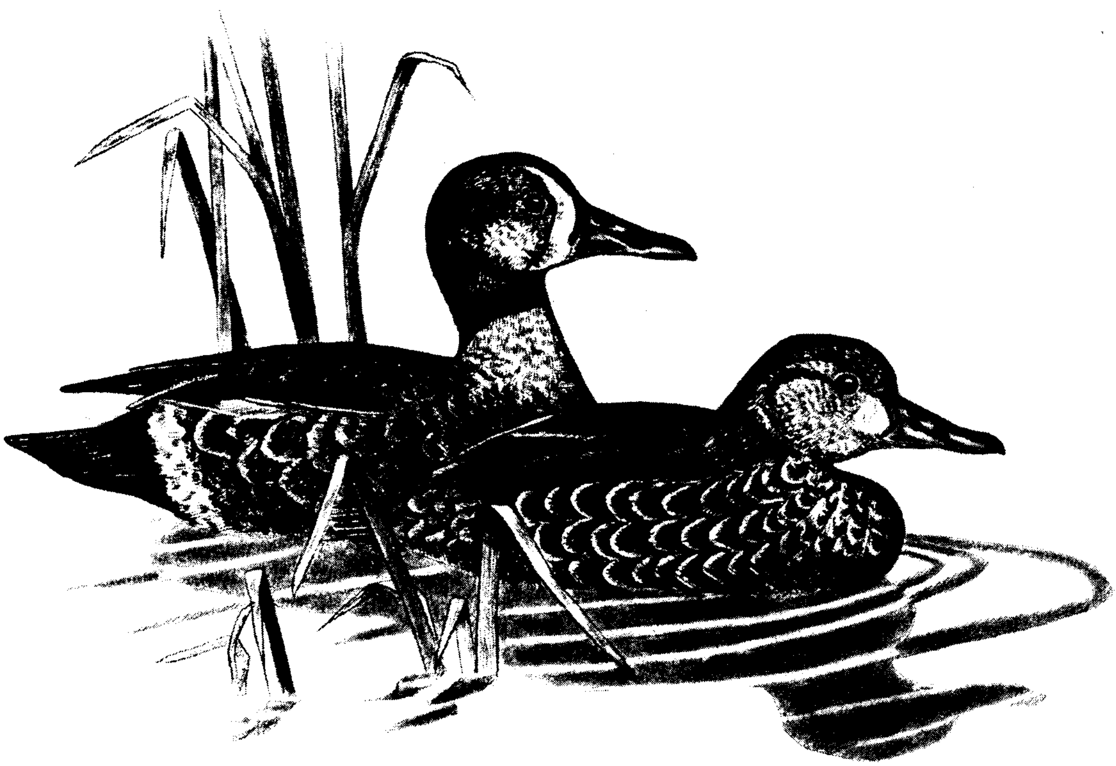
BIOLOGICAL REPORT 82(10.114)
SEPTEMBER 1985

HABITAT SUITABILITY INDEX MODELS: BLUE-WINGED TEAL (BREEDING)



Fish and Wildlife Service

S. Department of the Interior

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September 1985

HABITAT SUITABILITY INDEX MODELS: BLUE-WINGED TEAL (BREEDING)

by

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This report should be cited as:

Sousa, P. J. 1985. Habitat suitability index models: Blue-winged teal (breeding). U.S. Fish Wildl. Serv. Biol. Rep. 82(10.114) 36 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is a formalized synthesis of biological and habitat information published in the scientific literature and may include unpublished information reflecting the opinions of identified experts.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 fo that species. User feedback concerning model improvements and other sugges tions that may increase the utility and effectiveness of this habitat-base approach to fish and wildlife planning are encouraged. Please send suggestion to:

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CONTENTS

FIGURES

ACKNOWLEDGMENTS

The basis for this HSI model was 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 we could develop the most reasonable HSI model possible with the current knowledge of waterfowl habitat requirements. L. Kirsch, J. Lokemoen, and G. Swanson also reviewed the model that resulted from the workshop. L. Kirsch provided unpublished data that were used in the development of the nesting component portion of this model.

In addition to the waterfowl authorities, the following potential users of the models participated in the workshop and/or the 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 this model. Michael Armbruster and Arthur Allen (U.S. Fish and Wildlife Service, Ft. Collins, CO) served as facilitators for the modeling workshop.

The cover of this document was illustrated by Jennifer Shoemaker. Word processing was provided by Carolyn Gulzow, Dora Ibarra, and Elizabeth Graf. Kay Lindgren assisted with literature searches.

Funding for the development of this model was provided to the U.S. Fish and Wildlife Service's Habitat Resources Program (Region 6) by the U.S. Bureau of Reclamation under the provisions of the Fish and Wildlife Coordination Act. Additional funds were provided by the U.S. Bureau of Reclamation's Program Related Engineering and Scientific Studies (Environmental, Evaluation, and Planning Project).

BLUE-WINGED TEAL (*Anas discors*)

HABITAT USE INFORMATION

General

The blue-winged teal (*Anas discors*) primarily is associated with the northern prairies and parklands and "... is the most abundant breeding duck on the mixed prairie grasslands of the Dakotas and the Prairie Provinces of Canada ..." (Bellrose 1976:277). Blue-winged teal arrive late on the breeding grounds compared to other waterfowl species and may be affected more by reduced numbers of small shallow wetlands due to drought than are earlier nesting species (Swanson and Meyer 1977).

Food

The diet of the blue-winged teal has been described as one-fourth animal food (Bellrose 1976), although animal food is of increased importance during the breeding season (Swanson et al. 1974). The proportion of animal foods in the diet of both males and females in North Dakota increased from 45% when the birds first arrived on the breeding grounds to 95% later in the breeding season (Swanson et al. 1974). The breeding season diet of females included 91% animal material by volume, and the diet of males averaged 85% animal material by volume. During the egg-laying period, animal foods accounted for 99% of the diet of female blue-winged teal (Swanson and Meyer 1977). Major invertebrate prey items in North Dakota were snails (Gastropoda) (32% aggregate percent volume), insects (35%), and crustaceans (19%) (Swanson et al. 1974). Aquatic insects and snails accounted for 44 and 40%, respectively, of the diet of hens during the egg-laying period (Swanson et al. 1979). Animal foods were most important in the May and June diet of blue-winged teal in Saskatchewan, whereas plant foods became more important in August and September (Dirschl 1969). The esophageal contents of postflightless males in south-central Manitoba were principally gastropods (44.3% aggregate wet weight), culicids (Culicidae) (29.2%), seeds and vegetation (15.5%), and chironomids (Chironomidae) (5.6%) (DuBowy 1985). During spring migration, the diet of blue-winged teal in Missouri consisted of 65% animal food (aggregate percent weight) and 35% seeds (Taylor 1978).

Shallow, eutrophic, seasonal and semipermanent wetlands are dependable recyclers of the nutrients that support an available and abundant high protein food source for breeding blue-winged teal (Swanson et al. 1974). Permanent water bodies typically produce a comparatively lower invertebrate biomass (Kaminski and Prince 1981). The density of blue-winged teal pairs in Manitoba was positively correlated to the density of benthic invertebrates ($r = 0.91$; $P < 0.05$) and the number of families of benthic invertebrates ($r = 0.93$; $P < 0.01$) present in a wetland (Murkin et al. 1982). Food availability is also influenced by the environmental conditions and land use adjacent to a wetland (Swanson et al. 1974). As seasonal wetlands become dry, blue-winged teal shift their foraging activities to semipermanent and permanent wetland types, although heavy precipitation may temporarily reverse this trend. Seasonal wetlands adjacent to undisturbed cover contained the highest invertebrate standing crop, whereas wetlands adjacent to summer fallow lands contained much lower numbers of invertebrates.

Blue-winged teal feed in shallow water and shift their feeding activities to more permanent wetlands during drought periods when reduced water levels result in short term increases in invertebrate availability (Swanson and Meyer 1977). Blue-winged teal feed in and around vegetation that is on or near the surface, as well as by tipping in shallow water (Swanson et al. 1974). They may feed in deeper water if floating or submerged vegetation provides a substrate for aquatic invertebrates or when aquatic insects emerge from the water. Postbreeding male blue-winged teal in Manitoba fed in shallow water (< 10 cm) by dabbling in mud (DuBowy 1985). Picking snails or seeds was a commonly used foraging method in deeper water with dense stands of aquatic vegetation.

Water

Wetlands are considered the primary factor in waterfowl production (Higgins 1977). Breeding waterfowl are highly dependent on invertebrate foods, and the availability of these foods varies among wetland types (Swanson et al. 1974). Seasonal and temporary wetlands become available earlier in the spring than deeper, more permanent water bodies that may still be frozen and, therefore, provide feeding habitat for waterfowl during early spring (Swanson et al. 1974). Habitat use may change to more permanent wetlands, however, as shallow wetlands become unavailable later in the breeding season or due to drought (Swanson and Meyer 1977).

The highest densities of breeding pairs of blue-winged teal in North Dakota occurred on ephemeral, seasonal, and temporary wetlands, although seasonal and semipermanent wetlands accounted for the largest proportion of breeding blue-winged teal (Kantrud and Stewart 1977). In South Dakota, natural basin wetlands were used by 62% of the breeding pairs of blue-winged teal over a 2-year study period (Ruwaldt et al. 1979). The largest proportion of pairs occurred on semipermanent wetlands, stock ponds, and seasonal wetlands. Ephemeral wetlands were heavily used when available but were absent during the second year of the study due to drought. Blue-winged teal pairs in another South Dakota study decreased by more than two-thirds in succeeding years due to loss of the more temporary wetlands during drought (Brewster et al. 1976).

