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Variables Associated With Breeding Waterfowl On South Dakota Stock Ponds

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VARIABLES ASSOCIATED WITH BREEDING WATERFOWL ON SOUTH DAKOTA STOCK PONDS

BY

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ON SOUTH DAKOTA STOCK PONDS

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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Abstract

Jay Roberson

Use of stock watering ponds by indicated breeding pairs of waterfowl was measured in the western two-thirds of South Dakota from 1973 to 1976. Multiple regression and discriminant analyses were used to describe the habitat associated with pairs of each species. Habitat variables explained 35 - 47 percent of the variation in pairs having small home ranges and 26 - 35 percent of the variation in pairs having large home ranges. Shoreline distance accounted for more variation in mallard (*Anas platyrhynchos*) and blue-winged teal (*A. discors*) pairs than any other single variable. Ponds used by these pairs had shoreline distances that averaged 590 m which was significantly ($P<0.005$) greater than the mean shoreline distances of ponds not used ($\overline{X}$ = 270 m). Numbers of blue-winged teal and pintail (*A. acuta*) pairs increased proportionately with increased shoreline irregularity. Pairs of all species except the American wigeon (*A. americana*) were observed on ponds with significantly ($P<0.005$) larger mean surface water area than the mean surface area of ponds where pairs were not observed. Pond basin area accounted for more variance in pintail, northern shoveler (*A. clypeata*), and green-winged teal (*A. carolinensis*) pairs than any other single variable including surface water area. Numbers of pairs of these species increased with increased basin area. The number of wetlands and types

of wetlands on the study plots appeared to be important variables associated with the use of stock ponds by breeding pairs.

Emergent vegetation species, height, and interspersion were important variables associated with breeding pair use of stock ponds. The presence of sedges (*Carex* spp.) accounted for more variation in numbers of gadwall (*Anas strepera*) and American wigeon pairs than any other variable. All breeding pairs were positively associated with roundstem bulrushes (*Scirpus validus* and *S. acutus*). Pintail and gadwall pairs used ponds with scattered dense patches or diffuse open stands of emergents but tended not to use completely open ponds. Pintails, American wigeons, northern shovelers, and green-winged teal tended not to use ponds with a dense band of emergents around the shore. Mallard and pintail pairs per pond declined with increased grazing intensity on the upland.

Geographic location of stock ponds was associated with pair use. Mallard, pintail, blue-winged teal, gadwall and northern shoveler pairs tended to use ponds located east rather than west of the Missouri River. American wigeon pairs were more abundant on ponds located in the northern portion of western South Dakota than on ponds located elsewhere.

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INTRODUCTION

Breeding dabbling ducks (Anatini) intensively utilize stock ponds even though these ponds have been constructed and managed primarily for livestock (Bue 1956, Duebbert 1972). Smith (1958) found that stock ponds supported 23 percent of the breeding waterfowl population in Montana, North Dakota, and South Dakota but made up only 16 percent of the number of wetlands in these states. Kruse (1972) observed that stock ponds comprised less than one percent of the surface water area on Arrowwood National Wildlife Refuge in North Dakota but supported 25 percent of the breeding pairs. Ruwaldt (1975) found that stock ponds made up only 14 percent of the total wetland area in South Dakota but supported about half of the American wigeon and about one-third of the pintail and mallard breeding pair populations. Stock ponds will likely increase in importance in the future because of their compatibility with agricultural land use.

More efficient use of the waterfowl resource will be made by managing breeding waterfowl on a species basis (Smith 1971). Species specific management of breeding pairs on stock ponds will require information on the ecological requirements of each species. Wetland and upland habitat variables that can be managed to improve production on existing ponds or implemented in the development of new ponds are of particular importance. The objectives of this study were to identify those wetland and upland habitat variables which were most associated with variation in numbers and occurrence of breeding pairs of waterfowl on stock ponds.

STUDY AREA

South Dakota has been divided into eight major physiographic strata based on differences in vegetation, climate, topography, and soil parent material (Flint 1955) (Figure 1). Four of these strata lie east and four lie west of the Missouri River. Ninety-seven percent of the stock ponds in South Dakota are located in one east-river and three west-river strata (Ruwaldt 1975). These four strata are the Missouri Coteau (stratum IV), Northern Plateau (stratum V), Pierre Hills (stratum VI), and Southern Plateau (stratum VII) (Figure 1). This study was restricted to these four strata which comprises 66 percent of the total land area (199,552 km^2) in South Dakota.

The Missouri Coteau is an unevenly dissected plateau-like highland of glacial drift underlain by Pierre shale (Flint 1955). Glaciation has altered the original east-west drainage pattern into the present north-south pattern of the James River to the east and Missouri River to the west. Glacial wetlands are abundant in the northern portion of the Coteau where drainage is poor. Eastern slopes are drained by short parallel streams to the James River while western slopes are drained by a more irregular stream pattern to the Missouri River. The narrow southern portion of the Coteau is well drained by tributaries of both the James and Missouri Rivers. These drainage patterns, particularly westward into the Missouri River, have provided a number of sites for stock pond construction.

The Northern Plateau is characterized by a series of plateaus,

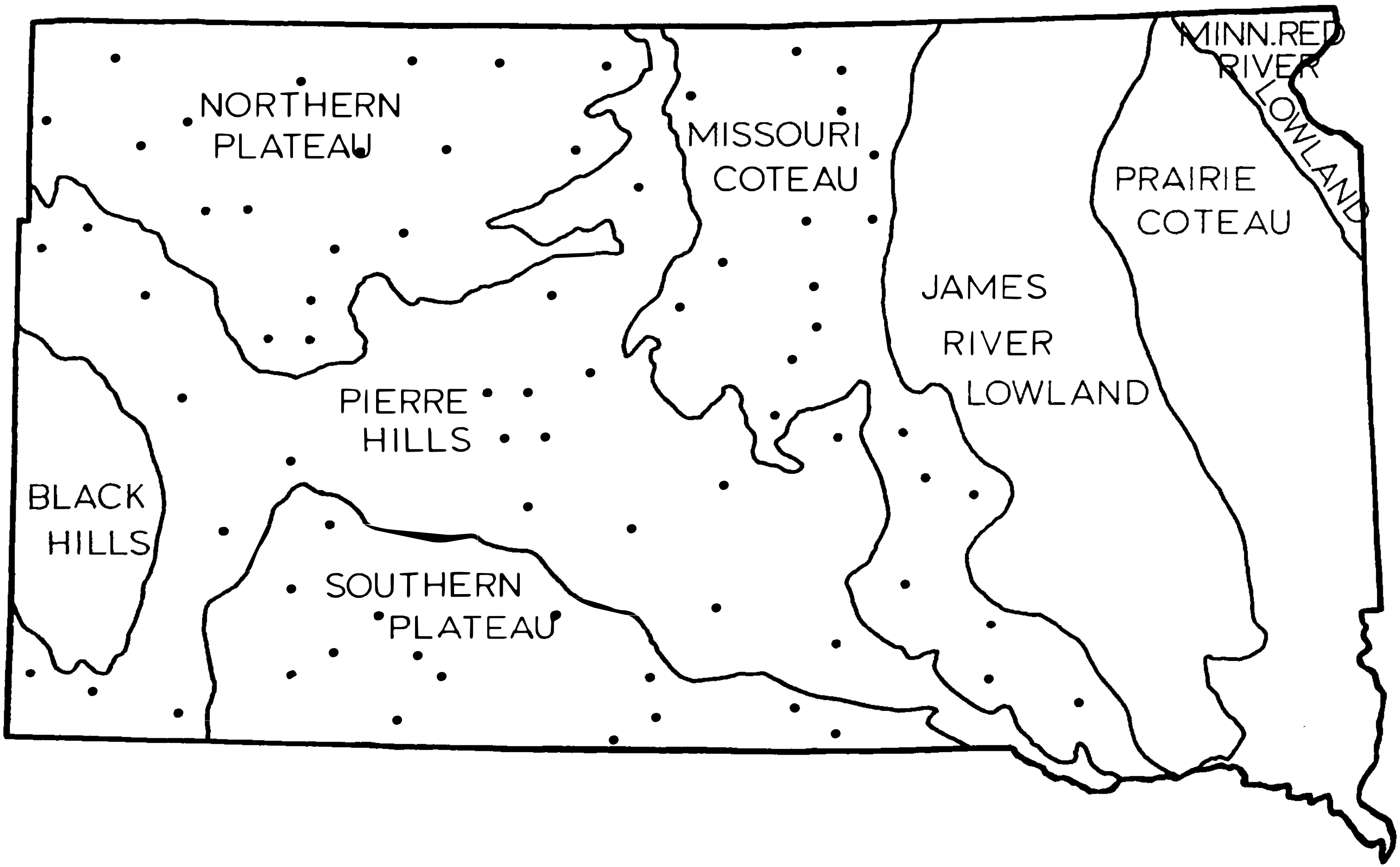

Figure 1. Distribution of randomly located sample cluster centers in the four major physiographic strata having greatest numbers of stock ponds in South Dakota.

benches, and isolated buttes (Flint 1955). The dissected, steplike surface rises from 610 m near the Missouri River to over 915 m above sea level near the extreme northeastern corner of the state. Shales and sandstone lie under the silt and clay loam soils (Westin et al. 1970). The Grand and Moreau Rivers drain eastward to the Missouri River. The dispersed drainage pattern of the tributaries provides ample sites for stock ponds.

The southern most stratum borders the Sand Hills of Nebraska to the south. The Southern Plateau appears as undulating tableland and badlands due to the plateaus and broad benches that have weathered to varying degree. Underlying sandstones, siltstones, and shale yield a silt and clay loam soil over most of the area. This region slopes upward from 853 m near the Missouri River to 1097 m above sea level near the Black Hills. Drainage northward occurs through tributaries of the White River and southward by the Keya Paha River.

Between these two west-river strata and lower in elevation lies a region of rolling plain interrupted by a few steep valley sides and isolated buttes. This stratum, the Pierre Hills, obtained its name from the rolling hills and underlying bedrock of Pierre shale. This shale erodes quite readily to produce smooth hills and ridges with convex tops covered by a dark plastic clay soil. A well integrated system of tributaries of the Cheyenne, Bad, and White Rivers drains this stratum eastward to the Missouri River. Stock ponds are most abundant in this stratum.

METHODS

This study on stock ponds was part of a broader statewide waterfowl survey conducted from 1973 to 1976. Sample design for this study was the same as the design for the overall statewide survey previously described in detail by Brewster et al. (1976). Sampling consisted of ground counts of breeding waterfowl on randomly located 64.8 ha (quarter section) plots in the four study strata. Numbers of plots per stratum were as follows: Missouri Coteau (80), Northern Plateau (72), Pierre Hills (92), and Southern Plateau (56). The proportion of the total area of each stratum sampled is given in Table 1 of Appendix A.

All stock ponds containing surface water on these plots were considered sample units. A stock pond was defined as the impoundment resulting from damming a natural waterway. Each stratum was well represented although the number of stock ponds containing water varied by stratum and year (Table 2, Appendix A).

Census Methods

Two censuses were conducted on the stock ponds each year. Average census dates for early-nesting pairs were 11 May to 26 May while mid- and late-nesting pairs were censused from 7 June to 18 June. Early-nesting pairs included mallard (*Anas platyrhynchos*) and pintail (*A. acuta*) (Hammond 1969). Mid- and late-nesting species were northern shoveler (*A. clypeata*), blue-winged teal (*A. discors*), gadwall (*A. strepera*), green-winged teal (*A. carolinensis*), American wigeon (*A. americana*), ruddy duck (*Oxyura jamaicensis*), and lesser scaup (*Aythya affinis*). Numbers of pairs of lesser scaup and ruddy duck were not sufficient for statistical analysis (Appendix C). Consequently, these two species were dropped from further study. No confirmed observations of any other duck species occurred on study ponds over the four years.

Indicated breeding pairs rather than actual observed pairs were used in all analyses. Pairs, lone drakes, and pairs in groups were tabulated as indicated breeding pairs (Hammond 1969). Lone females in excess of lone males on a given plot were also recorded as indicated breeding pairs (Stewart and Kantrud 1972).

Censuses of plots containing study ponds were conducted by two two-man crews. The state was censused in a southern to northern direction to reduce effects of latitude on the pair counts. Ponds were censused by the walk, wade, and vehicular methods as described by Hammond (1969). The method used depended on the amounts of emergent cover and size of the stock pond. Censuses were conducted from one-half hour before sunrise to one-half hour after sundown.

