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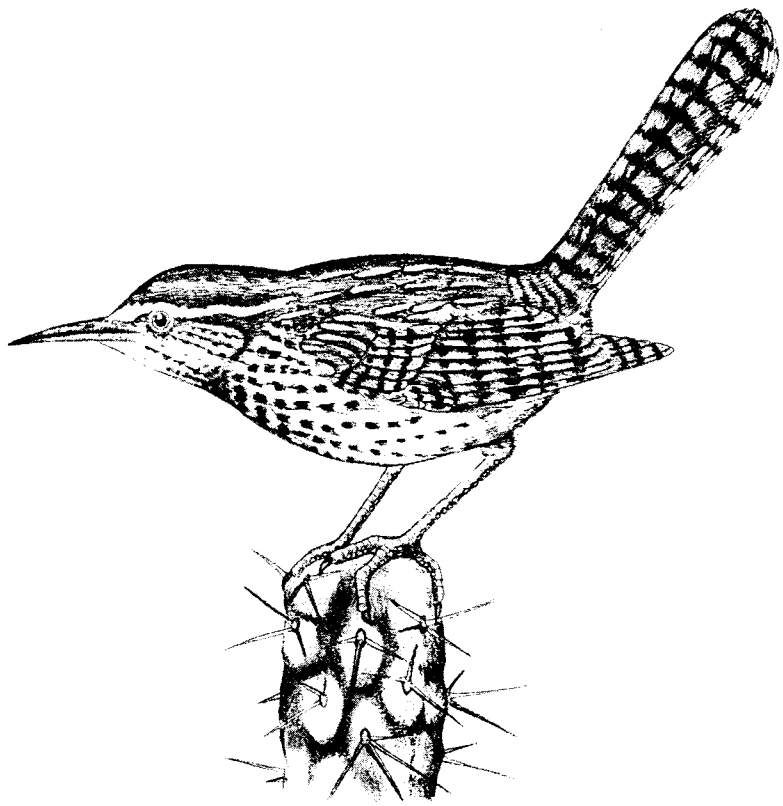
HABITAT SUITABILITY INDEX MODELS: CACTUS WREN



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HABITAT SUITABILITY INDEX MODELS: CACTUS WREN

by

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PREFACE

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

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

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is a formalized synthesis of biological and habitat information published in the scientific literature and may include unpublished information reflecting the opinions of identified experts.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

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CONTENTS

	Page
PREFACE	iii
ACKNOWLEDGMENTS	vi
HABITAT USE INFORMATION	1
General	1
Food	1
Water	2
Cover	2
Reproduction	3
Interspersion	4
HABITAT SUITABILITY INDEX (HSI) MODEL	4
Model Applicability	4
Model Description	6
Application of the Model	11
SOURCES OF OTHER MODELS	14
REFERENCES	14

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I gratefully acknowledge Dr. Ralph J. Raitt, Dept. of Biology, New Mexico State University, Las Cruces, for his critical review of this cactus wren model. The cover of this document was illustrated by Jennifer Shoemaker. Word processing was provided by Carolyn Gulzow, Dora Ibarra, and Elizabeth Graf.

CACTUS WREN (Campylorhynchus brunneicapillus)

HABITAT USE INFORMATION

General

The cactus wren (Campylorhynchus brunneicapillus) is resident (American Ornithologists' Union 1983:524): "from southern California ..., southern Nevada, southwestern Utah, central Arizona, central New Mexico, and central and southern Texas south to southern Baja California, the Pacific lowlands to northwestern Sinaloa ..., and in the Mexican highlands to Michoacan, the State of Mexico and Hildalgo".

The cactus wren is considered, in the guilding context of Short (1983), to nest usually in shrub vegetation (the midstory layer) and to be both a primary and a secondary consumer within the midstory and terrestrial surface layers.

Food

Bent (1948) summarized food habit data for cactus wrens sampled from southern California in July through January. Animal matter constituted 83% and vegetable matter constituted 17% of the stomach contents; no differentiation was made by month of collection. The animal matter in 41 stomachs consisted of 27% beetles, 27% hymenoptera (wasps, bees, and ants), 15% grasshoppers, 5% hemiptera (bugs), 5% lepidoptera (caterpillars), and 3% spiders. Seeds, such as those from sumac (Rhus spp.), filaree (Erodium spp.), and fiddleneck (Amsinckia spp.), and fruit pulp from cactus (Opuntia spp.), elderberry (Sambucus spp.), and buckthorn (Rhamnus spp.) were important foodstuffs during cooler months when many animal items were unavailable.

Anderson et al. (1982) determined that animal matter comprised 96.3% of the contents of the gizzards of 12 wrens collected from March through October and 90.1% of the contents of the gizzards of five wrens collected between November and February. The birds all were collected in riparian vegetation along the lower Colorado River.

Wrens glean among branches of midstory shrubs and also forage on the ground (Anderson and Anderson 1973). They frequently forage on paloverde (Cercidium spp.), mesquite (Prosopis spp.), cholla (Opuntia spp.), and saguaros (Carnegiea gigantea) by midsummer, after deciduous, perennial vegetation has leafed out.