Potholes > 0.8 ha were preferred early season habitat for blue-winged teal in South Dakota (Evans and Black 1956). Use of smaller wetlands increased as teal density increased. The single variable providing the most discriminating power for predicting the presence of blue-winged teal pairs in South Dakota was the percentage of the water body in hemi-marsh, defined as emergent vegetative cover and water in approximately equal proportions (Flake et al. 1977). Significantly more blue-winged teal pairs occurred on experimental wetlands in Manitoba with an open water to emergent vegetation ratio of approximately 50:50, when compared to wetlands with 30:70 and 70:30 ratios (Kaminski and Prince 1981). Trauger (1967) recommended that open water cover at least 40% of a wetland to be used by dabbling duck broods. Murkin et al. (1982) concluded that a water to vegetation ratio of 50:50 resulted in the maximum density of waterfowl pairs. Ponds with greater than two-thirds open water in Saskatchewan had low use by blue-winged teal broods (Stoudt 1971).

Numbers of blue-winged teal pairs over a 15-year period in Saskatchewan were positively correlated with the number of wetlands available in May (third-order, Spearmen-rank, partial correlation coefficient = 0.67; $P < 0.01$), the number of pairs present in the previous year (third-order, Spearman-rank, partial correlation coefficient = 0.45; $P < 0.05$), and the number of wetlands available in the previous August (third-order, spearman-rank, partial correlation coefficient = 0.60; $P < 0.01$) (Leitch and Kaminski 1985).

Cover

The cover requirements of the blue-winged teal during the reproductive period are discussed in the following section.

Reproduction

Pair habitat. Seasonal and semipermanent wetlands accounted for 36 and 18%, respectively, of the available wetland area (Stewart and Kantrud 1973), and 61.2 and 31.2%, respectively, of pair use in North Dakota (Kantrud and Stewart 1977). Pair density on ephemeral wetlands was 137.7 pairs/km^2 on wetlands with water, 122.4 pairs/km^2 on seasonal wetlands, and 112.6 pairs/km^2 on temporary wetlands. A 2-year average of 62% of blue-winged teal pairs in South Dakota used natural basin wetlands that accounted for 75% of the area of all wetland basins (Ruwaldt et al. 1979). Semipermanent wetlands, stock ponds, and seasonal wetlands in South Dakota accounted for a 2-year average of 42.9, 20.3, and 10.6%, respectively, of blue-winged teal pair use and 32.1, 14.0, and 13.4%, respectively, of the wetland area. Use of constructed wetlands (stock ponds and dugouts) accounted for a 2-year average of 28.1% of blue-winged teal pair use. Use of stock ponds by blue-winged teal pairs in South Dakota increased with shoreline irregularity (Flake and Vohs 1979). Average height of emergent vegetation and the percent of a wetland in hemimarsh were important variables for predicting use of South Dakota stock ponds by blue-winged teal pairs (Flake et al. 1977). Pairs in South Dakota used larger wetlands shortly after arriving on the breeding grounds but later dispersed to smaller wetlands (Drewien and Springer 1969).

Blue-winged teal pairs under drought conditions in South Dakota were positively associated with basin size, area of surface water, and ratio of open water to basin size (Pendleton 1983). These variables accounted for 86% of the variation in pair numbers on natural and modified wetlands (modified wetlands refers to a dug brood complex which is a system of ponds and channels designed to provide waterfowl brood habitat). During a year with improved water conditions, blue-winged teal pairs were positively associated with basin size and water depth and negatively associated with height of emergent vegetation and the ratio of exposed mud to open water. These variables accounted for 59% of the variation in pair use of natural and modified wetlands.

Nesting habitat. Blue-winged teal typically select grassy vegetation for the establishment of nest sites (Bellrose 1976); low shrubs, such as snowberry (*Symphoricarpos* spp.), are not often used (J. T. Lokemoen, U.S. Fish and Wildlife Service, Northern Prairie Wildlife Research Center, Jamestown, ND; pers. comm.). Early successional stages of smooth bromegrass (*Bromus inermis*), intermediate wheatgrass (*Agropyron intermedium*), and alfalfa (*Medicago sativa*) provided attractive and secure nesting cover for dabbling ducks, in South Dakota including blue-winged teal (Duebbert and Lokemoen 1976). The highest densities of blue-winged teal nests in a North Dakota study were located in untilled upland, followed by standing stubble and growing grain crops (Higgins 1977). Seventy-eight percent of the nests were in untilled uplands. Fields of seeded native grasses supported the highest number of initiated nests of blue-winged teal in North and South Dakota, followed by seeded introduced grasses and unplowed prairie (Klett et al. 1984).

Nests in Wisconsin were located in denser and taller cover than random sites (Livezey 1981a). The presence of residual herbaceous vegetation may be an important habitat factor in nest site selection for upland nesting waterfowl (Duebbert and Lokemoen 1976; Kirsch et al. 1978), although new growth may partially compensate for the loss of residual vegetation (Martz 1967). Data (Table 1) provided by L. M. Kirsch (U.S. Fish and Wildlife Service, retired, Woodworth, ND; unpubl.) revealed an increase in blue-winged teal nesting densities with an increase in the average height and density of residual herbaceous vegetation, as evaluated by an average visual obstruction measurement (the height at which a round pole 3 x 150 cm is totally obscured by vegetation when viewed from a distance of 4.0 m) (Robel et al. 1970). Linear regression analysis of the data in Table 1 resulted in a regression equation of $Y = 7.54 + 2.83x$, a correlation coefficient (r) of 0.71 ($P < 0.05$), and a coefficient of determination (r^2) of 0.51. Nesting densities within a given class of visual obstruction measurements of residual vegetation varied widely, however, as indicated by the ranges in nesting density in Table 1, suggesting that other factors also had a major influence on nest density. One reason for the high variability in nest densities within given visual obstruction classes is that some nests may have been initiated after new growth had begun (Kirsch, pers. comm.), resulting in situations where residual vegetation was not a cue used in nest site selection. Kirsch (pers. comm.) and Lokemoen (pers. comm.) indicated that a field with an average visual obstruction measurement of residual vegetation ≥ 2.5 dm would be ideal nesting habitat for blue-winged teal.

A study on 15 areas in North Dakota, Saskatchewan, and Manitoba suggested that blue-winged teal will not nest in fields where the average visual obstruction measurement of vegetation in early spring (i.e., residual vegetation) is ≤ 0.2 dm (Shaffer et al. 1985). Beyond the apparent threshold of 0.2 dm, "...[average] cover height and density do not appear to constitute determining factors in nest site selection" (Shaffer et al. 1985:10). Regression of nest density (scaled by available pairs, field size, and a correction factor for different numbers of searches between fields) on the average visual obstruction measurement yielded a slope that was not significantly different from zero ($n = 77$, $P = 0.37$), although study area effects were significant ($P < 0.001$). The coefficient of multiple determination (R^2) was 0.51, indicating that 51% of the observed variation in nest density was explained by available pairs, visual obstruction measurements, or study area effect.

Table 1. Blue-winged teal nesting densities by classes of residual vegetation for fields on the Woodworth Study Area, North Dakota, 1974-1978 (data provided by L. Kirsch).

$\bar{x}$ visual obstruction measurement in dm (range)	Number of observations in class	Mean number of blue-winged teal nests/40.5 ha (range)
0.17 (0.12-0.24)	7	9.67 (1.00-20.45)
0.30 (0.25-0.34)	7	6.57 (0.00-18.18)
0.42 (0.35-0.49)	7	9.09 (0.00-21.95)
0.55 (0.50-0.60)	7	6.12 (0.00-20.00)
0.66 (0.62-0.72)	7	8.20 (0.00-21.00)
0.78 (0.74-0.83)	7	13.70 (0.00-24.24)
0.91 (0.86-0.98)	7	12.31 (0.00-39.13)
1.06 (1.01-1.14)	7	14.67 (5.26-25.56)
1.32 (1.18-1.44)	7	10.00 (0.00-25.00)
1.52 (1.45-1.60)	7	11.60 (0.00-30.48)
1.73 (1.62-1.91)	7	7.60 (2.50-26.09)
2.31 (2.01-2.86)	7	12.11 (0.00-30.00)
3.70 (3.18-4.22)	2	20.24 (15.15-25.33)

The annual loss of untilled upland nesting cover is a major factor contributing to suppressed duck production, regardless of water conditions (Higgins 1977). Untilled uplands in North Dakota supported a nest density 5.4 times greater than standing stubble, 12.9 times greater than growing grain, and more than 49 times greater than mulched stubble or summer fallow lands. Waterfowl pairs and broods increased in Montana where there was an increase in available residual herbaceous cover (Gjersing 1975). Blue-winged teal in Iowa showed a strong preference for dense vegetation, having highest nest success in tall, dense herbaceous vegetation containing deep litter (Heiser 1971, cited by Kirsch et al. 1978). Blue-winged teal nest density and success in North Dakota increased with an increase in the height and density of residual herbaceous vegetation (Kirsch et al. 1978), and blue-winged teal in an Iowa study area selected the densest cover available (Miller 1976). Consistently fewer blue-winged teal nests were associated with mowed and burned cover in North Dakota than areas where residual cover was not removed (Martz 1967). Residual cover height of 30.4 cm was believed to be sufficient to conceal nests. Height of herbaceous vegetation at blue-winged teal nests averaged 44.4 ± 4.1 cm in Iowa (Krapu et al. 1970) and 38 ± 1 cm in Wisconsin (Livezey 1981b). The average herbaceous height at blue-winged teal nests in another Iowa study was 40.9 cm and ranged from 22.9 to 71.1 cm (Miller 1976). Cover at Wisconsin nests averaged 33% ± 2% (Livezey 1981b). Kirsch et al. (1978:492) stated that they "... have not found grassland vegetation that was too tall and dense for use by nesting ducks nor have ...[they] found evidence that such conditions exist in the prairies." Livezey (1981b) concluded, however, that blue-winged teal preferred short-grass cover for nesting and used tall grasses and alfalfa only until the short grasses were sufficiently dense for nesting.

