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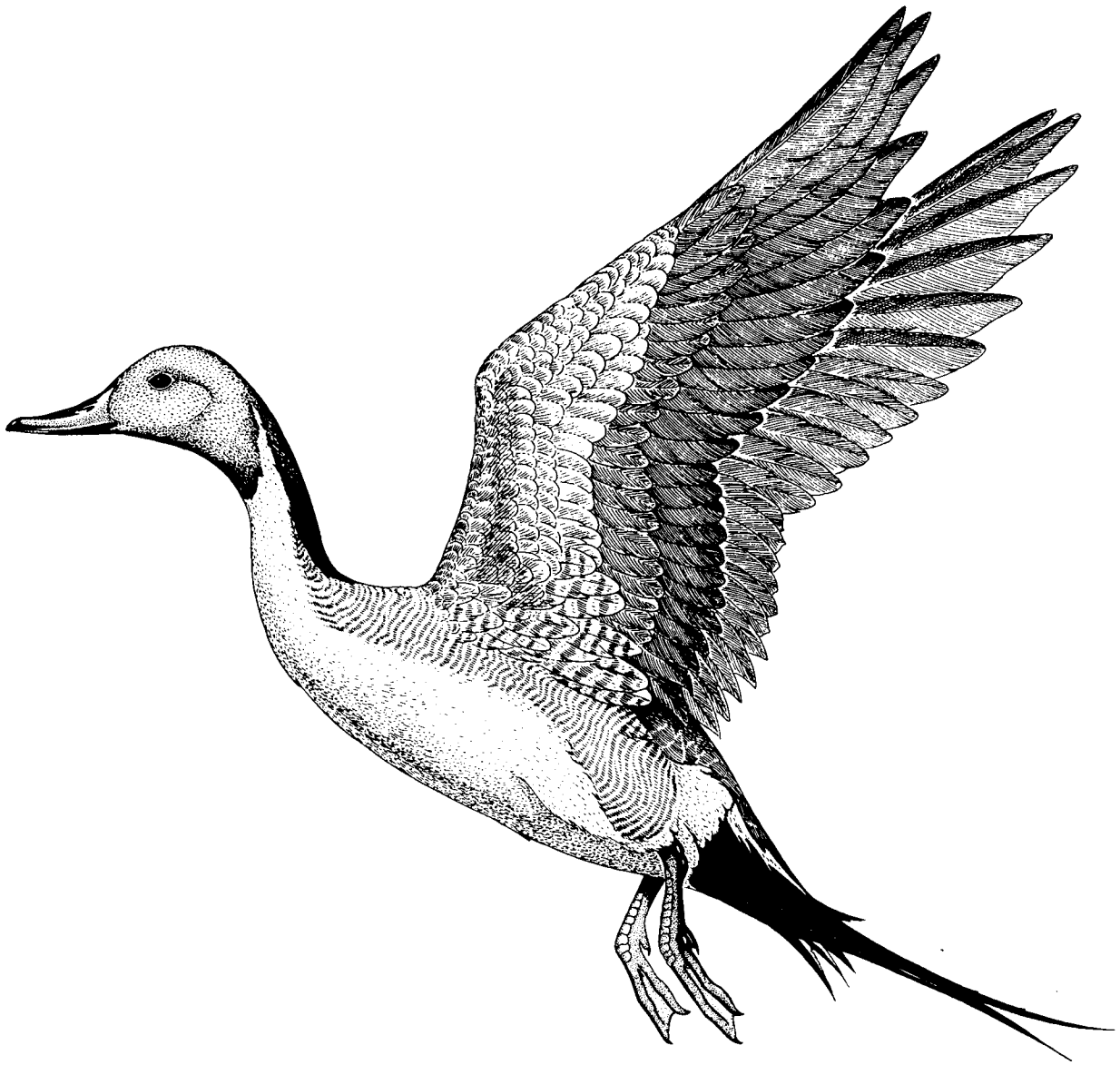
HABITAT SUITABILITY INDEX MODELS: NORTHERN PINTAIL (GULF COAST WINTERING)



Fish and Wildlife Service

U.S. Department of the Interior

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

MODEL EVALUATION FORM

Habitat models are designed for a wide variety of planning applications where habitat information is an important consideration in the decision process. It is impossible, however, to develop a model that performs equally well in all situations. Each model is published individually to facilitate updating and reprinting as new information becomes available. Assistance from users and researchers is an important part of the model improvement process. Please complete this form following application or review of the model. Feel free to include additional information that may be of use to either a model developer or model user. We also would appreciate information on model testing, modification, and application, as well as copies of modified models or test results. Please return this form to:

National Wetlands Research Center
U.S. Fish and Wildlife Service
1010 Gause Boulevard
Slidell, LA 70458

Thank you for your assistance.

Species_____ Geographic Location_____

Habitat or Cover Type(s)_____

Type of Application: Impact Analysis_____ Management Action Analysis _____
Baseline_____ Other_____

Variables Measured or Evaluated_____
_____
_____
_____

Was the species information useful and accurate? Yes_____ No____

If not, what corrections or improvements are needed?_____
_____
_____
_____

Were the variables and curves clearly defined and useful? Yes ____ No ____

If not, how were or could they be improved? _____

_____

_____

_____

Were the techniques suggested for collection of field data:

Appropriate? Yes ____ No ____

Clearly defined? Yes ____ No ____

Easily applied? Yes ____ No ____

If not, what other data collection techniques are needed? _____

_____

_____

_____

Were the model equations logical? Yes ____ No ____

Appropriate? Yes ____ No ____

How were or could they be improved? _____

_____

_____

_____

Other suggestions for modification or improvement (attach curves, equations, graphs, or other appropriate information) _____

_____

_____

_____

Additional references or information that should be included in the model:

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Model Evaluator or Reviewer _____ Date _____

Agency _____

Address _____

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_____

Telephone Number Comm: _____ FTS _____

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PREFACE

This document is part of the habitat suitability index (HSI) model series and is designed for use with the U.S. Fish and Wildlife Service's (1980) habitat evaluation procedures in impact assessment and habitat management activities. The model was developed from a review and synthesis of existing information. It is scaled to produce an index of habitat suitability between 0 (unsuitable habitat) and 1 (optimally suitable habitat). Model documentation and guidelines for model applications, including methods for measuring model variables, are provided.

