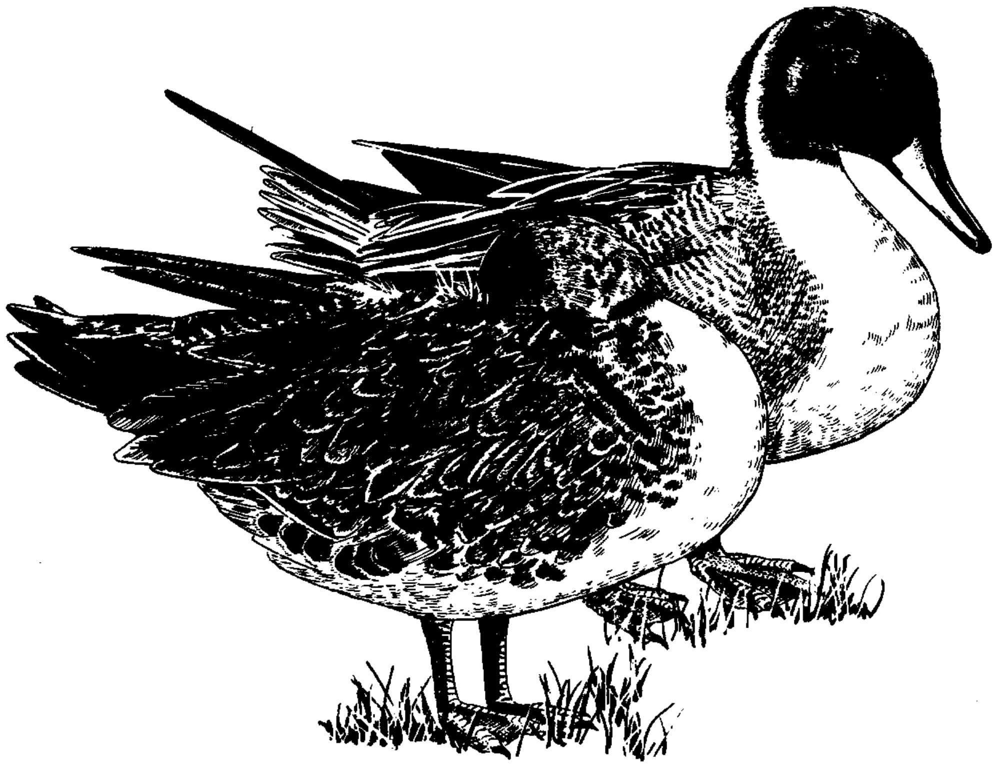
BIOLOGICAL REPORT 82(10.145)
SEPTEMBER 1987

HABITAT SUITABILITY INDEX MODELS: NORTHERN PINTAIL



Fish and Wildlife Service

S. Department of the Interior

Biological Report 82(10.145)
September 1987

HABITAT SUITABILITY INDEX MODELS: NORTHERN PINTAIL

by

Willie J. Suchy
and
Stanley H. Anderson
Wyoming Cooperative Fishery and
Wildlife Research Unit
University of Wyoming
Laramie, WY 82071

U.S. Department of the Interior
Fish and Wildlife Service
Research and Development
Washington, DC 20240

Suggested citation:

Suchy, W.J., and S.H. Anderson. 1987. Habitat suitability index models: northern pintail. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.145). 23 pp.

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is a formalized synthesis of biological and habitat information published in the scientific literature and may include unpublished information reflecting the opinions of identified experts.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 suitability 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:

Resource Evaluation and Modeling Section
National Ecology Center
U.S. Fish and Wildlife Service
2627 Redwing Road
Ft. Collins, CO 80526-2899

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FIGURES

ACKNOWLEDGMENTS

This model closely parallels the conceptual framework of two earlier habitat models developed for the gadwall (*Anas strepera*) (Sousa 1985a) and blue-winged teal (*A. discors*) (Sousa 1985b). Those models were developed in a workshop by a group of individuals familiar with the reproductive requirements of waterfowl nesting in the Prairie Pothole Region of the United States and Canada. While not directly involved in the development of this model for the pintail (*A. acuta*), we feel that the contribution of these individuals to modeling the habitat requirements of nesting dabbling ducks is significant enough to warrant acknowledgment here.

The gadwall and blue-winged teal habitat models were developed in a workshop that included the following waterfowl biologists of the Northern Prairie Wildlife Research Center, Jamestown, ND: Leo Kirsch (retired), John Lokemoen, and George Swanson. These individuals contributed freely of their experience so that the most reasonable models possible could be developed with the current knowledge of waterfowl habitat requirements. L. Kirsch and J. Lokemoen also reviewed the models resulting from the workshop. L. Kirsch graciously provided unpublished data that formed the basis for the nesting component portion of the models.

In addition to the waterfowl authorities, the following potential users of the models participated in the workshop and/or model review: Michael McEnroe and Steven Young (U.S. Fish and Wildlife Service, Bismarck, ND); Richard McCabe and Robert Schultz (U.S. Bureau of Reclamation, Bismarck, ND); and Fred Ryckman and Terry Steinwand (North Dakota Department of Game and Fish, Bismarck, ND). The inputs of all these individuals contributed to the content of the models.

The pintail model was reviewed by Gary Krapu, Michael Miller, and Patrick Sousa. The document was illustrated by Jennifer Shoemaker. Word processing was provided by Dora Ibarra, Carolyn Gulzow, and Elizabeth Graf. Funding for the development of the model was provided to the Wyoming Cooperative Research Unit by the U.S. Fish and Wildlife Service and the Army Corps of Engineers.