Cactus wrens in Chihuahuan desert habitats foraged principally on grasshoppers (Trimerotropis spp.) when they were feeding nestlings (Marr 1981). They foraged on the ground in open areas with sparse, low vegetation, and in and under shrubs (Raitt, pers. comm.).

Water

Pools of water rarely are available in the desert during the hottest months of the year. Adult cactus wrens infrequently drink free water in July and August (Anderson and Anderson 1973); they apparently obtain the necessary water from their diet. Immature wrens, on the other hand, often have been observed drinking water in August. Adult birds begin to drink free water in September, and the rate of water consumption apparently increases to high levels in December and January (Anderson and Anderson 1973). The insect food eaten during the winter months presumably does not have as high a water content as does the insect food consumed during the summer. Rainfall totals in the Sonoran desert decrease during the spring. However, succulent plant growth and associated insect populations increase in biomass, and foraging adult wrens apparently can satisfy their water needs from their diet.

Ricklefs and Hainsworth (1968) stated that the cactus wren relies exclusively on water obtained from its food during the period of greatest heat stress. The cactus wren also conserves water by behavioral mechanisms, such as reduced activity and selection of cooler microhabitats.

Cover

The cactus wren is associated with the shrub life form within the warm deserts of the southwestern United States and northern Mexico. The abundance of appropriate shrub vegetation presumably affects the distribution and abundance of the wren within its range. Activities that impact suitable desert scrub vegetation should be expected to directly impact the numbers and distribution of any resident wrens.

Habitat for the cactus wren consists of thorny shrubs and trees or the more arborescent species of cacti that occur on sunny hillsides and mesas next to mountains and along gravelly watercourses, primarily in lowlands (Bent 1948). Selection of nest sites seems to favor placement among the protective spines of desert vegetation. Cactus wrens use nests for both reproductive purposes and roosting. A covered roosting nest is used throughout the year (Anderson and Anderson 1973). The location of roosting nests in the Saguaro National Monument near Tucson, Arizona, was associated with the presence of cholla cactus. About 65% of 528 roosting nests were in jumping cholla (Opuntia fulgida), 12% in Staghorn cholla (O. versicolor), and 13% in saguaros. The use of a variety of desert shrubs and cacti as reproductive nest sites is described below.

Cover, such as shrubs and trees, also is important in providing shade and cooler microhabitats, which cactus wrens use when temperatures within desert habitats are high (Ricklefs and Hainsworth 1968). Wrens ignore open ground at this time and hunt on shady ground or in the lower branches of midstory vegetation.

Reproduction

The cactus wren apparently mates for life and, at least in part of the Sonoran desert, remains in its established territory for life. Cactus wrens, at least in the Chihuahuan desert, however, may not be resident on their breeding territories throughout the year (Raitt, pers. comm.). The wrens may remain in the general area, but overwinter in more mesic riparian habitats.

Reproductive nests characteristically are bulky, cylindrical to football-shaped, and comprised of plant stems and grasses, which rest horizontally on branches of cacti or thorn trees. A passageway up to 15 cm long leads into the closed-roofed, "retort-shaped" nest (Bailey 1922). The nest usually is placed in bushes, thickets, cacti (especially prickly pear and cholla, Opuntia spp.), yucca (Yucca spp.), catclaw acacia (Acacia greggii), mesquite, and various other thorny shrubs in Texas (Oberholser 1974); in yucca (Bent 1948), little-leaf sumac (Rhus microphylla), whitethorn (Acacia constricta) (Marr 1981), mesquite, condalia (Condalia spp.), catclaw mimosa (Mimosa biuncifera), desert willow (Chilopsis linearis), and netleaf hackberry (Celtis reticulata) (Raitt, pers. comm.) in New Mexico; in the largest specimens of cholla and prickly pear, large bushes, such as sugar sumac (R. ovata), and occasionally in fruit trees in southern California (Bent 1948); and in a variety of desert shrubs and cacti in southern and central Arizona. Jumping cholla was the preferred nest site in desert shrublands near Tucson, Arizona; in the cholla meadows of the Santa Rita Experimental Range south of Tucson; and in the saguaro-paloverde (C. microphyllum) cacti association of the Saguaro National Monument east of Tucson (Anderson and Anderson 1973). Nearly half of the breeding nests were placed in jumping cholla; 11% in staghorn cholla; 3% in paloverdes; and about 35% in the crotches, holes, or stumps of saguaro cacti (Anderson and Anderson 1973:63). Nests in cacti were from 0.9 to 2.3 m above ground, nests in paloverdes were 2 to 3.7 m above ground, and nests in saguaros frequently were 3 to 4.3 m above ground (Anderson and Anderson 1973). Thorny trees and bushes, especially catclaw (A. greggii) and jujube (Ziziphus spp.), were used extensively, whereas mesquite and dense, shrubby hackberry (Celtis spp.) were used only occasionally for nest sites at about the 1,210 m level at the base of the Santa Rita mountains south of Tucson (Bailey 1922).

