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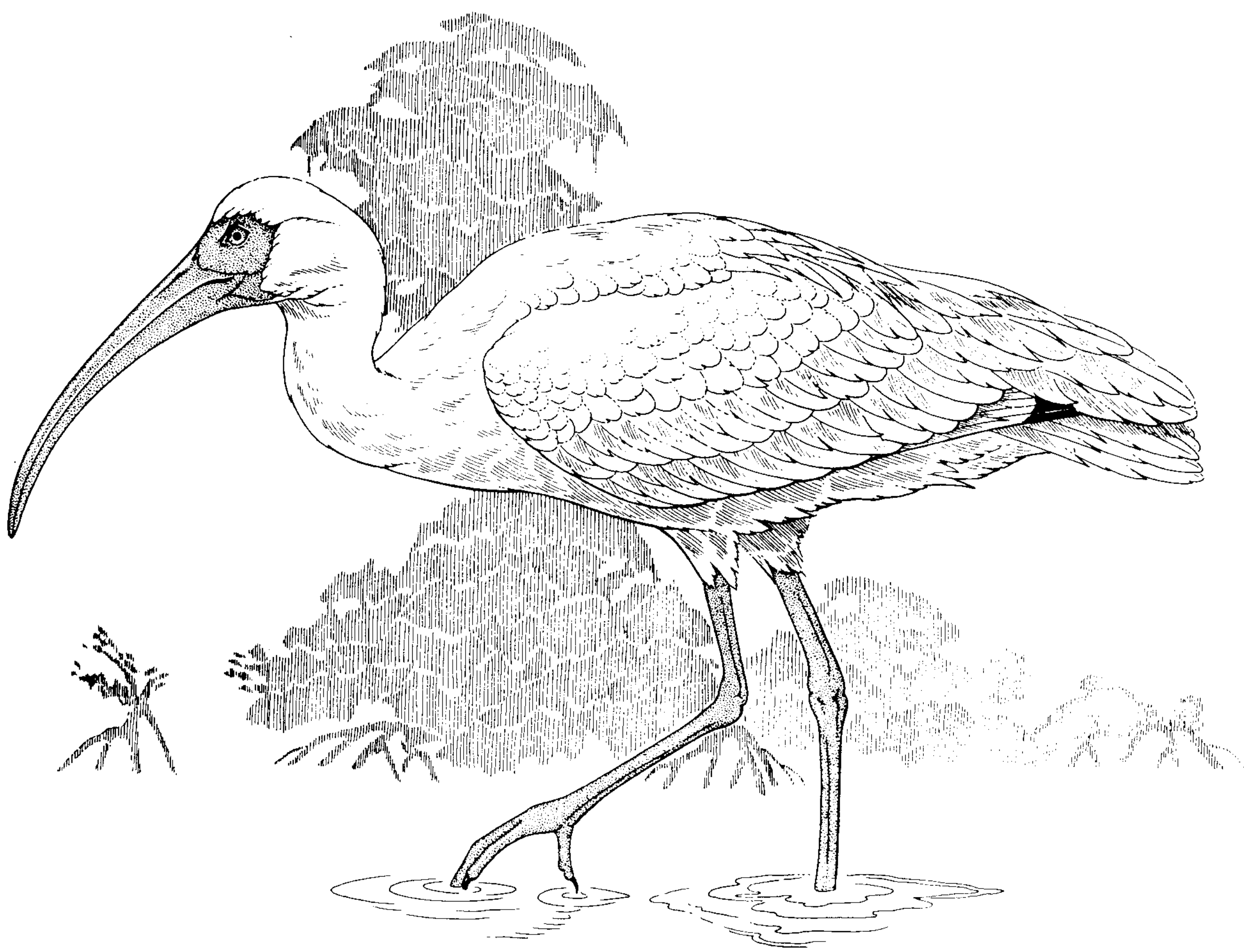
HABITAT SUITABILITY INDEX MODELS: WHITE IBIS



Fish and Wildlife Service

U.S. Department of the Interior

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HABITAT SUITABILITY INDEX MODELS: WHITE IBIS

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PREFACE

The habitat suitability index (HSI) models in this report on the white ibis are intended for use in the habitat evaluation procedures (HEP) developed by the U.S. Fish and Wildlife Service (1980) for impact assessment and habitat management. The models were developed from a review and synthesis of existing information and are scaled to produce an index of habitat suitability between 0 (unsuitable habitat) and 1 (optimally suitable habitat). Assumptions involved in developing the HSI models and guidelines for their application, including methods for measuring model variables, are described.

These models are hypotheses of species-habitat relationships, not statements of proven cause and effect. The models have not been field-tested. 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 to the following address:

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CONTENTS

ACKNOWLEDGMENTS

Development of the habitat suitability index models for the white ibis was reviewed and constructively criticized by Barbara B. Black, School of Forest Resources and Conservation, University of Florida, Gainesville; Keith L. Bildstein, Baruch Institute for Marine Biology and Coastal Research, University of South Carolina, Columbia; James A. Kushlan, Everglades National Park South Florida Research Center, Homestead; and James A. Rodgers, Florida Game and Fresh Water Fish Commission, Wildlife Research Laboratory, Gainesville. The U.S. Fish and Wildlife Service's (FWS) National Coastal Ecosystems Team (NCET) thoroughly evaluated model structure and functional relationships. Supportive narrative and model reviews were also provided by Regional personnel of the FWS. Funding for model development and publication was provided by the FWS. The cover illustration was prepared by Patrick J. Lynch.