During each visit to the stock ponds, wetland and upland habitat information was recorded. Some of this information was sketched on photo duplicates of aerial photographs obtained from the Agricultural Stabilization and Conservation Service (ASCS). High water line (basin area), actual water line (shoreline), emergent pattern (cover type), and upland cover type were mapped on these photo duplicates. Breeding pairs and remaining habitat information were tabulated on field forms. The explanation of habitat variables and how each was recorded is given in Table 1.

Two variables, pond age and shoreline development, were analyzed separately because values were not available for all the ponds studied. Pond age was defined as years since dam construction. Dates of dam construction were copied from permits for cost sharing submitted to the ASCS and filed in Pierre, South Dakota, with the Department of Natural Resources. Construction dates for privately funded ponds were obtained from land owners. Shoreline development was computed as the ratio of shoreline distance to the circumference of a circle having the same area as the surface water area of the pond (Lagler 1956:245). Shoreline development is a measure of shoreline irregularity and is commonly used as an index of biological productivity of lakes.

Statistical Methods

Three basic types of analyses were used in exploring the relationships between breeding pairs and breeding habitat. These analyses were multiple regression, discriminant analysis, and polynomial regression. Multiple regression has been used in other ecological studies to describe breeding habitats and coexistence of bird species (Sturman 1968, Lokemoen 1973). Similarly, stepwise forward solution multiple regression (Steel and Torrie 1960, Kim and Kohout 1975) was used to provide evidence for ecological preferences of species of breeding waterfowl using stock ponds.

Stepwise forward solution multiple regression analysis consists

Table 1. List of independent variables and explanations for multivariate analysis. The mnemonic form will be used to refer to the variables in tables of the Appendices

Mnemonic	Independent Variable	Explanation
Wetland Habitat Variables:		
HPB	Hectares of stock pond basin	: HPB measured by polar planimeter
HPSW	Hectares of stock pond surface water	: HPB multiplied by PSW
HPOW	Hectares of stock pond open water	: HPSW multiplied by POW
PSW	Percent surface water of basin area	: Visual estimate made in the field
POW	Percent open water of surface water area	: Visual estimate made in the field
SLDI	Stock pond shoreline distance in meters	: Measured by map measure from drawings on photo duplicates
VEGH	Emergent vegetation height in centimeters	: Visual estimate made in the field
CRAT2	Cover type 2 (1 = present, 0 = absent)	: Cover type is the same as defined by Stewart and Kantrud (1971) for natural ponds and lakes. Open water or bare soil covering 5 to 95 percent of the wetland area, with scattered dense patches or diffuse open stands of emergent cover was designated as cover type 2. Closed stands of emergent cover (cover type 1) with open water or bare soil covering less than 5 percent of the wetland area was not characteristic of any of the study ponds over the 4 years.
CRAT3	Cover type 3 (1 = present, 0 = absent)	: Central expanses of open water or bare soil (comprising more than 5 percent of the wetland area) surrounded by peripheral bands of emergent cover averaging 1.82 meters or more in width was defined as cover type 3. Cover type 4 was designated as open water or bare soil covering more than 95 percent of the wetland area and small ponds with emergent cover restricted to marginal bands less than 1.82 meters in width. Cover type 4 was the most common cover type for stock ponds so it was used as a reference category and not entered as a dummy variable in multiple regression (Kim and Kohout 1975:377).
DRAT1	Depth rating 1 (1 = present, 0 = absent)	: Water level above normal high-water mark, surface water present within the wet-prairie or the wet-meadow zone constituted a depth rating 1. Depth rating 2 was defined as the normal or full condition, with surface water restricted to shallow-marsh, deep-marsh, and open-water zones. Depth rating 2 was the reference category.
DRAT3	Depth rating 3 (1 = present, 0 = absent)	: Shallow-marsh zone at least 25 percent dry
DRAT4	Depth rating 4 (1 = present, 0 = absent)	: Shallow-marsh zone at least 75 percent dry
DRAT5	Depth rating 5 (1 = present, 0 = absent)	: Deep-marsh zone at least 25 percent dry; mudflats or draw-down plant communities present. Depth rating 6, deep-marsh zone at least 75 percent dry, was not common enough for analysis. Dry ponds were not analyzed.
PGR	Percent of the shoreline being grazed	: Visual estimate made in the field
Upland Habitat Variables:		
GINT	Grazing intensity of upland	: (0 = no grazing, 1 = light, 2 = moderate, 3 = heavy)
HSMG	Hectares of small grain on the quarter	: Measured by polar planimeter from cover map
HFARM	Hectares of farmstead on the quarter	:
HPAS	Hectares of pasture on the quarter	:
HFALO	Hectares of fallow on the quarter	:
HROAD	Hectares of roadside on the quarter	:
HTREE	Hectares of treeland on the quarter	:
HCOR	Hectares of corn on the quarter	:
HALF	Hectares of alfalfa on the quarter	:
HHAY	Hectares of hayland on the quarter	:

Table 1 (continued). List of independent variables and explanations for multivariate analysis. The mnemonic form will be used to refer to the variables in tables of the Appendices.

Mnemonic	Independent Variable	Explanation
Dominant Emergents:		
ELE	Spikerush (Eleocharis spp)	: 0 = absent, 1 = present if among the dominant emergents. (Saggittaria spp. is the reference category.)
SCF	River bulrush (Scirpus fluviatilis)	:
SCS	Roundstem bulrush (Scirpus acutus and S. validus)	:
TYP	Cattail (Typha latifolia and T. angustifolia)	:
CAR	Sedge (Carex spp.)	:
POL	Smartweed (Polygonum spp.)	:
Wetland Association Variables:		
NWC	Number of wetland classes on the quarter	: Variables obtained from the quarter sections on which stock ponds were located.
NASW	Number of artificial wetlands with surface water	: Artificial means dugouts and stock ponds
HSWA	Hectares of surface water of artificial wetlands	: Calculated from previous information
NNSW	Number of natural wetlands with surface water	: Natural means natural ponds and lakes (Stewart and Kantrud 1971)
HSWN	Hectares of surface water of natural wetlands	:
NOW	Number of wetlands with open water	:
HOWB	Hectares of open water of other wetlands	:
NDB	Number of dry basins	:
TSLD	Total shoreline distance of other wetlands	:
DWBMC	Distance to nearest wet basin	: 1 = 0 to 99 meters, 2 = 100 m to 199 m, 3 = 200 m to 299 m, 4 = 300 m to 399 m, 5 = 400 m to 499 m, 6 = 500 m to 599 m, 7 = 600 m to 699 m, 8 = 700 m to 799 m, 9 = 800 m or more meters.
Disturbance Variables:		
DNRMC	Distance to nearest highway	: same as above.
DOFMC	Distance to nearest occuppied farmstead	: same as above.
Physiographic Strata:		
D4	Missouri Coteau	: 0 = absent, 1 = presence of stock pond in the particular strata; dummy variables used to account for the uncommon variance of stock pond variables between strata. The Southern Plateau is the reference category because discriminant analysis showed ponds in this strata to be least extreme in variability.
D5	Northern Plateau	:
D6	Pierre Hills	:
Other Variables:		
TIME	Census time of day (24 hour system)	:
TEMP	Air temperature in degrees celsius	:
RAIN	Presence (1) or absence (0) of rain	:

of computing simple correlation coefficients (r) between all habitat variables (the independent variables), and numbers of indicated breeding pairs (the dependent variable). Independent variables are then entered, one at a time, into a linear regression equation in the order in which each variable, when combined with previously entered variables, reduces the residual variance about the least squares regression line the most. An F test was then applied to examine the statistical significance of each step in reducing this residual variance. At the conclusion of the analysis, a reduced set of significant habitat variables, known as the multiple linear regression equation, is obtained which accounts for a proportion of the variance in the dependent variable.

Careful interpretation of multiple regression results is necessary in order not to be misled. The value of the linear equation in explaining response by breeding pairs is indicated by the proportion of variance of the dependent variable accounted for by the set of independent variables. This proportion is known as the coefficient of determination (R^2) (Snedecor and Cochran 1967). Once the importance of this set of variables has been determined, the individual contributions of the variables can be examined. The magnitude of the simple correlation coefficients indicate how closely associated the independent variables are with the dependent variable. The sign (+ or -) of the simple correlation coefficient indicates the direction of the association when no other independent variables are considered. The magnitude of the standardized regression coefficients indicates the relative effect the independent variable would have on the dependent variable when all independent variables in the linear equation are considered together. The sign (+ or -) of the standardized partial regression coefficient indicates the direction of change in the dependent variable when all the independent variables are considered together. The sign of the simple correlation coefficient may not be the same as the sign of the partial regression coefficient due to intercorrelations between previously entered variables. Interpretation of the sign of the partial regression coefficients should be made carefully in view of the simple correlation sign and intercorrelations among independent variables.

Stepwise discriminant analysis was used to distinguish between waterfowl species based on habitat variables utilized (Morrison 1967). The analysis was also used to differentiate between ponds used by pairs and ponds not used by pairs of the same species. Discriminant analysis has been used for similar purposes in ecological bird studies by other researchers (James 1971, Whitmore 1975).

The analysis consists of entering habitat variables, one at a time, into a linear function based on improvement in discrimination. Variables which maximize the variance between groups are entered successively until all the variables are in each discriminant function. Discriminant functions are linear combinations of the habitat variables. The number of functions derived equals one less than the number of groups to be differentiated.

Even though all habitat variables are eventually entered into the function, only a few are necessary. The number of variables used can be truncated at the point where addition of one more variable does not significantly improve the differentiation between groups based on change in Rao's V statistic (Klecka 1975).

The merit of the reduced set of significant variables in distinguishing between groups is indicated by the number of ponds correctly classified. High percentages of correctly classified ponds indicates that the significant variables give good separation of groups; conversely, low percentages indicate poor separation.

Once the value of the discriminant functions has been determined, the relative importance of the individual variables may be established based on the standardized discriminant function coefficients. These coefficients are interpreted with the same care as the multiple regression coefficients.

Since the discriminant functions may be thought of as orthogonal axes in geometric space, spatial relationships between groups, known as an ordination, can be more easily understood (Klecka 1975). An ordination of the first two discriminant functions was used to clarify the relationship between variables and waterfowl species. Discrimination between early-and mid- or late-nesting ducks would not be valid because seasonal differences rather than differences in habitat preferences would discriminate between the two groups.

Stepwise multiple regression and stepwise discriminant analysis are based on the assumptions (1) that residual variances of the variables within each stratum are normally and independently distributed with a mean of zero and common variance, (2) that the independent and dependent variables are measured without error, and (3) that the true relationships between the dependent and independent variables are linear. The first assumption was accepted without testing.

The second assumption implies strict homogeneity of error variances. Measurement error did occur but differences in subjective judgments between the two crews between years was negligible. Each crew member had previous experience collecting data with members of the other crew. Meetings were held prior to the censuses to clarify and unify data collecting methods. Also, one person remained on the census team all four years which standardized the data.

The third assumption that the true relationship between the independent and dependent variable is linear may not be a valid assumption for certain variables. Most animal populations tend to be limited over time by environmental constraints other than living space, i.e. food, cover, weather, disease. Therefore, an increase in living space does not necessarily lead to an increase in numbers of individuals. Lokemoen (1972) has shown that pairs per pond increase at a decreasing rate with surface water area.

Variables such as surface area, shoreline distance, pond age and time of day were analyzed for deviation from a linear relationship by polynomial regression. The true relationship between breeding pairs and these variables may be illustrated by fitting a curve to pair response. Only those ponds with pairs using them were analyzed by polynomial regression because we were more interested in determining the response by additional pairs rather than explaining why pairs did or did not use certain ponds. Discriminant and multiple regression analyses were run on all wet ponds to indicate why pairs did or did not use ponds.

Polynomial regression analysis involves fitting a least squares line or curve to the response variable by successively entering higher degree polynomials. The linear relationship is given by the first degree polynomial, X. Successively higher degree polynomials, i.e. X^2, X^3, X^4, etc., yield successively more complex curvilinear relationships. The process is continued until the succeeding polynomial does not significantly reduce the residual error about the least squares curve. At this point the curve significantly fits the true relationship. The proportion of variance of the dependent variable (R^2) is interpretted in the same manner as in multiple linear regression.

Homogeneity of variance in independent variables was tested to determine if stock ponds located in the four physiographic strata could be pooled and considered a single sample. Multiple regression and discriminant analyses are robust procedures which do not require strict homogeneity in order to obtain unbiased results. Heterogeneity was small enough that strata were pooled. Dummy variables were added to account for some of this unexplained strata variance.

Ponds were pooled across years and considered a different sample each year. Effects of year on stock pond variables were assumed to be random from 1973 to 1976. Pooling of ponds within strata and years greatly simplified the analysis and increased the sample size.