NORTHERN PINTAIL (Anas acuta)

HABITAT USE INFORMATION

General

A single race of the northern pintail (Anas acuta) inhabits the northern hemisphere, with breeding populations existing from the Arctic south to the marshes around the Great Salt Lake (Bellrose 1976). It is the most abundant duck breeding in the Arctic, and densities are comparable to mallard (Anas platyrhynchos) densities in the mixed-grass and shortgrass prairie (Bellrose 1976). Pintails are less abundant than mallards in the parklands, boreal forest, and subarctic deltas. Nesting populations also occur in California, Kansas, New Mexico, and Texas (Bellrose 1976). Although nesting pintails prefer the open grasslands, many overfly the prairies and nest in the north. Smith (1970) notes that this number increases in drought years and total production decreases. Bellrose (1979) regressed pintail densities on pond densities and found that pintail densities increased at a higher rate in the shortgrass and mixed-grass prairie associations than in parklands or tallgrass prairies.

Food

The pintail eats a variety of plants and animals depending on availability (Swanson et al. 1979). Animal foods are of particular importance to hens during prelaying and laying periods, when they compose 56% and 77% of the diet, respectively (Krapu 1974b). Comparatively, the diet of postlaying and nonlaying hens consists of 28.9% and 4.6% animal foods. Drake pintails eat significantly less animal matter than do hens during these periods of the annual cycle (Krapu 1974a). Animal foods consist of dipterans (primarily larva), snails (Gastropoda), fairy shrimp (Anostraca), and earthworms (Oligochaeta). Hens eating a diet of wheat (Triticum aestivum) laid 46% to 50% fewer eggs than did hens fed a control diet (Krapu 1979).

Animal foods (mainly dipterans) compose 60% to 85% of the fall and winter diet in the San Joaquin Valley of California (Connelly and Chesmore 1980), whereas the diet of wintering pintails on the coast of Texas consists of almost 100% shoalweed (Halodule beaudettei) (McMahan 1970).

Pintails make extensive use of cereal grains when available. These include wheat, barley (Hordeum vulgare), and sorghum (Sorghum vulgare) in the northern plains and rice (Oryza sativa) in the south and west (Bellrose 1976).

Other important foods of pintails include bulrush (Scirpus spp.) seeds and pondweeds (Potamogeton spp.) at Pel Lake, Saskatchewan (Keith and Stanislawski 1960), and in Utah (Fuller 1953). Bulrush seeds and muskgrass (Chara spp.) spores and branches are used at Swan Lake, British Columbia (Munro 1939). Along the Columbia River, buckwheat (Fagopyrum spp.), smartweed (Polygonum spp.), and grass culms and seeds are eaten. The seeds of oats (Avena sativa), smartweeds, bulrushes, and saltgrass (Distichlis spicata) are used in central Washington (Yocum 1951), whereas pintails in California use barley, bulrushes, spikerush (Eleocharis acicularis), widgeongrass (Ruppia maritima), and clams. In the Midwest, millets (Echinochloa spp.), nutgrasses (Cyperus spp.), smartweeds, rice cutgrass (Leersia oryzoides), and waterhemp (Acnida altissima) are part of the pintail's diet (Korschgen 1955; Anderson 1959). In the coastal marshes of Louisiana, nutgrasses, fall panicum (Panicum dichotomiflorum), brownseed paspalum (Paspalum plicatulum), and millet seeds are eaten.

The diet of pintail ducklings during their first few days of life consists almost entirely of insects caught on the water surface (Sugden 1973). Animal foods compose about two-thirds of the diet in the first 50 days.

Water

Waterfowl are always associated with wetlands of some type. It is assumed that all physiological needs for water are met by wetlands. Furthermore, the distribution and density of waterfowl are influenced to a large degree by water permanence in available wetlands (Kantrud and Stewart 1977). Wetlands are considered to be the primary factor in waterfowl production (Higgins 1977). Because of their importance to breeding pintails, wetlands are treated in the discussion of reproductive requirements.

Cover

Pintails wintering on freshwater habitats in Texas concentrated their activity in water 88 to 114 cm deep, with abundant aquatic vegetation and sparse emergent vegetation (White and James 1978). Considerable variability in winter habitat selection is exhibited by the pintail, ranging from grain fields to marshes and impoundments (Chabreck 1979).

Cover needs for the pintail during the reproductive and brood-rearing period are discussed in the following section.

Reproduction

The highest densities of breeding pairs of pintails in North Dakota occurred on ephemeral, temporary, seasonal, and undifferentiated tillage wetlands (Kantrud and Stewart 1977). Seasonal and semipermanent wetlands accounted for the largest proportion of breeding pintails. Pintails readily use stock-watering ponds in North Dakota (Lokemoen 1973). Pond size and vegetative escape cover determine suitability for brood use (Mack and Flake 1980). Trauger (1967) recommended that 40% of a wetland should be open water for brood use by dabbling ducks. Use by pintail pairs was highest on an experimental pond where the ratio of open water to emergent vegetation was 50:50, compared to 30:70 and 70:30 ratios, although the difference in use between ponds was not statistically significant (Kaminski and Prince 1981). Maximum numbers of waterfowl pairs occurred in wetlands with a vegetation to water ratio of 50:50 (Murkin et al. 1982).

Reproductive habitat for the pintail includes sites for courtship, nesting, and brood-rearing. Seasonal, semipermanent, and undifferentiated tillage wetlands accounted for 61.7%, 22.4%, and 10.4% of use by pintail pairs in North Dakota (Kantrud and Stewart 1977). Semipermanent and seasonal wetlands accounted for an average of 14.5% and 22.8% of pintail pair use in South Dakota over a 2-year period (Ruwaldt et al. 1979). Dugouts and stock ponds in the same area accounted for a 2-year average of 46.5% of pintail use. Pond size and vegetative cover were positively correlated with duck use (Lokemoen 1973).