WHITE IBIS (*Eudocimus albus*)

INTRODUCTION

White ibises (*Eudocimus albus*) are members of the family Threskiornithidae in the order Ciconiiformes. They are medium-sized wading birds with a tapering decurved bill. Adults are white with black tips on the four largest primaries. Males tend to be 35% larger than females, averaging 1,036 ± 30 g (33 ± 1 oz) (Kushlan 1977c). White ibises inhabit open marshes and other wetlands where they are one of the most important predators in the food chain in terms of energy flow (Kushlan 1977b; Rodgers and Nesbitt 1979). In the past, white ibises have been occasionally harvested by humans for food (Baynard 1913; Bent 1926).

Distribution

White ibises are found along coastal and inland regions of the Southeastern United States from North Carolina south to Florida and around the Gulf of Mexico coast. The species is also found along coastal regions of Central America and the Caribbean Islands and along the northern coasts of South America south to northwestern Peru and French Guiana (Palmer 1962; American Ornithologists' Union 1983).

In the United States, breeding colonies are located in North Carolina, South Carolina, Georgia, and in all Gulf Coast States (Custer et al. 1980; Nesbitt et al. 1982; Texas Colonial Waterbird Society 1982; Keller et al. 1984; Colonial Bird Register, unpublished data). Colonies are present in freshwater wetlands as far as 257 km (160 mi) inland as well as in estuarine wetlands and on islands with estuarine habitat (Colonial Bird Register, unpublished data; Texas Colonial Waterbird Society 1982). White ibises are one of the most numerous species of nesting wading birds in the Southeastern Coastal States (Kushlan and White 1977; Custer et al. 1980). In 1975 and 1976, 64,180 and 38,278 white ibises, respectively, nested in colonies along the southeastern Atlantic coast of the United States (Custer et al. 1980).

Life History Overview

White ibises breed in mixed-species colonies with anhingas (*Anhinga anhinga*), herons, egrets, and other ibises (Girard and Taylor 1979). Breeding colonies vary in size from less than 100 pairs to 10,000 or more pairs of white ibises but average 1,060 ± 240 pairs (Mean ± SE) in the Southeastern United States (Colonial Bird Register, unpublished data; see also Custer et al. 1980). Many colony sites are used year after year (Custer and Osborn 1977).

Age at first breeding has not been determined in the wild but may be as early as 2 years (Beebe 1914). The breeding season extends from early March to November and requires an average of 74 days from beginning of nest construction to independence of young (Kushlan 1973, 1976a, 1977b; Rudegeair 1975). Clutch size varies from 1 to 5 eggs, averaging from 2.0 eggs in Louisiana (Hammatt 1981) and South Carolina to 2.8 eggs in North Carolina (Custer and Osborn 1977). Eggs are incubated for 21 days, and chicks remain in the nest about 40 days (Rudegeair 1975). The fledging rate for nestling white ibis in Florida is about one per nest (Kushlan 1977b). Most second and third hatchlings in a nest starve because of asynchronous hatching and feeding of the oldest and largest chick first by the adults. Girard and Taylor (1979) found a nestling mortality rate of 40.2%, due to starvation and accidents in the first 2 weeks. The estimated percentage of nests producing fledglings in a Georgia colony was 36% (N=14 nests; Teal 1965). In Louisiana, about 1 of every 10 eggs produced a fledgling (Hammatt 1981). Besides the raccoon (Procyon lotor), the major mammalian predator (Jenni 1969), rat snakes (Elaphe sp.) are known to take heron eggs and young (Dusi and Dusi 1968), and avian predators of eggs and young herons include fish crows (Corvus ossifragus), boat-tailed grackles (Quiscalus major), and barred owls (Strix varia) (Dusi and Dusi 1968; Girard and Taylor 1979).

White ibises tend to be resident in the area where they breed (Palmer 1962). After the breeding season, movement of white ibis in southern Florida is regional, following patterns of changing water levels and seasonal variation in foraging habitat suitability (Kushlan 1976a, 1979). Birds in Louisiana and Texas move to local feeding and roosting areas during the nonbreeding season (Palmer 1962). Birds at inland locations in Alabama and Mississippi tend to leave the area in late fall and winter, but some do winter in coastal areas (C. Dwight Cooley, U.S. Fish Wildl. Serv., Daphne, Alabama, pers. comm.).

Coastal colonies of white ibises may produce only a small fraction of the average annual recruitment to the population in some years but are more consistently productive than inland colonies (Kushlan 1977b; Ogden et al. 1980). Coastal colonies may produce the only recruitment during years of heavy rain when nesting failure occurs inland because of reduced availability of food in deeper water (Kushlan 1976b, 1978, 1979).

SPECIFIC HABITAT REQUIREMENTS

Food and Foraging Habitats

White ibises are primarily tactile foragers that search for food in soft, flocculent organic sediments in open, shallow areas of wetlands covered by 0 to 25 cm (0 to 10 inches) of water (Kushlan and Kushlan 1975; Kushlan 1979). The preferred water depth for foraging is 5 to 10 cm (2 to 4 inches). Ibises also will pick up prey items seen out of water (Palmer 1962; Kushlan 1977a). The diet differs between birds foraging in freshwater and brackish or saltwater habitats but not between young and adult birds (Nesbitt et al. 1974; Kushlan and Kushlan 1975). In Florida, crayfish (Procambarus sp.) constitute 45% of the dietary volume in both coastal and inland foraging habitats (Nesbitt et al. 1974). The remainder of the diet in inland areas consists primarily of insects (37%), especially beetles; in coastal areas, fiddler crabs (Uca spp.) and insects compose 23% and 24% of the dietary volume, respectively. Fish, however, may account for as much as 31% of the diet by weight in coastal areas and 19% in inland areas during low water periods (Kushlan and Kushlan 1975). In Louisiana, mud crabs (Panopeus herbstii; 89% by item frequency) and cyprinodont fish (11%) made up most of the food items in the diet (Hammatt 1981). In Georgia, most of the food fed to nestlings was grass shrimp (Palaemonetes sp.; Teal 1965).