All statistical analyses were conducted using the digital computer located at the Computing Center, South Dakota State University. Statistical programs used were subprograms from the Statistical Package for the Social Sciences (Nie et al. 1975).

RESULTS

Mallard

Eight variables accounted for 26 percent (R^2) of the variation in numbers of indicated mallard pairs using stock ponds (Table 2). Shoreline distance accounted for more of this variation than any other variable. Mallard pairs per pond increased with increasing shoreline distance and taller emergent vegetation but decreased with increasing grazing intensity.

Stepwise discriminant analysis differentiated between used and unused ponds based on nine variables which correctly classified 61 percent of the ponds used by mallard pairs (Table 3). Shoreline distance was the best discriminating variable. Mallard pairs tended to occur on ponds with longer shoreline. The mean shoreline distance on which one or more pairs were observed ($\overline{X}$ = 584 m) was twice as large as the mean shoreline distance of ponds not used ($\overline{X}$ = 265 m). Ponds located in the Missouri Coteau or on plots with farmsteads were more likely to have mallard pairs. Pairs tended to be absent from ponds located on plots with a greater diversity of wetland types.

Wetland habitat variables were the most important group of variables associated with breeding mallard pairs (Appendix D). Simple correlation coefficients (r) indicated that emergent vegetation cover type and kinds were important but were not significant in either regression or discriminant functions. Mallard pairs were positively

TABLE 2. Summary table of significant results of multiple regression analysis, 1973 - 1976. Variables are listed in order of entry in accounting for successive maximum variability in pairs. Standardized partial regression coefficients are listed for those variables which were significant (A:P<0.05) and (B:P<0.005) in reducing the error sum of squares at each step.

Independent variables	Coefficient of determination (R^2)	Simple correlation coefficient (r)	Standardized partial regression coefficient A	Standardized partial regression coefficient B
MALLARD				
Shoreline distance	0.1478	0.3845	0.7159	0.7066
Ha of surface water	0.1828	0.2414	-0.3954	-0.3510
Grazing intensity	0.2060	-0.1243	-0.1543	-0.1538
Ha of open water of other wetlands on the plot	0.2210	-0.1631	-0.1148	
Emergent vegetation height	0.2323	0.2437	0.2020	
Depth rating 1	0.2426	-0.0739	-0.1014	
Percent open water	0.2523	-0.0896	0.1263	
Ha of fallow on the plot	0.2623	0.0069	-0.1057	
PINTAIL				
Ha of pond basin	0.0901	0.3001	1.8158	1.9821
Missouri coteau	0.1647	0.2867	0.1731	0.1981
Ha of surface water	0.1987	0.2046	-1.7689	-1.6470
Ha of farmstead on the plot	0.2450	0.0786	-0.3627	-0.4031
Percent surface water	0.2808	-0.0402	0.1804	0.2088
Cover type 2	0.2966	0.1673	0.1457	0.1311
Ha of pond open water	0.3066	0.2441	0.3158	
Grazing intensity	0.3164	-0.0517	-0.1388	
Ha of pasture on the plot	0.3244	-0.0161	0.1012	
Number of dry basins on the plot	0.3320	0.2817	0.0996	
BLUE-WINGED TEAL				
Shoreline distance	0.3211	0.5666	0.5185	0.5286
<u>Carex spp.</u>	0.3603	0.2698	0.1821	0.1702
Ha of farmstead on the plot	0.3847	0.0115	-0.2928	-0.2855
Ha of pond basin	0.4046	0.5214	0.5370	0.5004
Ha of pond open water	0.4259	0.5002	-0.4540	-0.4340
Ha of surface water of natural wetlands on the plot	0.4476	0.1928	0.1583	0.1555
<u>Scirpus validus</u> and <u>S. acutus</u>	0.4616	0.3507	0.1096	0.1303
<u>Eleocharis spp.</u>	0.4690	0.0847	0.0901	
GADWALL				
<u>Carex spp.</u>	0.1287	0.3587	0.3027	0.3027
Ha of pond open water	0.1847	0.2701	0.6702	0.6702
Number of dry basins on the plot	0.2376	0.2512	0.2410	0.2410
Ha of pond surface water	0.2689	0.1669	-0.4495	-0.4495
Cover type 2	0.2877	0.1452	0.1538	0.1530
Distance to nearest farmstead	0.3095	0.0779	0.1544	0.1544

TABLE 2. (continued)

AMERICAN WIGEON				
Carex spp.	0.0477	0.2183	0.2109	0.1892
Scirpus validus and *S. acutus*	0.0767	0.2118	0.2223	0.2182
Cover type 3	0.1014	-0.0847	-0.1583	-0.1635
Polygonum spp.	0.1131	-0.0524	-0.1072	
Northern plateau	0.1236	0.1111	0.1026	
NORTHERN SHOVELER				
Ha of pond basin	0.1233	0.3512	0.6786	0.3913
Carex spp.	0.2157	0.3224	0.2593	0.2855
Ha of farmstead on the plot	0.2424	-0.0113	-0.2479	-0.1702
Depth rating 5	0.2648	0.1731	0.1291	0.1520
Ha of surface water of natural wetlands on the plot	0.2844	0.1892	0.2577	0.1411
Number of natural wetlands with surface water on the plot	0.2989	-0.0231	-0.1587	
Scirpus fluviatilis	0.3159	-0.0243	-0.1909	
Hectares of pond open water	0.3273	0.3029	-0.2865	
Scirpus validus and *S. acutus*	0.3403	0.2270	0.1209	
Ha of small grain on the plot	0.3479	0.0348	0.0689	
GREEN-WINGED TEAL				
Ha of pond basin	0.0421	0.2052	0.1306	0.1588
Ha of fallow on the plot	0.0747	0.1874	0.1518	0.1769
Scirpus validus and *S. acutus*	0.0972	0.2026	0.1521	0.1552
Scirpus fluviatilis	0.1141	0.1968	0.1408	
Number of dry basins on the plot	0.1282	0.1213	0.1194	

TABLE 3. Major discriminating variables as indicated by discriminant analysis between ponds with no indicated pairs and ponds with at least one pair, 1973 - 1976. All variables were significant (P<0.05) in discriminating based on change in Rao's V at each step.

Groups	Number of cases	Percent of cases correctly classified	Centroids in reduced space	Discriminating variables	Standardized discriminant function coefficients	Group Means without (A) and with (B) indicated breeding pairs present A	B
Ponds with Mallard	158	61.4	0.5816	Shoreline Distance	1.2986	266.00	584.00
Ponds without Mallard	213	85.4	-0.4314	Ha of open water of other wetlands on the plot	-0.2293	0.39	0.20
Total	371	75.2		Ha of pond surface water	-1.7588	0.44	1.25
				Number of wetland classes on the plot	-0.4391	1.57	1.14
				Missouri coteau	0.2828	0.12	0.17
				Ha of farmstead on the plot	-0.5227	0.19	2.42
				Distance to nearest road	-0.2214	8.57	7.96
				Ha of pond basin	1.1378	0.59	1.66
				Depth rating 2	0.2397		
Ponds with Pintail	65	66.2	-1.0337	Ha of pond basin	-1.1919	0.73	2.51
Ponds without Pintail	306	90.4	0.2196	Missouri coteau	-0.4279	0.10	0.34
Total	371	87.1		Census time of day	0.2051	14.59	13.23
				Grazing intensity	0.2510	2.01	1.84
				Scirpus validus and *S. acutus*	-0.2208	0.09	0.25
				Cover type 3	0.2482	0.09	0.06
				Number of dry basins on the plot	-0.2068	0.55	1.34
				Percent surface water	-0.2658	74.46	75.62
				Ha of pond surface water	0.5736	0.57	1.79
Ponds with Blue-Winged Teal	109	55.0	-0.8411	Shoreline distance	-1.1718	284.00	679.00
Ponds without Winged Teal	246	92.3	0.3726	Emergent vegetation height	-0.2986	20.00	48.00
Total	355	80.9		Missouri coteau	-0.2096	0.11	0.22
				Ha of pond surface water	0.6413	0.47	1.55
				Eleocharis spp.	-0.2135	0.17	0.30
				Southern plateau	-0.1801	0.11	0.20
				Number of artificial wetlands with surface water on the plot	0.1731	0.76	0.45
				Ha of surface water of natural wetlands on the plot	-0.1955	0.09	0.40
				Ha of farmstead on the plot	0.1774	0.10	3.62

TABLE 3. (continued)

				Depth rating 5	-0.1339	0.00	0.01
				Temperature	-0.1403	21.70	22.50
				Ha of road on the plot	-0.1416	0.20	0.31
Ponds with Gadwall	55	74.5	-1.0008	Ha of pond open water	-1.5272	0.52	1.18
Ponds without Gadwall	300	98.0	0.1835	Ha of pond surface water	1.0364	0.69	1.39
Total	355	86.8		Missouri coteau	-0.4212	0.12	0.27
				Scirpus validus and _S. acutus_	-0.2321	0.14	0.33
				Distance to nearest farmstead	-0.4336	8.22	8.65
				Northern plateau	-0.3120	0.21	0.29
				Ha of road on the plot	-0.2811	0.22	0.29
				Cover type 2	-0.2400	0.15	0.27
Ponds with American Wigeon	26	84.6	1.2195	_Scirpus validus_ and _S. acutus_	0.7231	0.15	0.46
Ponds without American Wigeon	329	99.1	-0.0964	Cover type 3	-0.4703	0.10	0.00
Total	355	93.0		_Carex_ spp.	0.5231	0.01	0.12
				Polygonum spp.	-0.3179	0.04	0.00
				Ha of treeland on the plot	0.2764	0.31	1.61
Ponds with Northern Shoveler	14	50.0	-2.8493	Ha of pond basin	-0.5643	0.95	4.15
Ponds without Northern Shoveler	341	97.7	0.1170	_Carex_ spp.	-0.4144	0.01	0.21
				Depth rating 5	-0.4221	0.00	0.07
Total	355	95.8		Ha of surface water of natural wetlands on the plot	-0.5280	0.15	1.11
				Ha of farmstead on the plot	0.2499	1.23	0.00
				Number of natural wetlands with surface water on the plot	0.3144	0.68	0.64
				Scirpus fluviatilis	0.2537	0.02	0.00
				Ha of small grain on on the plot	-0.2177	2.14	5.18
				Typha spp.	-0.2546	0.15	0.50
				Cover type 3	0.2032	0.09	0.14
Ponds with Green-Winged Teal	11	27.3	-1.7006	Emergent vegetation height	-0.6324	27.58	66.73
Ponds without Green-Winged Teal	344	98.3	0.0546	Number of dry basins on the plot	-0.5092	0.83	2.18
Total	355	96.1		Cover type 3	0.5036	0.09	0.09
				Shoreline Distance	-0.4714	391.00	842.00
				Census time of day	0.3161	14.22	11.98

correlated with ponds dominated by roundstem bulrush (*Scirpus acutus* and *S. validus*) and cattail (*Typha* spp.) in scattered dense patches or diffuse open stands.

The negative sign of the regression and discriminant coefficients indicated that numbers and occurrences of pairs decreased with increasing surface area. This was not the case. Intercorrelation between surface water area and shoreline distance (r = 0.87) caused regression and discriminant coefficients to be negative. Surface water area was significantly ($P<0.01$) and positively correlated (r = 0.24) with mallard pairs.

Surface water area accounted for only six percent (R^2) of the variation in mallard pairs (Figure 2). This low percentage of shared variance and gentle sloping curve could account for the relative stability in numbers and density of pairs over the four years while surface water area varied considerably (Appendix C). Densities of mallard pairs fluctuated less from year to year than densities of blue-winged teal, American wigeons, northern shovelers, and green-winged teal.

Mallard pairs used ponds that averaged 1.25 ha in surface area. This mean was significantly ($P<0.005$) different from the mean surface area of ponds not used (0.44 ha). Mallard pairs used smaller ponds more efficiently in terms of pairs per unit area.

Mallards were the only species significantly fitted by a curve on pond age (Figure 3). Pond age accounted for more of the variation (R^2 = 0.12) in mallard pairs than did surface water area. Ponds older than 16 years were used less by mallard pairs.