Pintails select open areas with low or sparse vegetation for their nests (Bellrose 1976). In an intensively farmed area of North Dakota, pintails nested in almost equal densities in all habitats (summer fallow, mulched stubble, standing stubble, and untilled uplands), but low densities occurred in growing grain (Higgins 1977). Pintails were the principal nesters in summer fallow, mulched stubble, and standing stubble habitats. The value of nesting cover to pintails is reduced by grazing (Kirsch 1969), mowing (Oetting and Cassel 1971), and tillage (Milonski 1958). Farming operations destroyed an average of 49% of the pintail nests discovered during a 2-year study in the Pothole region (Higgins 1977). Tillage destroyed 34% of all nests and 93% of the active nests in croplands. Nest densities for pintails were similar in summer fallow, mulched stubble, standing stubble, and untilled uplands; 1.00, 1.45, 1.77, and 1.52 nests/km² (Higgins 1977).

High pintail brood densities (57.5/km²) were found in ideal nesting and brooding conditions created on St. Andres Bog, Manitoba (Hochbaum and Bossenmaier 1972). This response occurred when wet weather conditions caused large areas of standing stubble to be left undisturbed through late summer, resulting in high nest success.

Brood use is strongly related to stock pond size in North Dakota (Lokemoen 1973). The highest density of broods was found on ponds of 0.4 to 0.8 ha, with 0.28 broods/ha recorded. Ponds ≤0.2 ha supported few broods. Average brood size was 7.0 on ponds of 0.85 to 2.02 ha and 5.1 on ponds 0.45 to 0.8 ha. Pintail broods generally used emergent vegetation for escape cover on stock ponds.

<u>Interspersion and Composition</u>

Pintails often locate their nests farther from water than other ground-nesting ducks, often several kilometers, but most nests are found within 91.5 m of water (Bellrose 1976). Munro (1944) also reports nests several hundred meters from water.

Pintail hens lead their broods farther overland to water than other prairie ducks (Bellrose 1976). Sowls (1955) observed a hen move her brood 731.5 m the first 24 hours after hatching. Pintail broods did not stay at one pothole for longer than 2 weeks in one study (Evans et al. 1952).

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area. This HSI model was developed from information obtained from central and eastern North Dakota and eastern South Dakota. It is considered to be applicable throughout the Prairie Pothole region, where the greatest breeding densities of pintails occur (Figure 1). Other important adjacent areas within the United States include: the mixed-grass prairie of North Dakota and South Dakota; the tallgrass prairie in western Minnesota, eastern North Dakota and South Dakota, and the sandhills of Nebraska; and the shortgrass prairie west of the Missouri River through Montana (Bellrose 1976, 1979). The model should be applicable within the Prairie Provinces of Canada and may be applicable in other portions of the pintail's breeding range.

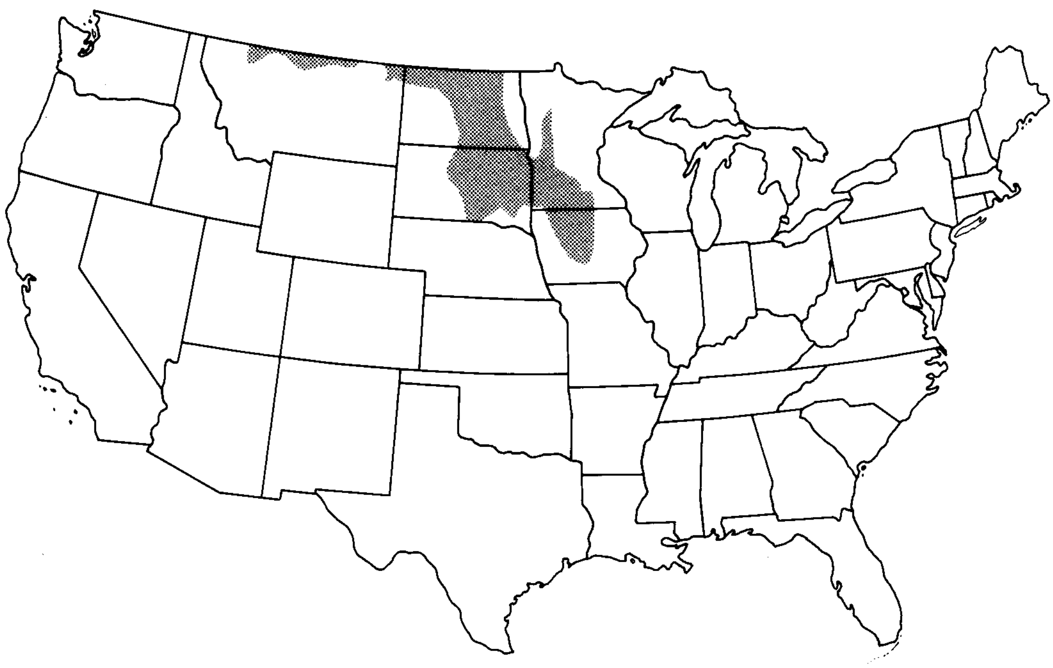

Figure 1. Approximate area of pintail model applicability. The range of the northern pintail is much larger than the area depicted, but the model should be most useful in the Prairie Pothole region.

Season. This HSI model was developed to evaluate the quality of spring and summer habitat for pintails.

Cover types. During the breeding season, pintails may use a variety of upland types, however, the model focuses only on evaluation of Herbaceous Wetlands (HW) (U.S. Fish and Wildlife Service 1981), and the water regime modifiers of Cowardin et al. (1979). Data presented in the model follow the Stewart and Kantrud (1971) classification used in the original references, and these classes generally correspond to the Cowardin et al. (1979) water regime modifiers (Table 1). Constructed wetlands (e.g., stock ponds, dugouts, and reservoirs) can be included in this model by classifying them as one of the wetland cover types based on a comparison of their physical and vegetational characteristics to the criteria used in the classification system of Stewart and Kantrud (1971).

Minimum habitat area. Minimum habitat area is defined as the minimum amount of contiguous suitable habitat that is required before an area will be occupied by a species. This specific information was not found in the literature for the pintail.