White ibises feed on small prey averaging 2 cm (0.8 inch) long, presumably to reduce handling time and kleptoparasitism (Kushlan 1979). The energy content of prey in the most extensively used foraging sites in the Everglades was 6.0 to 7.2 $kcal/m^2$ (0.6 to 0.7 $kcal/ft^2$), and white ibises continued to initiate nesting at levels of 3.5 $kcal/m^2$ (0.3 $kcal/ft^2$) (Kushlan 1979). Adults require about 165 kcal/day during the breeding season, and an additional 9,940 kcal/breeding season is necessary to produce a fledgling. Newly fledged birds require about 148 kcal/day (Kushlan 1977b); this is obtained within and immediately adjacent to the colony (Rodgers and Nesbitt 1979). Juvenile birds are less efficient at capturing prey than adults and have a capture rate of only 40% of the adult rate (Bildstein 1983).

White ibises generally feed in flocks and may be attracted to feeding areas by the presence of herons and other ibises, especially white individuals (Kushlan 1977d). Feeding aggregations of white ibises may reach 5,000 birds (Kushlan 1979) but probably average between 6.5 and 28.5 birds (Bildstein 1983). During the breeding season, white ibis flocks show differential use of several foraging habitats in south Florida. Coastal colonies used mangrove-lined streams and ponds (61%, N = 108 flocks), marl prairie (19%), and tidal mangrove swamp (14%); inland colonies in the Everglades National Park used marsh prairie (47%, N = 75 flocks), sawgrass pond edge (29%), and willow pond edge (15%) (Kushlan 1979). Birds of inland colonies outside the Everglades also extensively used pastures (56%, N = 63 flocks) as foraging habitat. Along the South Carolina coast, ibises feed in Salicornia-Distichlis marsh where they capture fiddler crabs at higher rates than in Spartina marsh or on mud flats (Henderson 1981). However, birds in other coastal regions feed mostly in Spartina marsh (Custer and Osborn 1978; Bildstein 1983).

White ibises in North Carolina coastal colonies foraged within 4 km (2.4 mi) of the nesting colony in 90% (N=139 flights) of foraging flights, but foraging distances as great as 6.7 km (4 mi) have been reported (Custer and Osborn 1978). The average foraging distance for an inland colony in Alabama was 10.3 km (6.2 mi) (Bateman 1970; Custer and Osborn 1978), with a maximum distance of 22.9 km (13.7 mi). No more than two different feeding areas were used daily. Ibises that nested on mangrove keys in the upper Florida Bay area returned to the mainland to feed (Kushlan and Robertson 1977).

Water

A salt gland allows white ibises to use saltwater as well as freshwater for their physiological needs (James Rodgers, Florida Game and Fresh Water Fish Commission; pers. comm.). Breeding and colony site selections are influenced by water levels (Kushlan 1976a; Ogden et al. 1980); moreover, white ibises will not nest during extreme drought (Dusi and Dusi 1968).

Cover

White ibis nesting colonies reported to the Colonial Bird Register have been located on spoil areas or spoil islands (27%, N = 389 colonies), on coastal islands (15%), in swamps (14%), on inland islands (9%), in freshwater marshes (7%), and on mangrove islands (5%). Nests occurred in mangroves (*Avicennia germinans*, *Laguncularia racemosa*, *Rhizophora mangle*; 30%, N = 232 colonies) and in other types of trees and shrubs (57%). These may include Australian pine (*Casuarina equisetifolia*), Brazilian pepper (*Schinus terebinthifolius*), cabbage palm (*Sabal palmetto*), lantana (*Lantana camara*), buttonwood (*Conocarpus erectus*), live oak (*Quercus virginiana*), laurel oak (*Q. laurifolia*), bay (*Persea borbonia*), red cedar (*Juniperus silicicola*), elder (*Iva frutescens*), willows (*Salix* sp.), wax myrtle (*Myrica cerifera*), swamp tupelo (*Nyssa aquatica*), common baldcypress (*Taxodium distichum*) (Bent 1926; Dusi and Dusi 1968; Rudegeair 1975; Schreiber and Schreiber 1978; Girard and Taylor 1979). White ibises will occasionally use herbaceous marsh such as sawgrass (*Cladium jamaicense*) (Kushlan 1973) or bulrush (*Scirpus* sp.) (Palmer 1962) for nesting. Such use occurs where foraging habitat is abundant but no arboreal nesting sites are available (Keith Bildstein, University of South Carolina; pers. comm.).

Nests are found from ground level to a height of about 9 m (30 ft). They average 1.78 ± 0.04 m (Mean ± SE) (5.9 ± 0.13 ft) high in white mangroves (*Laguncularia racemosa*) in Florida (Girard and Taylor 1979) and 0.14 ± 0.01 m (0.5 ± 0.03 ft) in black mangroves (*Avicennia germinans*) in Louisiana (Hammatt 1981). The spacing of nests in colonies is probably related to vegetative physiognomy; i.e., nests in taller vegetation may be further apart (Beaver et al. 1980). Distance between white ibis nests from rim to rim averaged 0.54 ± 0.05 m (Mean ± SE) (1.8 ± 0.2 ft) (Girard and Taylor 1979), which could allow numerous nests in a limited area. In coastal colonies, the white ibis has been found breeding in 0.1 ha (0.25 acres) or less of suitable habitat (Nesbitt et al. 1982).