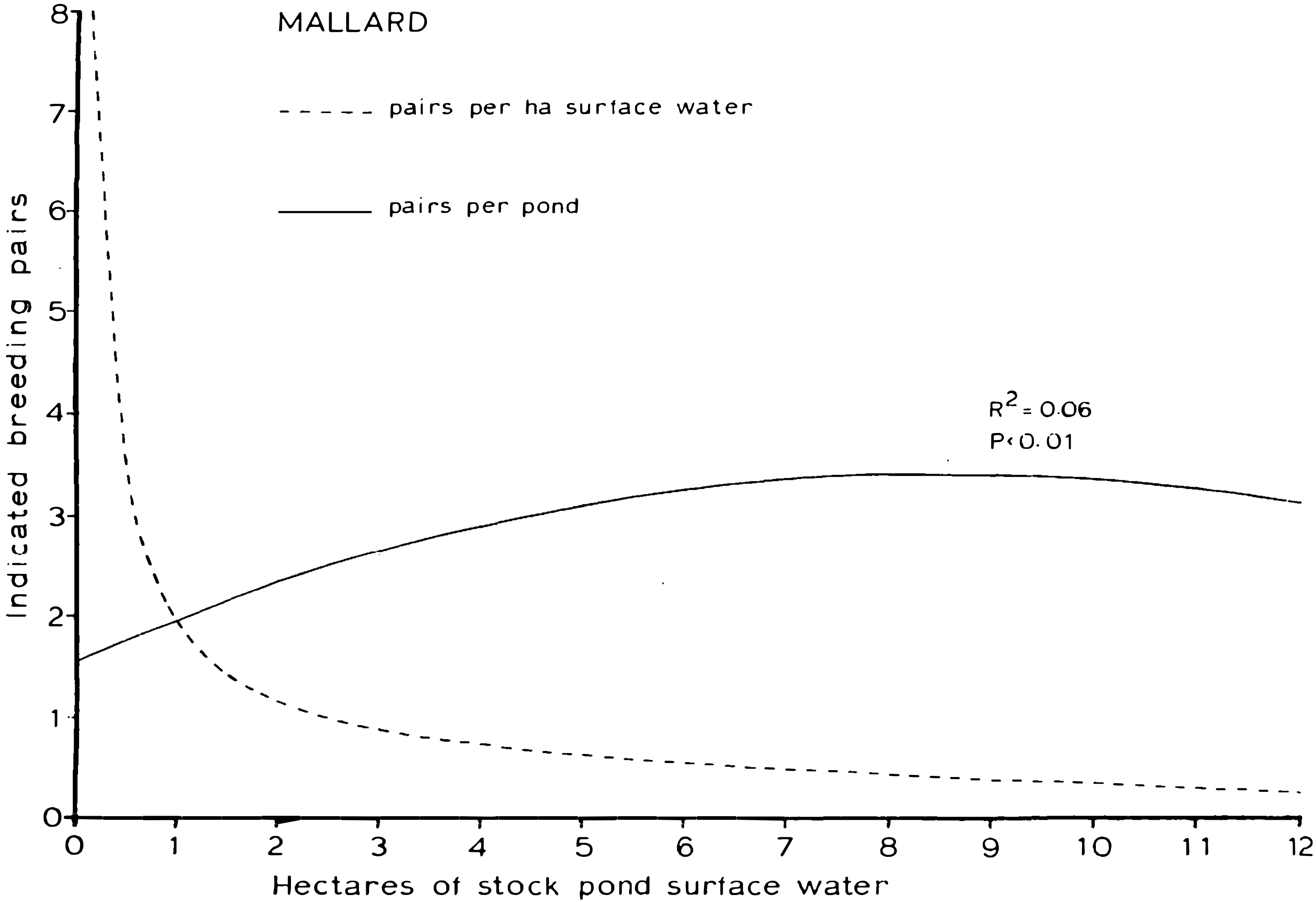

Figure 2. Polynomial regression of indicated pairs of mallards on surface water area, 1973 - 1976.

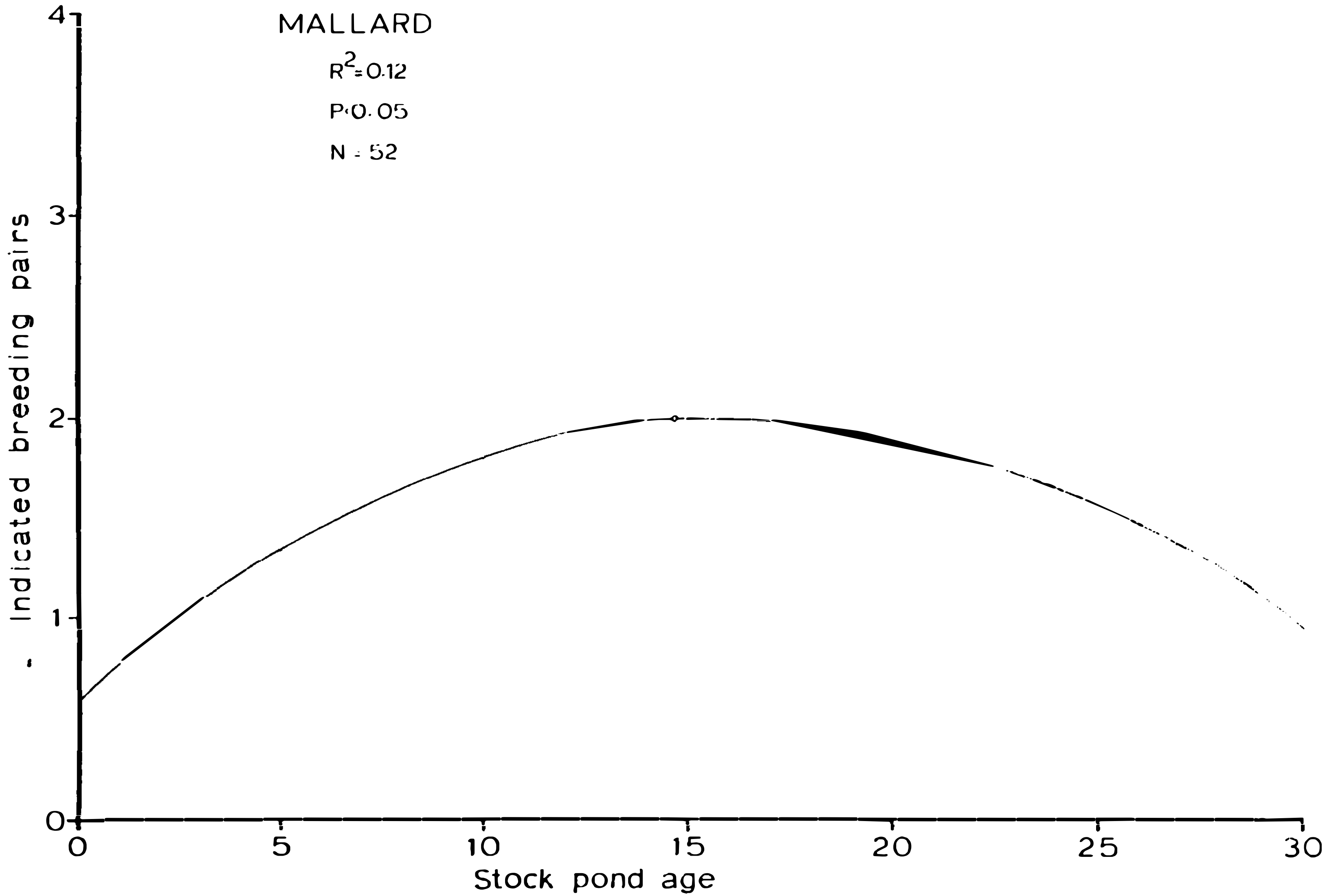

Figure 3. Polynomial regression of indicated pairs of mallards on pond age, 1973 - 1976.

Census time of day accounted for as much variation in mallard pairs as did surface water area (Figure 4). Pair use was greatest before 0700 Central Daylight Time and least after 1900 CDT. The linear relationship was not significant and did not represent the true relationship between time of day and response by pairs. The curvilinear response of pairs to time of day explained why time of day did not enter the multiple regression equation or discriminant functions as a significant variable.

Pintail

Ten variables accounted for 33 percent (R^2) of the variation in numbers of indicated pintail pairs per pond (Table 2). The first five variables accounted for 28 percent of the variation. As basin area and open water area increased, numbers of pairs per pond increased. Pintail pairs were most abundant on ponds in the Missouri Coteau with scattered dense patches or diffuse open stands of emergents (cover type 2).

Nine variables correctly classified 66 percent of the ponds with pintail pairs present (Table 3). Discriminant analysis also indicated that more pintail pairs were observed on larger basins. Mean basin area of ponds used was 2.51 ha compared to 0.73 ha for ponds not used. Pintail pairs tended to be present on ponds located in the Missouri Coteau with roundstem bulrush as a dominant emergent but were absent on ponds intensively grazed or with a peripheral band of emergents surrounding the shore.

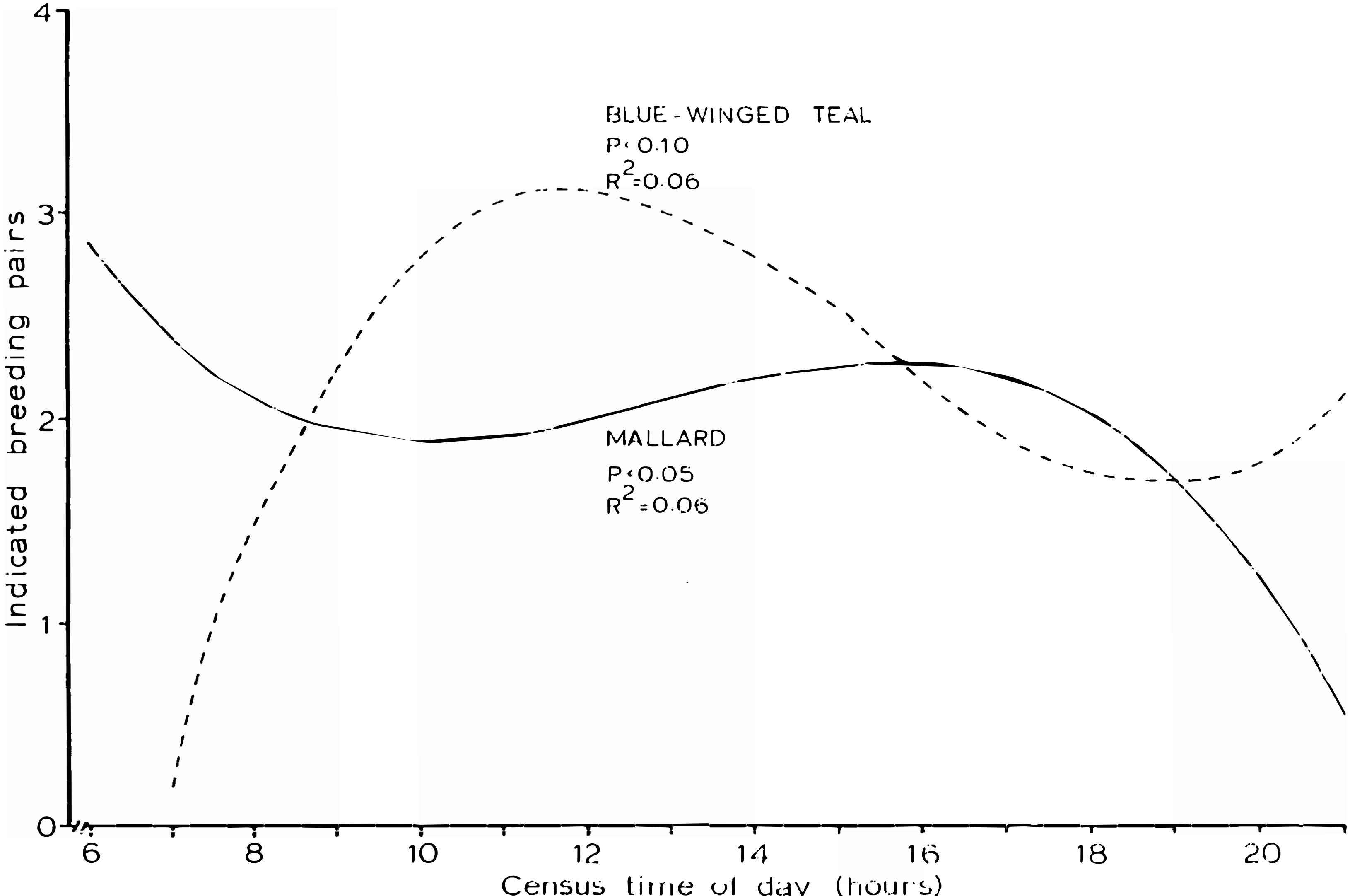

Figure 4. Polynomial regression of indicated breeding pairs on census time of day in Central Daylight time, 1973 - 1976.

The number and area of natural ponds on the plot were positively associated with the number of pairs using stock ponds (Appendix D). Pairs were positively correlated with diversity of wetlands and number of dry basins on the plot.