Verification level. This model is intended to provide information useful for baseline assessments and habitat management where the northern pintail is a species of interest. We have reviewed the pintail literature, selected the criteria described below, supplied values for each criterion (including optimum), and suggested aggregation mechanisms. This approach, which closely parallels previous waterfowl models (Sousa 1985a,b), will produce a single index representing the assumed relative suitability of a site for pintail pairs and broods. The identified criteria should serve as hypotheses of habitat use by the species, but their evaluation individually, or in total, against long-term population data, awaits further research.

Comments and suggestions by G.L. Krapu, M.R. Miller, and P.J. Sousa on an earlier draft of this model have been incorporated where possible. These reviewers also raised concerns that could not be directly addressed, but that potential users of this model should understand. Pintails are a highly nomadic pioneering species. Hence, the model may not adequately address the importance of annual variation in water conditions to breeding pairs and, ultimately, recruitment. A particular site may contain the proper mix and amount of wetlands as described below, but provide water conditions suitable for breeding pintails only a small percentage of the time over the long term.

Finally, the reviewers expressed concern about the brood-preference indices. In years of high runoff and good water conditions, seasonal (Class III) wetlands may carry water into midsummer and beyond, and receive high use by pintail broods. Pintail broods exhibit a tendency to seek cover, and the abundant vegetation and good water conditions of seasonal wetlands during these exceptional years make them highly attractive. Brood observations may be biased toward wetland classes with good visibility and may underestimate the importance of seasonal wetlands for pintail broods during good water years. The preference index for seasonal wetlands was increased in response to these comments, but users may wish to adjust the indices further if they feel conditions on their study areas are not adequately represented.

Table 1. Comparison of the wetland classes of Stewart and Kantrud (1971) with the water regime modifiers of Cowardin et al. (1979).

Stewart and Kantrud (1971)	Cowardin et al. (1979)	
Wetland class	Water regime	Water regime definitions
I. Ephemeral ponds	None, not considered a wetland	
II. Temporary ponds	Temporarily flooded	Surface water present for brief periods during growing season, but water table usually lies well below soil surface for most of season.
III. Seasonal ponds and lakes	Seasonally flooded	Surface water present for extended periods, especially early in growing season, but absent by end of season in most years.
IV. Semipermanent ponds and lakes	Semipermanently flooded	Surface water persists throughout growing season in most years.
None [a]	Intermittently exposed	Surface water present throughout year except in years of extreme drought.
V. Permanent ponds and lakes	Permanently flooded	Water covers land surface throughout year in all years.
VI. Alkali ponds and lakes	Intermittently flooded (with saline or hypersaline water)	Substrate usually exposed, but surface water is present for variable periods without detectable seasonal periodicity.
VII. Fen (alkaline bog) ponds	Saturated	Substrate saturated to surface for extended periods during growing season, but surface water seldom present.

[a] No corresponding wetland class exists for the intermittently exposed water regime.

Model Description

Overview. Breeding habitat suitability for the pintail is evaluated by assessing the wetland requirements for pairs and broods. This approach is based on the observation that areas without wetlands will neither attract nor produce waterfowl, including pintails (Higgins 1977). Pintail nests do not require extensive cover (Bellrose 1976); rather, pintails may rely on nest dispersal rather than nest concealment as an antipredator strategy (McKinney 1973). Similar nesting densities have been recorded in summer fallow (1 nest/km^2), mulched stubble (1.45 nests/km^2), standing stubble (1.77 nests/km^2), and untilled uplands (1.52 nests/km^2) (Higgins 1977). Therefore, it is assumed that pintails will use existing upland sites for nesting if suitable wetlands are available for pair and brood use. Pairs are able to use all wetland classes, but appear to be attracted to shallow water (Hochbaum and Bossenmaier 1972); brood use is restricted to more permanent wetlands.

The following sections identify important habitat variables, describe suitability levels of the variables, and describe the relationships between variables.

Pair habitat component. Pairs use wetlands for feeding, resting, and courtship prior to nesting. Use of wetland basins in the Prairie Pothole region of North Dakota (Kantrud and Stewart 1977), and South Dakota (Ruwaldt et al. 1979) indicate that various classes of wetlands (Stewart and Kantrud 1971) are used to varying degrees by pintail pairs. An index of preference for wetland classes can be developed based on wetland use compared to wetland availability (Tables 2 and 3). Based on these analyses, the highest quality natural wetlands for pintail pairs are either temporary, or seasonal wetlands. Although specific indices vary between data sets, the trend reflects the assumed affinities of pintail pairs for abundant shallow water and an absence of tall emergents (Smith 1970; Hochbaum and Bossenmaier 1972).

Pintail pairs also use impounded wetlands. Preference indices for pintail pairs in impounded wetlands are not included in this model because of a lack of information comparable to that available for natural wetlands. If impounded wetlands are to be considered in a given application of this model, preference indices must be developed by the users of the model. Similarities in water conditions and vegetation between natural wetlands and constructed wetlands may be used to assign pair preference indices to constructed wetlands.

Optimum conditions for pintail pairs are assumed to exist when a minimum of 150 optimum wetlands account for a minimum of 65 ha per 259-ha section. This assumption is based on the perceived need for a large number of small wetlands within a section in order to support maximum numbers of pintail pairs, while still providing potentially optimum brood habitat (discussed below). The selection of 150 as the standard of comparison for the number of optimum wetlands per section is based on the opinion of species experts that this is an attainable figure and would represent optimum conditions (Sousa 1985a,b). A complete lack of wetlands provides no suitability. The value of

Table 2. Determination of wetland preference index for pintail pairs in the Prairie Pothole region.

Wetland class[a]	Pintail use (% total distribution)[b]	Availability of wetland class (% of total wetland area)[c]	Use/ availability	Index[d]
Ephemeral (I)	0.1	1	0.10	0.05
Temporary (II)	4.1	2	2.05	1.00
Seasonal (III)	61.7	33	1.87	0.91
Semipermanent (IV)	22.4	18	1.24	0.61
Permanent (V)	0.9	3	0.30	0.15
Alkali (VI)	0.3	6	0.05	0.02
Fen (VII)	0.1	≤0.5	0.20	0.10
Undifferentiated[e] tillage	10.4	25	0.42	0.20

[a]The classification used here is that of Stewart and Kantrud (1971), since data on waterfowl use presented by Kantrud and Stewart (1977) was based on this classification. See Application of the Model for guidelines on using other wetland classification systems.

