, and upland. This model is not designed for use in agricultural lands.

Minimum habitat area. Minimum habitat area is defined as the minimum amount of contiguous suitable habitat required for a species to live and reproduce successfully. The minimum habitat area for breeding black-bellied whistling-ducks is unknown. The minimum land area needed for nesting is not recorded in the literature.

Verification level. This HSI model is a hypothesis of species-habitat relationships and does not reflect proven cause and effect. Reviewers of this

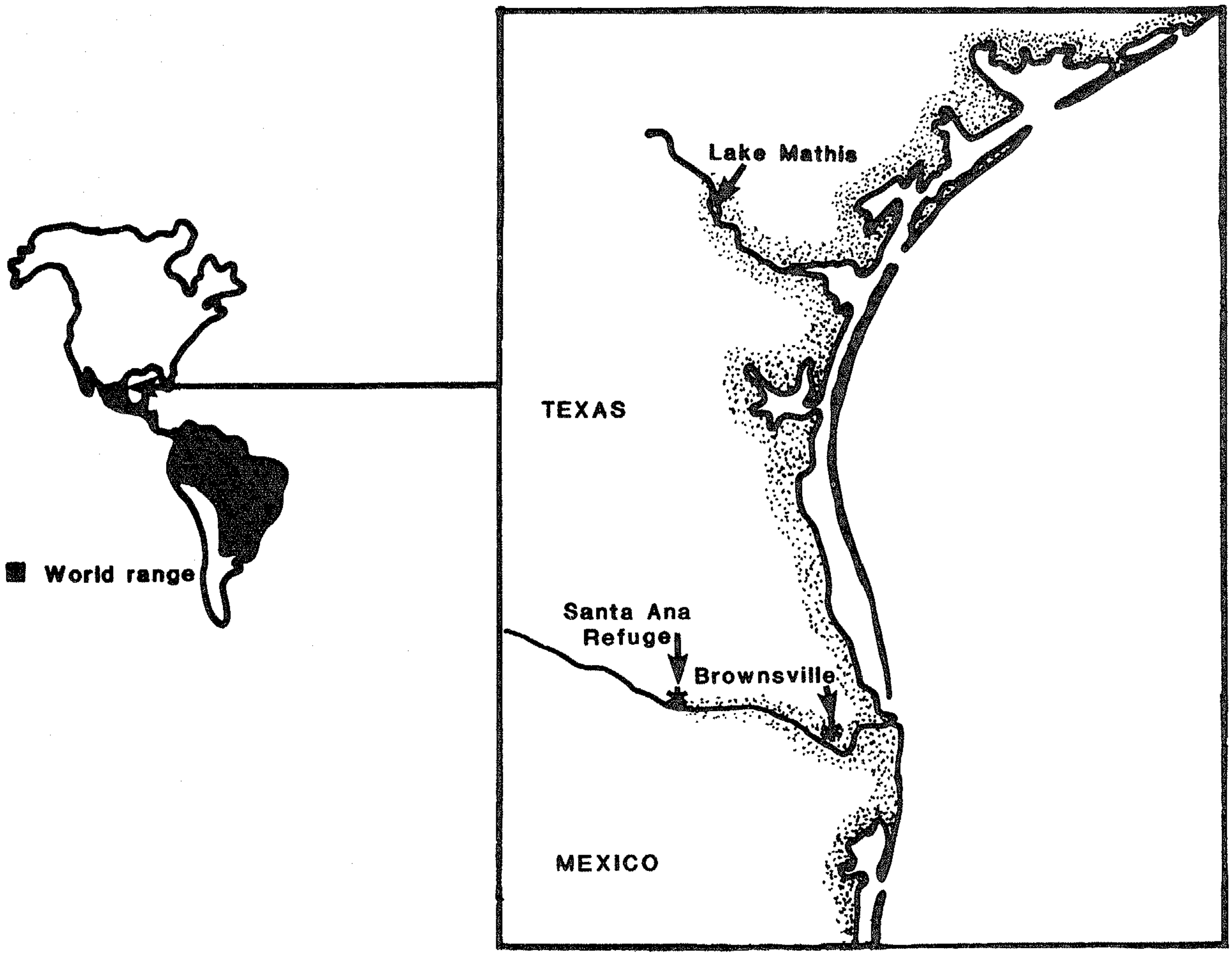


Figure 1. Approximate breeding range of the black-bellied whistling-duck in southern Texas during the 1960's. Scale: 1 cm = 38 km (Bolen 1967a).