Four requisites for wading bird rookeries were identified by Jenni (1969). They need to be reasonably close to suitable feeding areas, have sufficient space for territories, be near an adequate supply of nesting materials, and be free from excessive predation and disturbance. The presence of predators (chiefly the raccoon) may prevent the use of otherwise suitable nesting habitat. Landin (1978) identified four factors that could prevent colonial birds from nesting on dredged-material islands. These included proximity to the mainland, proximity to recreational areas, an island size large enough to allow year-round occupancy by quadruped predators, and an elevation less than 1 m (3.3 ft) above mean high tide. Island size for ibis colonies reported to the Colonial Bird Register (unpubl. data) ranged from 0.1 to 130 ha (0.2 to 321 acres) and averaged 20 ± 5.7 ha (49 ± 14 acres) (Mean ± SE, N = 27). An area with appropriate nest sites, isolated by surface water, and lacking mammalian predators provides excellent white ibis nesting habitat if food resources are available. Variations in food resources from year to year probably account for annual changes in nesting locations (Kushlan 1976a).

Special Considerations

Human disturbance is not only disruptive but can prevent colony establishment or cause colonial nesting birds to abandon a site (Buckley and Buckley 1978; Schreiber and Schreiber 1978). The degree of disturbance that will cause white ibises to abandon a site has not been quantified, but colony abandonment is more likely when disturbances occur during egg laying (Tremblay and Ellison 1979). The failure of a white ibis colony in Tampa Bay, Florida, was attributed to human disturbance at the onset of breeding (Schreiber and Schreiber 1978).

White ibises exhibit great site tenacity and use traditional nesting sites year after year (Custer and Osborn 1977; Buckley and Buckley 1978; Custer et al. 1980). Custer et al. (1980) found that new colonies tend to be satellites of nearby reused colonies. The value of a site is enhanced by a pattern of traditional use.

Interspersion

White ibises that nest on mangrove islands in the northern part of Florida Bay fly to mainland sites to feed. In addition, ibises in southern Florida move from inland to coastal foraging habitat as water levels rise during the summer wet season (Kushlan 1979). The presence of foraging areas near a colony site may be important for fledgling white ibises during their first week away from the nest (Rudegair 1975; Rodgers and Nesbitt 1979). The required proximity of these areas has not been determined.

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

The habitat suitability index (HSI) models were developed for application within the breeding range of the white ibis in the continental United States. This includes coastal regions and inland wetlands up to 257 km (160 mi) from the coast in all the Gulf Coast States and in Atlantic Coast States from North Carolina south. If no historical information on model variables exists, the model should be used immediately before or during the nesting season to determine the suitability of a site as nesting habitat for white ibises. Surface water conditions at other seasons may be quite different from conditions during the nesting season.

The models may be used to evaluate habitat quality in both estuarine and palustrine systems (Cowardin et al. 1979). The minimum area required for a successful colony is unknown.

Verification level. The model outputs are an index ranging between 0 and 1.0 that reflects the suitability of an area for a nesting colony of white ibises. Habitat with an HSI of 1.0 is optimum; an HSI of 0 indicates unsuitable habitat. The models have not been field tested. Hypothetical data sets were used to demonstrate model calculations and output. Barbara B. Black, School of Forest Resources and Conservation, University of Florida, Gainesville; Keith L. Bildstein, Baruch Institute for Marine Biology and Coastal Research, University of South Carolina, Columbia; James A. Kushlan, Everglades National Park, South Florida Research Center, Homestead; and James A. Rodgers, Florida Game and Fresh Water Fish Commission Wildlife Research Laboratory, Gainesville, reviewed the white ibis models. The authors remain responsible for their content.

Model Descriptions

Overview. Two separate models were developed, one for use in wetlands (including mangrove islands) and one for use in island (upland) habitat. Evaluation of nesting habitat in both models is based on one life requisite: cover (Figure 1). Foraging habitat may be limiting in some years but not in others, depending on water levels. In addition, detailed information on foraging habitat requirements was not available. For these reasons, plus the fact that ibises will fly long distances to feeding areas, foraging habitat was not included in the models. For model application, however, foraging habitat (see Specific Habitat Requirements) must be present within at least 23 km (14 mi) and preferably within 10 km (6 mi) of nesting/roosting cover. If such habitat is not present within 23 km (14 mi), the HSI for white ibises becomes 0.

Island habitat. Quality of nesting cover is related to the protection provided against predators, to suitable nesting substrate, and to isolation from human disturbance. For island colonies in estuarine and freshwater habitat, protection from predation is determined by distance from mainland (V_1), by island surface area (V_2), and by average height of vegetation (V_3). A distance of 0.4 km (0.25 mi) is assumed to isolate an island colony from mainland predators. Small islands may not provide adequate food resources for year-round residency by predators. Relatively small islands also are less likely to be developed for human use. The upper bound of the 99% confidence interval of mean island size (UB = 36 ha (89 acres); Colonial Bird Register, unpubl. data) was used as the upper bound for the optimal island size category. The largest value in the range of reported island sizes was used as the upper bound of the second island size category. Suitable nesting substrate may consist of expanses of sawgrass as well as areas of trees and shrubs. However, suitability is presumed to increase with increasing height of cover (V_3) because of protection from predation, flooding, and human disturbance.

The final variable affecting island habitat suitability is human disturbance (V_4). Human disturbance should be absent in the early nesting season and minimal or absent during nestling stages. Habitat suitability is assumed to increase with the distance of the colony from sources of human disturbance up to 2 km or 1.2 mi. Nonconsumptive human use of nesting areas during the nonbreeding season is probably not detrimental.