Model documentation is provided for several reasons. First, it provides a means of explaining the model's structure and its inherent assumptions. Second, the model-building process involves considerable judgment on the part of the model builder, and documentation provides the insights necessary to modify the model when these judgments are inconsistent with local or new knowledge. Finally, the documentation should facilitate modification of the model to meet individual study constraints on time and human resources.

The model presented is a hypothesis of species-habitat relationships, not a statement of proven cause and effect. For this reason, users of the model are encouraged to suggest improvements that may increase the utility and effectiveness of this habitat-based approach to fish and wildlife management. Please send suggestions to the following address:

Information Transfer Specialist
National Wetlands Research Center
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1010 Gause Boulevard
Slidell, LA 70458.

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ACKNOWLEDGMENTS

The habitat suitability index model for wintering northern pintail was reviewed and constructively criticized by Robert Chabreck, Louisiana State University, Baton Rouge, and Stuart Paulus, Louisiana Department of Wildlife and Fisheries, Grand Chenier. Many other waterfowl biologists provided information used in the development of the model; their names are noted in the report. Personnel of the U.S. Fish and Wildlife Service's National Wetlands Research Center evaluated the model's structure and functional relationships. Other reviewers of the model were FWS Ecological Services personnel from the following offices: Clear Lake, Texas; Corpus Christi, Texas; Daphne, Alabama; and Lafayette, Louisiana. Model development and publication were funded by the FWS. Patrick J. Lynch illustrated the cover.

NORTHERN PINTAIL (Anas acuta)

INTRODUCTION

Populations and Seasonal Distribution

The northern pintail (Anas acuta), commonly called the pintail, is one of the three most abundant ducks in North America and is distributed over a greater proportion of the earth's surface than any other species of waterfowl (Bellrose 1976). Its North American breeding range covers most of the nonforested area northwest of a line from central California to Quebec.

From their principal breeding grounds in the prairie and parkland pothole region of south-central Canada and the north-central United States, pintails migrate to their wintering grounds along two major corridors. These corridors extend southwest to the Central Valley of California and south to the gulf coast and Mexico. About 2.1 million pintails wintered in the United States during 1985-86 (Gamble 1986). Percentages of this population found in the four administrative waterfowl flyways (discussed in Glover 1964) were 61%, Pacific; 16%, Central; 21%, Mississippi; and 2%, Atlantic. This report's habitat suitability model is based on descriptions of pintail wintering habitat found in the Central and Mississippi flyways.

The northern pintail is a highly mobile and opportunistic species. Authorities have attributed long- and short-term shifts in the areas and types of habitats used by pintails to both normal and catastrophic weather events; changes in regional agricultural practices; construction, destruction, or degradation of wetlands; hunting pressure; competition for food; and enhancement of food supplies by humans. Temporal aspects of habitat use are especially difficult to ascertain because influxes of southbound birds classed as "late winter arrivals" on the wintering grounds may be met by a vanguard of northbound "early migrants" (J. Lynch, Lafayette, Louisiana; pers. comm.).

Few detailed studies of pintail winter habitat requirements have been attempted on the Gulf of Mexico coast because of unpredictable population movements and behavior and the ill-defined patterns of habitat use on the wintering grounds (J. Teer, Welder Wildlife Foundation, Sinton, Texas; pers. comm.)

Major Wintering Areas

Wintering northern pintail use three major areas in the U.S. Gulf of Mexico coastal region and an additional three areas in inland Texas and Louisiana. Brief descriptions of these six wintering areas follow.

Lagoon-Brushland Pasture Zone. This zone is located along the Gulf of Mexico from Matagorda Bay, Texas, to the Mexican border and beyond. Shallow mixohaline to hyperhaline lagoons (defined as estuarine wetland in Cowardin et al. 1979) are bordered by brushy pastureland containing many shallow wetlands (Heit 1948; Buller 1964; Saunders and Saunders 1981). The lagoons are almost devoid of emergent vegetation.

In years with average or above average rainfall, pintails in this zone spend much of their time on the shallow inland wetlands. In the United States, the inland wetlands of this zone (mostly palustrine and lacustrine wetlands as defined by Cowardin et al. 1979) may be found within 60 km of the coastline (W. Kiel, Kingsville, Texas; pers. comm.). Pintails primarily use those wetlands within about 16 km of the coast (C. Stutzenbaker, Texas Parks and Wildlife Department, Beaumont, Texas; pers. comm.), possibly because of the area's greater wetland density (W. Kiel, pers. comm.). The inland wetlands are mostly fresh to brackish and provide an abundant variety of both plant and animal foods (Buller 1964; Koenig 1969; White and James 1978; Saunders and Saunders 1981; W. Kiel, pers. comm.; C. Stutzenbaker, pers. comm.; G. Unland, Alamo, Texas, pers. comm.). Most of the inland wetlands become dry about 1 year out of 3, causing the pintails to spend nearly all of their time on the lagoons and bays (W. Kiel, pers. comm.).

Chenier Plain Zone. This zone in southwestern Louisiana and adjacent Texas consists of brackish-to-fresh coastal wetlands adjacent to low-lying agricultural land and pasture that in pristine times were tallgrass prairie (Chabreck 1972). The climate is subtropical, and the area receives more than 125 cm of rainfall per year. Aerial inventories of waterfowl made each January from 1977 to 1982 showed that more than 70% of Texas pintails were found in this area (Texas Parks and Wildlife Department files).