Blue-winged teal in Iowa preferred wet meadows over uplands for nesting (Miller 1976), but wetlands and hayfields were used equally in Wisconsin (Gates 1965). Ungrazed Kentucky bluegrass (*Poa pratensis*) was preferred over alfalfa hayland for nesting cover in Iowa (Krapu et al. 1970). Bluegrass was reported as a heavily used or preferred nesting cover in several other studies (Burgess et al. 1965; Miller 1976; Weller 1979; Livezey 1981b). Smooth bromegrass was a preferred nesting cover in South Dakota (Kaiser et al. 1979) and Iowa (Krapu et al. 1970).

Adequate cover for upland nesting ducks has been removed in the Prairie Pothole Region as a result of wetland drainage, annual hay cutting, and intensive tillage (Nelson and Duebbert 1974). Tillage operations destroyed 34% of all nests located in a North Dakota study area and 93% of the nests on croplands (Nelson and Duebbert 1974). Haying operations destroyed 78% of the mallard (*Anas platyrhynchos*) and blue-winged teal nests in a Wisconsin study area (Labisky 1957) and 32% of the blue-winged teal nests in a Nebraska study (Evans and Wolfe 1967). Increased grazing intensity has frequently been associated with lower dabbling duck nest success (Kirsch 1969; Miller 1971; Oetting and Cassel 1971; Kirsch et al. 1978). Pastures in South Dakota were considered unsuitable for blue-winged teal nesting due to heavy grazing (Drewien 1968). Results of studies in Iowa (Krapu et al. 1970), North Dakota (Higgins 1977; Kirsch et al. 1978), and Wisconsin (Livezey 1981b) suggested that undisturbed vegetation is the preferred and most productive nesting habitat for blue-winged teal. Blue-winged teal production on a South Dakota study area increased following grazing (Kaiser et al. 1979), however, and higher nest density and success were reported on moderately grazed areas than on ungrazed fields in Iowa (Burgess et al. 1965). Duebbert et al. (1981) recommended periodic disturbance to native and introduced grassland nesting habitat in order to maintain optimum conditions, although annual mowing or grazing was not recommended.

Brood habitat. Blue-winged teal broods in South Dakota used emergent vegetation as cover > 50% of the time (Ringelman and Flake 1980). Stock ponds used by blue-winged teal in South Dakota had significantly greater shoreline length ($\bar{x}$ = 737 m) than did unused ponds ($\bar{x}$ = 322 m), significantly greater cover of round-stemmed bulrushes (*Scirpus* spp.) (48 vs. 10%), significantly greater cover of spike rush (*Eleocharis* spp.) (33 vs. 18%), significantly greater area of stock pond surface water/0.65 km^2 (1.7 vs. 0.8 ha), and significantly more idle grassland (0.9 vs. 0.1 ha) (Mack and Flake 1980). Blue-winged teal broods in South Dakota used shallow, flooded emergent vegetation for feeding and open channels and ponds for swimming (Pendleton 1983). Use of North Dakota stock ponds by blue-winged teal broods was inversely correlated ($t = -1.84$, $P < 0.10$) with the distance to other water (Lokemoen 1973).

Fifty-five percent of 1,115 blue-winged teal broods observed during a 20-year period in North and South Dakota occurred on semipermanent wetlands (Class IV of Stewart and Kantrud 1971), 32% were on seasonal wetlands (Class III), and 6% were on permanent wetlands (Class V) (Duebbert and Frank 1984). The proportion of the total wetland area accounted for by these wetland types in North Dakota was 18% semipermanent, 36% seasonal (including 3% in tilled condition), and 3% permanent (Stewart and Kantrud 1973). However, these wetland availability figures were for 1 year only, apparently reflected the availability of wetlands to pairs, and may not be a valid estimate of the wetland distribution available to broods. Blue-winged teal broods during a 15-year period in Saskatchewan were positively correlated with the number of pairs in the preceding spring (second-order, Spearmen-rank, partial correlation coefficient = 0.62; $P < 0.01$) and the number of wetlands containing water in August (second-order, Spearman-rank, partial correlation coefficient = 0.32; $P < 0.1$) (Leitch and Kaminski 1985).

Interspersion

Blue-winged teal have small home ranges and commonly use nearby wetlands in their daily activities (Flake et al. 1977). Maximum waterfowl production in the pothole region depends upon the availability of a number of different wetland types, each of which fulfills certain requirements of duck species. Closely associated wetland complexes are especially important for waterfowl with small home ranges, such as the blue-winged teal. Decreased use of semipermanent wetlands and stock ponds by blue-winged teal pairs in South Dakota was associated with the drying up of ephemeral, temporary, and seasonal wetlands during a drought (Ruwaldt et al. 1979). Use of stock ponds by blue-winged teal pairs and broods in North Dakota decreased as the distance to other water bodies increased (Lokemoen 1973).

The average distance from blue-winged teal nests to open water ranged from 37.5 (Bennett 1938) to 95.8 m (Krapu et al. 1970) in Iowa. The average nest to water distance in two Wisconsin studies was 155.0 ± 24.0 m (Livezey 1981b) and 202.2 m (Labisky 1957). Blue-winged teal nests in North Dakota averaged 256.0 m from water, and no nests were located more than about 1,000 m from a wetland > 1.2 ha (Duebbert and Lokemoen 1976). G. A. Swanson (U.S. Fish and Wildlife Service, Northern Prairie Wildlife Research Center, Jamestown, ND; pers. comm.) suggested that selection of nesting habitat by blue-winged teal is based on proximity to pair feeding habitat rather than on proximity to potential brood-rearing habitat.

Blue-winged teal territories in Manitoba averaged 0.27 ha from nest site selection through the third week of incubation and rarely overlapped the territories of other blue-winged teal (Stewart and Titman 1980). Fourteen blue-winged teal pairs in South Dakota had an average home range size of 68.4 ha, with a range of 30.0 to 87.1 ha (Drewien 1968). However, activity centers of 12 pairs averaged 9.7 ha and ranged from 4.0 to 15.8 ha.

Information on nesting densities of blue-winged teal has been reported from several study areas. For ease of comparison, information from the studies referred to below has been standardized to the number of nests per km^2. Maximum reported blue-winged teal nest density in a North Dakota study was 96.7 nests/km^2 based on 12 nests in a 9.3 ha field (Kirsch, unpubl.); a 12.1 ha ungrazed island in Iowa supported 190 nests/km^2 (Glover 1956). Most average densities reported in the literature are below these levels. For example, blue-winged teal nest density in South Dakota averaged 23.1 nests/km^2 in native prairie and 20.6 nests/km^2 in tame grasses (Kaiser et al. 1979). Blue-winged teal in North Dakota initiated an estimated 69 nests/km^2 in seeded native grasses, 63/km^2 in seeded introduced grasses, and 54/km^2 in unplowed prairie (Klett et al. 1984). Estimated nest initiation rates in South Dakota were 71/km^2 in seeded native grasses, 34/km^2 in seeded introduced grasses, and 28/km^2 in unplowed prairie. Nest density in Iowa was 24.7 nests/km^2 in a grazed grassland and 14.5 nests/km^2 in an ungrazed grassland (Burgess et al. 1965). Other Iowa studies reported densities in bluegrass habitats of 20.2 nests/km^2 (Glover 1956) and 19.0 nests/km^2 (Krapu et al. 1970); sedge (Carex spp.)-meadow habitats supported 21.5 nests/km^2 (Glover 1956), bromegrass supported 24.7 nests/km^2, and alfalfa-hayland only supported 3.4 nests/km^2 (Krapu et al. 1970). Untilled upland habitats in an intensively farmed area in North Dakota supported only 7.4 nests/km^2, and blue-winged teal nests in agricultural lands ranged from 0.10 nests/km^2 in summer fallow lands to 1.36 nests/km^2 in standing stubble (Higgins 1977). Maximum blue-winged teal nest density in an area with intensive predator control was 16.0 nests/km^2 (Duebbert and Lokemoen 1980). The observed success rate of 87% resulting from intensive predator control is the highest success rate located in the literature.

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area. This HSI model was originally developed for use in central and eastern North Dakota. It is considered applicable throughout the

Prairie Pothole Region, where the greatest breeding densities of blue-winged teal occur (Fig. 1). Within the United States, this region includes the mixed-grass prairie of North and South Dakota; the tallgrass prairie in western Minnesota, eastern North and South Dakota, and the sandhills of Nebraska; and the shortgrass prairie west of the Missouri River through Montana (Bellrose 1976, 1979). The model also should be applicable within the Prairie Provinces of Canada and may be applicable in other portions of the breeding range of blue-winged teal.