model include Eric G. Bolen, Texas Tech University, Lubbock; David S. Lobpaies, Texas Parks and Wildlife Department, Wharton; and Robert H. Chabreck, Louisiana State University, Baton Rouge. Their comments and suggestions for model improvement were considered in development of the final version, but the model is solely the responsibility of the authors. The model has not been field-tested. Further comments for improvement of this model are welcomed.

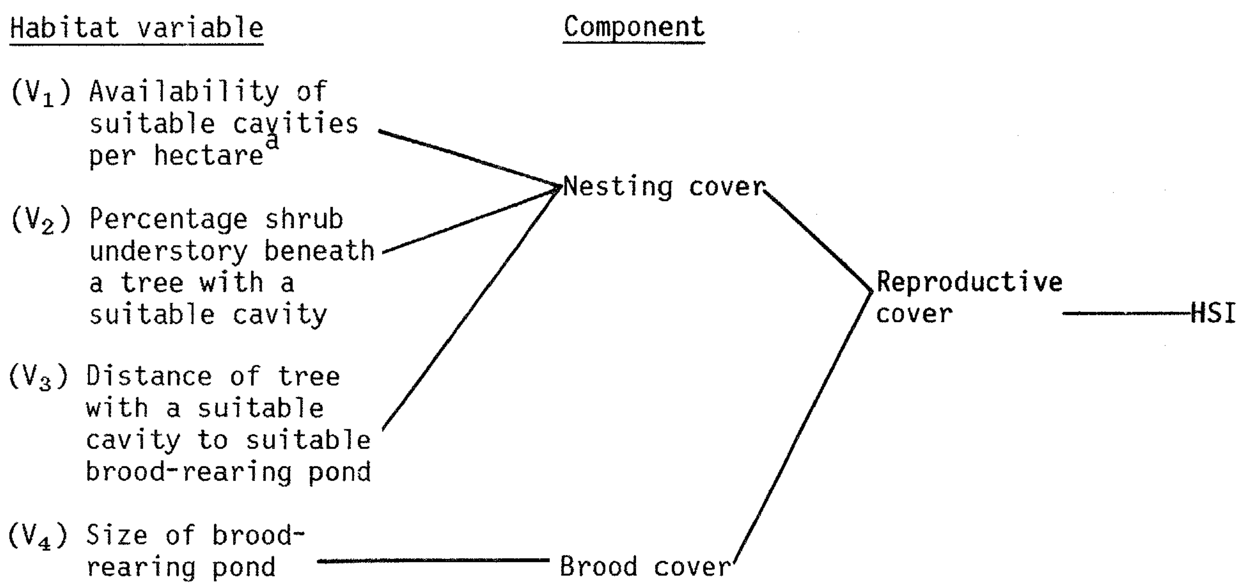
Model Description

Overview. The HSI model for the black-bellied whistling-duck includes four habitat variables that affect habitat suitability for nesting adults and adults with broods. Areas suitable for reproduction are assumed to be suitable for black-bellied whistling-ducks during the remainder of the time they are present. The habitat requirements of black-bellied whistling-ducks on the wintering grounds are not addressed. The model considers a single life requisite--cover. Because this species feeds on a variety of vegetative types, the quantity and quality of foods were assumed to be suitable in areas of suitable cover for breeding. Grit and water requirements are also assumed to be met in areas with adequate cover. The relationship of habitat variables and cover types to the HSI value is illustrated in Figure 2.

The model is structured around wetland and deep-water habitats that have potential as brood-rearing sites. A potential brood-rearing site is defined as any palustrine or lacustrine (as defined by Cowardin et al. 1979) habitat with water present during the breeding season (April to October). The area to be evaluated with this model includes the pond, lake, or wetland and a surrounding band of vegetation within 1 km. This surrounding band represents the area available for nesting.