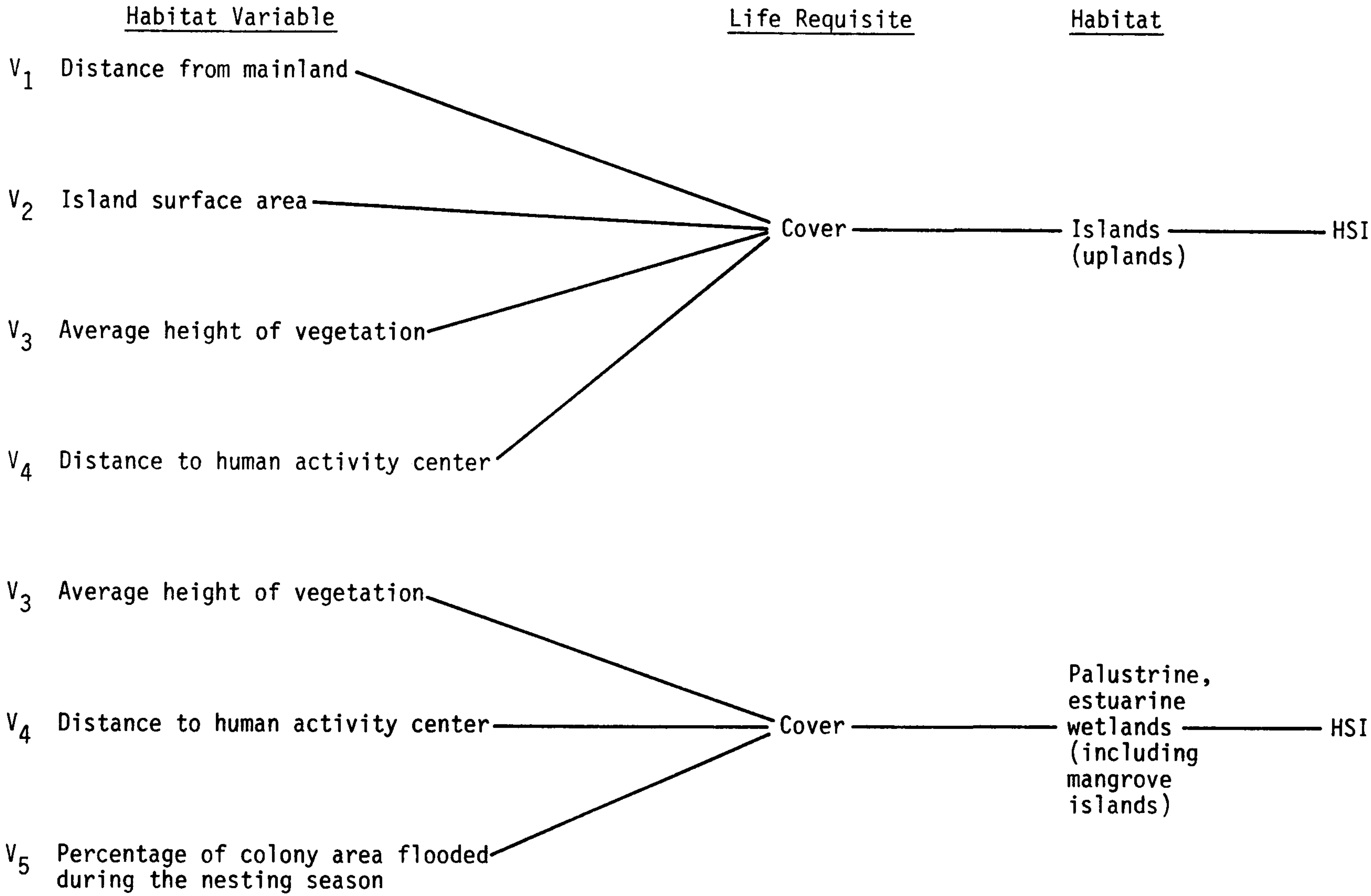


Figure 1. Relationship of habitat variables and life requisite for islands and wetlands in the white ibis HSI models.

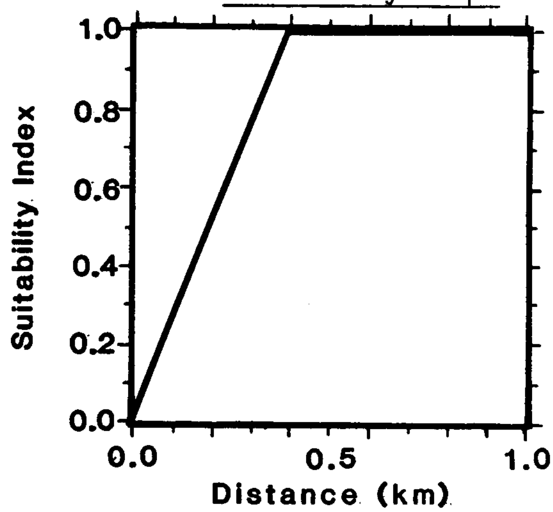
Wetland habitat. Both average height of vegetation (V_3) and human disturbance (V_4) are assumed to influence habitat suitability for nesting or roosting white ibises in wetlands as well as on islands. In addition, vulnerability to predators for wetland colonies is determined by the proportion of flooded ground during the nesting season (V_5). Potential colony sites surrounded by large expanses of flooded ground are less accessible to predators so that suitability increases as the proportion of flooded ground increases. Decreased height of nesting cover may be compensated for by increased proportion of flooded ground.

Suitability Index (SI) Graphs for Model Variables

This section contains suitability index graphs relating data to SI values for the five habitat variables essential to white ibises in estuarine (E) and palustrine (P) wetlands and upland (U) island habitats. Assumptions for the following graphical relationships are summarized in Table 1. A value of 1.0 on the SI scale represents optimal suitability while 0.0 represents unsuitable habitat.