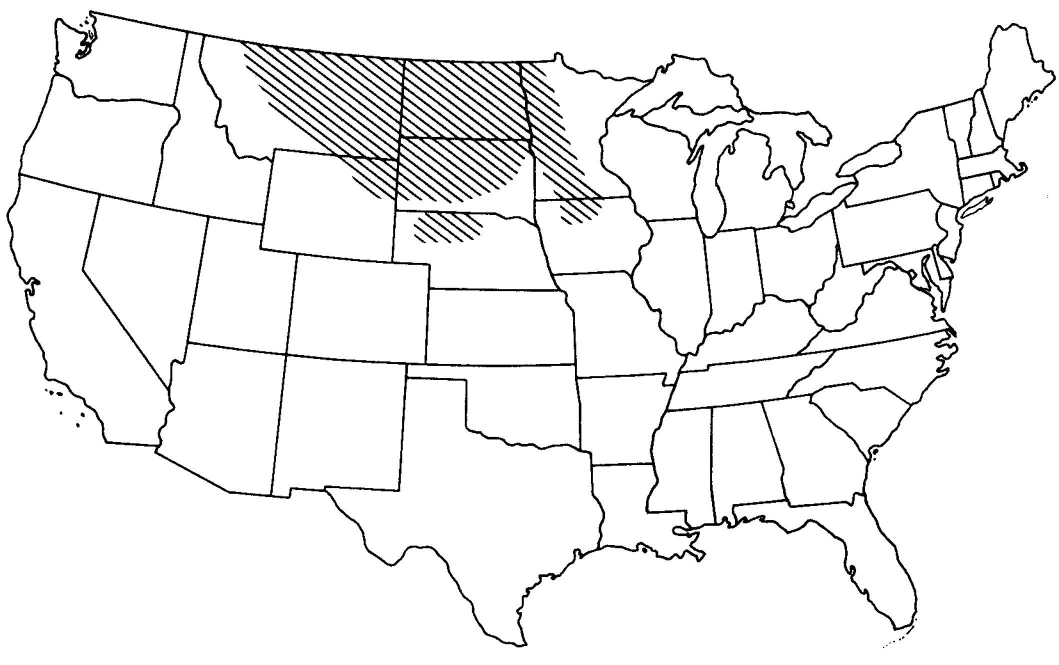

Figure 1. Geographic applicability of the blue-winged teal HSI model within the United States (corresponds to areas of highest blue-winged teal breeding densities, as shown in Bellrose 1976).

Season. This HSI model was developed to evaluate the quality of potential spring and summer habitat for blue-winged teal.

Cover types. During the breeding season, blue-winged teal may use any of the following upland cover types for nesting (terminology follows that of U.S. Fish and Wildlife Service 1981): Cropland (C); Pasture and Hayland (P/H); Grassland (G); and Forbland (F). Blue-winged teal pairs and broods use a variety of wetlands classes in the Palustrine and Lacustrine Systems (terminology from Cowardin et al. 1979). The data that were used to develop the pair and brood components of this model, however, were based on the classification system of Stewart and Kantrud (1971). Data presented in this model follow the Stewart and Kantrud (1971) classification used in the original references. The seven wetland classes defined by Stewart and Kantrud (1971) generally correspond to the water regime modifiers of Cowardin et al. (1979) (Table 2). The model can be used with either classification system using the relationships in Table 2. Definitions of the wetland classes and water regime modifiers listed in Table 2 are provided in the model section titled Application of the Model. Constructed wetlands (e.g., stock ponds, dugouts, and reservoirs) can be included in this model by classifying them into one of the wetland classes or water regime modifiers based on a comparison of their physical and vegetational characteristics to the criteria used in the appropriate classification system.

Minimum habitat area. Minimum habitat area is defined as the minimum amount of contiguous habitat that is required before an area will be occupied by a species. Specific information on the minimum habitat area for blue-winged teal was not located in the literature.

Verification level. The critical habitat requirements and associated habitat variables identified in this model resulted from a modeling workshop held April 13-16, 1982, in Fort Collins, Colorado. The purpose of the workshop was to develop habitat models for the blue-winged teal and gadwall (*Anas strepera*) based on the available literature and the expertise of the following individuals:

John Lokemoen, U.S. Fish and Wildlife Service, Northern Prairie Wildlife Research Center, Jamestown, North Dakota.

George Swanson, U.S. Fish and Wildlife Service, Northern Prairie Wildlife Research Center, Jamestown, North Dakota.

Leo Kirsch, U.S. Fish and Wildlife Service (retired), Woodworth, North Dakota.

Michael McEnroe, U.S. Fish and Wildlife Service, Ecological Services, Bismarck, North Dakota.

Richard McCabe, Bureau of Reclamation, Bismarck, North Dakota.

Table 2. Comparison of the wetland classes of Stewart and Kantrud (1971) with the water regime modifiers of Cowardin et al. (1979). (Modified from Cowardin et al. 1979)

Wetland class (Stewart and Kantrud 1971)	Water regime modifier (Cowardin et al. 1979)
I Ephemeral ponds	None, not considered a wetland
II Temporary ponds	Temporarily flooded
III Seasonal ponds and lakes	Seasonally flooded
IV Semipermanent ponds and lakes	Semipermanently flooded
None[a]	Intermittently exposed
V Permanent ponds and lakes	Permanently flooded (with mixohaline water)
VI Alkali ponds and lakes	Intermittently flooded (with saline or hypersaline water)
VII Fen (alkaline bog) ponds[b]	Saturated

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

[b]Fens are not included in the blue-winged teal HSI model.

A meeting was held May 25-28, 1982 in Bismarck, North Dakota, to review the waterfowl models developed from the workshop. Results of the review indicated that the pair and brood components of the model appeared to meet the perceptions of the participants about the suitability of several study areas for which data were available. The reliability of the nesting component of the model was questioned, but could not be evaluated with the available data. Participants in the review meeting were J. Lokemoen, L. Kirsch, M. McEnroe, R. McCabe, and F. Ryckman and M. Johnson (North Dakota Department of Game and Fish, Bismarck, North Dakota).

A review of the assumptions and limitations of the model was conducted May 24-25, 1983 in Jamestown, North Dakota. Participants in the review were J. Lokemoen, L. Kirsch, R. McCabe, R. Schultz (Bureau of Reclamation, Bismarck, North Dakota), S. Young (U.S. Fish and Wildlife Service, Ecological Services, Bismarck, North Dakota), and T. Steinwand (North Dakota Department of Game and Fish, Bismarck, North Dakota). Participants in the model review meeting concluded that the HSI model was realistic and as good as could be expected without further field testing and/or application. J. Lokemoen and L. Kirsch concluded that the model would adequately predict potential habitat quality for blue-winged teal in the Prairie Pothole Region. Data provided by L. Kirsch at this meeting were used to develop the nesting component portion of the current model.

A study was conducted on several study areas in North Dakota and Canada to further evaluate the relationship between average vegetative conditions of a field and use of of the field by nesting blue-winged teal (Shaffer et al. 1985). Results of the study were used to modify the nesting component of the current model.

Model Description

Overview. Habitat suitability for breeding blue-winged teal can be evaluated by assessing the habitat requirements for pairs, nesting hens, and broods. Habitat suitability for pairs and broods is a function of the availability and distribution of wetlands; pairs are able to use all wetland types, but broods are restricted to more permanent wetlands that provide a reliable source of water during the brood-rearing period. Suitability of nesting habitat is dependent on the abundance of dense, tall herbaceous cover.

This HSI model provides a method to evaluate blue-winged teal habitat suitability within the context of habitat suitability for all species of upland nesting waterfowl in the Prairie Pothole Region. The standards of comparison used in the pair, nesting, and brood components of this model are based on the needs of all upland nesting waterfowl. Evaluation of the habitat in a given area, however, is modified by the specific habitat requirements of the blue-winged teal to obtain a Habitat Suitability Index for this species.

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

Pair habitat component. Blue-winged teal pairs use wetlands for feeding, loafing, and courtship prior to nesting. Data on the use of basin wetlands in the Prairie Pothole Region of North Dakota (Kantrud and Stewart 1977) and in South Dakota (Ruwaldt et al. 1979) indicate that various classes of wetlands (as defined by Stewart and Kantrud 1971) are used to different degrees by blue-winged teal pairs. An index of preference for wetland classes can be developed, based on pair use compared to the availability of wetland classes. These indices are presented in Table 3, based on North Dakota data (Stewart and Kantrud 1973; Kantrud and Stewart 1977), and in Table 4, based on data from South Dakota wetlands (Ruwaldt et al. 1979). Based on this analysis, the highest quality natural wetlands for blue-winged teal pairs in North Dakota are semipermanent wetlands, followed by seasonal and temporary wetlands (Table 3). Semipermanent wetlands were also the most preferred wetland class by blue-winged teal pairs in South Dakota, followed by seasonal and permanent wetlands (Table 4). Use of preference indices assumes that all wetlands within a given class have the same value for blue-winged teal pairs. Variability associated with other factors, such as available food, open water to vegetation ratio, and shoreline length and irregularity, are not addressed in this model. Although variability within a wetland class certainly occurs, this model is intended for evaluation of large areas with numerous wetlands, rather than an evaluation of each wetland.

Blue-winged teal pairs also use constructed wetlands. Preference indices for blue-winged teal pairs in constructed wetlands are not included in this model, however, because the classification of constructed wetlands is not based on ecological characteristics. If constructed wetlands are to be included in an application of this model, preference indices must be developed by the model users. Similarities in water conditions and vegetation between constructed and natural wetlands can be used to assign pair preference indices to constructed wetlands. Data provided by Ruwaldt et al. (1979) for South Dakota may be useful in developing pair preference indices for stock ponds and dugouts.

Optimum conditions for waterfowl pairs, including blue-winged teal, in the Prairie Pothole Region are assumed to exist when a minimum of 150 optimum wetlands account for a minimum of 64.8 ha/259 ha. This assumption was based on the perceived need for a large number of small wetlands within a section (259 ha) in order to support the maximum number of waterfowl pairs, while still providing potentially optimum nesting and brood habitat (discussed below). The selection of 150/section as the standard of comparison for the density of optimum wetlands was based on the opinion of species experts in the modeling workshop that this is an attainable figure that represents optimum conditions.

A complete lack of wetlands provides no pair suitability. The value of wetlands to pairs is assumed to decrease in a linear relationship as the number and area of wetlands approaches zero. Pair densities on smaller wetlands are usually greater than on larger wetlands, because 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 64.8 ha/section) equate 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, a condition considered by workshop participants to be optimum for pairs.