The following sections document the logic and assumptions used to interpret the known habitat information for the black-bellied whistling-duck and used to explain the relationships among variables and equations used in the HSI model.

Cover component. Nesting cover suitability in this HSI model is influenced by the following three variables: the availability of suitable cavities per hectare (V_1), percentage of shrub understory beneath trees with suitable cavities (V_2), and the distance of trees with suitable cavities to suitable brood-rearing habitat (V_3). Because the percentage of black-bellied



[a]Suitable cavity is assumed to have a minimum width of 10 cm.

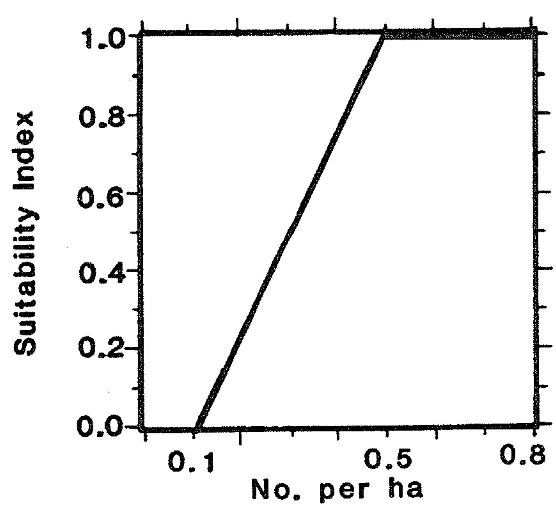
Figure 2. Relationship of habitat variables and cover life requisites to the Habitat Suitability Index value for nesting black-bellied whistling-ducks and for adults with broods.

whistling-ducks nesting on the ground in southern Texas is unknown (Bolen 1979; Bolen and Rylander 1983) but is presumed low (Bolen et al. 1964; Bolen 1967a), ground nesting was not included in the model. Mean dbh of trees was not considered to be a reliable indicator of the availability of nest cavities. Based on Delnecki and Bolen's (1975) study, it is assumed for this model that nesting habitat is unsuitable if there are less than 0.1 suitable cavities/ha on the study area (V_1). Suitability for this variable increases from 0.1 cavities/ha to an optimum of 0.5 cavities/ha. For V_2, nesting habitat suitability decreases if the understory beneath trees with suitable cavities exceeds 20%. Suitability is considered 0 when the percentage of the understory cover is 100% and considered optimum when it is 20% or less. Habitat is assumed optimal when trees with suitable cavities (V_3) have a mean distance of 400 m or less from suitable brood-rearing habitat; suitability decrease from that point to a value of 0 when the distance equals 1,000 m.

Brood-rearing habitat quality is determined by the presence of emergents, the interspersion of emergents and open water, and water depth. We were unable to quantify these factors, so they were not considered as separate variables. The size of the water body (V_4) is assumed to be the only variable critical to the brood cover component in this model. An optimal site is characterized as being between 2 and 30 ha; suitability then decreases from that point to 0 when the size of the brood-rearing pond equals or exceeds 100 ha.

Suitability Index (SI) Graphs for Model Variables

This section presents graphic representations of the relationships between values of habitat variables and habitat suitability for nesting black-bellied whistling-ducks and adults with broods in palustrine (P), lacustrine (L), and upland (U) habitats. Optimal habitat has an SI value of 1.0, and totally unsuitable habitat has an SI value of 0.0. Data sources and assumptions associated with the SI graphs are explained in Table 3.

Habitat	Variable		Suitability Graph
P,U	V_1	Availability of suitable cavities with a minimum entrance width of 10 cm.	