The wren begins to defend breeding territories in January in southern Arizona, and breeding territories frequently are established by mid-February. The size of breeding territories averaged about 1.0 ha on the Saguaro National Monument, about 1.9 ha on the cholla meadows of the Santa Rita Experimental Range (Anderson and Anderson 1973), and about 4.7 ha in areas of the Chihuahuan desert (Marr 1981).

Breeding nests usually are built in late February and early March, and egg laying commences by early to mid-March in the Tucson area (Anderson and Anderson 1973). Egg laying may be initiated by an adequate rainfall which, when coupled with rising temperatures, produces an abundant growth of ephemeral plants and their associated insect fauna. The breeding season, in years of normal rainfall, may last from March to July.

Cactus wrens in southcentral New Mexico seemed to initiate clutches during a period of high temperatures during early spring. Marr and Raitt (1983) hypothesized that this warm period would likely precede periods of favorable temperatures that would occur during the period when the wren would be feeding nestlings. Cactus wrens in this area fed heavily on band-winged grasshoppers (Trimerotropis spp.), which emerged after soils warmed in the spring. Cactus wrens started to develop eggs during the last week in April.

Each pair of wrens within the Tucson study area averaged two clutches/year (Anderson and Anderson 1973). Incubation was 16 to 17 days, and nestlings remained in the nest an additional 19 to 23 days after the eggs were hatched. The second clutch frequently was initiated about 1 week after the first clutch was fledged. Both parents fed insects to nestlings. About four young were fledged/pair/year, with higher nesting success in chollas than in saguaros (Anderson and Anderson 1973). Young birds, after fledging, use roosting nests within the parental territory and initiate roosting nest construction at about 4 months of age (Anderson and Anderson 1973). Dispersal of immature birds may be voluntary or initiated by the parents. Dispersal movement is only as far as necessary to find an unoccupied territory (Anderson and Anderson 1973).

Interspersion

The cactus wren is attracted to the shrub life form (Dixon 1959) within the hot deserts and arid lands of the southwestern United States and northern Mexico. They apparently are most abundant where arborescent cacti and prickly shrubs are most abundant. The life form of thorny bushes and trees and arborescent cacti characteristically produces an open midstory canopy and an open understory. This habitat structure is preferred by the wren, and no interspersion of different vegetation structures or cover types is considered necessary.

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area. This model for the cactus wren was developed from descriptive data collected largely from Sonoran desert habitats. The model should have applicability throughout the Sonoran biogeographic province of southcentral and southwestern Arizona and extreme southeastern California and may also have some utility in the Mohavian province in southeastern California and southern Nevada, the Chihuahuan province in southeastern Arizonia, southern New Mexico and west Texas, and the Tamaulipan province of south Texas. The approximate range of the Sonoran biogeographic province in the United States as well as the range of the cactus wren in the southwestern United States is indicated in Figure 1.

Season. This model will provide an estimate of the quality of habitat for the cactus wren at least during the breeding season and perhaps throughout the year. The bird builds conspicuous nests in preferred plants and frequently