Surface water area was significantly ($P<0.01$) and positively correlated ($r = 0.20$) with pintail pair abundance but the sign of the regression and discriminant coefficients indicated that numbers of pairs decreased with increasing surface area. Regression and discriminant coefficient signs were not the same as the sign of the simple correlation coefficient because of intercorrelations with previously entered variables. Pintail pairs used ponds with a mean surface area of 1.79 ha while ponds not used averaged significantly ($P<0.005$) lower ($\overline{X} = 0.57$ ha). A curve fitting pintail pair response to surface water area was similar to the curve fitting response by mallard pairs (Figure 5).

Numbers of pintail pairs per pond increased with increasing shoreline irregularity (Figure 6). Pintail pairs responded linearly and positively to increasing shoreline development. Shoreline distance did not enter either the discriminant or regression equations due to correlation with previously entered variables.

Blue-winged teal

Eight variables accounted for 47 percent (R^2) of the variance in blue-winged teal pair abundance (Table 2). Shoreline distance alone accounted for 32 percent (R^2) of the variance in pairs. Numbers of

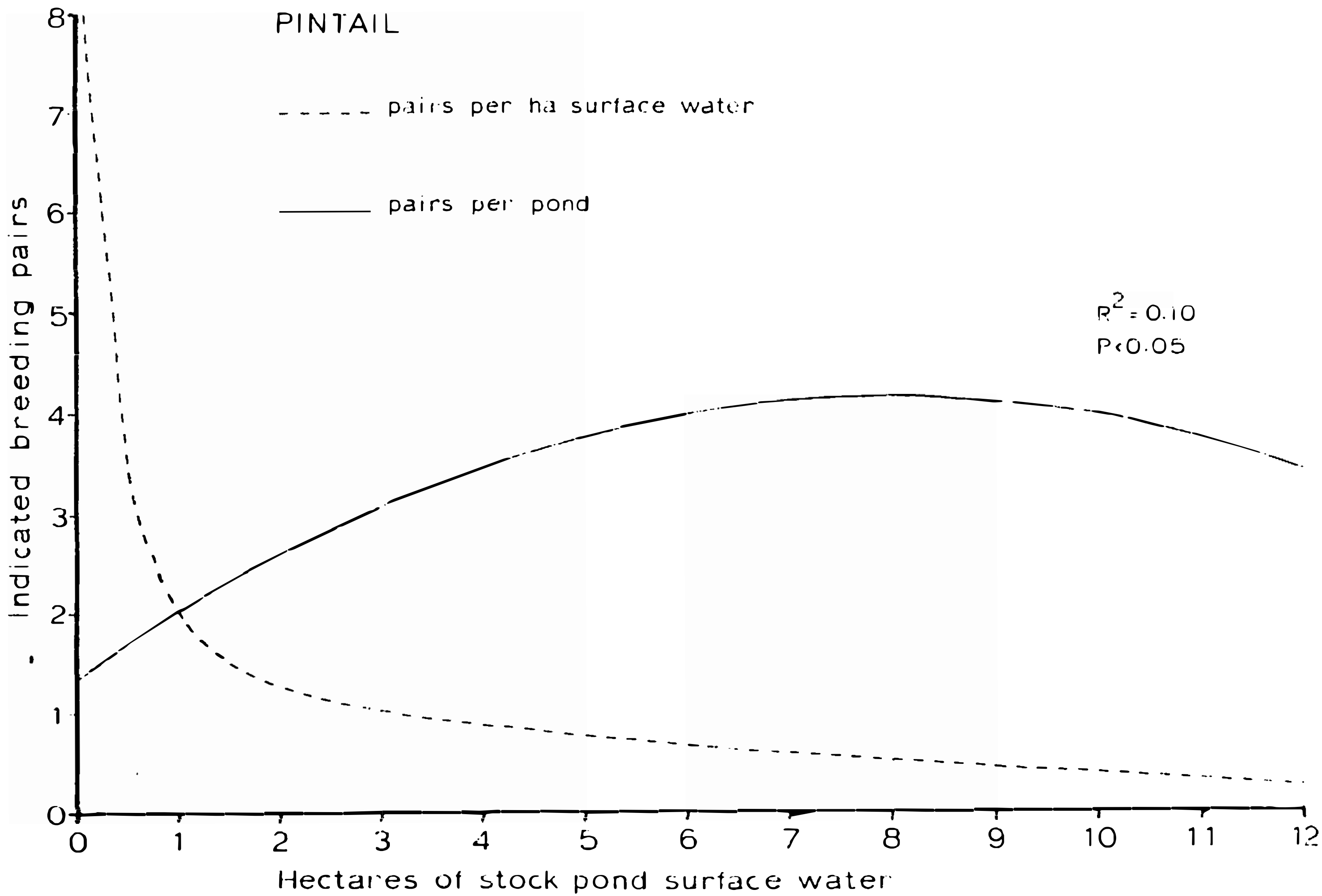

Figure 5. Polynomial regression of indicated pairs of pintails on surface water area, 1973 - 1976.

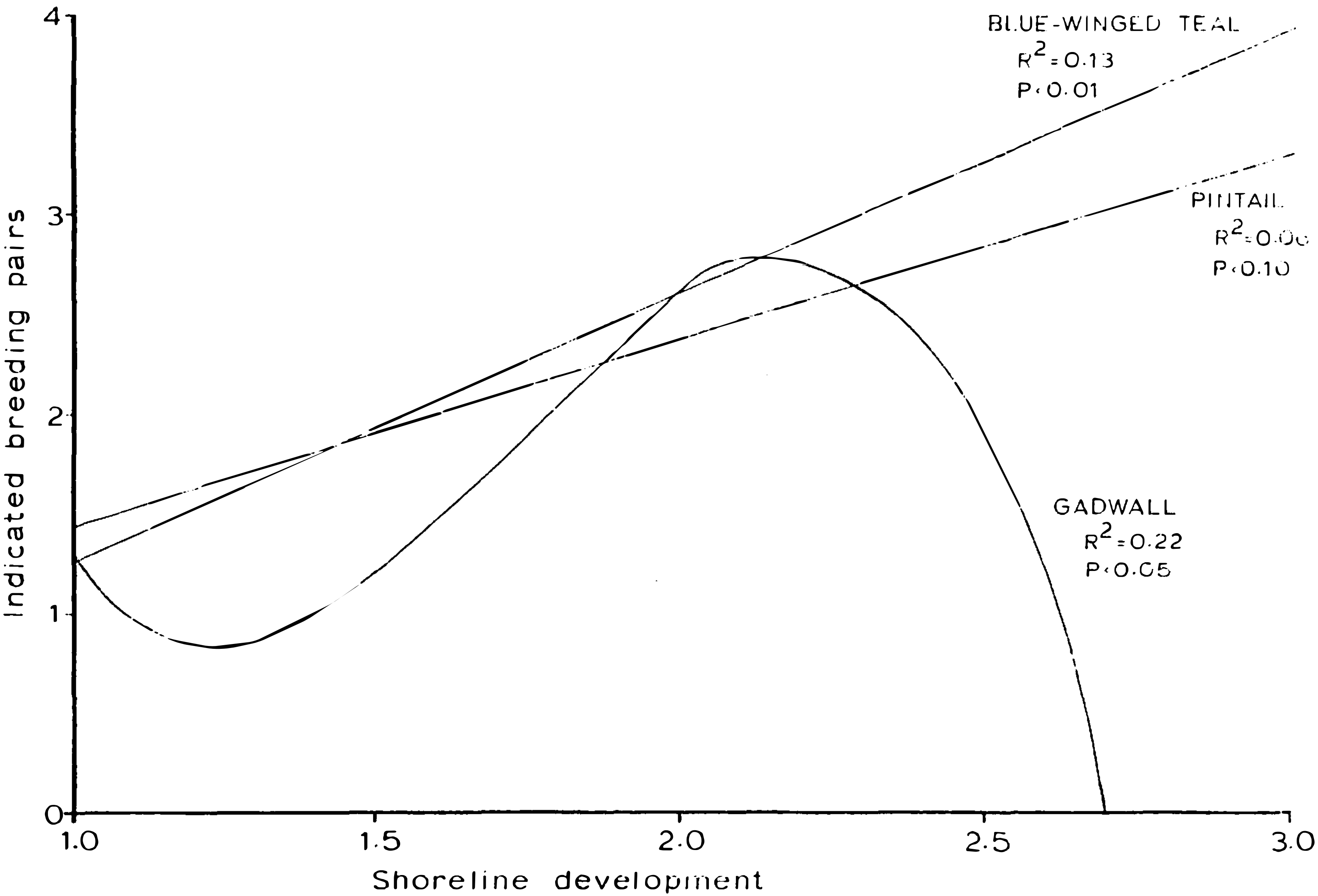

Figure 6. Polynomial regression for those species which were significantly regressed on shoreline development, 1973 - 1976.

blue-winged teal pairs increased with increasing shoreline distance and basin area. Presence of sedges (*Carex* spp.), roundstem bulrush, and spikerush (*Eleocharis* spp.) on the ponds was positively associated with use by more pairs. Pairs were less abundant on ponds located on plots with large farmsteads. Discriminant and regression coefficients for pond open water area were negative due to intercorrelations.

Twelve variables correctly classified 55 percent of the ponds which had at least one pair of blue-winged teal present (Table 3). Pairs were present on ponds with mean shoreline distance ($\overline{X}$ = 597 m) twice as large as the mean shoreline distance of ponds not used ($\overline{X}$ = 274, $P<0.005$). Numbers of pairs per pond increased with increasing emergent vegetation height. Ponds located in the Missouri Coteau and Southern Plateau were used more than ponds in the other two strata. Pairs tended not to use ponds where the number of other artificial basins on the plot was large and where farmsteads were large.

Emergent vegetation height and kinds were more highly correlated with blue-winged teal pairs than for mallard and pintail pairs (Appendix D). Blue-winged teal pairs were negatively correlated (r) with numbers and area of surface water of artificial wetlands but were positively correlated (r) with area of surface water of natural wetlands on the plot. Upland habitat variables were not significantly correlated with pair use.

Shoreline distance per unit surface area accounted for 13 percent

(R^2) of the variance in blue-winged teal pairs (Figure 6). The fitted line was significant ($P<0.01$) and positively related to use by more pairs.

Blue-winged teal pairs were more highly correlated ($r = 0.54$) with surface water area than any of the other variables except shoreline distance. Surface water area did not enter the regression equation due to correlations with previously entered variables. Likewise, intercorrelations caused surface area in the discriminant function to be related to ponds not used by pairs. Blue-winged teal pairs were positively related to ponds with greater surface area. The mean surface area of ponds with blue-winged teal present was 1.54 ha. The mean surface area of ponds without teal ($\overline{X} = 0.47$ ha) was significantly ($P<0.005$) smaller than those with teal.

Surface water area accounted for 30 percent (R^2) of the variation in blue-winged teal abundance (Figure 7). This high percentage and steep slope may explain the greater fluctuation in total numbers of blue-winged teal pairs observed on stock ponds over the four years (Table 1, Appendix C).

More blue-winged teal were observed from mid-morning (0900) to early afternoon (1500) than during any other part of the day. This is consistent with discriminant analysis results which indicated that temperature was an important variable associated with ponds having at least one pair of blue-winged teal. Higher temperatures corresponded with time of day when peak numbers of pairs were observed on ponds. Temperature and time were significantly ($P<0.01$, $r = 0.17$) correlated with each other.