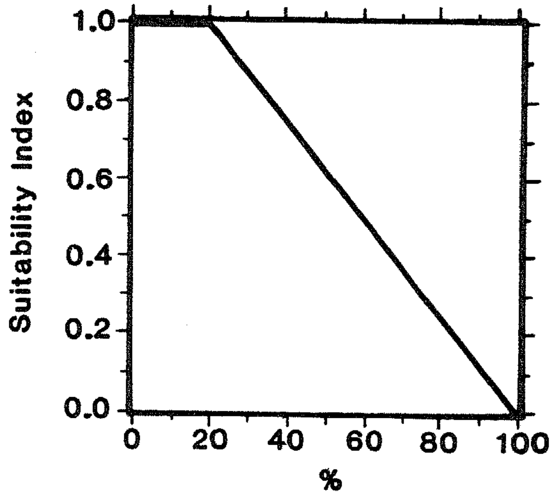
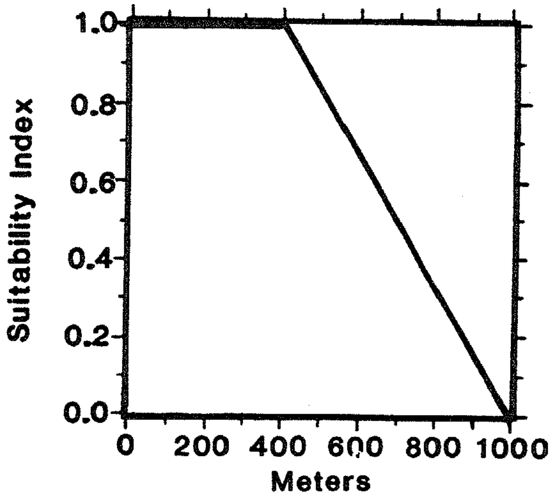
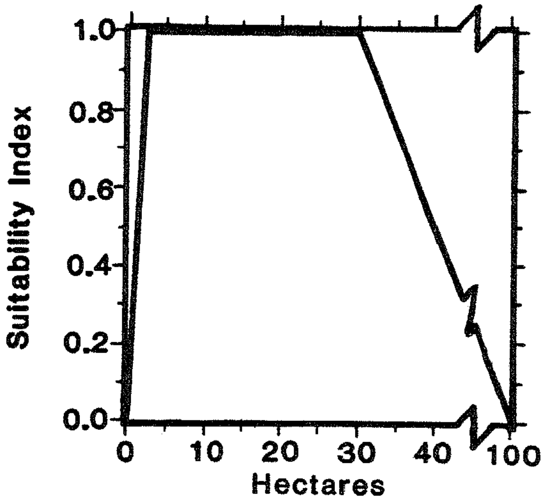
Habitat	Variable		Suitability Graph
P,U	V_2	Mean percentage of shrub understory beneath trees with suitable cavities.	
P,U	V_3	Mean distance from trees with suitable cavities to suitable brood-rearing habitat. Suitable brood-rearing habitat is defined as shallow water with interspersion of emergents and open water.	
P,L	V_4	Size of brood-rearing area.	

Table 3. Data sources and assumptions for black-bellied whistling-duck indices.

Variable and source	Assumption
V_1 Delnicki and Bolen 1975	Nesting habitat suitability is assumed to increase linearly above 0.1 cavities per ha and to be optimal at 0.5 per ha and above. Cavities with an entrance width less than 10 cm are considered unsuitable for nesting.
V_2 Bolen et al. 1964 Delnicki and Bolen 1975	The quality of nesting habitat is related to the percentage of shrub understory; potential nest trees with suitable cavities but an understory greater than 20% are less suitable.
V_3 Delnicki and Bolen 1975 Heins 1984	The number of ducklings lost en route to water is proportional to the distance traversed.
V_4 Heins 1984	Optimal brood-rearing habitat consists of water bodies between 2 and 30 ha.

HSI Determination

This model was developed to evaluate overall potential of nesting and brood-rearing habitat over an entire study area. Individual SI values are averaged to obtain the mean SI value for each variable. The following equations integrate the suitability index values for the habitat variables to determine component index values.