Table 3. Determination of a wetland preference index for blue-winged teal pairs in the Prairie Pothole Region of North Dakota.

Wetland class[a]	Blue-winged teal use (% of total distribution)[b]	Availability of wetland class (% of total wetland area)[c]	Use/availability	Index[d]
Ephemeral (I)	≤0.05	1	≤0.05	≤0.03
Temporary (II)	2.70	3	0.90	0.52
Seasonal (III)	61.20	36	1.70	0.98
Semipermanent (IV)	31.20	18	1.73	1.00
Permanent (V)	2.50	3	0.83	0.48
Alkali (VI)	0.30	6	0.05	0.03

[a]The classification used is that of Stewart and Kantrud (1971), because data on waterfowl use presented by Kantrud and Stewart (1977) were based on this classification. See Table 2 and Application of the Model for guidelines on using other wetland classification systems.

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

[c]From Stewart and Kantrud (1973:45, Table 2). The number represents the proportion of total wetland acreage accounted for by the individual wetland class. Total is 67% because only those wetland classes of the Stewart and Kantrud (1971) classification system referred to in Kantrud and Stewart (1977) were used. The remaining wetlands were undifferentiated tillage ponds (25%), streams and oxbows (5%), and constructed wetlands (≤ 3%).

[d]Determined by dividing the use/availability value by 1.73, the maximum use/availability value.

Table 4. Determination of a wetland preference index for blue-winged teal pairs in South Dakota.

Wetland class[a]	Blue-winged teal use (% of total distribution)[b]	Availability of wetland class (% of total wetland area)[c]	Use/availability	Index[d]
Ephemeral (I)	0.25	14	0.02	0.01
Temporary (II)	5.05	11	0.46	0.34
Seasonal (III)	10.60	13	0.82	0.61
Semipermanent (IV)	42.90	32	1.34	1.00
Permanent (V)	2.90	4	0.72	0.54
Alkali (VI)	--	--	--	--

[a]The classification used here is that of Stewart and Kantrud (1971). See Table 2 and Application of the Model for guidelines on using other wetland classification systems.

[b]From Ruwaldt et al. (1979:378, Table 3). Figures represent the average of use data provided for 1973 and 1974. Use of natural wetland basins equals 61.7%; remaining use was on streams and constructed wetlands.

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

[d]Determined by dividing the use/availability value by 1.34, the maximum use/availability value.

The number of wetlands on a study area can be converted to an equivalent number of optimum wetlands by weighting the number of wetlands in each class by the wetland preference indices for pairs (Table 3 or Table 4):

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

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

n = the number of wetland classes available

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

p_i = preference index for blue-winged teal pairs for wetland class i.

Equation 1 determines the sum of the number of wetlands per section weighted by the quality of the wetland classes for blue-winged teal pairs. The relationship between the number of equivalent optimum wetlands/259 ha and a suitability index (SIV1) for blue-winged teal pairs is presented in Figure 2a.

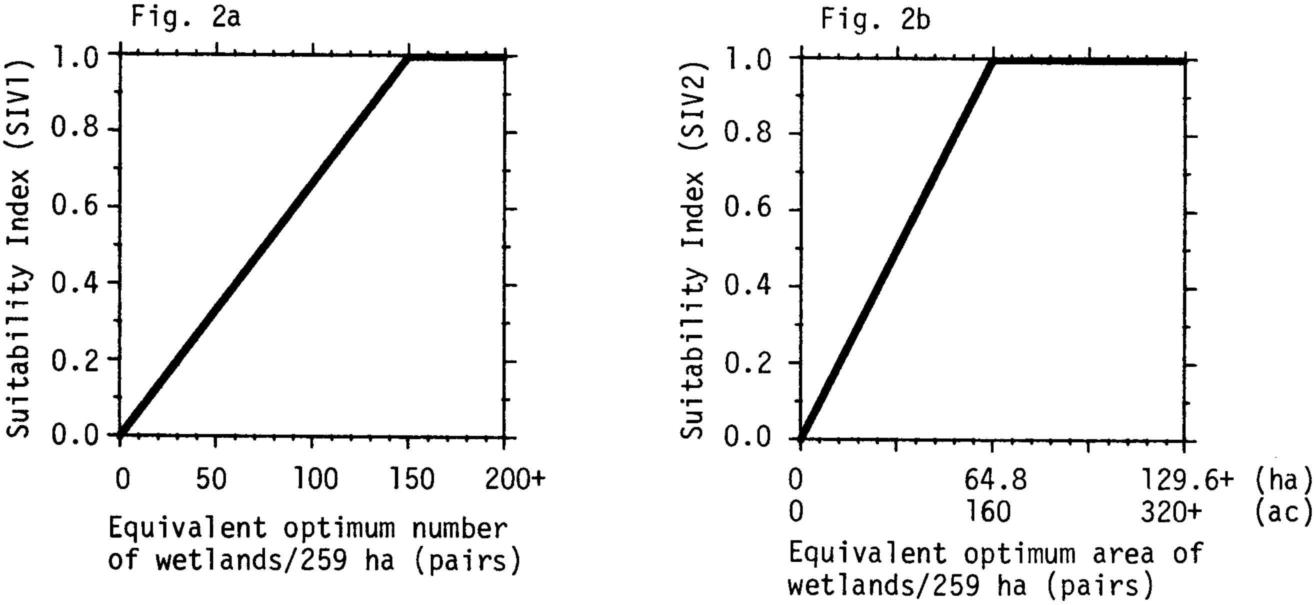

Figure 2. The relationship between values of variables used to evaluate blue-winged teal pair habitat and suitability indices for the variables.

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

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

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

a_i = area of wetlands of class i/259 ha

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

Number and area of wetlands are assumed to be of equal importance in determining habitat suitability for blue-winged teal pairs. These two variables are not entirely independent. For example, an increase in the number of equivalent optimum wetlands will likely result in an increase in equivalent optimum area of wetlands for blue-winged teal 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 index for pair habitat suitability (SIP). This relationship is best expressed by a geometric mean of the suitability indices for the two variables:

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

Nesting habitat component. Blue-winged teal typically select the tallest, most dense herbaceous vegetation available in which to nest. As herbaceous height and density increase, the potential for nest establishment and success is enhanced. Residual herbaceous cover (i.e., vegetation available before the growing season begins) is a particularly important source of suitable nest cover. Herbaceous height and density are assumed to be more important than herbaceous composition. Herbaceous vegetation < 0.5 dm tall, however, is rarely used for nesting cover by blue-winged teal, regardless of the density (Kirsch, unpubl.). A recent study in North Dakota and Canada suggested that an average visual obstruction measurement of 0.2 dm appeared to be a threshold below which blue-winged teal would not nest (Shaffer et al. 1985).

A visual obstruction measurement that incorporates height and density into a single descriptor of vegetative structure (Robel et al. 1970) can be used to determine an index of the quantity and quality of residual vegetative cover. A visual obstruction measurement is the height, to the nearest 0.5 dm, at which a round pole 3.0 x 150.0 cm is totally obscured by vegetation when viewed from a distance of 4.0 m (Robel et al. 1970). Table 1 displays the mean nesting density of blue-winged teal by visual obstruction classes from 1974 to 1978 on the Woodworth Study Area, Woodworth, North Dakota. Workshop participants believed that a field with a mean visual obstruction measurement of ≥ 2.5 dm represented ideal nesting conditions. Therefore, a mean visual obstruction measurement of ≥ 2.5 dm is considered equal to optimum nesting quality (corresponding to a 1.0 Suitability Index). The regression equation determined for the data in Table 1 is:

$$Y = 7.54 + 2.83x \qquad (4)$$

where Y = blue-winged teal nests/40.5 ha

x = mean visual obstruction measurement (dm) for a given field

Equation 4 can be modified to provide an output that is an index of the nesting suitability of a habitat. This is accomplished by first assuming that a mean visual obstruction measurement ≥ 2.5 dm equals a suitability index of 1.0. The nest density prediction from Equation 4 when the mean visual obstruction measurement equals 2.5 (i.e., nest density equals 14.6) is used as the maximum nest density. The predicted nest density of 7.88 nests/40.5 ha when the mean visual obstruction measurement equals 0.12 (the lowest observed value reported in Kirsch's data) can be compared to the maximum nest density. The resulting index for this predicted nest density is 0.54 [i.e., (7.88 nests/40.5 ha)/(14.6 nests/40.5 ha)]. The same approach when the mean visual obstruction measurement equals 0.0 yields a suitability index of 0.52. However, sites that have a visual obstruction measurement of 0.0 throughout the nesting season (e.g., summer fallow) will not provide any cover for nests. Therefore, a mean visual obstruction measurement of 0.0 prior to spring vegetative growth is assigned a suitability index of 0.0. This approach may underestimate areas of growing grain or alfalfa that may provide some nesting cover later in the nesting season, however, far fewer nests are placed in intensively farmed areas than in untilled uplands (Higgins 1977). Therefore, assigning a 0.0 suitability to areas with a mean of 0.0 for the visual obstruction measurement of residual vegetation may not be a significant underestimate of habitat suitability for the blue-winged teal.

The relationship between a suitability index (SIV3) for nesting blue-winged teal and an average visual obstruction measurement in a given field is shown in Figure 3a. The index obtained from Figure 3a represents the potential of a cover type to support maximum blue-winged teal densities based on residual vegetation conditions. The limited range of suitability values indicated in Figure 3a for visual obstruction measurements between 0.12 to 2.5 dm ($0.54 \leq SIV3 \leq 1.0$) is supported by a recent study indicating that the height and density of residual vegetation appears to have little influence on nest site selection by blue-winged teal as long as the average visual obstruction measurement exceeds 0.2 dm (Shaffer et al. 1985).