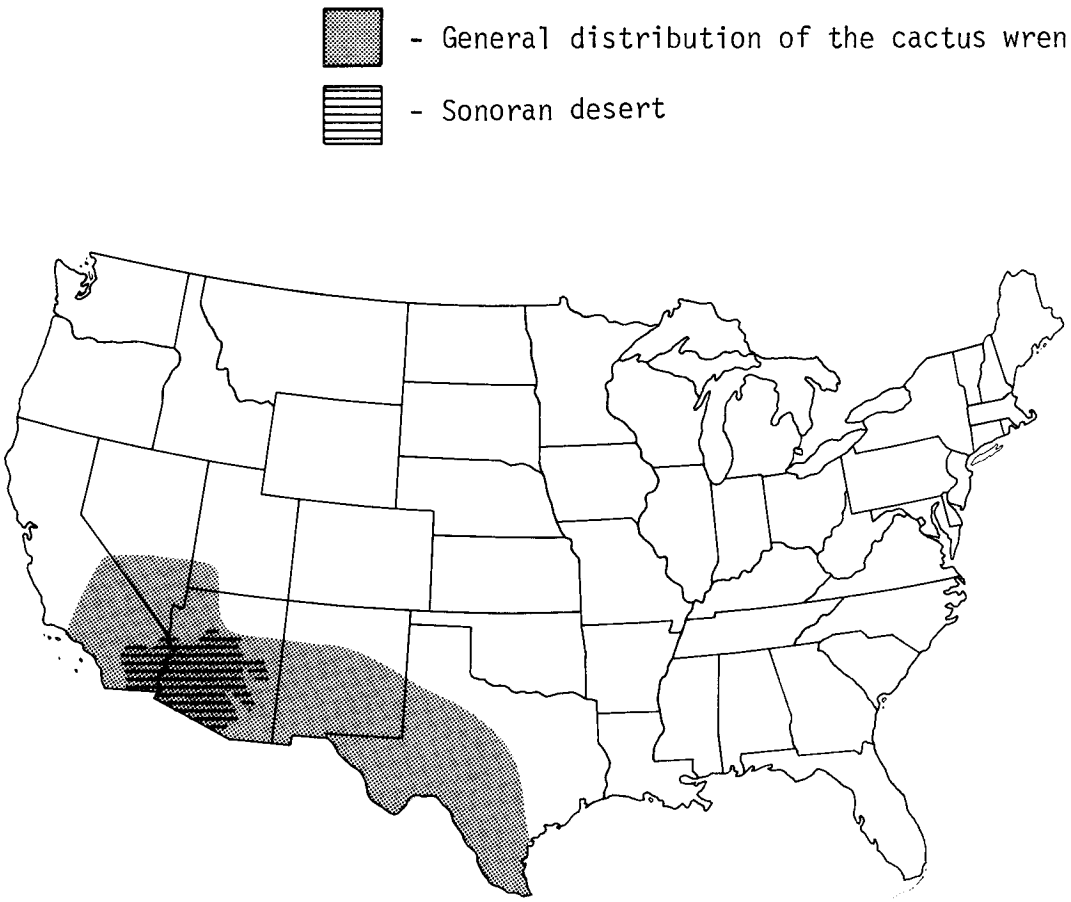


Figure 1. Distribution of the cactus wren in the southwestern United States (adapted from a map prepared by D. B. Inkley and C. M. Raley, Wyoming Cooperative Fishery and Wildlife Unit, Laramie, from information in American Ornithologists' Union 1983). The distribution of the Sonoran biogeographic province within the United States also is indicated on the map (after Brown 1982:13).

uses these nests as roosting sites throughout the year. Thus, the presence of nests may be an indicator of habitation by cactus wrens, and the number of useable nests in a given area of the Sonoran desert may be a rough indicator of the number of cactus wrens present in that area (Anderson and Anderson 1973). This model estimates the suitability of habitat structure in terms of providing nest sites for the wren.

Cover types. This model was developed for application in habitats described as desertic shrublands (DS) and desertic woodlands (DW) (U.S. Fish and Wildlife Service 1981).

Minimum habitat area. The minimum habitat area is the area required before that habitat will be occupied by cactus wrens. The cactus wren is a nonmigratory species that defends a territory. The minimum territory reported in the literature was about 0.4 ha (Anderson and Anderson 1973). A habitat block of desert shrubland must, therefore, be at least 0.4 ha to be considered as potential habitat for the cactus wren in this model.

Verification level. This model was developed from descriptive information about nesting and foraging habitats published in the literature. The HSI derived from this model describes the potential of an area as habitat for the cactus wren. The model is designed to rank the suitability of various thorn forest and semi-desert habitats as would a biologist with expert knowledge about the wren. The model should not be expected to rank habitats in the same way as population data because many nonhabitat-related criteria can significantly impact populations of wildlife species.

Model Description

Overview. This HSI model estimates the quality of arid shrubland habitats in the southwestern United States for the cactus wren. The model assumes that the wren prefers thorny shrubs and arborescent cacti for nest sites and actively selects that vegetative structure.

The following sections provide documentation of the logic and assumptions used to translate habitat information for the cactus wren into the variables selected for the HSI model. Specifically, these sections describe: (1) the variables used in the model; (2) the assumed suitability level of each variable; and (3) the assumed relationships between variables.

The logic used to develop the HSI model is illustrated in Figure 2.

Roost and reproductive component. The nonmigratory cactus wren is assumed to be restricted to arid savanna, open thorn forest, and semidesert cactus and deciduous tree cover types (Selander 1964) in the southwestern United States. These cover types provide the combination of a scattered midstory layer of shrubs with dense foliage for nest placement and an insect population that is available as food throughout the year.