[b]From Kantrud and Stewart (1977), Table 1, p. 247.

[c]From Stewart and Kantrud (1973), Table 2, p. 45. Number represents the proportion of the total wetland acreage accounted for by the individual wetland class. Total of percentages equals 88% since only those wetland classes referred to in Kantrud and Stewart (1977) were used. The remaining wetlands were classed as tillage ponds (4%), streams and oxbows (5%), and manmade wetlands (≤3%).

[d]Determined by dividing the use/availability value by 2.05, the maximum use/availability value.

[e]Undifferentiated tillage wetlands are those natural wetland basins with tilled bottoms (Classes II and III).

Table 3. Determination of wetland preference index for pintail pairs in South Dakota.

Wetland class[a]	Pintail use (% total distribution)[b]	Availability of wetland class (% of total wetland area)[c]	Use/ availability	Index[d]
Ephemeral (I)	--	14	--	--
Temporary (II)	7.6	11	0.69	0.51
Seasonal (III)	17.7	13	1.36	1.00
Semipermanent (IV)	28.9	32	0.90	0.66
Permanent (V)	0.3	4	0.08	0.06
Alkali (VI)	--	--	--	--

[a]The wetland classification is that of Stewart and Kantrud (1971). Table 1 and Application of the Model offer guidelines on using other classification systems.

[b]From Ruwaldt et al. (1979:378, Table 3). Figures are from 1973, a good water year. Use of natural wetland basins equals 54.5%; remaining pintail pairs were observed using streams, constructed ponds, and tillage ponds and ditches.

[c]From Ruwaldt et al. (1979:376, Table 1). Total percent area of natural wetland basins equals 74%; the remaining area was streams and constructed wetlands.

[d]Determined by dividing the use/availability value by 1.36.

wetlands to pairs is assumed to decrease in a linear relationship as the number and area of wetlands approach zero. Pair densities on smaller wetlands are usually greater than on larger wetlands, since larger wetlands generally have large areas of open water that do not provide the required isolation for pair use. The conditions described as optimum for pairs (150 wetlands totalling 65 ha per 259-ha section) equates to an average wetland size of 0.43 ha. If it is assumed that a few large wetlands will be present, then most of the wetlands will be <0.4 ha.

The number of wetlands on a study area can be converted to the number of optimum wetlands by weighting the number of wetlands in each class by the wetland preference indices for pairs (Table 2) as in Equation 1:

$$EONWP = \sum_{i=1}^{n} (w_i p_i) \qquad (1)$$

where EONWP = equivalent optimum number of wetlands/259 ha for pairs (i.e., weighted by preference indices)

n = the number of wetland classes available

w_i = number of wetlands/259 ha of wetland class i

p_i = preference index for pintail pairs for wetland class i

Equation 1 simply determines a sum of the number of wetlands per section weighted by the quality of the wetland classes for pintail pairs. The relationship between the number of equivalent optimum wetlands/259 ha and a suitability index for pintail pairs is presented in Figure 2a.

A value for equivalent optimum area of available wetlands can be determined by Equation 2:

$$EOAWP = \sum_{i=1}^{n} (a_i p_i) \qquad (2)$$

where EOAWP = the equivalent optimum area of wetlands/259 ha for pairs

a_i = area of wetlands of class i/259 ha

n and p_i are as described above

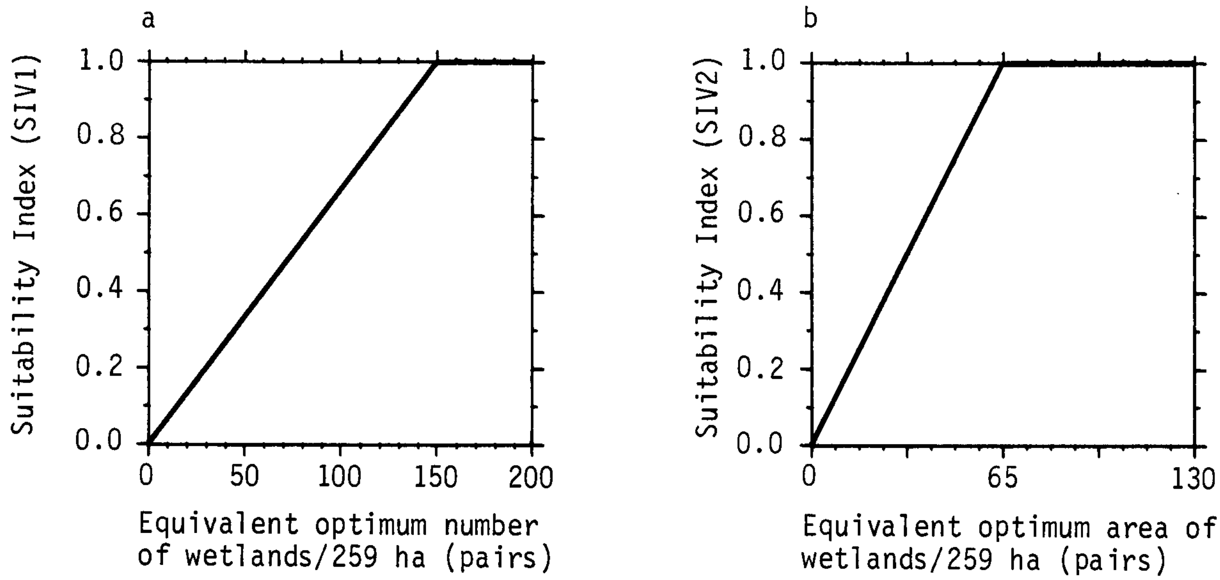

Figure 2. The relationships between equivalent optimum number and area of wetlands used to evaluate pintail pair habitat and their respective suitability indices.