Component	Equation
Nesting cover (NC)	$(SI_{V_1} \times SI_{V_2} \times SI_{V_3})^{1/3}$
Brood cover (BC)	SI_{V_4}

HSI = Lowest value, NC or BC

Nesting cover variables are aggregated in a manner that partially compensates for low values of one variable with high values of another. If any variable, however, is unsuitable (SI=0), then the nesting cover component also will be unsuitable. Because this compensatory relationship is perceived as weak, an equation including a geometric mean was incorporated into the model. The brood cover component is equal to the SI value of V_4. A limiting relationship between the nesting and brood cover components determines the HSI for breeding black-bellied whistling-ducks. Data representing three hypothetical study areas were used to calculate HSI values (Table 4).

Field Use of the Model

Habitat variables for this model should be measured during the nesting season. Discretion is advisable when determining the value of V_4. When the model is being applied to large lakes, especially those exceeding 100 ha, it would be prudent to consider the shape of the water body. Small, isolated coves may be functioning as separate ponds in providing brood-rearing habitat for black-bellied whistling-ducks. Suggested field measurement techniques are given in Table 5.

The utility of this model is limited because it is partially based upon transitory habitat variables: availability of suitable cavities and percentage of shrub understory beneath the cavities. Future suitability of a study site for nesting based upon current density and location of suitable nesting cavities is difficult to predict because of the low correlation between tree size and age and number of suitable cavities. For these reasons, we recommend that this model be used only to determine current suitability.

The proportion of black-bellied whistling-ducks that nest on the ground should be determined for areas covered under this model. If future investigations indicate that ground nesting is important to the success of the species

Table 4. Calculation of suitability indices (SI), component indices, and habitat suitability indices for three sample data sets using habitat variable (V) measurements and black-bellied whistling-duck HSI model equations.

Model	Study area 1		Study area 2		Study area 3	
component	Data	SI	Data	SI	Data	SI
V_1	0.4	0.75	0.4	0.75	0.2	0.25
V_2	40	0.75	90	0.13	40	0.75
V_3	500	0.83	850	0.25	650	0.58
V_4	35	0.93	2	0.67	35	0.93
NC	0.78		0.29		0.48	
BC	0.93		0.67		0.93	
HSI	0.78		0.29		0.48	

Table 5. Suggested methods for field measurement of variables used in the black-bellied whistling-duck HSI model.

Variable	Method
V_1	Determination of the number of suitable cavities per hectare with a minimum width of 10 cm can be made by an on-site inspection or by using a modification of the methodology developed by Prince (1968) to evaluate tree cavities for wood duck and common goldeneye (*Bucephala clangula*). Minimum width of potential cavities can be first measured with a graduated rod; subsequent measurements can be made by visual estimation. Cavities deemed suitable should be plotted on a topographic map or aerial photograph of the study area under consideration.
V_2	The percentage of shrub understory beneath trees containing suitable cavities can be estimated by using the line intercept method described by Canfield (1941) or by using a density board (De Vos and Mosby 1971).
V_3	Once suitable cavities are located on a topographic map or aerial photograph, the distance of suitable cavities to water can be measured with a ruler.
V_4	The size of potential brood-rearing ponds can be calculated on maps using a dot grid or an electronic digitizer and planimeter.

in southern Texas, the model should be modified to incorporate related variables.

Additional variables (e.g., water depth, presence of emergents) that more completely characterize optimal brood-rearing habitat should be quantified and incorporated into the model as more information becomes available. Other factors that possibly affect reproductive habitat, such as dbh and structural characteristics of potential nest trees, may also need to be added to the model when quantitative information is available.

Interpreting Model Outputs

A nesting black-bellied whistling-duck HSI derived with this model reflects only habitat potential, based on the habitat variables under consideration. The model output does not necessarily correlate with population levels because other biological and environmental factors not included in the model influence the population. These factors include diseases, density and impact of predators, water quality, and severe weather conditions (e.g., drought, hurricanes).

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A review and synthesis of existing information were used to develop a model for evaluating the quality of habitat for breeding black-bellied whistling-ducks. The model is scaled to produce an index between 0 (unsuitable habitat) and 1.0 (optimal habitat). Habitat suitability index models are designed for use with the Habitat Evaluation Procedures previously developed by the U.S. Fish and Wildlife Service. Guidelines for model application and techniques for measuring model variable are provided.

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