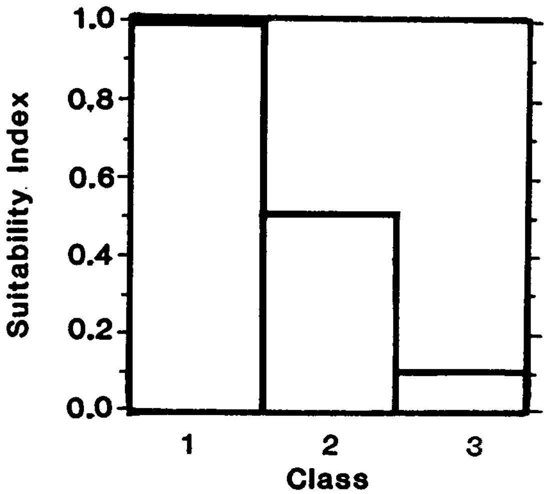
Habitat | Variable | Description | Suitability Graph

U | V_1 | Distance from mainland.



U | V_2 | Island surface area (islands in saltwater, brackish water, and freshwater lakes and ponds included).

1) < 36 ha (< 89 acres)
2) 36 to 130 ha (89 to 321 acres)
3) > 130 ha (> 321 acres)



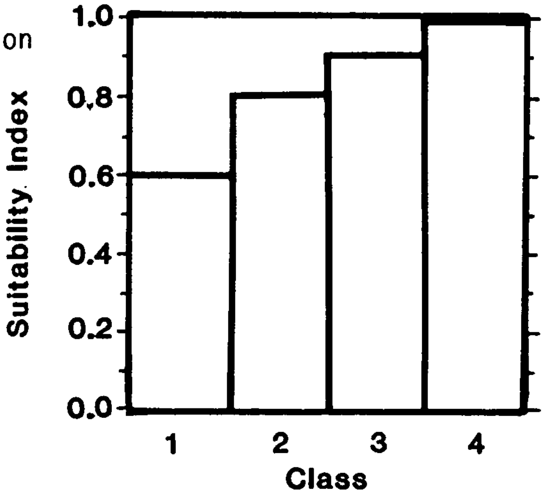
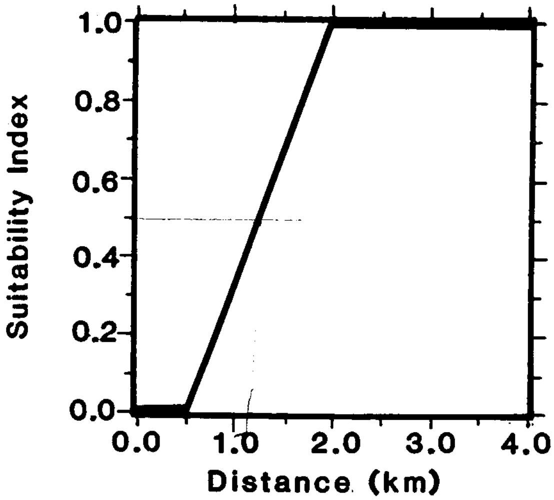
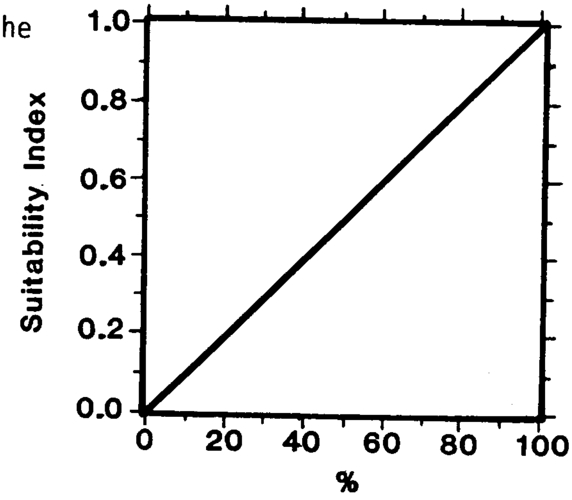
Habitat	Variable	Description	Suitability Graph
U, E, P	V_3	Average height of vegetation above high water level for wetland areas or above ground level for island areas. 1) 0 to 0.9 m (0 to 3.0 ft) 2) 1 to 1.9 m (3.3 to 6.2 ft) 3) 2 to 4 m (6.6 to 13 ft) 4) > 4m (> 13 ft)	
U, E, P	V_4	Distance to potential source of human disturbance.	
E, P	V_5	Percentage of colony area wetlands flooded during the nesting season with sufficient water to deter travel of mammalian predators in area.	

Table 1. Data sources and assumptions for white ibis suitability indices.

Variable and sources		Assumptions
V_1	Landin 1978 Buckley and Buckley 1980	Islands close to mainland are more accessible to terrestrial nest predators. Islands at least 0.4 km (0.25 mi) from mainland are inaccessible.
V_2	Landin 1978 Schreiber and Schreiber 1978 Colonial Bird Register, 1978	Smaller islands are preferred. Larger islands are able to support nest predators year round. Islands less than 36 ha (89 acres) are considered optimal.
V_3	Rudegeair 1975 Schreiber and Schreiber 1978 Girard and Taylor 1979 Hammatt 1981	White ibis nests have been located 1 to 9 m above (3.3 to 29.5 ft) high water level and 0.1 to 9 m (0.3 to 29.5 ft) above unflooded ground. A limiting nest height has not been reported. Greater height reduces danger of flooding, predation, and disturbance by humans. Above 1 m (3.3 ft) nests are free of flooding. Above 2 m (6.6 ft) nests have less predation by terrestrial nonclimbing predators. Above 4 m (13.2 ft) nests are least vulnerable to predators and human disturbance.
V_4	Schreiber and Schreiber 1978 Tremblay and Ellison 1979 Lewis 1983	Human disturbance reduces breeding success. More remote colonies are less likely to be disturbed. Colonies that are at least 2 km (1.2 mi) from human activities centers are most suitable.
V_5	Kushlan 1976a Landin 1978	Surface water decreases accessibility of predators to nesting sites. It may also indicate availability of a food resource proximate to the colony.