The resulting sum from Equation 2 is the total area of wetlands available per section weighted by the quality of the available wetlands for pintail pairs. The relationship between this value and a suitability index for pintail pairs is shown in Figure 2b.

Number and area of wetlands are assumed to be of equal importance in determining habitat suitability for pintail pairs. These two variables are not entirely independent of each other. For example, an increase in the number of equivalent optimum wetlands will likely result in an increase in equivalent optimum area of wetlands for pintail pairs. Although area and number of wetlands are not independent, the variable with the lowest suitability level is considered to have the greatest influence on the final value for pair habitat suitability (SIP). This relationship is best expressed by a geometric mean of the suitability indices for the two variables, as in Equation 3:

$$SIP = (SIV1 \times SIV2)^{1/2} \qquad (3)$$

Brood habitat component. Habitat suitability for pintail broods is a function of wetland availability, distribution, water permanence, vegetative cover, water depth, and potential food resources, as defined by observed brood usage of wetland classes. As they mature, pintail ducklings shift from surface feeding to bottom feeding in shallow water ≤31 cm deep (Sugden 1973). Pintail broods are often found in wetlands with extensive emergent vegetation (Mack and Flake 1980), and also seek vegetation as cover when alarmed (Rumble and Flake 1982). These characteristics, coupled with the comments of model reviewers concerning the attractiveness of seasonal wetlands during good water years, caused us to reexamine the use/availability approach used to evaluate wetland value for pairs, as it applies to pintail broods.

Table 4 lists the preference indices obtained by comparing pintail brood observations by wetland class (Duebbert and Frank 1984) with wetland class availability (Stewart and Kantrud 1973). Because of the brood visibility concerns discussed above, we offer an alternative to the preference index obtained for seasonal wetlands. Rumble and Flake (1982) evaluated differential observability of duck broods on stock ponds in South Dakota and found that pintail broods were the least visible among gadwall, blue-winged teal, mallard, and pintail broods. They developed visibility correction factors for use in brood survey work from this information. We have applied the factor for pintail broods (1.65) to the preference index for seasonal wetlands, and increased its value to 0.56 in Table 4. Users of the model are encouraged to use the most appropriate value for their conditions, or develop other indices based on more site-specific data.

Temporary wetlands and undifferentiated tillage wetlands (not addressed in Table 4) are assigned values of 0 since they would typically be unavailable during the brood-rearing period. Only those wetlands ≥0.4 ha are considered in the evaluation of brood-rearing habitat. This limitation is based on the need for an adequate sized wetland to minimize predation and to ensure that only those wetlands that will have water available during the brood-rearing period will be considered.

Optimum habitat conditions for pintail broods are assumed to exist when at least 20.2 ha of optimum wetlands are present on a 259-ha section of land and at least 6 optimum wetlands ≥0.4 ha are present. A total lack of wetlands provides no brood suitability. The value of wetlands to broods is assumed to decrease linearly as the number and area of optimum wetlands approaches zero. The selection of 20.2 ha as the standard of comparison is based on the opinion of waterfowl biologists that 100 waterfowl broods/259 ha is an attainable production level (Sousa 1985a,b). Further, the model assumes that a semi-permanent wetland (optimum brood habitat) could support 2 broods/0.4 ha. Therefore, 20.2 ha of optimum wetlands can support the maximum production of 100 broods/259 ha. The selection of a minimum of 6 optimum wetlands/259 ha is also based on experiences of waterfowl biologists (Sousa 1985a,b).

Table 4. Wetland preference indices for pintail broods in the Prairie Pothole region.

Wetland class[a]	Preference index[b] (use/availability)	Preference index[c] (visibility factor applied)
Temporary (II)	0.00	
Seasonal (III)	0.34	0.56
Semipermanent (IV)	1.00	
Permanent (V)	0.60	
Alkali (VI)	0.03	

[a]Terminology from Stewart and Kantrud (1971).

[b]Based on pintail brood data from Duebbert and Frank (1984) and wetland availability data from Stewart and Kantrud (1973) as presented in Table 1.

[c]Based on a visibility correction factor of 1.65 developed by Rumble and Flake (1982) for pintail broods on stock ponds in South Dakota.

The number of wetlands on a study area can be converted to the number of equivalent optimum wetlands available for brood-rearing by weighting the number of wetlands in each class by the preference indices for broods (Table 4) as in Equation 4:

$$EONWB = \sum_{i=1}^{n} (w_i b_i) \quad (4)$$

where EONWB = equivalent optimum number of wetlands/259 ha available for pintail brood-rearing

n = the number of wetland classes available

w_i = the number of wetlands ≥0.4 ha of class i/259 ha

b_i = preference index for pintail broods for wetland class i (from Table 4)

Equation 4 simply determines a sum of the number of wetlands per section weighted by the quality for broods of the classes of wetlands available. The relationship between the number of equivalent optimum wetlands per section and a suitability index for pintail broods is presented in Figure 3a.