During winters with above average rainfall, which occur about once every 2 years in the Chenier Plain (R. Chabreck, Louisiana State University, Baton Rouge; pers. comm.), pintails have a strong affinity for the flooded rice fields, soybean fields, and pastures. Although pintails use dry rice fields, it is estimated that 1 acre of flooded rice field is as valuable to the pintail for habitat as 100 acres of dry rice field (C. Stutzenbaker, pers. comm.). Pintails usually shift from the rice and soybean areas back to the coastal marshes in February, after the hunting seasons are over and the fields are drained and prepared for the next crop (R. Chabreck, pers. comm.).

Use of coastal wetlands by dabbling ducks has been documented for the Chenier and Deltaic Plains by Palmisano (1972), based on data gathered by H. Bateman and N. Summerell of the Louisiana Department of Wildlife and Fisheries. Ratios of use versus wetland availability, based on Palmisano's (1972) data for the Chenier Plain, reveal that wetlands of intermediate salinity were most heavily used (ratio of percentage of ducks observed to percentage of intermediate wetland in sample = 2.2). Use ratios for fresh and brackish wetland were 1.7 and 1.4, respectively. Although saline wetlands are uncommon in the Chenier Plain, they are used by pintails (S. Paulus, Louisiana Department of Wildlife and Fisheries, Grand Chenier; pers. comm.). Pintails avoid very large, deep wetlands because they are subject to excessive wind and wave action (C. Smith, Ducks Unlimited; pers. comm.). Large, deep wetlands also often have

limited food supplies and provide poor loafing habitat (S. Paulus, pers. comm.).

Atchafalaya Delta Zone. This zone in the Deltaic Plain of southeastern Louisiana contains about 30,000 ha of open, shallow wetlands and mudflats that recently have become a wintering area for more than 100,000 pintails (R. Chabreck, pers. comm.). If the pintail can be assumed to be a typical dabbling duck, the calculation of simple ratios of use to availability, based on Palmisano's (1972) figures for the Deltaic Plain, reveals that fresh marshes were most heavily used (ratio of percentage of ducks observed to percentage of fresh marshes in sample = 2.1). Use ratios for intermediate, brackish, and saline wetlands were 1.0, 0.6, and 0.2, respectively.

Playa Lake-Irrigated Corn Zone. Some 25,000 playas in a 52-county area of the Southern Great Plains annually collect 2.5 to 3.7 km^3 of water (Templer 1978; Guthery et al. 1981). Most of these playas are in a 44-county area in the Texas Panhandle; about half are less than 4 ha each (Guthery et al. 1981).

This zone is the only major pintail wintering area where the birds forage on dry ground. Recent January surveys (1978-82) indicated that an average of 14% of Texas pintails wintered in this zone (Texas Parks and Wildlife Department files); an estimated 635,000 pintails have been recorded in selected areas (Simpson et al. 1981).

This zone averages about 1 unit area of wetland for every 10 unit areas of corn (E. Bolen, Texas Technical University, Lubbock; pers. comm.). Although the natural playas are dry about 3 years in 5, pintail use of the zone does not diminish because many playas have been modified to receive irrigation tailwater or have been deepened to serve as livestock ponds (E. Bolen, pers. comm.). The larger (>5 ha) playas are preferred by pintails; those smaller than about 0.5 ha receive little use.

Catahoula Lake-Rice and Soybean Zone. This wintering area in central Louisiana supports up to a quarter million pintails (C. Smith, pers. comm.). Prior to the installation of water-control structures in 1973, the use of Catahoula Lake by waterfowl varied greatly each year, depending on precipitation patterns and seasonal river stages (Wycoff et al. 1971). Today with water-level control, the lake consistently attracts large numbers of wintering pintails.

The 100-km^2 lake is managed to create concentric zones of annual emergent plants that are valuable waterfowl foods. The lake is drained in July, except for a deep 20-km^2 central pool, to allow grasses and sedges to grow. In fall the water level is raised to a depth of about 0.6 m to allow waterfowl access to the food source. Emergent plants cover about 60% of the water surface when the birds arrive. Frost, wave action, and extensive use by birds and hunters break down the stands of vegetation, and by the end of the hunting season the lake is mostly open water. As hunting increases and water levels are raised, pintails make extensive use of flooded rice, sorghum, and soybean fields within 30 km of the lake (J. Emphinger, Louisiana Department of Wildlife and Fisheries; pers. comm.).

Upper Boeuf River-Bayou Macon Alluvial Plains Zone. This zone is in extreme northeastern Louisiana, west-central Mississippi, and extreme southeastern Arkansas. It has rapidly become a major waterfowl wintering area and may support more than 100,000 pintails annually (R. Chabreck, pers. comm.; R. Yancey, Williams Inc., pers. comm.).

This area is mostly devoted to soybean production and, to a lesser degree, rice and cotton. Wet soybean fields are the principal pintail habitat in this zone. Almost the entire area is former bottomland forest; consequently, it is subject to flooding from overflowing rivers. Many of the zone's major soils have poor internal drainage and lie in areas that contain natural shallow depressions. Undrained or unimproved fields in these soils hold water for long periods after heavy winter rains (R. Yancey, pers. comm.).

In summary, the pintail's six major wintering areas are widely spaced and differ greatly in geology, hydrology, and land use. However, three common characteristics are evident: (1) at least some of the wetland units are large, (2) heavily used water areas are shallow, and (3) vegetative cover on all heavily used habitats is open to sparse.