Habitat Suitability Index (HSI) Equations

Equations 1 and 2 are unique for each habitat type as indicated below. The suggested procedure for HSI determination yields a value between 0.0 and 1.0.

Equation 1

Island habitat $$HSI = (V_1 \times V_2 \times V_3 \times V_4)^{1/4}$$

Equation 2

Wetland habitat $$HSI = (V_3 \times V_4 \times V_5)^{1/3}$$

HSI values have been calculated for three sets of hypothetical habitat data (Table 2). The generated HSI values are believed to reflect the value of the habitat to nesting white ibises.

Table 2. Calculation of suitability indices (SI), component indices (CI), and habitat suitability indices (HSI) for three hypothetical data sets on the basis of habitat variables (V) and model equations.

Model component	Data set 1		Data set 2		Data set 3	
	Data	SI	Data	SI	Data	SI
V_1	0.4 km	1.0	-	-	1.0 km	1.0
V_2	36 ha	0.5	-	-	5 ha	1.0
V_3	2 m	0.9	0.5 m	0.6	1 m	0.8
V_4	2 km	1.0	0.5 km	0.0	4 km	1.0
V_5	-	-	25%	0.25	-	-
HSI	0.82		0.00		0.94	
Habitat	U		E		U	

Field Use of Models

The models should not be applied in an area unless there is an available food resource within at least 23 km (14 mi) and preferably within 10 km (6 mi) of potential nesting/roosting cover, and it is relatively free of human disturbance during the breeding season. Suggested methods for measuring habitat variables are listed in Table 3.

Table 3. Suggested techniques for measuring breeding habitat variables for the white ibis HSI model.

Habitat variable	Technique
V_1	Measure shortest linear distance between island and mainland at low tide. Can be determined using a topographic map or in the field.
V_2	Measure area of island on a map or aerial photo taken at mean high tide.
V_3	Measure vegetation with stereoscope on aerial photograph. Visit site to confirm appropriate configuration and height of nesting cover (i.e., height, species).
V_4	Measure shortest linear distance to permanent center of human activity on a map or aerial photo.
V_5	Measure the area of ground surface water on aerial photo taken at the beginning of the nesting season and compare to total area. Visit site to confirm depth of water sufficient to deter travel of mammalian predators in area.

Interpreting Model Outputs

The white ibis HSI determined by these models does not necessarily represent the population of white ibis in an area. Non-habitat factors excluded from the models may limit population levels. Habitat with an HSI of 0 may contain some white ibises, and habitats with a high HSI may contain only a few. The proper interpretation of the HSI is one of comparison. On average, habitats with high HSI's would be able to support higher populations of white ibises than habitats with low HSI's. A close correlation between population size and HSI is unlikely.

The spatial relationship of colony site to foraging sites requires more study that will undoubtedly lead to modifications of the HSI model. Further definition of the relationship between colony size and nesting success would be useful in calibration of the model.

These models will identify potential habitat for colonies of nesting white ibises. The susceptibility of coastal sites to natural destruction and the susceptibility of inland colonies to drought make maintenance of alternate nesting habitat a valuable management practice.

NP

REFERENCES

American Ornithologists' Union. 1983. Checklist of North American birds, 6th edition. Allen Press, Inc. Lawrence, Kans. 877 pp.

Bateman, D. L. 1970. Movement-behavior in three species of colonial-nesting wading birds: a radio-telemetric study. Ph.D. Thesis. Auburn University, Auburn, Ala. 210 pp.

Baynard, O. E. 1913. Home life of the glossy ibis (Plegadis autumnalis Linn.) Wilson Bull. 25:103-117.

Beaver, D. L., R. G. Osborn, and T. W. Custer. 1980. Nest-site and colony characteristics of wading birds in selected Atlantic coast colonies. Wilson Bull. 92:200-220.

Beebe, C. W. 1914. Notes on the ontogeny of the white ibis, Guara alba. Zoologica 1:240-248.

Bent, A. C. 1926. Life histories of North American marsh birds. U.S. Natl. Mus. Bull. 135. 392 pp + 98 pls.

Bildstein, K. L. 1983. Age-related differences in the flocking and foraging behavior of white ibis in a South Carolina salt marsh. Colonial Waterbirds 6:45-53.

Buckley, P. A., and F. G. Buckley. 1978. Guidelines for the protection and management of colonially nesting waterbirds. North Atlantic Regional Office, Natl. Park Serv., Boston, Mass. 52 pp.

Buckley, F. G., and P. A. Buckley. 1980. Habitat selection and marine birds. Pages 69-112 in J. Burger, B. L. Olla, and H. E. Winn, eds. Behavior of marine animals, Vol. 4: Marine birds. Plenum Press, New York.

Colonial Bird Register. Unpublished data courtesy of N.P. McGinnis and D. A. McCrimmon, Jr. National Audubon Society Research Department, Cornell Laboratory of Ornithology, Ithaca, N.Y.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish Wildl. Serv. FWS/OBS-79/31. 103 pp.

Custer, T. W., and R. G. Osborn. 1977. Wading birds as biological indicators: 1975 colony survey. U.S. Fish Wildl. Serv. Spec. Sci. Rep. Wildl. No. 206. 28 pp.

Custer, T. W., and R. G. Osborn. 1978. Feeding habitat use by colonially-breeding herons, egrets, and ibises in North Carolina. Auk 95:733-743.

Custer, T. W., R. G. Osborn, and W. F. Stout. 1980. Distribution, species abundance, and nesting-site use of Atlantic coast colonies of herons and their allies. Auk 97:591-600.