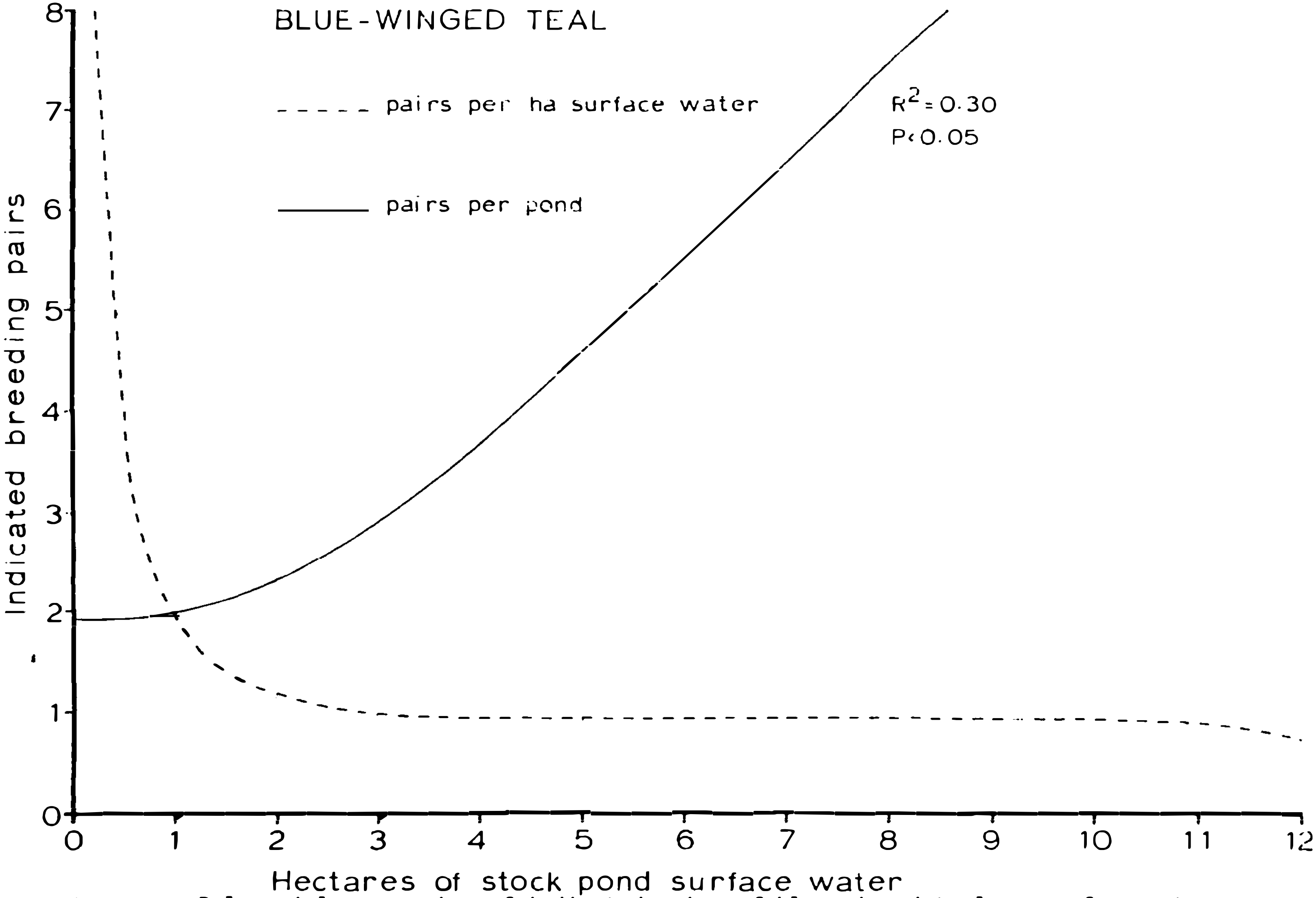

Figure 7. Polynomial regression of indicated pairs of blue-winged teal on surface water area, 1973 - 1976.

Gadwall

Six variables accounted for 31 percent of the variation in gadwall pair abundance (Table 2). The presence of sedges was the single best variable explaining gadwall pair use. Ponds having sedges and emergents scattered in dense patches or diffuse open stands (cover type 2) were used by more pairs than ponds without emergents. As pond open water area increased, numbers of pairs per pond increased.

Discrimination between ponds with gadwall pairs and ponds without pairs was good using eight variables (Table 3). Seventy-five percent of the ponds used by pairs were correctly classified. Pairs tended to be present on ponds with more open water area ($\overline{X}$ = 1.18 ha). Ponds located in the Missouri Coteau and Northern Plateau were more likely to have gadwall pairs than ponds in the other two strata.

Wetland diversity and surface area of natural ponds near stock ponds are potentially important variables positively correlated (r) with numbers of gadwall pairs per pond (Appendix D). However, these variables did not enter either the regression or discriminant functions as statistically significant.

The sign of the regression and discriminant coefficients for surface water area indicated that numbers of pairs decreased with increasing surface area. Again, this was due to intercorrelations with previously entered variables. Gadwall pairs were positively correlated ($r = 0.17$) with surface area. The mean surface area of ponds on which at least one pair of gadwall was observed was 1.39 ha. This was significantly ($P<0.005$) greater than the mean surface area of ponds lacking gadwall pairs. Again, smaller ponds were increasingly more efficient in amount of surface area utilized (Figure 8).

Unlike pintail and blue-winged teal pairs, gadwall pairs responded non-linearly to increasing shoreline development (Figure 6). The cubic relationship was significant ($P<0.01$) and accounted for 22 percent of the variation in gadwall pairs. Pairs were most abundant on ponds with shoreline development of about 2.2. Ponds with twice the shoreline distance necessary to just enclose the surface water area were used by more gadwall pairs than ponds with greater or less shoreline development.

American wigeon

Five variables accounted for 12 percent (R^2) of the variation in pair abundance using multiple regression analysis (Table 2). The presence of sedges and roundstem bulrushes on the pond accounted for most of this variation. Pairs were more abundant on ponds where these emergents were dominant. Pairs were absent on ponds with a peripheral band of emergents.

Eighty-five percent of the ponds having American wigeon pairs were correctly classified using five variables (Table 3). Pairs were observed on ponds having roundstem bulrush and sedges as dominant emergents but were absent from ponds with a peripheral band of emergents. Pairs tended to occur on ponds located on plots with treeland.

American wigeon pairs were least like pairs of any other species

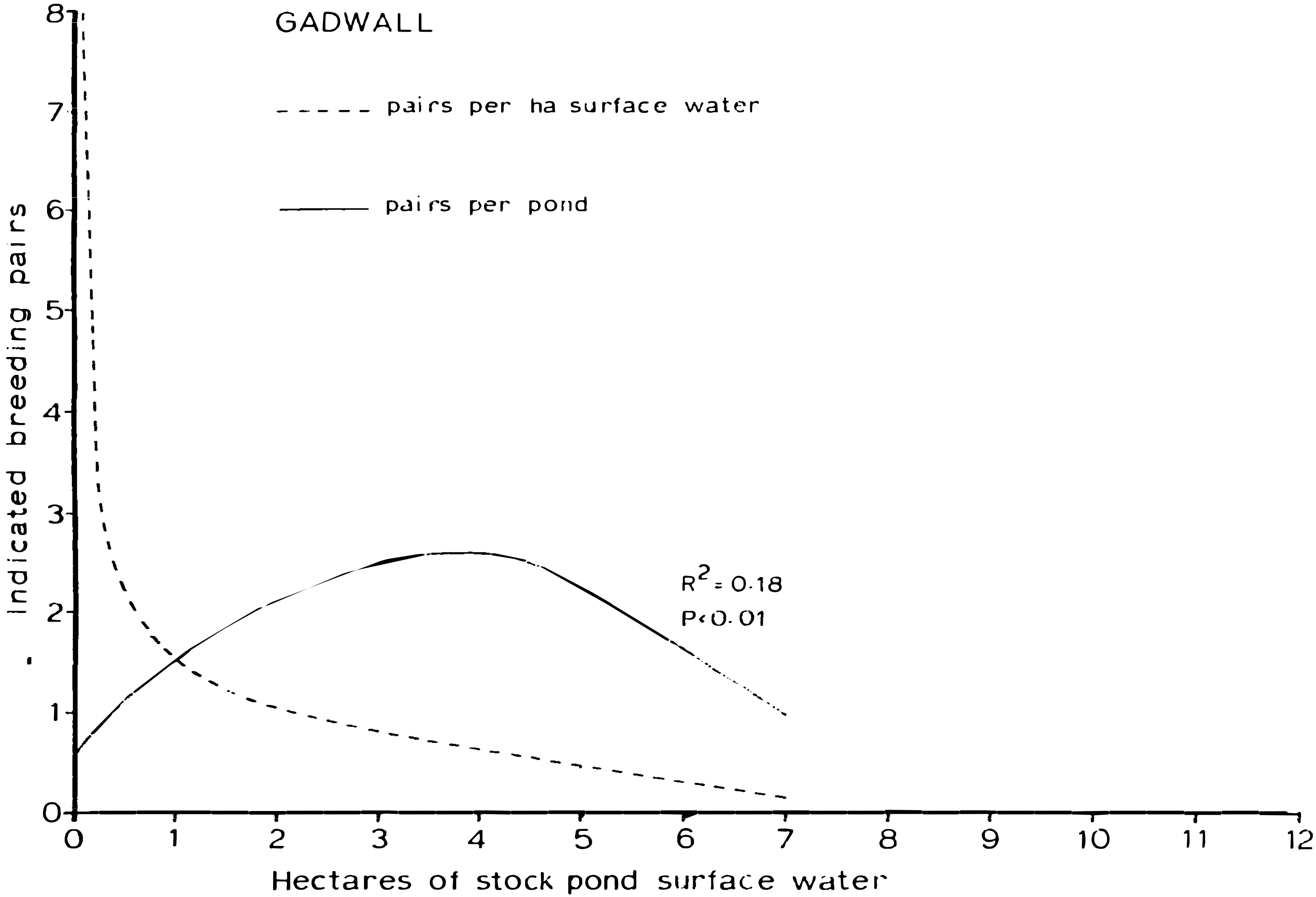

Figure 8. Polynomial regression of indicated pairs of gadwall on surface water area, 1973 - 1976.

in terms of the kinds of independent variables which were significantly correlated with numbers of pairs per pond (Appendix D). Wetland and upland habitat variables were not significantly correlated with pairs. Pond open water area and emergents in scattered dense patches or diffuse open stands (cover type 2) were the only wetland habitat variables correlated with pair abundance.

American wigeon pairs were positively correlated with number of natural ponds in the vicinity of the stock pond but were negatively correlated with numbers of artificial basins in the same area (Appendix D). Pairs were positively correlated with ponds located in the Northern Plateau.

Surface water area was not significantly correlated with numbers of pairs per pond (Appendix D) nor was it significant in either multiple regression or discriminant functions. However, a curve significantly ($P<0.05$) explained pair response on surface water area (Figure 9). Pairs were not observed on ponds larger than 5 ha in surface area. There was no significant difference in the surface area of ponds used by pairs (1.08 ha) and surface area of ponds not used (0.77 ha). Ponds with surface area less than 1.0 ha had higher numbers and densities of pairs than ponds between 1.0 ha and 2.0 ha in surface area.

Northern shoveler

Ten variables accounted for 35 percent (R^2) of the variation in abundance of northern shoveler pairs (Table 2). Pond basin area accounted for more of this variation than any other variable. Numbers

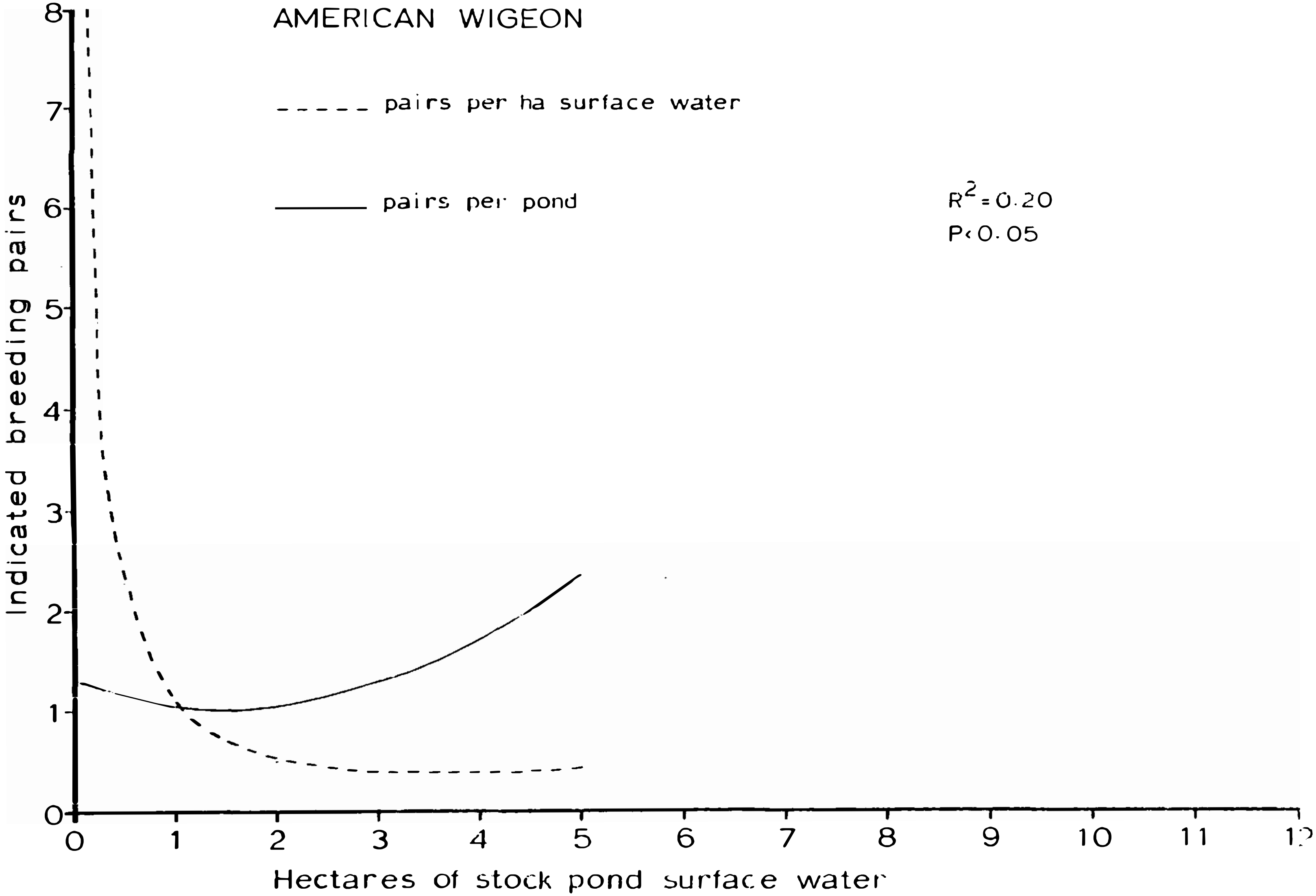

Figure 9. Polynomial regression of indicated pairs of American wigeon on surface water area, 1973 - 1976.

of pairs per pond increased with increasing basin area. Pairs were more abundant on ponds with sedges and roundstem bulrush than on ponds with river bulrush (*Scirpus fluviatilis*). Pairs per pond increased with increasing surface area of natural wetlands on the plot but decreased with increasing numbers of natural wetlands and area of farmsteads.