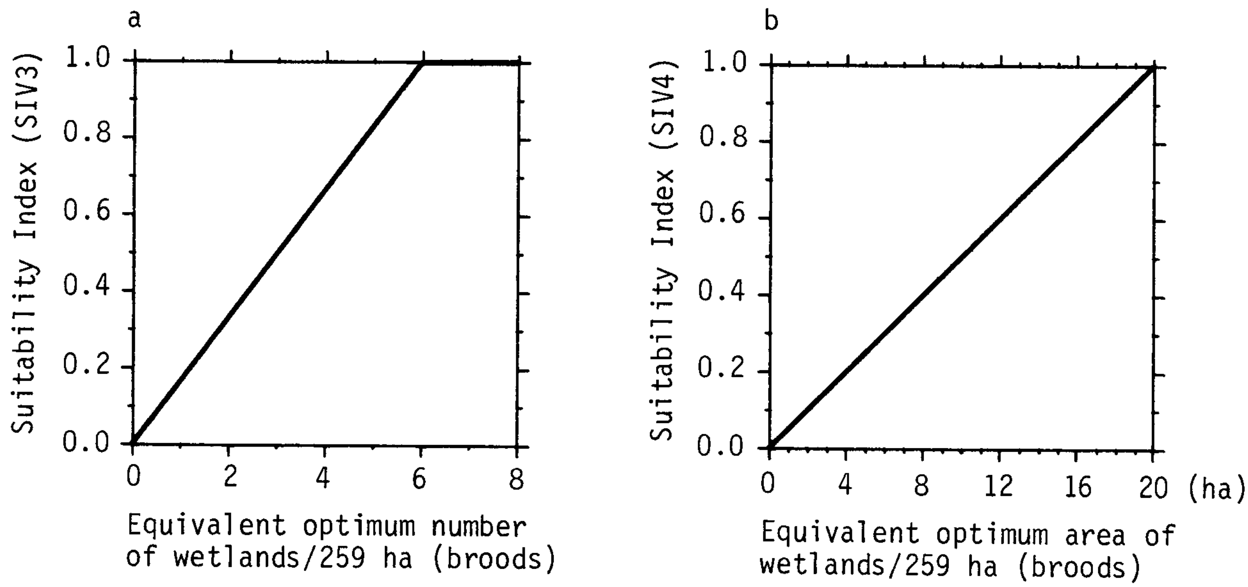

Figure 3. The relationships between habitat variables used to evaluate pintail brood habitat and suitability indices for the variables.

A value for the equivalent optimum area of wetlands per section for broods can be determined by Equation 5:

$$EOAWB = \sum_{i=1}^{n} (a_i b_i) \qquad (5)$$

where EOAWB = equivalent optimum area of wetlands/259 ha available for pintail brood-rearing

a_i = the area of wetlands ≥0.4 ha in wetland class i/259 ha

n and b_i are as described above

Equation 5 determines a sum of the area of wetlands per section weighted by the quality for pintail broods of the classes of wetlands available. The relationship between this value and a suitability index for pintail broods is shown in Figure 3b.

The two variables selected for evaluating brood cover are not entirely independent of each other. For example, an increase in the number of equivalent optimum wetlands will likely result in an increase in equivalent optimum area for pintail broods. Although the variables are not independent, the variable with the lowest suitability level will have the greatest influence on the final value for brood-rearing habitat suitability (SIB). This relationship is best expressed by a geometric mean of the suitability indices for the two variables, as in Equation 6:

$$SIB = (SIV3 \times SIV4)^{1/2} \qquad (6)$$

HSI determination. The calculation of life requisite values should occur on a section (259 ha) basis. Since the production of pintails on a particular area will ultimately be determined by that component with the lowest potential to support the pintail's needs, the Habitat Suitability Index is based on the limiting factor theory and equals the lowest of the values determined for pair (SIP) or brood habitat (SIB).

Application of the Model

Summary of model variables and equations. A number of habitat variables and equations are used in this model to evaluate pair and brood-rearing habitat for the pintail. The equations in this model are summarized in Figure 4. The relationships between the habitat variables and life requisites in this model and an HSI value for the pintail are summarized in Figure 5.

Pair Component		Page
Equation (1)	$EONWP = \sum_{i=1}^{n} (w_i p_i)$	10
(2)	$EOAWP = \sum_{i=1}^{n} (a_i p_i)$	10
(3)	$SIP = (SIV1 \times SIV2)^{1/2}$	11
Brood Component		
Equation (4)	$EONWB = \sum_{i=1}^{n} (w_i b_i)$	13
(5)	$EOAWB = \sum_{i=1}^{n} (a_i b_i)$	15
(6)	$SIB = (SIV3 \times SIV4)^{1/2}$	15

Figure 4. Summary of equations used in the pintail HSI model (definitions of variables within an equation may be found on the page indicated).

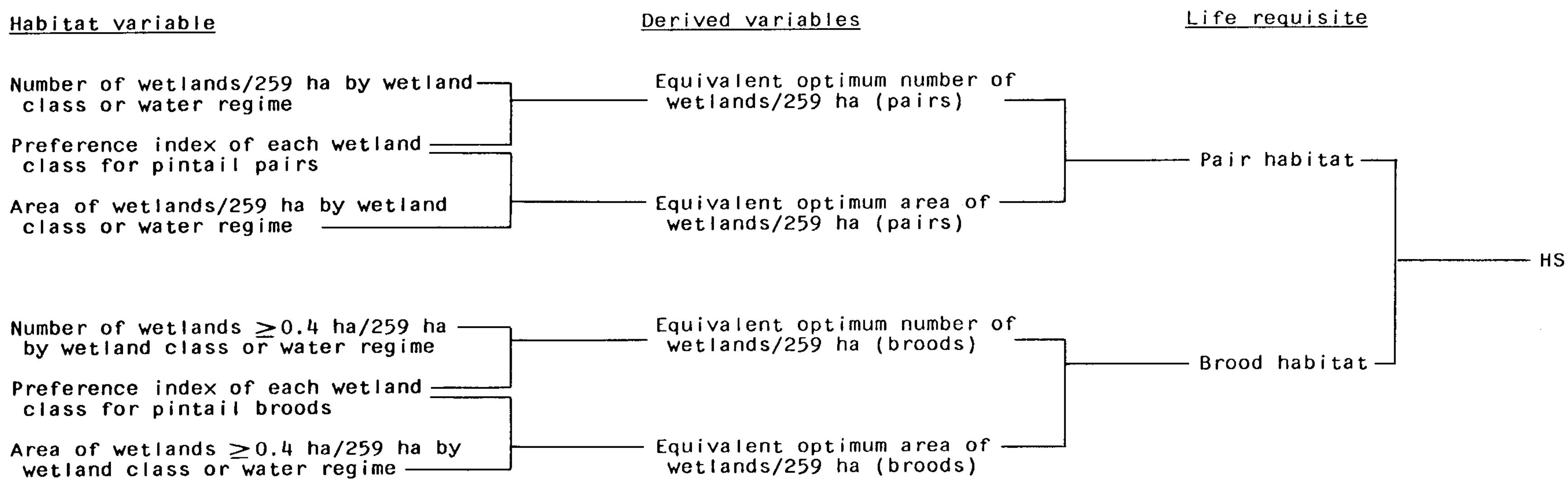

Figure 5. The relationships between habitat variables, derived variables, and life requisites to an HSI value for the northern pintail.