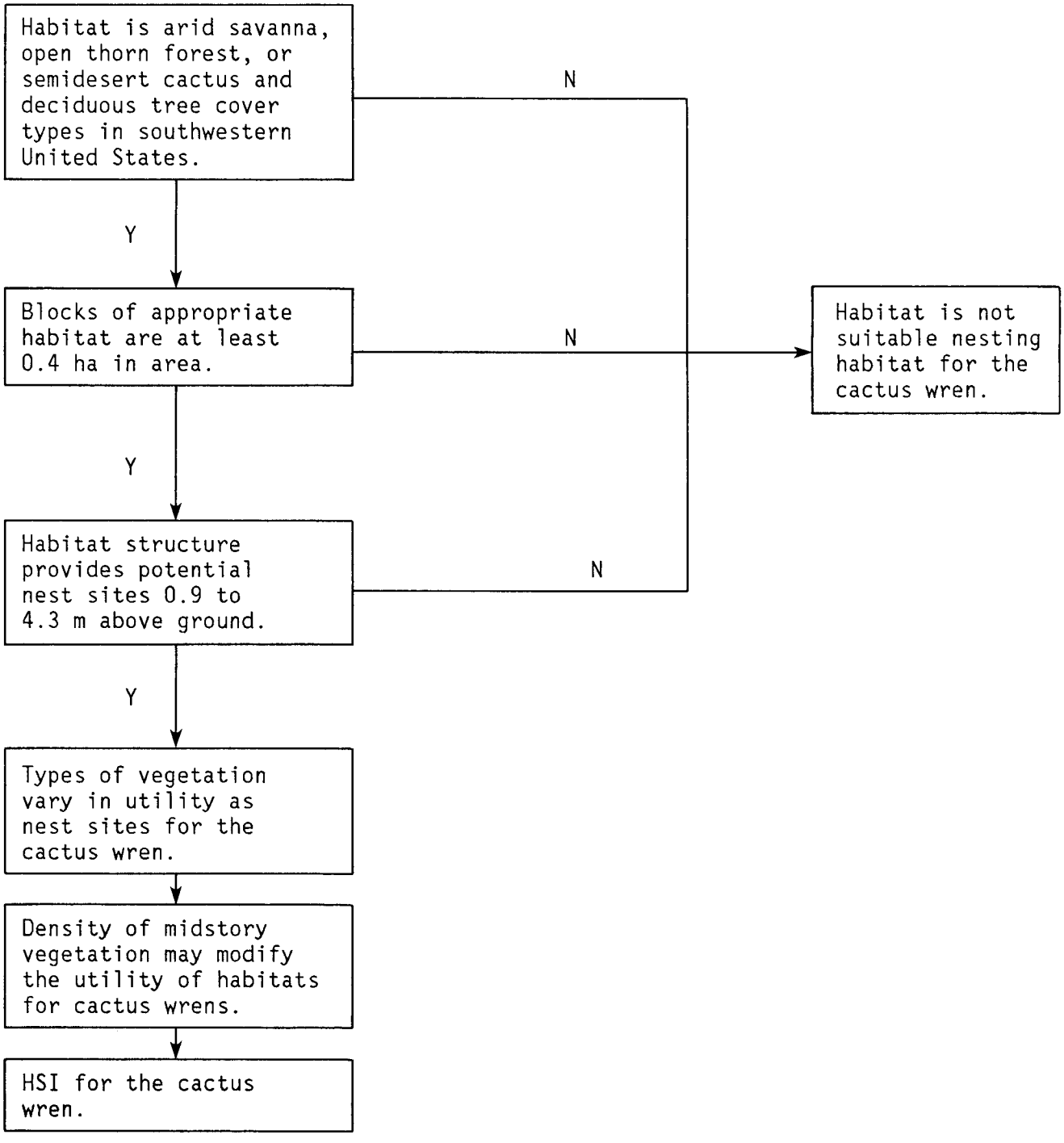


Figure 2. Logic used to develop the HSI model to estimate the quality of habitat for the cactus wren.

The cactus wren is highly territorial. The minimum territory size cited in the literature is about 0.4 ha (Anderson and Anderson 1973). A patch of suitable habitat must, therefore, be ≥ 0.4 ha to be considered as habitat for the cactus wren in this model.

The cactus wren makes and repairs nests that are used as roost sites throughout the year and as reproductive sites in spring and early summer. The usefulness of a habitat for nest placement is dependent on the presence of vegetation where the large, bulky, retort-shaped nest can be sturdily positioned horizontally on limbs. The cactus wren often selects vegetation with spines that offer protection to the nest and its occupants. Suitable midstory vegetation must provide nest sites within 0.9 to 4.3 m of the ground for the area to be considered habitat for the cactus wren.

The abundance of cactus wrens in a habitat is assumed to be represented by the abundance of preferred midstory vegetation that provides nest sites. The species of midstory vegetation are represented by Variable 1 (V1), and the abundance of each species of suitable midstory vegetation is represented by Variable 2 (V2) in the model. Suitability indices for Variables 1 and 2 may be regionally biased because they were developed from descriptive data gathered mostly in Sonoran desert habitats, which represent only a fraction of the range of the cactus wren (Fig. 1). For example, high SI's are assigned to jumping chollas and saguaros in V1, below, even though these species have a restricted range in the southwestern United States. The SI's suggest that these plant species are highly preferred as nest substrates of the cactus wren. Other species of midstory vegetation are regionally important to the wren. Their relative importance, compared to that of jumping chollas or saguaros, is estimated by the SI's listed in V1.

Cactus wrens, in Sonoran desertscrub habitats near Tucson, commonly build their nests in the periphery of the crown of jumping cholla (Anderson and Anderson 1973). Over 48% of 154 breeding nests and 65% of 528 roosting nests were located in jumping cholla on the Saguaro National Monument. Hensley (1959) found 21 of 22 active nests on the Organ Pipe National Monument in jumping cholla. It appears that cactus wrens "select" suitable jumping cholla as nest sites when this cactus is available in habitats. Therefore, jumping cholla is assigned an SI of 1.0 in V1. The range of jumping cholla in the United States is restricted to southwestern and southcentral Arizona (Lamb 1975).