The discriminant analysis results showed the same trend as multiple regression results with pairs present on ponds with larger basin area ($\overline{X}$ = 4.15 ha). Fifty percent of the ponds used by indicated pairs were correctly classified using 10 variables. Ponds used tended to have sedges and cattail but not river bulrush. Pairs tended to occur on ponds located on plots with more surface area of natural wetlands ($\overline{X}$ = 1.15 ha versus 0.15 ha) than on ponds not used. Ponds located on plots with larger area of small grain but smaller farmsteads tended to have pairs present.

Correlation coefficients (r) were significant ($P<0.01$) for nearly the same set of independent variables as were gadwall pairs (Appendix D). Northern shoveler pairs were negatively correlated with number of artificial wetlands but were positively correlated with number of natural wetlands on the same plots. The larger the surface area of these natural wetlands the more northern shoveler pairs were present on stock ponds. Pairs were also positively correlated with ponds located in the Missouri Coteau. Missouri Coteau stock ponds were positively correlated with greater wetland diversity (r = 0.43) and greater number of dry basins (r = 0.40) (Appendix E).

Surface water area accounted for a greater proportion of the variation (R^2 = 0.54) in numbers of northern shoveler pairs per pond than for any other species using polynomial regression (Figure 10). Yet, surface area did not enter either the linear regression or discriminant functions due to intercorrelations with such variables as pond basin area (r = 0.92). Hectares of surface water would have entered as the best variable accounting for more variation in pair use than any other had hectares of pond basin been omitted from the analysis. Mean size of ponds used (3.15 ha) was significantly different ($P<0.005$) from the mean surface area of ponds not used (0.70 ha). The mean surface area of ponds used was larger than the mean for any other waterfowl species studied.

Green-winged teal

Five variables accounted for 13 percent (R^2) of the variation in green-winged teal pair abundance (Table 2). All five were positively correlated with numbers of pairs. Numbers of green-winged teal pairs per pond increased with increasing basin area and area of fallow on the plot.

Five variables correctly classified 27 percent of the ponds used by green-winged teal pairs (Table 3). Pairs used ponds with emergent vegetation twice as tall as the mean vegetation height of ponds with pairs absent. On the average, green-winged teal pairs used ponds with three times as many dry natural basins on the plot as the number of dry basins associated with ponds not used. Mean shoreline distance of ponds with pairs present ($\overline{X}$ = 842 m) was twice as large

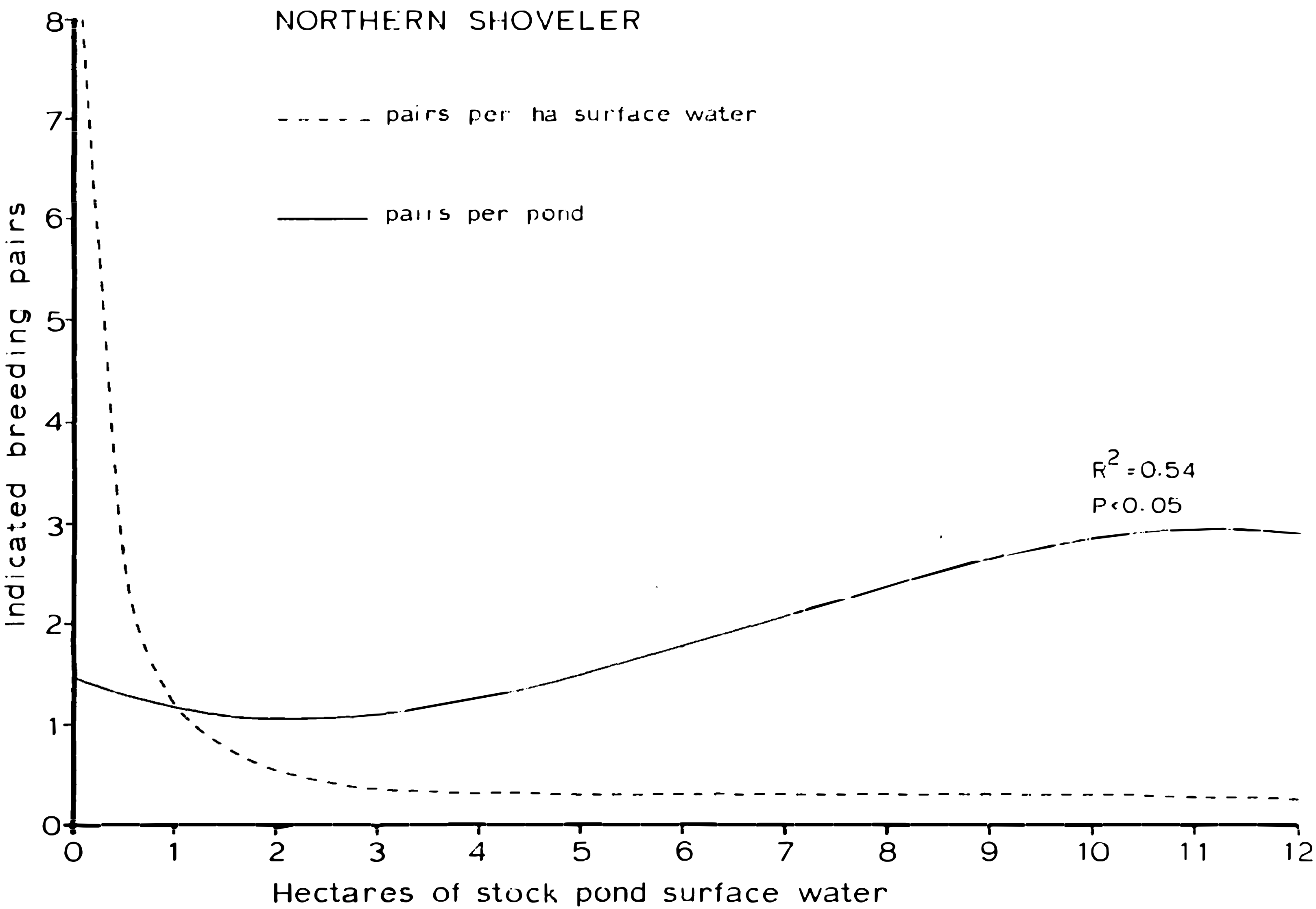

Figure 10. Polynomial regression of indicated pairs of northern shoveler on surface water area, 1973 - 1976.

as the mean distance of ponds not used ($\overline{X}$ = 391 m, P<0.005).

Number of pairs was significantly correlated (r = 0.17) with surface water area (Appendix D) but was not a significant variable in either the regression or discriminant functions. Pair response on surface water area could not be significantly (P<0.05) fitted by a curve.

Early-nesting species

Discriminant analysis was used to distinguish between ponds used by mallard pairs and ponds used by pintail pairs. Six variables correctly classified 91 percent of the ponds with mallard pairs present and 26 percent of the ponds with pintail pairs present (Table 4). Pintail pairs tended to occur on ponds with a greater diversity of associated wetlands than did mallard pairs. Pintail pairs also occurred on larger basins than mallard pairs. Mean basin area of ponds used by pintail pairs ($\overline{X}$ = 2.51 ha) was significantly (P<0.05) different from the mean basin area of ponds used by mallard pairs ($\overline{X}$ = 1.66 ha). Ponds located further from farmsteads tended to have more mallard pairs and fewer pintail pairs. Pintail pairs were less likely to be present on ponds with the shoreline obscured by a dense band of peripheral emergent vegetation.

Mid- and late-nesting species

Discrimination was not good between ponds utilized by different species of mid- and late-nesting ducks (Table 5). Overall, 50 percent

Table 4. Discriminant analysis between ponds with one or more indicated pairs of mallard and ponds with one or more indicated pairs of pintail, 1973 - 1976. All variables were significant (P<0.10) using Rao's V.

Groups	Number of cases	Percent of cases correctly classified	Centroids in reduced space	Discriminating variables	Standardized discriminant function coefficients
Ponds with mallard	158	90.5	0.2044	Number of wetland classes on the plot	-0.8497
Ponds with pintail	65	26.2	-0.4969	Distance to nearest farmstead	0.2552
Total	223	71.8		Number of artificial wetlands with surface water on the plot	0.3450
				Cover type 3	0.3683
				Ha of pond basin	-0.3551
				Depth rating 1	-0.2830

Table 5. Discriminant analysis between ponds with blue-winged teal, gadwall, American wigeon, northern shoveler, and green-winged teal indicated breeding pairs, 1973 - 1976. The percent correctly classified is based on four discriminant functions. Only the first (A) and second (B) are listed in this table. Variables were significant (P<0.15) using Rao's V.

Groups	Number of cases	Percent of cases correctly classified	Centroids in reduced space A	Centroids in reduced space B	Discriminating variables	Standardized discriminant function coefficients A	Standardized discriminant function coefficients B
Ponds with blue-winged teal	110	82.7	-0.0818	0.3076	Percent of the shoreline grazed	0.1020	-0.5139
Ponds with gadwall	56	25.0	0.3095	-0.2554	Ha of pond basin	-0.3686	-0.1354
Ponds with American wigeon	27	0.0	0.4406	-0.3430	Depth rating 5	-0.4673	-0.0588
Ponds with northern shoveler	14	28.6	-1.1631	-0.6728	Southern Plateau	-0.0110	0.5992
Ponds with green-winged teal	11	9.1	-0.3592	-0.0776	Ha of surface water of natural wetlands on the plot	-0.4013	-0.0356
Total	218	50.46					
					Depth rating 4	-0.4101	-0.0948
					Depth rating 1	-0.3435	-0.0613
					Temperature	-0.3958	0.1404
					Number of artificial wetlands with surface water on the plot	0.0577	0.4065
					Number of wetland classes on the plot	0.1619	-0.1589
					Distance to nearest farmstead	0.3342	-0.3321

of the ponds were correctly classified using 11 variables. An ordination of these species on the discriminating variables helps clarify the relationships between pairs and habitat (Figure 11). Northern shoveler and blue-winged teal pairs were observed on ponds with larger basin area than gadwalls and American wigeons. Mean basin area of ponds used by these four species was northern shovelers (4.15 ha), blue-winged teal (2.05 ha), gadwalls (1.63 ha), and American wigeons (1.37 ha). Blue-winged teal and northern shoveler pairs tended to be present on ponds with variable water levels while gadwall and American wigeon pairs were present on ponds with stable water levels at the normal high water mark. Northern shoveler pairs were present on more ponds which had water levels above the normal high water mark than the other species. Northern shoveler pairs were present on ponds located on plots with mean surface area of natural wetlands of 1.11 ha. This was significantly ($P<0.05$) different from the mean surface area of natural wetlands for American wigeon pairs ($\overline{X}$ = 0.13 ha). Blue-winged teal used more ponds located in the Southern Plateau and were associated with more artificial wetlands than were northern shoveler pairs.