SPECIFIC HABITAT REQUIREMENTS

Food and Foraging Habitat

Wintering pintails consume a wide array of plant foods in different wintering areas and some animal foods. Examples of pintail food items include 18 plant species representative of 10 families found by Wills (1971) in pintails from Catahoula Lake, Louisiana; shoalgrass (Halodule wrightii), widgeongrass (Ruppia maritima), and a variety of pelecypods, gastropods, decapods, and fish fragments found in birds from Laguna Madre, Texas, by Koenig (1969) and McMahan (1969); 25 plant species representative of seven families found in southern Louisiana pintails by Glasgow and Bardwell (1962); and 40 plant species representative of 14 families found in pintails collected in the Texas Panhandle (Moore 1980). Agricultural crops--principally rice, soybeans, sorghum (milo), corn, and wheat--are eaten extensively by pintails in many wintering areas. Rice and corn are preferred, followed by soybeans, sorghum, and wheat (E. Bolen, pers. comm.; R. Chabreck, pers. comm.).

In the Laguna Madre, Texas, McMahan (1969) found that portions of lagoons containing water less than 25 cm deep and supporting beds of shoalgrass and widgeongrass were principal feeding areas; these two species composed 92% of the pintails' diet. In general, pintails preferred open wetlands with submerged or short emergent vegetation. Although optimal water depth for both feeding and resting is less than 25 cm, food plants such as Chara spp. and widgeongrass often grow in water as deep as 1.25 m. In these situations, pintails will eat the tops of the plants down to about 25 cm below the water surface before abandoning the area (G. Unland, pers. comm.).

In the Chenier Plain during dry falls, newly arrived pintails feed on turtlegrass (Thalassia testudinum) and widgeongrass, found mostly in brackish coastal waters (Chabreck 1971; C. Stutzenbaker, pers. comm.). They move to

fresh marshes later in the season if stands of annual food plants that have developed during a dry summer become flooded by fall or winter rains. Winter rains normally result in a large influx of pintails inland, where rice fields are the favored habitat, followed by soybean fields, fallow rice fields, native pasture, and planted pasture. Improved and unimproved fields attract pintails equally if their water levels are similar (R. Chabreck, pers. comm.). If disturbance is great, pintails feed in the agricultural districts at night and return to the open, shallow marshes along the coast to preen and rest during the day (Tamisier 1976). If disturbance is slight, pintails will linger several weeks as far as 120 km inland (W. Hobaugh, Texas A&M University, College Station, pers. comm.; C. Smith, pers. comm.). Flights up to 80 km from the coastal marshes to the rice fields are common (R. Chabreck, pers. comm.).

In the Atchafalaya Delta Zone, principal pintail foods include Sagittaria spp., Najas spp., Potamogeton spp., and annual grasses (R. Chabreck, pers. comm.). Agricultural land in this zone is mostly devoted to sugarcane and is of little or no value to pintails.

Waste corn from irrigated fields is the principal food of wintering pintails in the Playa Lake-Irrigated Corn Zone (Moore 1980). Heavily used fields are usually within 5 km of the playas occupied by pintails, but pintails have been observed to fly as far as 15 km from the playas (E. Bolen, pers. comm.). Pintails feed twice daily; the morning meal is usually consumed during the half hour before sunrise and the evening meal begins about a half hour after sunset and lasts about 40 min. Supplementary foods are plants of the genera Potamogeton, Ruppia, Najas, Scirpus, Echinochloa, and Polygonum, and the abundant animals of the playas.

In Catahoula Lake, pintails feed on the seeds or tubers of chufa flat-sedge (Cyperus esculentus), spikerushes (Eleocharis spp.), coast barnyardgrass (Echinochloa walteri), and bearded sprangletop (Leptochloa fascicularis) (Wills 1971; C. Smith, pers. comm.). The deep central pool produces aquatic food plants, including roundleaf waterhyssop (Bacopa rotundifolia), longleaf mud plantain (Heteranthera limosa), arrowheads (Sagittaria spp.), and dwarf spikerush (Eleocharis parvula). When water levels rise in the lake, pintails feed on domestic rice, sorghum, and soybeans. Agricultural crops are the major food of pintails wintering in the Upper Boeuf River-Bayou Macon Alluvial Plains Zone.

No literature references indicated that food is a limiting factor for the pintail on its wintering grounds. In the southern Louisiana coastal wetlands studied by Chabreck (1971), most of the vegetation was composed of species rated as fair to excellent as waterfowl foods by Martin and Uhler (1951). In areas where waste agricultural crops are extensively used by pintail, there is usually far more food available than birds to consume it (J. Emphinger, pers. comm.). In the Texas Panhandle, pintails can fill their gullets with waste corn in only 25 to 40 min (E. Bolen, pers. comm.). No authorities familiar with current conditions considered food abundance and availability a problem for pintails in the Laguna Madre area of Texas. Indeed, the amount of food available to wintering pintails is continually increasing because of forest clearing and wetland drainage for rice and soybean culture and because of the encroachment of irrigated agriculture in areas formerly devoted to grazing.

Water

Although obviously a critical life requisite, dietary water can be supplied by flooded cropfields or almost any type of wetland. Pintails seem to have little problem finding dietary freshwater in the Lagoon-Brushland Pasture Zone of Texas, even during drought, because some brackish or freshwater wetlands are always present (W. Kiel, pers. comm.). Other postulated sources include morning dew accumulations on the birds themselves, the cellular water in foods, and precipitation that may accumulate on the surface of hyperhaline water before slowly mixing with it (J. Lynch, pers. comm.). In any event, pintails do not fly daily or twice-daily to freshwater as do redheads (Aythya americana) wintering on coastal lagoons in this area (W. Kiel, pers. comm.; J. Lynch, pers. comm.).