Thirteen percent of the roosting nests and about 36% of the breeding nests of the cactus wren on the Saguaro National Monument were located in saguaro cacti (Anderson and Anderson 1973:63). Saguaros were used about 74% as frequently as jumping cholla as sites for breeding nests. Therefore, saguaros are assigned an SI of 0.7 in V1. A variety of other chollas occur throughout the Southwest and may be used as nest sites by the cactus wren. For example, chollas are uncommon in southcentral New Mexico but those of large stature are often selected as nest sites by the cactus wren (Raitt, pers. comm.). Staghorn cholla (O. versicolor) was used about 23% as frequently as was jumping cholla as a site for breeding nests within the Saguaro National Monument (Anderson and Anderson 1973:63); this cholla is assigned an SI of 0.2

in V1. Other arborescent forms of cacti (including chollas and prickly pears) and yuccas (Yucca spp.) that occur throughout the Southwest and provide a horizontal structure suitable for the placement of the bulky nest of the cactus wren at a height at least 1 m above the ground are assigned an SI of 0.2 in V1.

The cactus wren also nests in a variety of thorn shrubs. Bailey (1922) found that catclaw and jujube were used extensively, and mesquite and hackberry were used occasionally as nest sites in southern Arizona. Thornbushes with horizontal branches 1 m from the ground that can support the bulky nest of the cactus wren are assigned an SI of 0.2 in V1. Bailey (1922) found that 34 of 64 nests located in catclaw, jujube, and hackberry near the foothills of the Santa Rita Mountains south of Tucson actually were placed in clusters of mistletoe (Phoradendron californicum) in those bushes. The presence of mistletoe in a thornbush habitat is assumed to increase the SI of those thornbushes to 0.4.

The SI of V1 differs depending on the type of midstory vegetation providing potential nest sites to the cactus wren. SI's for different types of vegetation are estimated as follows:

V1 = 1.0 if vegetation consists of jumping cholla at least 1 m tall.

V1 = 0.7 if vegetation consists of saguaros with branches.

V1 = 0.4 if vegetation consists of thorn shrubs with horizontal branches 1 m and more above ground and if the thorn shrubs also contain mistletoe.

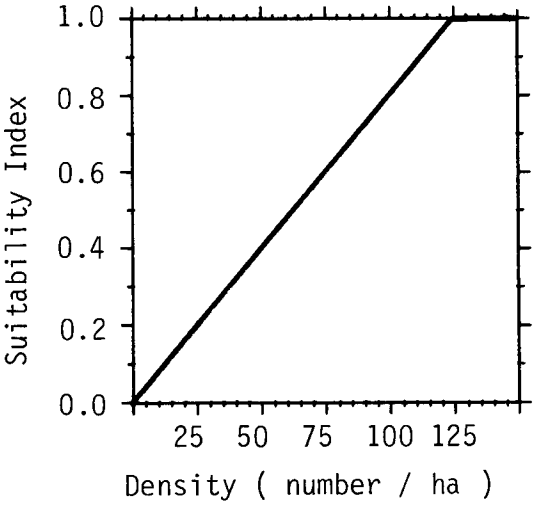
V1 = 0.2 if vegetation consists of thorn shrubs with horizontal branches 1 m and more above ground but without mistletoe, or if vegetation consists of arborescent forms of other cacti and yucca with a structure 1 m and more above ground capable of supporting wren nests.

V1 = 0.0 if vegetation consists of open shrubs and other forms of cacti and yucca (< 1 m tall) or vegetation ≥ 1 m tall that does not have the necessary structure to support wren nests.

The quantity of potential nest sites available to the cactus wren is assumed to increase (to some limit) as the density of arborescent cacti and thorn shrubs increases per unit of habitat. A measure of cacti and shrub density is Variable 2 (V2) in the model. The numbers of individuals in each of the plant groups identified for V1 are counted because of the assumption that a mix of the plant groups provides a preferred habitat condition for the cactus wren. Presumably, a mixture of suitable plant species should result in a higher HSI for a habitat because it provides a variety of nest sites and foraging areas. Anderson and Anderson (1973:14) indicated that the number of saguaros on a study area within the Saguaro National Monument varied from 0 and 98/ha, the number of paloverdes varied from 5 and 118/ha, and the total number of jumping and staghorn cholla plants varied from 0 and 108/ha. These densities of suitable midstory vegetation species are assumed to represent optimum conditions for the cactus wren. Therefore, the suitability of a habitat unit is assumed to increase as the number of large jumping chollas,

saguaros, and thorn shrubs per acre of habitat each increase from 0 to 125. Densities greater than 125 plants/ha for any of these species presumably does not provide any additional habitat benefits to the highly territorial wren.

V2 Density of each type of midstory vegetation providing potential nest sites.