Values for habitat variables used to evaluate pair and brood habitat can be estimated through wetland classification and measurement using aerial photographs.

The definitions and suggested measurement techniques of variables used in this model are given in Figure 6.

Variable (definition)	Suggested technique
Number of wetlands/259 ha by wetland class or water regime.	Classify all wetlands; tally numbers by wetland class or water regime; convert density for each class or water regime to number/259 ha.
Area of wetlands/259 ha by wetland class or water regime.	Classify all wetlands; determine area of each wetland; convert total area of each class or water regime to ha/259 ha.
Number of wetlands ≥0.4 ha/259 ha by wetland class or water regime.	Classify wetlands ≥0.4 ha; tally numbers by wetland class or water regime; convert density for each class or water regime to number/259 ha.
Area of wetlands ≥0.4 ha/259 ha (640 ac) by wetland class or water regime.	Classify wetlands ≥0.4 ha; determine area of each wetland by class or water regime; convert total area of each class or water regime to ha/259 ha.

Figure 6. Definitions of variables and suggested measurement techniques.

Use of other wetland classification systems. In order to use this model without modification, wetlands on a study area must be classified according to the system developed by Stewart and Kantrud (1971). Other classifications that are generally available include those of Shaw and Fredine (1956) and Cowardin et al. (1979). In order to use this model where wetlands are classified by a system other than that of Stewart and Kantrud (1971), the terminology of the classification system being used must be equated to that used in this model. For areas where the system of Shaw and Fredine (1956) is used, guidelines relating that system to Stewart and Kantrud (1971) are provided by Stewart and Kantrud (1971). Guidelines for cross-referencing between the classification system of Stewart and Kantrud (1971) and that of Cowardin et al. (1979) are provided in the latter publication, and are summarized in Table 1 of this model.

Model assumptions. This model is constructed around the basic assumption that areas without wetlands will neither attract nor produce pintails. Pintail pairs appear to use temporary, seasonal, and semipermanent wetlands (Stewart and Kantrud 1971) in a greater proportion than available, whereas semipermanent wetlands receive the most brood use. The model attempts to reflect these differential use patterns by assigning preference indices to different wetland types in relation to their observed use/availability. Indexed wetlands are then compared to standard equivalent optimum numbers and areas of wetlands for both pairs and broods.

Standards of comparison were identified by a group of waterfowl biologists familiar with the habitat requirements of ducks nesting in North Dakota and South Dakota, and the prairie provinces of Canada. These standards are a minimum of 150 optimum wetlands covering a minimum of 65 ha of optimum wetlands for pintail pairs, and a minimum of 6 optimum wetlands covering a minimum of 20.2 ha of optimum wetlands for broods. These standards were developed for all species of dabbling ducks, including pintails, but may not apply outside the Prairie Pothole region of North America.

The second major assumption in the model deals with nesting requirements. We have assumed that if the appropriate quality and number of wetlands are available, pintails will find a place to nest. We are assuming in effect that the availability of quality wetlands will always be more limiting to breeding pintail populations than will the availability of nesting sites. This appears to be a reasonable assumption given the existing information concerning the placement of pintail nests in a wide variety of habitat conditions, including bare soil. This approach should not be interpreted to mean that we assume equal nesting success and production in all cover types. This model does not address the impacts of nest predation (Duebbert and Lokemoen 1980), or destruction resulting from agricultural activities (Higgins 1977). We have assumed that the nesting strategy of pintails evolved in the absence of a need for large amounts of physical cover surrounding the nest site, and if provided with the opportunity, pintails would not differentially select dense upland cover over sparse cover for nesting.

SOURCES OF OTHER MODELS

No other models to predict spring and summer habitat suitability for the pintail were located in the literature. Howard and Kantrud (1986) recently discussed the needs of pintails wintering along the Gulf of Mexico coast. The current model closely parallels earlier models for the gadwall (Sousa 1985a) and blue-winged teal (Sousa 1985b).

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50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. Biological Report 83(10.145)	2.	3. Recipient's Accession No.
4. Title and Subtitle: Habitat Suitability Index Models: Northern Pintail			5. Report Date: September 1987
			6.
7. Author(s): W. J. Suchy and S. H. Anderson			8. Performing Organization Rept. No.
9. Performing Organization Name and Address: Wyoming Cooperative Fishery and Wildlife Research Unit, University of Wyoming, Laramie, WY 82071			10. Project/Task/Work Unit No.
			11. Contract(C) or Grant(G) No. (C) (G)
12. Sponsoring Organization Name and Address: U.S. Department of the Interior, Fish and Wildlife Service, Research and Development, Washington, DC 20240			13. Type of Report & Period Covered
			14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

A review and synthesis of existing information were used to develop a Habitat Suitability Index (HSI) model for the northern pintail (Anas acuta). 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.

17. Document Analysis a. Descriptors

Birds
Wildlife
Habitability
Mathematical models

b. Identifiers/Open-Ended Terms

Northern pintail
Anas acuta
Habitat suitability

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Release unlimited	Unclassified	23
	20. Security Class (This Page): Unclassified	22. Price

(See ANSI-Z39.18) See Instructions on Reverse

OPTIONAL FORM 272 (4-77)
(Formerly NTIS-35)
Department of Commerce

☆ U.S. GOVERNMENT PRINTING OFFICE: 1988—574-144/85,051 REGION NO. 8