Cover

Throughout the wintering grounds, pintails favor open shallow water for resting and preening; in many instances this condition occurs on the same areas used for feeding (J. Emphinger, W. Kiel, C. Smith, R. Yancey; pers. comm.). In coastal Texas, use of wetlands by pintails was high if relatively tall emergent growth covered less than 20% of the surface; ponds with greater than 60% coverage by tall emergent growth were used little (White and James 1978; G. Unland, pers. comm.). "Feather edge" shorelines where water depths range from 0 to 0.5 m are considered optimal because they usually furnish a large variety of foods as well as ideal resting and preening areas (Tamisier 1976; R. Chabreck, pers. comm.). On the Rockefeller Refuge in southwestern Louisiana pintails use tidal mudflats for loafing during the day (S. Paulus, pers. comm.).

Although pintails are easily frightened by hunting, boating, fishing, and other human activities, disturbance does not limit the number of pintails that use the major wintering areas (E. Bolen, R. Chabreck, W. Kiel, C. Smith, G. Unland; pers. comm.). In heavily hunted areas, the birds orient themselves in space and time to avoid gunfire. Thousands of pintails can often be seen quietly resting near hunters' blinds, about 300 m or more beyond gun range (J. Lynch, pers. comm.). In addition, the birds quickly learn to restrict their feeding to periods during the day when hunting is not allowed. Other factors that mitigate disturbance in various wintering zones are large landholdings, restricted access, large bodies of open water, and the numerous wildlife refuges in the U.S. portion of the wintering grounds.

Special Considerations

The availability of food, whether in wetlands or agricultural lands, is largely determined by weather. Heavy summer rains result in poor germination of annual food plants in natural marshes. However, a dry summer followed by late fall or winter rains and frost makes tremendous numbers of these plants available to pintails (R. Chabreck, pers. comm.). Wind direction can affect tidal height, and several days of northerly winds attract large numbers of birds to exposed stands of submerged aquatic plants in the shallow bays and lagoons (W. Kiel, pers. comm.). Southerly winds, however, will cause the birds to move shoreward to coastal marshes, inland wetlands, or agricultural land.

Weather is also an important factor governing use of the inland rice and soybean fields. They are most attractive to pintails when shallowly flooded; the water to flood the fields may come from direct precipitation or from artificial reservoirs whose water supply is also largely rainfall-dependent. The birds shift from one area to another in response to changing water levels, increasing their vulnerability to hunters (R. Chabreck, pers. comm.). The ability of the fields to hold standing water depends largely on soil type. Precipitation also determines the number of natural inland wetlands that contain water each year.

Food availability is influenced by the distance the birds must fly to reach their feeding grounds. This distance is sometimes zero in the case of high quality natural wetlands, but may be up to 120 km in the case of choice flooded agricultural fields. (C. Smith, pers. comm.).

Cover needs for pintail may differ between day and night. Pintails have been noted to use denser cover at night than is typically used during the day in areas where food is abundant (S. Paulus, pers. comm.).

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area and cover types. The habitat suitability index model for northern pintails was developed for use in wetlands along the Gulf of Mexico coast in Texas and Louisiana. It can also be applied to the major inland wintering areas of Texas and Louisiana described in this report. Cover types where the model can be applied include lacustrine, palustrine, and estuarine wetlands as defined by Cowardin et al. (1979). Only those wetlands or deepwater areas with water less than 3 m deep should be considered as potential habitat for wintering northern pintails. Because pintails are associated with relatively large water areas, it is recommended that the model be applied to areas that exceed 4 ha. The model is not intended for evaluating the suitability of agricultural lands as pintail habitat. The model was designed to evaluate wintering habitat, so it should be applied from October through February.

Verification level. The following waterfowl biologists reviewed the model: Robert Chabreck, Louisiana State University, Baton Rouge, and Stuart Paulus, Louisiana Department of Wildlife and Fisheries, Grand Chenier. Their comments were incorporated when possible, but the authors are responsible for the final version of the model. The model has not been field-tested.

Model Description

Overview. The model has five habitat variables affecting two life requisites: cover and food. The cover component considers the value of a site for resting and preening birds. Both life-requisite components may be provided by a single location, but this situation is not required for application of the model. The relationships between habitat variables, components, and the HSI value are illustrated in Figure 1. Open water is defined for this model as water with less than 10% canopy coverage by emergent vegetation.

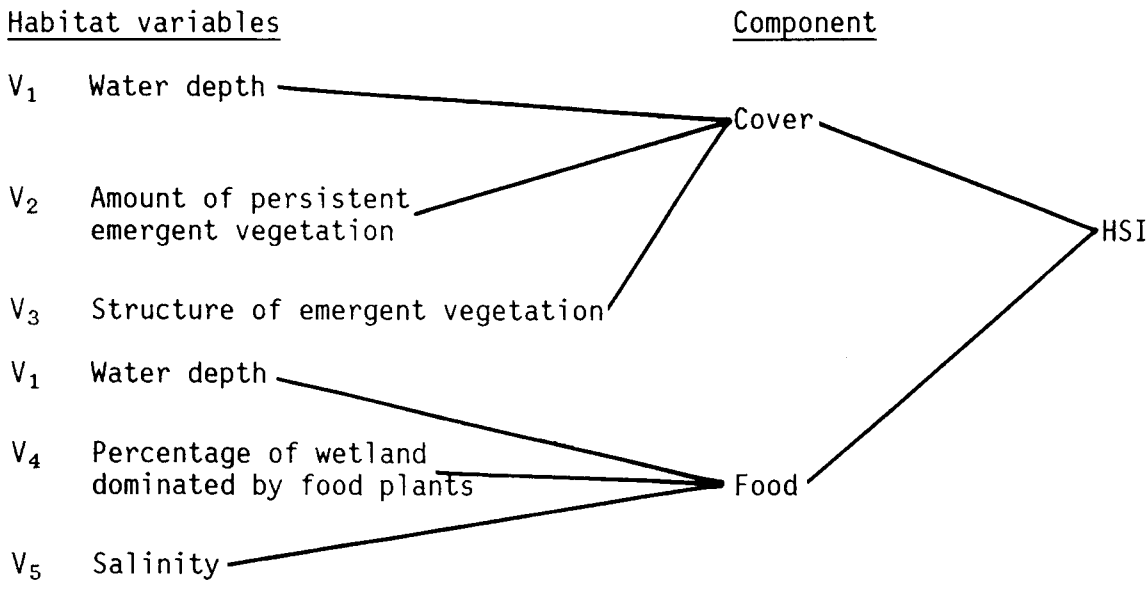


Figure 1. Relationship of habitat variables and life requisites to the Habitat Suitability Index (HSI) value for wintering habitat of northern pintails.