Suitable nest sites are present in some xeric habitats only where shrubs and cacti are linearly constrained along narrow arroyos (Raitt, pers. comm.). The density of arborescent cacti or thorn shrubs is calculated per ha of arroyo in this case. Cactus wrens occur in arroyos in southcentral New Mexico if the arroyos contain shrubs along the arroyo without sizeable gaps between clumps of shrubs (Raitt, pers. comm.).

HSI determination. The Habitat Suitability Index (HSI) for this cactus wren model is developed from the identification of the types and density of shrubs or cacti present on a study area. The model reflects the assumptions that: (1) some shrubs or cacti are more useful to the cactus wren than are other shrubs or cacti; (2) the suitability of a habitat is related to the abundance of preferred shrubs or cacti; and (3) the quality of a habitat is enhanced if a mixture of suitable shrubs and cacti are present because of an increase in the number of potential nest sites and foraging areas available to the cactus wren.

The equation for estimating the suitability of habitats for the cactus wren is listed below. HSI's greater than 1.0 are rounded to 1.0.

$$HSI = \left[\sum_{i=1}^{n} (SIV1_i \times SIV2_i)\right]^{1/2}$$

where $i = 1, \ldots, n$ = the individual types (or groups) of suitable shrubs or cacti present on an ha of habitat

V1 = the SI for each type (group) of suitable shrubs or cacti present on an ha of habitat

V2 = the SI that represents the density of each type (group) of suitable shrubs or cacti

This model was developed from a few data sets that associated the density of the cactus wren with quantitative or descriptive evaluations of habitat structure. These data sets are listed below. Anderson and Anderson (1973) determined that an average of 25 saguaros (range of 0 to 98), 55 paloverdes (0 to 118), and 38 chollas (0 to 108) occurred per ha on a study plot on the Saguaro National Monument. A cactus wren population of 18 to 38 pairs/40 ha occurred in this habitat. A second study area, on the Santa Rita Experimental Range, contained jumping cholla (density unknown) on about one-half the plot and mesquite, paloverde, and acacia (densities unknown) on the remaining portion. A cactus wren population equal to 8 to 22 pairs/40 ha occurred on the study area. A third plot occurred on residential acreages near Tucson where jumping chollas averaged about 13 (0-50)/ha and cactus wrens occurred at a maximum density of about 10 pairs/40 ha. A fourth study area occurred between Las Cruces and the Organ Mountains in the Chihuahuan desert of south-central New Mexico (Marr 1981). Nests of cactus wrens were placed in little-leaf sumac and whitethorn in the largest arroyos, which constituted a small portion of the total test area. Cactus wren populations were about 0.3 pair/40 ha. Densities were not calculated per ha of arroyo.

The selection of habitat variables, the determination of SI's for the habitat variables, and the development of the equation for combining the habitat variables are best judgments, based on descriptive data published in the literature, and personal communications with species experts. The model, if the assumptions are correct, should rank the relative importance of habitats for the cactus wren, at least in the Sonoran desert. More cactus wrens are expected to occur on habitats with a high HSI because more potential nest sites are available to wrens in these habitats. It should be remembered that the population level of the wren may be impacted by criteria other than the structure of habitat.

Application of the Model

Summary of model variables. A biologist applying this model to estimate the value of thorn desert habitat should conduct a terrestrial survey to map midstory vegetation that could provide nest sites for the cactus wren. Aerial photography is not recommended as a means of identifying potential habitat

because the structure and density of suitable desert scrub vegetation frequently is not clearly discernible on aerial photographs. The following questions should be considered for each land unit identified as potential nesting habitat: (1) Is the land unit to be evaluated within the range of the cactus wren (Fig. 1)? (2) Is the area to be evaluated arid savanna, open thorn forest, semidesert cactus, or semidesert deciduous tree cover? The Southwestern deserts contain many isolated mountain ranges that receive more precipitation than surrounding areas and support dense vegetation that is not suitable habitat for the wren. Thus, the wren has a spotty distribution pattern in lowlands and mountain foothills that support the preferred vegetation structure; (3) Is the block of habitat to be evaluated ≥ 0.4 ha? and (4) Is there a midstory vegetation structure that includes thorn shrubs or arborescent cacti capable of supporting the bulky nest of the cactus wren at a height of 0.9 to 4.3 m above the ground?

If the answers to all four questions are positive, the biologist should estimate the suitability of the land unit as habitat for the cactus wren. The types of midstory vegetation present on the study area (V1) and the density (number per ha) of each of the types of vegetation (V2), need to be determined. The SI's for V1 and V2 are combined to estimate the HSI for each unit of habitat (Fig. 3).