Dusi, J. L., and R. T. Dusi. 1968. Ecological factors contributing to nesting failure in a heron colony. Wilson Bull. 80:458-466.

Girard, G. T., and W. K. Taylor. 1979. Reproductive parameters for nine avian species at Moore Creek, Merritt Island National Wildlife Refuge, Florida. Fla. Sci. 42:94-102.

Hammatt, R. B. 1981. Reproductive biology in a Louisiana estuarine heronry. M.S. Thesis. Louisiana State University, Baton Rouge. 93 pp.

Henderson, E. G. 1981. Behavioral ecology of the searching behavior of the white ibis (Eudocimus albus). M.S. Thesis. University of South Carolina, Columbia. 71 pp.

Jenni, D. A. 1969. A study of the ecology of four species of herons during the breeding season at Lake Alice, Alachua County, Florida. Ecol. Monogr. 39:245-270.

Keller, C. K., J. A. Spendelow, and R. D. Greer. 1984. Atlas of wading birds and seabird nesting colonies in coastal Louisiana, Mississippi, and Alabama: 1983. U.S. Fish Wildl. Serv. FWS/OBS-84/13. 127 pp.

Kushlan, J. A. 1973. White ibis nesting in the Florida Everglades. Wilson Bull. 85:230-231.

Kushlan, J. A. 1976a. Site selection for nesting colonies by the American white ibis Eudocimus albus in Florida. Ibis 118:590-593.

Kushlan, J. A. 1976b. Wading bird predation in a seasonally fluctuating pond. Auk 93:464-476.

Kushlan, J. A. 1977a. Foraging behavior of the white ibis. Wilson Bull. 89:342-345.

Kushlan, J. A. 1977b. Population energetics of the American white ibis. Auk 94:114-122.

Kushlan, J. A. 1977c. Sexual dimorphism in the white ibis. Wilson Bull. 89:92-98.

Kushlan, J. A. 1977d. The significance of plumage colour in the formation of feeding aggregations of ciconiiforms. Ibis 119:361-364.

Kushlan, J. A. 1978. Feeding ecology of wading birds. Pages 249-297 in A. Sprunt IV, J. C. Ogden, and S. Winkler, eds. Wading birds. Natl. Audubon Soc. Res. Rep. No. 7.

Kushlan, J. A. 1979. Feeding ecology and prey selection in the white ibis. Condor 81:376-389.

Kushlan, J. A., and M. S. Kushlan. 1975. Food of the white ibis in southern Florida. Fla. Field Nat. 3:31-38.

Kushlan, J. A., and W. B. Robertson, Jr. 1977. White ibis nesting in the lower Florida Keys. Fla. Field Nat. 5:41-42.

Kushlan, J. A., and D. A. White. 1977. Nesting wading bird populations in southern Florida. Fla. Sci. 40:65-72.

Landin, M. C. 1978. National perspective of colonial waterbirds nesting on dredged material islands. Trans. North Am. Wildl. Nat. Resour. Conf. 43:89-99.

Lewis, J. C. 1983. Habitat suitability index models: roseate spoonbill. U.S. Fish Wildl. Serv. FWS/OBS-82/10.50. 16 pp.

Nesbitt, S. A., W. M. Hetrick, and L. E. Williams, Jr. 1974. Foods of white ibis from seven collection sites in Florida. Proc. Southeast. Assoc. Game Fish Comm. 28:517-532.

Nesbitt, S. A., J. C. Ogden, H. W. Kale III, B. W. Patty, and L. A. Rowse. 1982. Florida atlas of breeding sites for herons and their allies: 1976-78. U.S. Fish Wildl. Serv. FWS/OBS-81/49. 449 pp.

Ogden, J. C., H. W. Kale II, and S. A. Nesbitt. 1980. The influence of annual variation in rainfall and water levels on nesting by Florida populations of wading birds. Trans. Linn. Soc. N.Y. 9:115-126.

Palmer, R. S., ed. 1962. Handbook of North American birds. Vol. 1. Yale University Press, New Haven, Conn. 567 pp.

Rodgers, J. A., Jr., and S. A. Nesbitt. 1979. Feeding energetics of herons and ibises at breeding colonies. Proc. Colonial Waterbird Group 3:128-132.

Rudegeair, T. J., Jr. 1975. The reproductive behavior and ecology of the white ibis (Eudocimus albus). Ph.D. Thesis. University of Florida, Gainesville. 147 pp.

Schreiber, R. W., and E. A. Schreiber. 1978. Colonial bird use and plant succession on dredged material islands in Florida. Vol. 1: Sea and wading bird colonies. U.S. Army Engineer Waterways Exp. Stn., Vicksburg, Miss. Tech. Rep. D-78-14.

Teal, J. M. 1965. Nesting success of egrets and herons in Georgia. Wilson Bull. 77:257-263.

Tremblay, J., and L. N. Ellison. 1979. Effects of human disturbance on breeding of black-crowned night herons. Auk 96:364-369.

Texas Colonial Waterbird Society. 1982. An atlas and census of Texas waterbird colonies 1973-1980. Caesar Kleberg Wildlife Research Institute, Texas Agricultural and Industrial University, Kingsville. 358 pp.

U.S. Fish and Wildlife Service. 1980. Habitat evaluation procedures (HEP). ESM 102. Washington, D.C. n.p.

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16. Abstract (Limit: 200 words)

A review and synthesis of existing information were used to develop a model for evaluating White Ibis habitat quality. The model is scaled to produce an index of habitat suitability between 0 (unsuitable habitat) and 1.0 (optimal habitat) for Southern Atlantic and Gulf of Mexico coastal areas of the continental United States. 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 technique for measuring model variables are provided.

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