Cover component. The suitability of habitat for resting or preening pintails is assumed to be influenced by water depth and the amount and structure of emergent vegetation. Optimal depth conditions are represented in the model as an area where 50% or more of the open water is less than 0.5 m deep (V_1). Because pintails prefer open shallow waters and mudflats when resting, persistent emergent vegetation is assumed to decrease habitat suitability; optimal habitat, then, is an area with less than 30% coverage by persistent emergent vegetation (V_2). If persistent emergent vegetation is present, suitability of the habitat as cover for pintails decreases as the percentage of the vegetation that is taller than 30 cm and has greater than 40% canopy cover increases above 5% (V_3).

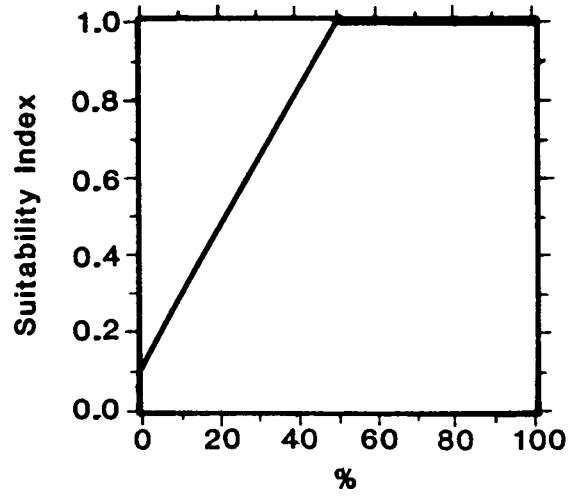
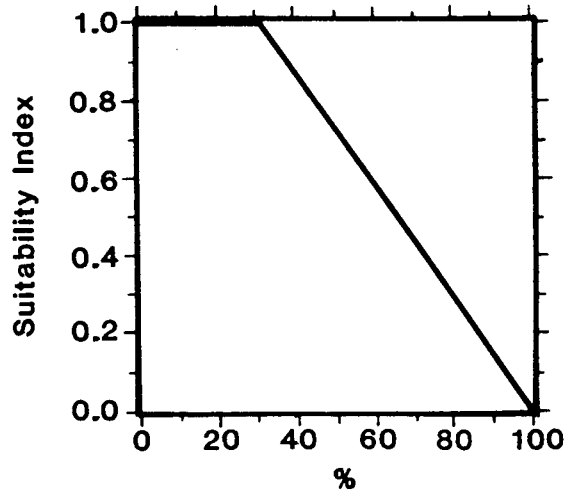
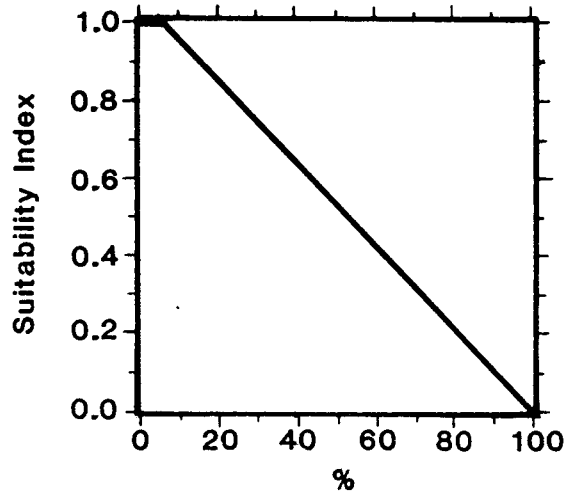
Food component. The HSI model assumes that the quality of pintail feeding habitat is determined by three variables: depth of open water, the percentage of wetland covered by food plants, and salinity. Because pintails feed in shallow water, the percentage of open water less than 0.5 m deep (V_1), influences the suitability of a site for feeding as well as resting. Optimal feeding habitat has 50% or more of the wetland dominated by submerged or emergent plants (or both) used as food by pintail (V_4). Salinity also influences the quality of pintail feeding habitat along the gulf coast. Except in areas southwest of Corpus Christi, Texas, that are dominated by shoalgrass or widgeongrass, pintails prefer vegetation that grows in freshwater to intermediate-salinity wetlands over vegetation of higher salinity wetlands. Habitat suitability is assumed to decrease as salinity increases above 5 parts per thousand (ppt); salinity levels greater than 20 ppt have a low suitability index of 0.2 (V_5).