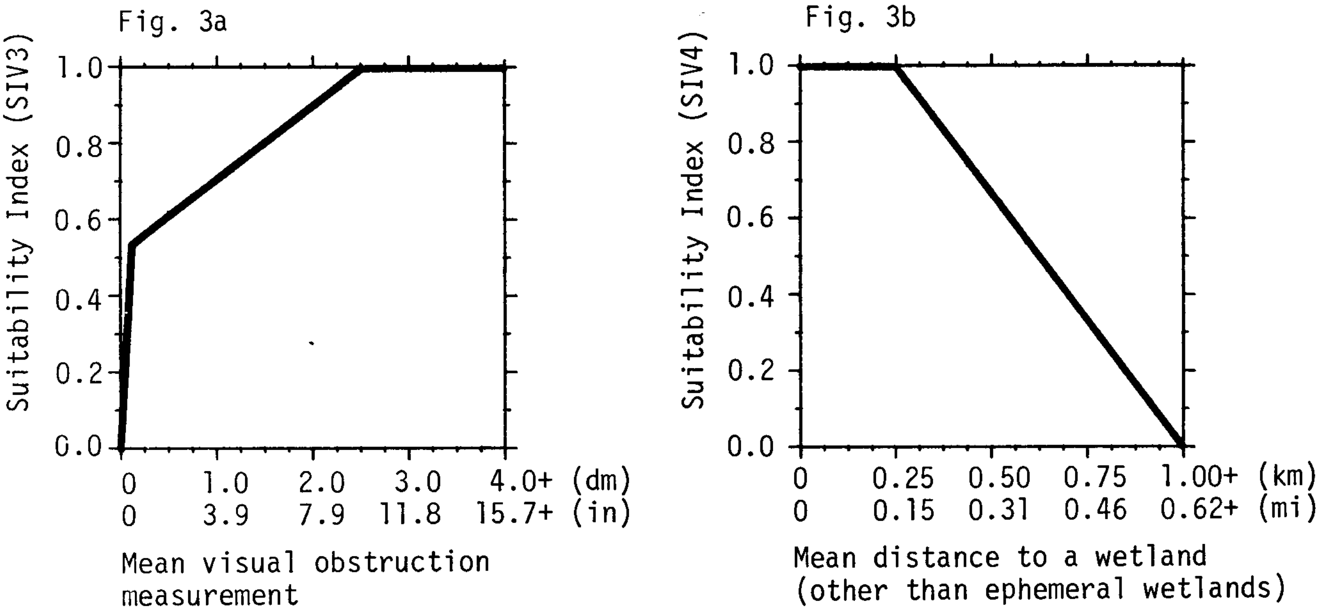

Figure 3. The relationships between values of variables used to evaluate blue-winged teal nesting habitat in a given field and suitability indices for the variables.

Distance from nesting cover to suitable wetland habitat influences the value of potential nesting cover. The majority of blue-winged teal in a South Dakota study nested within 250 m of wetlands > 1.2 ha and rarely nested > 1,000 m (1,093 yd) from such wetlands (Duebbert and Lokemoen 1976). Selection of nesting habitat is influenced more by proximity of wetlands available to pairs than by proximity of larger brood wetlands (Swanson, pers. comm.). Swanson (pers. comm.) suggested that the size of the nearest available wetland is less important than water regime, and that any wetland other than ephemeral wetlands will provide potential pair habitat. Therefore, optimum nest cover values are assumed to occur at ≤ 250 m from any wetland other than ephemeral wetlands (if the classification system of Stewart and Kantrud 1971 is used). Nesting cover located > 1000 m from a nonephemeral wetland is considered unavailable to nesting blue-winged teal hens. The relationship between these assumptions and a suitability index (SIV4) is depicted in Figure 3b.

The physical suitability of a cover type for blue-winged teal nesting is based on the suitability index obtained for the mean visual obstruction measurement for the cover type (SIV3). This suitability is directly modified by the availability of the cover type for nesting, which is evaluated by the suitability index obtained for distance to a wetland from the cover type (SIV4) to yield a suitability index for nesting (SIN). This relationship is expressed as:

$$SIN_i = SIV3_i \times SIV4_i \qquad (5)$$

Equation 5 determines the nesting suitability of a given cover type. In order to be directly comparable to the suitability of pair habitat and brood habitat (discussed below), the suitability values for each cover type must be combined to obtain an overall estimate of the suitability of available nesting habitat. The contribution of each cover type to nesting quality is a function of quality and area. The sum of the products of quality and area across all cover types yields an estimate of the equivalent optimum area of nesting habitat available to the blue-winged teal. This value can be determined by:

$$EOAN = \frac{259}{S} \sum_{i=1}^{m} (A_i SIN_i) \qquad (6)$$

where EOAN = the equivalent optimum area of blue-winged teal nesting habitat/259 ha

S = size of the total study area in hectares

m = the number of cover types potentially providing blue-winged teal nesting cover

A_i = the area of cover type i

SIN_i = the nesting suitability index for cover type i (from Equation 5)

The estimate obtained from Equation 6 must be compared to an optimum condition in order to obtain an overall index of nesting habitat quality for the area being evaluated. Optimum wetland habitat for pairs and broods is considered in this model to equal 64.8 ha of optimum wetlands/259 ha. Under the best wetland conditions, therefore, 194.2 ha of the section could be managed for optimum nesting habitat for blue-winged teal. Optimum conditions are, therefore, assumed to exist if there are 64.8 ha of optimum wetlands and 194.2 ha of optimum nesting habitat/259 ha. If no nesting habitat is available, the index of nesting quality is 0.0. A linear relationship is assumed to exist for values of equivalent optimum area of nesting habitat per section between 0 and 194.2 ha (Fig. 4). The estimated equivalent optimum nesting habitat per section from Equation 6 can be compared to Figure 4 to obtain an index of nesting habitat quality (SIN) for a given study area.

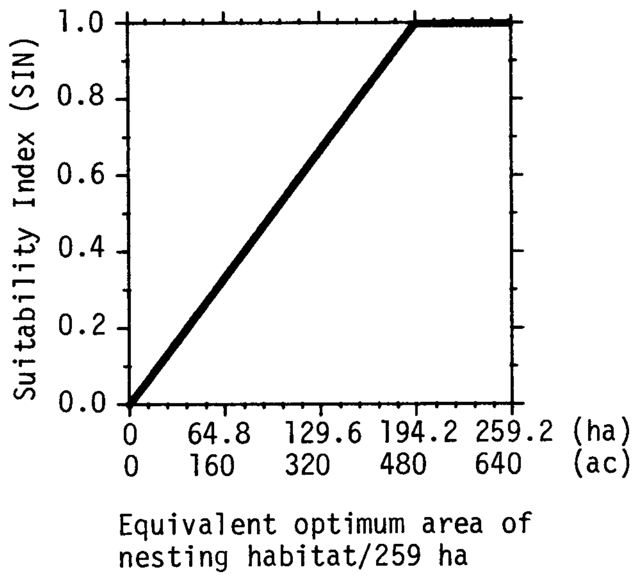

Figure 4. The relationship between the equivalent optimum area of blue-winged teal nesting habitat and an overall nesting habitat suitability index.

Brood habitat component. Habitat suitability for blue-winged teal broods is a function of wetland availability and distribution. Workshop participants believed that different wetland classes have different potentials to support blue-winged teal broods. Indices that indicate the relative value of each wetland class to blue-winged teal broods were assigned (Table 5). These values were based on the experiences of workshop participants and considered several factors, including water permanence, vegetative cover, water depth, potential food resources, and observed usage of the wetland classes. Semipermanent wetlands were considered the preferred natural wetland class for blue-winged teal broods, followed by permanent, seasonal, and alkali wetlands. Ephemeral and temporary wetlands were assigned a value of 0.0 because they typically are unavailable during the brood-rearing period. Support for these wetland rankings for blue-winged teal brood use is presented in Table 5, based on observed blue-winged teal brood use (Duebbert and Frank 1984) and the availability of wetlands (Stewart and Kantrud 1973). The only major discrepancy in the two brood indices is for alkali wetlands. This difference may be due to the low number of observed broods (n = 3 over 20 years; Duebbert and Frank 1984) that may have been a function of the large size of alkali wetlands (6% of wetland area; < 0.05% of wetland numbers; Stewart and Kantrud 1973). The indices proposed by workshop participants are recommended for use in model applications because the use/availability indices are based on a limited amount of wetland data.

Table 5. Wetland preference indices for blue-winged teal broods in the Prairie Pothole Region.

Wetland class[a]	Preference index[b] (expert opinion)	Preference index[c] (use/availability)
Ephemeral (I)	0.00	--
Temporary (II)	0.00	<0.001
Seasonal (III)	0.50	0.29
Semipermanent (IV)	1.00	1.00
Permanent (V)	0.50	0.65
Alkali (VI)	0.15	<0.001

[a]Terminology from Stewart and Kantrud (1971). See Table 2 and Application of the Model for guidelines on using other classification systems.

[b]Based on input from workshop participants; recommended for use in model applications.

[c]Based on brood use data from Duebbert and Frank (1984) and wetland availability data from Stewart and Kantrud (1973).

Blue-winged teal broods also use constructed wetlands (e.g., stockponds and dugouts). Preference indices for blue-winged teal broods in constructed wetlands are not included in this model because the classification of constructed wetlands is not based on ecological characteristics. If constructed wetlands are considered in a given application of this model, preference indices must be developed by model users. Similarities in water conditions and vegetation between constructed and natural wetlands can be used to assign brood preference indices to constructed wetlands.