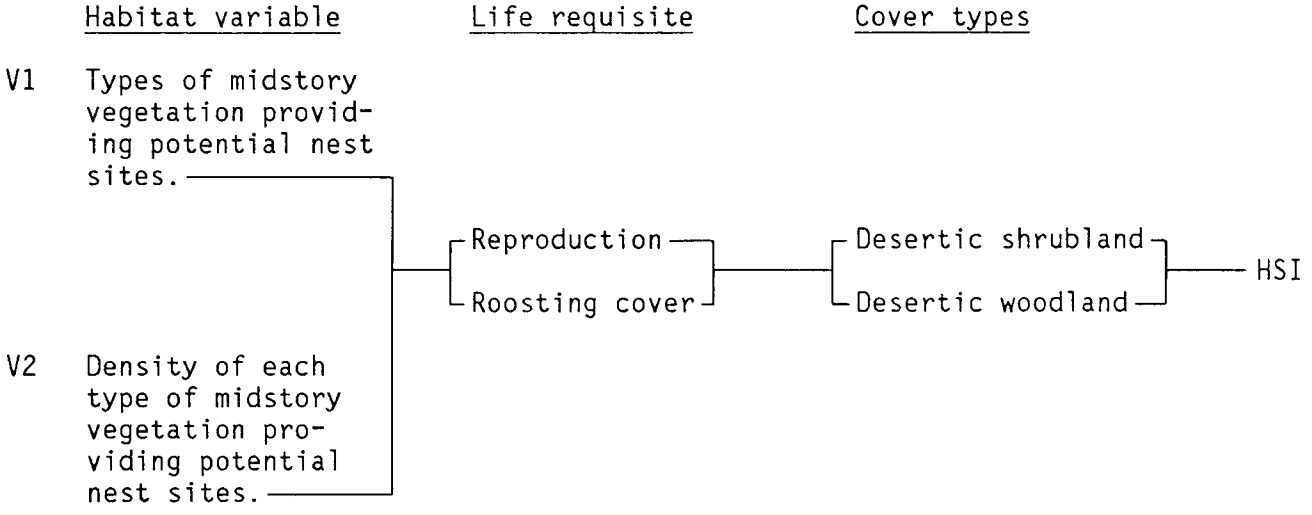


Figure 3. The relationship of habitat variables, life requisites, and cover types to an HSI for the cactus wren.

Definitions of variables and suggested field measurement techniques are presented in Figure 4.

Variable (definition)		Cover type	Suggested technique
V1	Types of midstory vegetation providing potential nest sites.	DS,DW	Taxonomic identification of apparently suitable midstory species.
V2	Density of each type of midstory vegetation providing potential nest sites.	DS,DW	Count numbers per unit area of each type of plant apparently suitable as a nest substrate for the cactus wren.

Figure 4. Definitions of variables and suggested measurement techniques.

Model assumptions. The cactus wren has been intensively studied in that portion of the Sonoran desert near Tucson, Arizona, and little studied in other portions of its range. My basic assumptions about habitat criteria important to this wren probably are most pertinent to Sonoran desert habitats containing thorny shrubs and arborescent cacti as the dominant vegetation. The model also may have relevance to appropriate habitats in the Mohavian, Chihuahuan, and Tamaulipan provinces. My description of habitat criteria important to the wren are based on descriptive and correlative relationships published in the literature. My description of habitat quality will be in error if authors have made incorrect judgements or measurements or if I have emphasized the wrong data sets or misinterpreted the meaning of published data.

I have assumed that: (1) the distribution of the cactus wren is limited to desert habitats where arborescent cacti and prickly shrubs are dominant vegetation and where insect populations are present during most of the year; (2) species of arborescent cacti and thorn shrubs vary in their value to the cactus wren and that the density of cactus wrens may increase as the density of individual species of cacti or thorn shrubs increases; and (3) a land unit must be at least 0.4 ha in area to be evaluated as habitat for the cactus wren.

The values for V1 and V2 are estimates. The ecological information available does not seem sufficient to suggest other pertinent variables or more appropriate values for the present variables. I also assumed that some sort of arithmetric relationship, like that suggested, adequately combines the estimates for V1 and V2 to provide an HSI for the cactus wren.

SOURCES OF OTHER MODELS

Aspects of the biology of the cactus wren have been intensively studied, especially in the Sonoran desert of southern Arizona. Anderson and Anderson (1973), for example, reported results of a 30-year study of the general life history of the wren around Tucson, whereas other authors have studied specific adaptations of the wren to hot desert conditions (e.g., Ricklefs 1975; Ricklefs and Hainsworth 1968, 1969). Marr (1981) reported on aspects of the breeding and foraging biology of the wren in the Chihuahuan desert of southcentral New Mexico. Data about the wren from the Mohave Desert in southern California and the Chihuahuan and Tamualipan thorn deserts of western and southern Texas are limited.

No other models describing the habitat requirements of the cactus wren were found in the literature. The number of assumptions required to develop the present model attest to the limitation in our understanding of habitat requirements of the cactus wren.

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A review and synthesis of existing information were used to develop a Habitat Suitability Index (HSI) model for the cactus wren (Campylorhynchus brunneicapillus). The model consolidates habitat use information into a framework appropriate for field application, and is scaled to produce an index between 0.0 (unsuitable habitat) and 1.0 (optimum habitat). HSI models are designed to be used with Habitat Evaluation Procedures previously developed by the U.S. Fish and Wildlife Service.

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