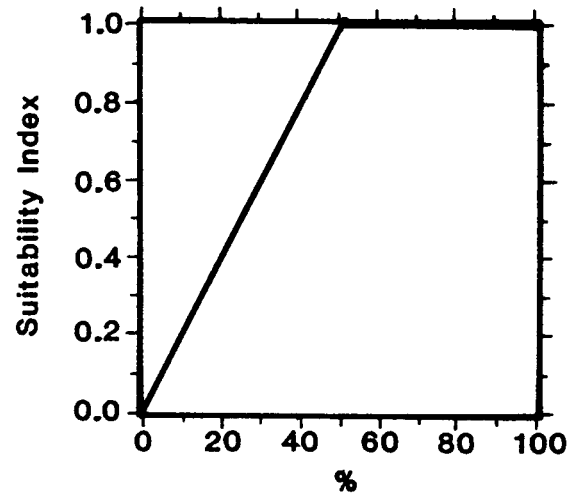
Suitability Index (SI) Graphs for Model Variables

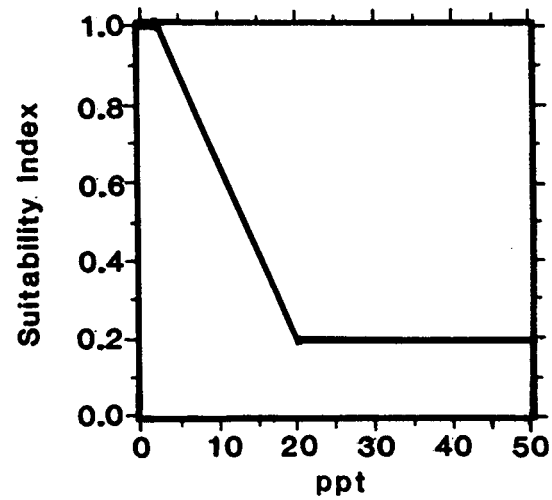
The relationships between the value of habitat variables and the quality of palustrine (P), lacustrine (L), and estuarine (E) coastal habitats for wintering northern pintails are demonstrated in the following graphs. Only areas with water less than 3 m deep should be considered pintail habitat. An SI value of 1.0 indicates optimal conditions, while a value of 0 indicates unsuitable conditions. Sources of the variables included in the model and assumptions involved in developing SI graphs are summarized in Table 1.

Table 1. Variable sources and assumptions for northern pintail suitability indices.

Variable and source		Assumptions
V_1	W. Kiel, pers. comm. G. Unland, pers. comm.	Areas where wintering pintails rest and feed are usually large, open, and <0.5 m deep.
$V_{2,3}$	White and James 1978 G. Unland, pers. comm.	Pintails rest in open portions of wetlands where dense stands of tall (>30 cm above the water surface) emergents have less than 40% canopy cover.
V_4	Harmon et al. 1960 Glasgow and Bardwell 1962 Buller 1964 Koenig 1969 McMahan 1969 Wills 1971 White and James 1978 Moore 1980 Saunders and Saunders 1981 R. Chabreck, pers. comm. J. Emphinger, pers. comm. W. Kiel, pers. comm. C. Smith, pers. comm. C. Stutzenbaker, pers. comm. G. Unland, pers. comm. R. Yancey, pers. comm.	Feeding areas are large, generally <0.5 m deep, and contain submerged or emergent and drawdown plants (mostly annuals) that produce an abundance of seeds.
V_5	McMahan 1969 Palmisano 1972 R. Chabreck, pers. comm. W. Kiel, pers. comm. J. Lynch, pers. comm. C. Stutzenbaker, pers. comm.	In coastal wetlands lacking extensive beds of Halodule wrightii or Ruppia maritima, pintails prefer freshwater areas. No such preference is shown by pintails wintering along the gulf coast southwest of Corpus Christi, Texas, where the birds often spend all their time on hyperhaline lagoons.

Habitat	Variable		Suitability graph
P,L,E	V_1	Percentage of open water (<10% canopy coverage of emergent vegetation) that is less than 0.5 m deep.	
P,L,E	V_2	Percentage of area that is covered by persistent emergent vegetation (≥10% canopy cover).	
P,L,E	V_3	Percentage of emergent vegetation that exceeds 30 cm in height above the water surface and has greater than 40% canopy cover. (Note: This variable can be included in the model only if some emergent vegetation is present).	

Habitat	Variable		Suitability graph
P,L,E	V_4	Percentage of study area dominated by (>50% canopy coverage) submerged or emergent food plants. (See discussion in Food and Foraging Habitat section for description of food plants.)	

E	V_5	Mean salinity during the growing season.	

HSI Determination

The following equations are suggested for determining values of the cover and food component indices for a potential wintering area of northern pintail and for determining the overall HSI value for the site.

Component	Habitat	Equation
Cover (C)	P,L,E	$\left[SI_{V_1} \times \left(\frac{SI_{V_2} + SI_{V_3}}{2}\right)\right]^{1/2}$
		or
		SI_{V_1} if $V_2 = 0$
Food (F)	P,L,E $\leq$ 5 ppt	$(SI_{V_1} \times SI_{V_4})^{1/2}$
	E > 5 ppt	$(SI_{V_1} \times SI_{V_4} \times SI_{V_5})^{1/3}$
	HSI = C or F, whichever is lower.	

Within components, the variables are assumed to interact in a compensatory manner so that a high SI value for one can help offset a low SI value for other variables. The relationship between components is limiting (i.e., the lower component index determines the overall habitat value). Examples of model output using hypothetical data sets appear in Table 2.

Table 2. Calculation of suitability indices (SI), component indices (CI) and habitat suitability indices (HSI) for the three sample study areas using habitat variable (V) measurements and northern pintail HSI model equations.

Model component	Study area 1 (P)		Study area 2 (E)		Study area 3 (E)	
	Data	SI	Data	SI	Data	SI
V_1	80%	1.00	20%	0.46	65%	1.00
V^2	0%	--	30%	1.00	50%	0.71
V^3	--	--	50%	0.54	100%	0
V^4	65%	1.00	30%	0.60	20%	0.40
V^5	--	--	15 ppt	0.43	20 ppt	0.20
C	1.00		0.59		0.60	
F	1.00		0.49		0.43	
HSI	1.00		0.49		0.43	

Field Use of the Model

It may not be appropriate to apply the HSI model as it is structured in some situations. As previously noted, two distinct patterns of habitat use by wintering northern pintails are found along the gulf coast. Wetlands may be used primarily as resting areas by birds that regularly feed in flooded croplands up to 80 km inland, or they may be used as both feeding and resting areas. If the former situation is likely to occur, the HSI value for the study area should be equal to the cover component value. Although the wetland may have some value as feeding habitat, it is not used as such by the birds, and low feeding value in these cases should therefore not limit the habitat value.