Use of preference indices (Table 5) implies that all wetlands within a given wetland class or water regime are of the same value to blue-winged teal broods. While differences in suitability for broods exist between wetlands of a given class or water regime, this model is intended for evaluation of large areas with numerous wetlands, rather than an evaluation of each wetland.

Optimum habitat conditions for waterfowl broods, including blue-winged teal, are assumed to exist when at least 20 ha of equivalent optimum wetlands and at least six equivalent optimum wetlands are present per section. A total lack of wetlands provides no brood suitability. The value of wetlands to waterfowl broods is assumed to decrease from optimum conditions in a linear relationship as the number and area of optimum wetlands approaches 0. The selection of 20 ha as the standard of comparison was based on the opinion of Lokemoen (pers. comm.) that 100 waterfowl broods/259 ha was an attainable production level. Further, he assumed that a semipermanent wetland (optimum brood habitat as defined by this model) could support two broods/0.4 ha. Therefore, 20 ha of optimum wetlands could support the maximum production of 100 broods/259 ha. The selection of a minimum of six optimum wetlands/259 ha is based on the experiences of workshop participants.

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 5), as follows:

$$EONWB = \sum_{i=1}^{n} (w_i b_i) \qquad (7)$$

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

n = the number of wetland classes available

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

b_i = preference index for blue-winged teal broods for wetland class i (from Table 5)

Equation 7 determines the sum of the number of wetlands per section weighted by the quality of the classes of wetlands available for blue-winged teal broods. The relationship between the number of equivalent optimum wetlands for broods per section and a suitability index (SIV6) for blue-winged teal broods is presented in Figure 5a.

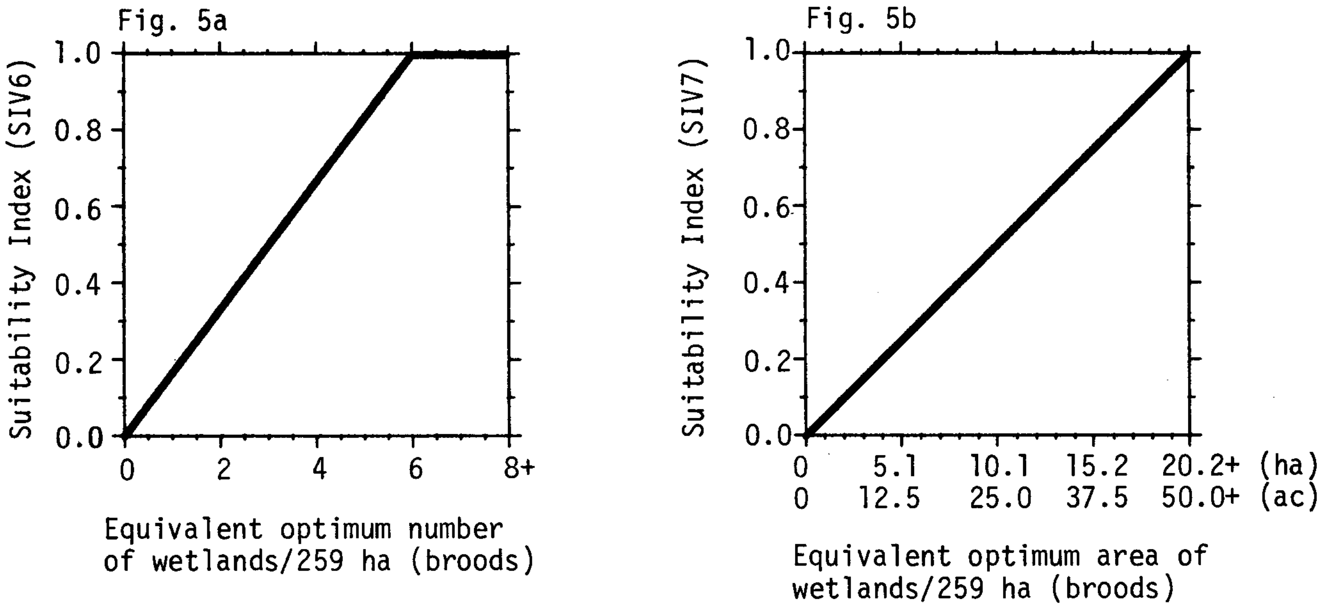

Figure 5. The relationships between values for habitat variables used to evaluate blue-winged teal brood habitat and suitability indices for the variables.

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

$$EOAWB = \sum_{i=1}^{n} (a_i b_i) \quad (8)$$

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

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

Equation 8 determines the sum of the area of wetlands per section weighted by the quality of the wetlands available for blue-winged teal broods. The relationship between this value and a suitability index (SIV7) for blue-winged teal broods is shown in Figure 5b.

The two variables selected for evaluating brood cover are not entirely independent. For example, an increase in the number of equivalent optimum wetlands will likely result in an increase in equivalent optimum area for blue-winged teal broods. Although area and number of wetlands 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:

$$SIB = (SIV6 \times SIV7)^{1/2} \tag{9}$$

HSI determination. The calculation of life requisite values considered composition and interspersion needs. The production of blue-winged teal on a particular area is assumed to be ultimately determined by the component with the lowest potential to support the needs of the species. The Habitat Suitability Index is based on the limiting factor theory and equals the lowest of the suitability indices determined for pair (SIP), nesting (SIN), or brood (SIB) habitat.

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, nesting, and brood-rearing habitat for the blue-winged teal (Fig. 6). The relationships between the habitat variables, derived variables, and life requisites used in this model and an HSI for the blue-winged teal are summarized in Figure 7. The definitions and suggested measurement techniques for the variables used in this model are listed in Figure 8.

Pair Component		Page
Equation (1)	$EONWP = \sum_{i=1}^{n} (w_i p_i)$	16
(2)	$EOAWP = \sum_{i=1}^{n} (a_i p_i)$	17
(3)	$SIP = (SIV1 \times SIV2)^{1/2}$	17
Nesting Component		**Page**
Equation (4)	$Y = 7.54 + 2.83x$	18
(5)	$SIN_i = SIV3_i \times SIV4_i$	20
(6)	$EOAN = \frac{259}{S} \sum_{i=1}^{m} (A_i SIN_i)$	20
Brood Component		**Page**
Equation (7)	$EONWB = \sum_{i=1}^{n} (w_i b_i)$	23
(8)	$EOAWB = \sum_{i=1}^{n} (a_i b_i)$	24
(9)	$SIB = (SIV6 \times SIV7)^{1/2}$	25

Figure 6. Summary of equations used in the blue-winged teal HSI model (equation variables are defined on the pages indicated).

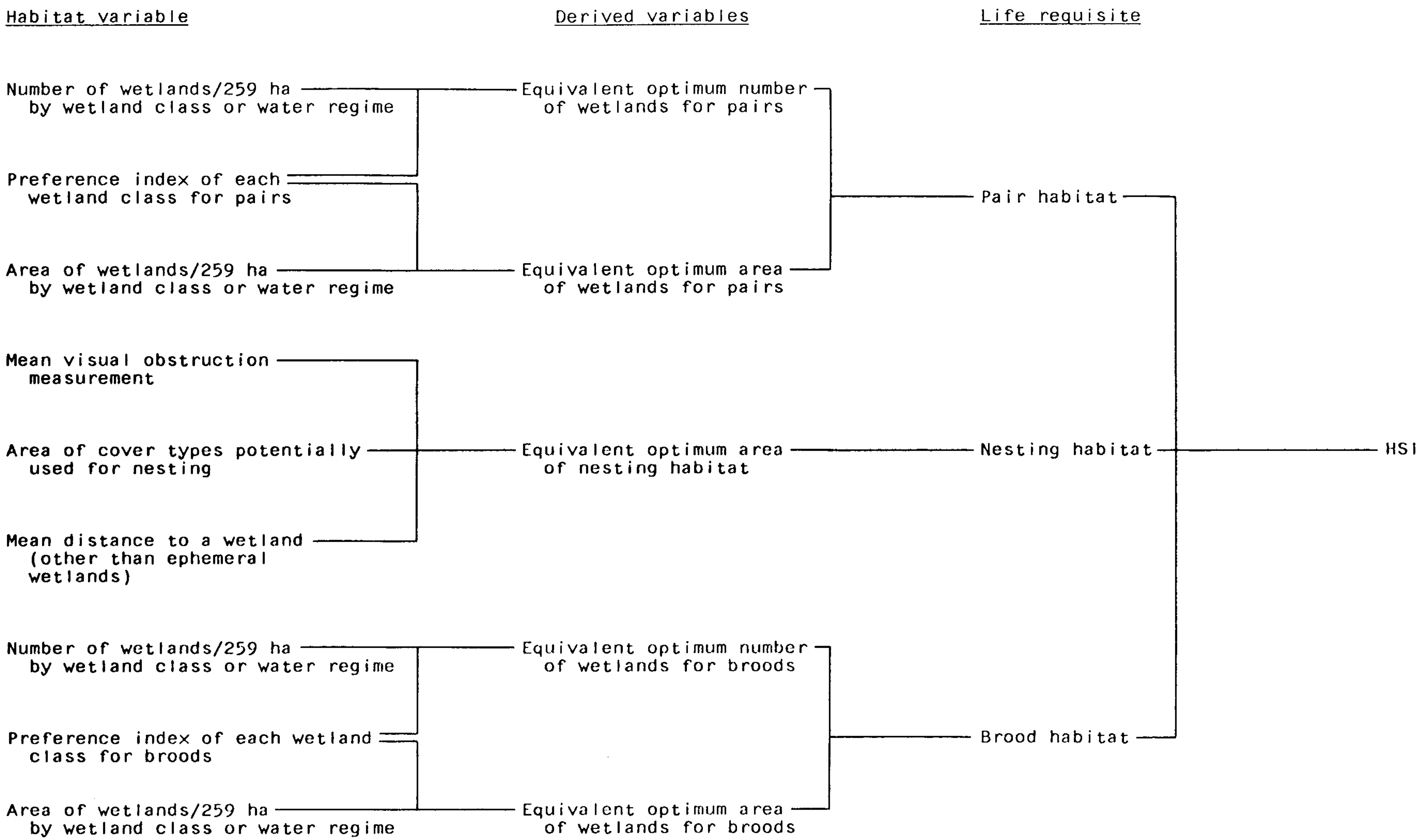

Figure 7. The relationships between habitat variables, derived variables, life requisites, and an HSI for the blue-winged teal.

Variable (definition)	Cover types	Suggested technique
Number of wetlands/259 ha (640 ac) by wetland class or water regime.	Entire study area	Classify wetlands and tally number within each wetland class (Stewart and Kantrud 1971) or water regime (Cowardin et al. 1979; convert density for each class or water regime to number/ 259 ha.
Area of wetlands/259 ha (640 ac) by wetland class or water regime.	Entire study area	Classify wetlands and determine area of each wetland; sum the areas of all wetlands in each wetland class or water regime; convert total area of each class or water regime to ha/259 ha.
Mean visual obstruction measurement of residual vegetation [an estimate of the amount of cover provided by residual vegetation within a cover type; measured as the height at which a pole is totally obscured by vegetation when viewed from a distance of 4 m (13.1 ft)].	C,P/H,G,F	Transect.
Mean distance to a wetland (other than ephemeral wetlands) (an average of the distances from randomly selected points within a cover type to the edge of the nearest wetland, other than ephemeral wetlands).	C,P/H,G,F	Aerial photographs, ruler.

Figure 8. Definitions of variables and suggested measurement techniques.

Data collection and analysis. Values for habitat variables used to evaluate pair and brood habitat can be estimated through wetland classification and measurement using aerial photographs. Evaluation of nesting cover with this model requires collection of field data for visual obstruction measurements, as well as a determination of the average distance to the nearest wetland for each cover type that provides potential nesting habitat. Indices for these two variables are combined with the area of each nesting cover type to determine an equivalent optimum area of nesting habitat/259 ha (Equation 6).

Although the variables used in this model are based on an area of 259 ha, any size study area can be evaluated as long as all variable estimates are standardized to 259 ha before suitability indices are determined.

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). When this model is used where wetlands are classified by a system other than that of Stewart and Kantrud (1971), the terminology of the classification system used must be equated to that used in this model. Guidelines relating the system of Shaw and Fredine (1956) to Stewart and Kantrud (1971) are provided in Stewart and Kantrud (1971). Equivalent terminology from Cowardin et al. (1979) is presented in Table 2. The primary discrepancy between the two systems is that ephemeral wetlands of Stewart and Kantrud (1971) are not considered wetlands by Cowardin et al. (1979). In practice, this will have little impact on the outputs of this model because ephemeral wetlands have very low suitability for blue-winged teal pairs (Tables 3 and 4) and no suitability for broods (Table 5).

The wetland classes of Stewart and Kantrud (1971) are "...distinguished by the vegetational zone occurring in the central or deeper part and occupying 5 percent or more of the total wetland area being classified" (Stewart and Kantrud 1971:7). Definitions of the wetland classes are as follows (Stewart and Kantrud 1971:7-8):

> Class I - ephemeral ponds. The wetland-low-prairie zone dominates the deepest part of the pond basin.
>
> Class II - temporary ponds. The wet-meadow zone dominates the deepest part of the wetland area. A peripheral low-prairie zone is usually present.
>
> Class III - seasonal ponds and lakes. The shallow-marsh zone dominates the deepest part of the wetland area. Peripheral wet-meadow and low-prairie zones are usually present.

Class IV - semipermanent ponds and lakes. The deep-marsh zone dominates the deepest part of the wetland area. Shallow-marsh, wet-meadow, and low-prairie zones are usually present, and isolated marginal pockets of fen zones occasionally occur.

Class V - permanent ponds and lakes. The permanent-open-water zone dominates the deepest part of the wetland area. Peripheral deep-marsh, shallow-marsh, wet-meadow, and low-prairie zones are often present, and isolated marginal pockets of fen zone occasionally occur.

Class VI - alkali ponds and lakes. The intermittent-alkali zone dominates the deepest part of the wetland area. Peripheral shallow-marsh, wet-meadow, and low-prairie zones are usually present. A deep-marsh zone is normally absent except occasionally for isolated patches near marginal seepage areas. A few isolated pockets of fen zone are normally present along the margins.

Class VII - fen (alkaline bog) ponds. The fen zone dominates the deepest part of the wetland area. Peripheral wet-meadow and low-prairie zones are often present.

The water regime modifiers of Cowardin et al. (1979) that are used in this model (Table 2) are described below (Cowardin et al. 1979:24):

Permanently Flooded. Water covers the land surface throughout the year in all years. Vegetation is composed of obligate hydrophytes.

Intermittently Exposed. Surface water is present throughout the year except in years of extreme drought.

Semipermanently Flooded. Surface water persists throughout the growing season in most years. When surface water is absent, the water table is usually at or very near the land surface.

Seasonally Flooded. Surface water is present for extended periods especially early in the growing season, but is absent by the end of the season in most years. When surface water is absent, the water table is often near the land surface.

Saturated. The substrate is saturated to the surface for extended periods during the growing season, but surface water is seldom present.

Temporarily Flooded. Surface water is present for brief periods during the growing season, but the water table usually lies well below the soil surface for most of the season. Plants that grow both in uplands and wetlands are characteristic of the temporarily flooded regime.

Intermittently Flooded. The substrate is usually exposed, but surface water is present for variable periods without detectable seasonal periodicity. Weeks, months, or even years may intervene between periods of inundation. The dominant plant communities under this regime may change as soil moisture conditions change.

Model assumptions. An abundance of literature exists on waterfowl in the Prairie Pothole Region. The majority of published literature concentrates on individual facets of waterfowl ecology, such as feeding habitat or nesting habitat, and very few studies attempt to evaluate the total habitat needs of individual species. As a result, numerous unifying assumptions were necessary to develop a model that attempts to evaluate overall habitat suitability. Another reason numerous assumptions were necessary in model development is that the purpose of the HSI model is to provide a tool that can be used to evaluate large areas of habitat in relatively short periods of time with limited data. As a result, simplification was necessary to develop a practical model to be used in habitat evaluation by field biologists. Increased practicality is generally made at the expense of complexity and predictive capabilities.

The major assumptions in this HSI model are:

1. Semipermanent wetlands (semipermanently flooded water regime) provide optimal habitat for pairs and broods and can be used as a standard against which to measure the suitability of other wetlands.

2. All wetlands within a given wetland class or water regime have the same level of suitability for blue-winged teal pairs and broods.

3. Under optimal conditions for pair, nesting, and brood habitat, the optimal ratio of upland to wetland habitat is 3 to 1.

4. Average conditions for the height and density of residual vegetation in upland habitat are suitable for predicting the quality of nesting habitat for blue-winged teal.

5. The distance between potential nesting habitat and brood habitat is less of a factor in nest site selection than the distance between potential nesting habitat and pair habitat.

Regarding the assumption that average conditions of residual vegetation in an upland cover type are adequate predictors of nesting suitability, evidence suggests that the predictive capability of average vegetative conditions is limited (Shaffer et al. 1985). This most likely results from simplifying complex relationships to produce a practical model. Other variables potentially important in nest site selection and nesting density include "...the quality of nearby wetlands, the attractiveness of competing nesting habitats, and the extent to which homing influences nest density in a particular field" (Shaffer et al. 1985:16). Other factors are probably involved in determining the overall attractiveness of a given habitat to nesting hens.

SOURCES OF OTHER MODELS

No other habitat models to predict overall habitat suitability for the blue-winged teal were located in the literature. Johnson (1982, cited by Shaffer et al. 1985) developed a model to predict pair densities from wetland area. Density of blue-winged teal pairs was estimated to be 0.371 pairs/ha of wetland. Shaffer et al. (1985) proposed a model to predict nest density based on available pairs and field size in fields with an average visual obstruction measurement of residual vegetation > 0.2 dm. Both of these models estimate specific population parameters; neither attempts to estimate overall habitat suitability.

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50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. Biological Report 82(10.114)	2.	3. Recipient's Accession No.
4. Title and Subtitle: Habitat Suitability Index Models: Blue-winged Teal (Breeding)			5. Report Date: September 1985
			6.
7. Author(s): Patrick J. Sousa			8. Performing Organization Rept. No.
9. Performing Organization Name and Address: Western Energy and Land Use Team, U.S. Fish and Wildlife Service, Drake Creekside Building One, 2627 Redwing Road, Fort Collins, CO 80526-2899			10. Project/Task/Work Unit No.
			11. Contract(C) or Grant(G) No. (C) (G)
12. Sponsoring Organization Name and Address: Western Energy and Land Use Team, Division of Biological Services, Research and Development, Fish and Wildlife Service, Department of the Interior, Washington, DC 20240			13. Type of Report & Period Covered
			14.

15. Supplementary Notes The Biological Report series was initiated in October 1984 to replace the FWS/OBS series published since 1976. The report number assigned to this model follows consecutively from the Habitat Suitability Index models published as FWS/OBS-82/10._, now numbered as Biological Report 82(10._).

16. Abstract (Limit: 200 words)

A review and synthesis of existing information were used to develop a Habitat Suitability Index (HSI) model for the blue-winged teal (Anas discors). 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

Blue-winged teal
Anas discors
Habitat suitability

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Release unlimited	Unclassified	36
	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: 1985--580-639 / 25403