A second problem with applying the complete model will be encountered in some wetlands in southwestern Texas along the Laguna Madre. In this region, the negative effects of high salinity on feeding habitat suitability are offset by the presence of the highly favored shoalgrass and widgeongrass. The mean salinity during the growing season (V_5) should be dropped from the HSI model when it is applied in these hyperhaline lagoons.

It is not appropriate to use this model when water quality has been degraded. The reduction in available habitat caused by environmental contaminants will interfere with proper interpretation of model results.

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

Visual estimates of water depths, areas of persistent emergent vegetation, and salinity levels (as judged by plant species composition) will greatly reduce the field hours necessary to compute the HSI. These are best estimated by inspection supplemented with aerial photographs. Investigators should be especially cautious when estimating water depth. Deep water is not necessarily indicated by the absence of emergent vegetation because high turbidity, currents, and saline water can also account for the absence. Suggested field measurement techniques are given in Table 3. Measurements in tidal areas should be taken at mean low tide.

Interpreting Model Outputs

A pintail HSI, determined by field application of this model, may not reflect the population density of pintails in the study area because other factors may have significant influence in determining species abundance. The model should, however, yield HSI values that have positive correlations with long-term abundance. This correlation has not been tested. The proper interpretation of the HSI is one of comparison. If different areas have different HSI's, then the area with a higher HSI should be capable of supporting more pintails than the area with a lower HSI.

Table 3. Suggested methods for field measurement of variables used in the pintail HSI model.

Variable	Methods
V_1	Field reconnaissance during winter; available depth contour maps superimposed on current aerial photographs.
V_2, V_3, V_4	Field reconnaissance during winter; interviews with area game managers familiar with pintail feeding patterns and cycles of annual drawdown/reflooding hydrology.
V_5	Field reconnaissance with personnel knowledgeable of the effects of salinity on wetland plant communities; regional maps of salinity isopleths.

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A review and synthesis of existing information were used to develop a model for evaluating wintering habitat quality for northern pintail (Anas acuta) along the Gulf of Mexico coast. 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 variables are provided.

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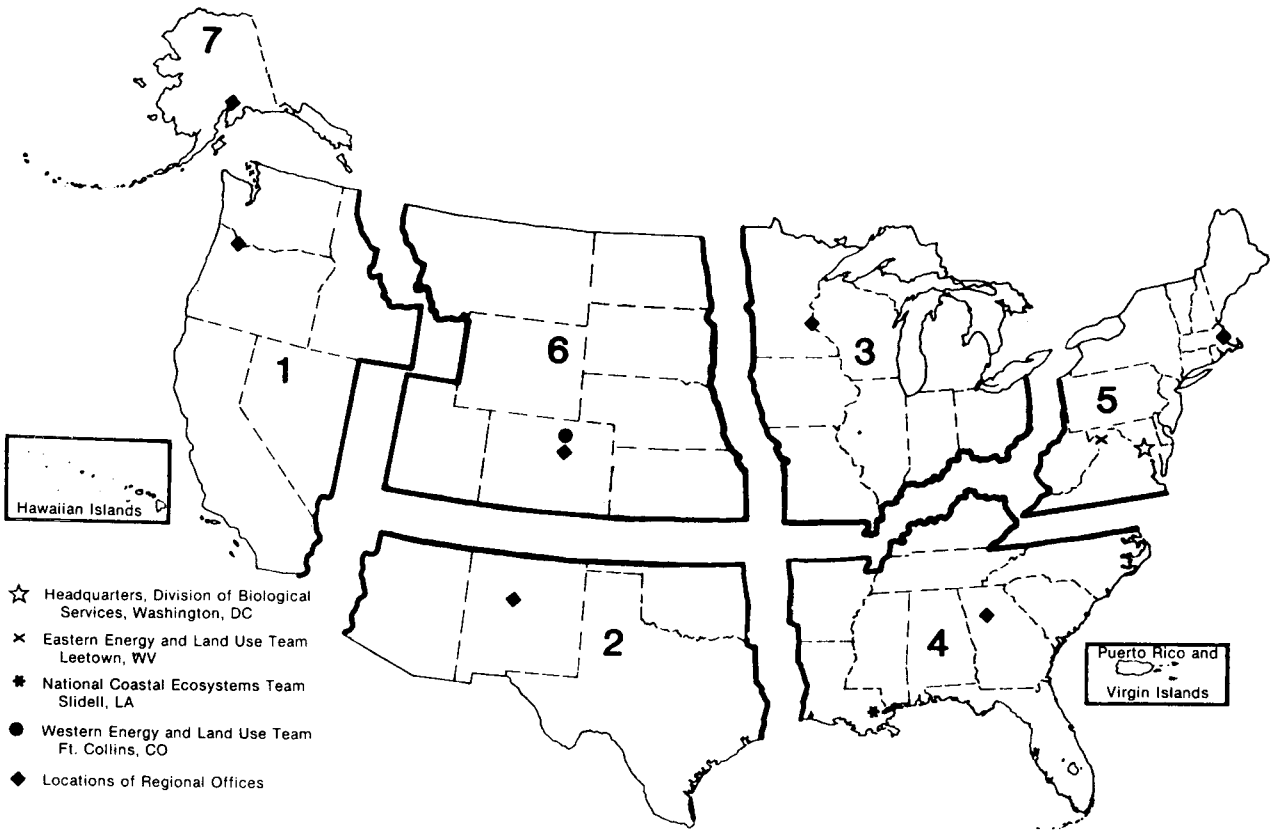

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