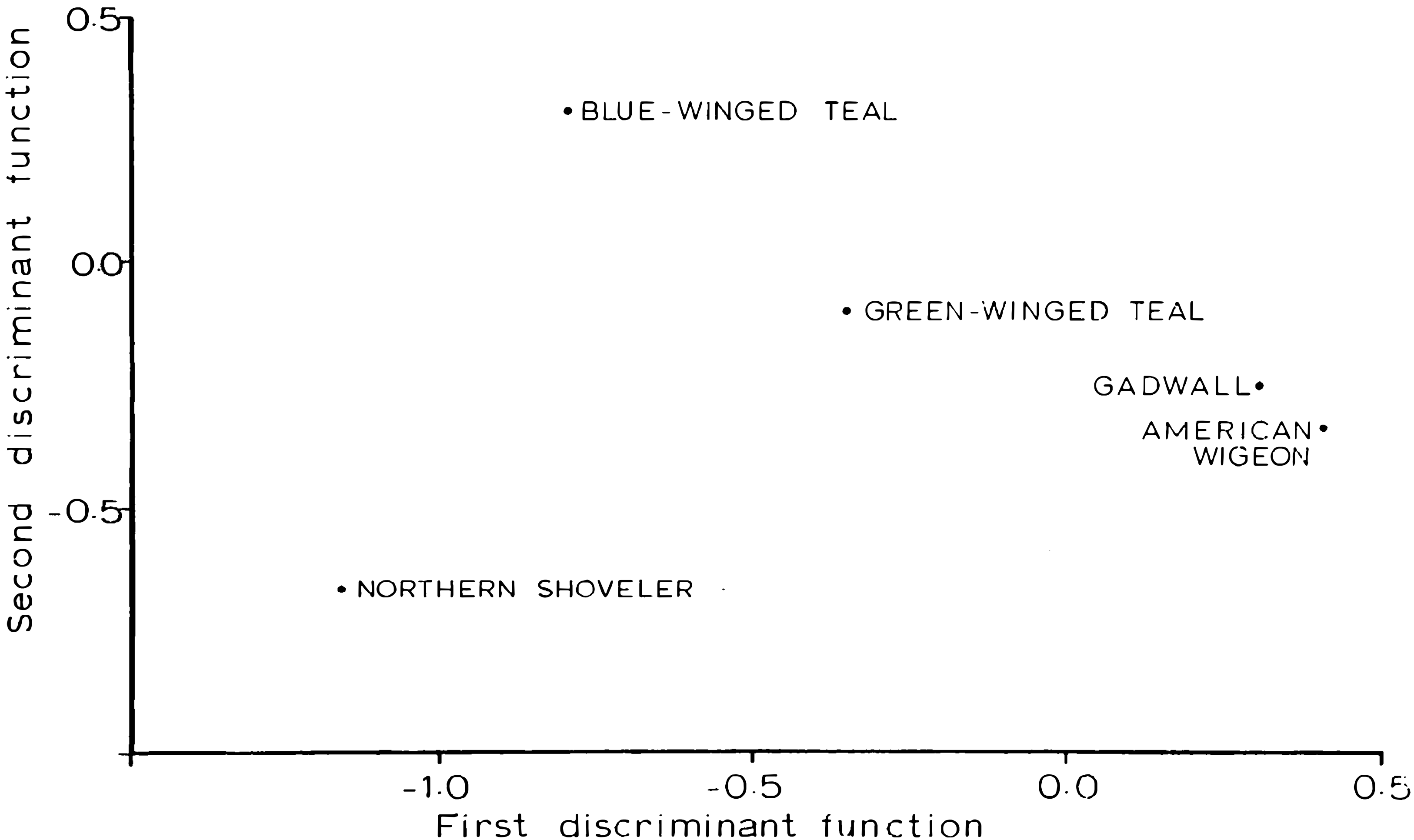

Figure 11. Ordination of mid- and late-nesting waterfowl species on the first two discriminant functions, 1973 - 1976.

DISCUSSION

Differences in percentages of variance explained (R^2) between species roughly followed the differences in home range sizes. Species with smaller home ranges would be expected to spend more of their time on fewer ponds so that variability in type of habitat would be less. Habitat variables would be able to account for more of the variability in numbers of pairs. Highest percentages of variance explained occurred for blue-winged teal (47 percent) and northern shovelers (35 percent) which use relatively smaller home ranges (Gates 1962, McHenry 1971, Poston 1974). Mallards, pintails, gadwalls, and American wigeons use larger home ranges (Dzubin 1955, Bellrose 1976) and had smaller percentages (26 to 35 percent) of the variance explained.

Wetland habitat

Shoreline distance accounted for more variation in mallard and blue-winged teal pairs than any other variable. Mallard and blue-winged teal pairs per pond increased with increasing shoreline length. Hochbaum (1944) observed that more breeding pairs used wetlands with greater shoreline length.

Increasing irregularity of shoreline appeared to attract more breeding pairs. Numbers of blue-winged teal and pintail pairs increased proportionately with increasing shoreline irregularity. Gadwall pairs per pond did not respond linearly to shoreline development. Numbers of gadwall pairs per pond may reach an upper limit (S.D. = 2.2) beyond which increasing shoreline irregularity has no additional value. More pairs may be observed on ponds with longer or more irregular shorelines for several reasons. Bennett (1938) and Smith (1955) observed that the number of male waiting sites limited the number of breeding pairs using the wetland. As shoreline length increased, the number of potential drake waiting sites increased.

Small bays and peninsulas may provide natural concealment between adjacent territorial pairs resulting in reduced strife, compressed territorial sizes, and increased local population. Drewien and Springer (1969) attributed greatest blue-winged teal densities on temporary glacial ponds to the greater ratio of edge of shoreline per unit surface area. Bue (1956) believed that stock ponds received greater use by breeding pairs than did natural wetlands because stock ponds provided more points and inlets for natural territorial boundaries.

More shoreline may indicate more available nesting cover. Bennett (1938) noted that there was a positive relationship between shoreline length of wetlands used by blue-winged teal and the amount of nesting cover within 200 m. Availability of nesting cover may positively influence blue-winged teal since blue-winged teal nest near water (Sowls 1955, Glover 1956). Mallard and pintail pairs are capable of nesting much further from water yet appear to be positively influenced by shoreline distance also. Bue (1956) found that where adjacent nesting cover was absent, mallards and pintails travelled further to nest without adversely influencing use of the stock pond. Apparently, several factors were interacting making shoreline distance an important variable associated with pair use.

Breeding dabbling ducks were more abundant on natural ponds with greater surface water area (Hochbaum 1944, Stoudt 1949, Evans et al. 1952) but more efficiently utilized smaller wetlands (Bennett 1938, Evans and Black 1956, Jenni 1956, Stoudt 1969). These same relationships applied to stock ponds (Lokemoen 1972). Lokemoen (1973) found that stock pond surface water area was the highest positively correlated variable with duck use of any of the habitat variables he studied. Flake et al. (1977) found similar results for total breeding pairs. It is interesting to note that neither of these two studies included pond basin area, shoreline distance, or presence of sedges as independent variables. Each of these variables was more highly correlated with one of the seven dabbling duck species studied here than was surface water area. The simple correlation coefficients indicate that surface water area would have been the highest positively correlated variable with blue-winged teal and northern shoveler pairs if these three variables had been omitted from the analysis.

The importance of surface water area to breeding pairs was often suppressed due to fractional differences in correlation between the wetland habitat variables and correlations (r) with previously entered variables. Standardized regression and discriminant function coefficients indicated surface water area was an important variable relative to the other variables entered. Mallard, pintail, and gadwall pairs were more abundant on ponds with larger surface water area. Surface area was also importantly associated with northern shovelers, blue-winged teal, and green-winged teal.

Flake et al. (1977) found that surface water area was importantly associated with mallard and gadwall pairs but was of lesser importance to blue-winged teal and American wigeon pairs. Emergent vegetation variables were associated more with blue-winged teal and American wigeons than was pond size.

Surface water area was not an important variable associated with American wigeons but was important to blue-winged teal pairs in this study. Blue-winged teal pairs increased in near proportion to pond size and appeared to be dependent on surface water area. American wigeon pairs may not be influenced by pond size as much as other species. The mean size of ponds used by American wigeon pairs was not significantly different from the mean size of ponds available. Smith (1971) found that American wigeon pairs preferred smaller ponds ranging in size from 0.24 ha to 0.66 ha in Alberta. Stoudt (1971) observed that American wigeon pairs appeared to be less affected by drought than any other species at Redvers, Saskatchewan.

Pond basin area accounted for more variance in pintail, northern shoveler, and green-winged teal pairs than any other variable including surface water area. Pairs of these species were more abundant on ponds with larger basins. Surface water area in combination with unknown factors associated with the shore appeared more important to these pairs than the area of surface water alone. The area between the high water mark and the actual water mark may be an important variable associated with northern shovelers, pintails, and blue-winged teal. Blue-winged teal and northern shovelers were present on more ponds with 25 percent of the deep marsh zone dry than were American wigeon or gadwall pairs. Pintail pairs used more flooded ponds than did mallard pairs. Shallow water has been shown to be an important characteristic of pintail breeding habitat (Smith and Stoudt 1968). Smith (1970) concluded that pintails preferred types of wetlands that were subject to seasonal and annual instability.

Emergent vegetation

Genera, height, and interspersion of emergent vegetation were important variables associated with breeding pair use of stock ponds. The presence of sedges accounted for more variation in numbers of gadwall and American wigeon pairs than any other single variable. Sedges were positively correlated with gadwall, American wigeon, blue-winged teal, and northern shoveler pairs. Sedges were not significantly associated with early-nesting mallard and pintail pairs presumably because sedges had not emerged at the time of the early pair counts. Emergents provide food and cover and may be related to abundance and availability of invertebrates (Mendall 1958). Keith (1961) found seeds of sedges were a food item for northern shovelers, mallards, blue-winged teal, and green-winged teal.

Roundstem bulrush was an important variable positively correlated with each breeding waterfowl species studied. Pairs of pintail, gadwall, and American wigeon used more ponds with roundstem bulrush than ponds without this emergent. The presence of roundstem bulrush was the best single variable distinguishing between ponds with and without American wigeon pairs. Flake et al. (1977) found emergents were associated with American wigeon pairs using stock ponds in Harding County, South Dakota. Achenes of roundstem bulrushes are an important food item for ducks (Bennett 1938, Keith 1961). Roundstem bulrush may have other values such as brood rearing cover and roosting cover.

Stock ponds with spikerush received greater use by blue-winged teal pairs than those without. Keith (1961) observed that seeds of spikerush were the preferred food of dabbling ducks on his study area in Saskatchewan.

The interspersion pattern of these emergent species also appeared to be important to pairs. Mallard, pintail, blue-winged teal, gadwall, and American wigeon pairs were positively correlated (r) with scattered dense patches or diffuse open stands of emergents. More pairs of pintail and gadwall occurred on ponds with this cover type than on completely open ponds. Pintails, American wigeons, northern shovelers, and green-winged teal tended not to use ponds surrounded by a dense band of emergents. Open shorelines may have been used because more loafing sites were available. Bue et al. (1964) stated that shallow protected shorelines produced tall emergents such as cattail and roundstem bulrush which were not attractice to pairs. Keith (1961) observed that cattail-bordered ponds supported the fewest breeding pairs per unit of shoreline and that blue-winged teal were least affected by differences in shoreline type. Stock ponds devoid of any shoreline vegetation also received little use by breeding waterfowl (Bue et al. 1952, Lokemoen 1973).

Open water lacking dense emergents appeared to be an important criterion for use by all pairs. Open water area was significantly ($P<0.01$) and positively associated with numbers of pairs of all species. More pintail, blue-winged teal, gadwall, and northern shoveler pairs occurred on ponds with larger open water area. Open water area was particularly important to gadwall pairs. Breeding waterfowl may avoid wetlands with congested dense stands of emergents (Bue 1956, Evans and Black 1956, Smith 1969).

Blue-winged teal may not be as selective in regard to shoreline vegetation as other pairs. Blue-winged teal were positively correlated with both sparse and dense shoreline cover types but neither was a significant variable in accounting for more blue-winged teal pairs using a pond. Blue-winged teal were positively correlated with cattails.

Mallard pairs were more likely to use ponds with a peripheral band of emergents than were pintails. Pintails preferred more open shoreline with exposed edges and open water than did mallards (Hochbaum 1944, Sowls 1955). Smith (1969) believed pintail pairs were much more specific in their habitat needs than mallards, preferring grassy, open ponds while mallard pairs used a variety of habitat types. Stoudt (1971) suggested that more closed ponds may have been selected by mallards because of the isolation afforded by the peripheral vegetation.

Grazing of the shoreline may open up dense stands of emergents and thus be beneficial to breeding pairs (Bennett 1938, Sowls 1955, Smith 1971, Rundquist 1973). Stoudt (1971) observed that ponds with ungrazed margins were used more frequently by mallards and blue-winged teal than were ponds with grazed margins. Flake et al. (1977) concluded that gadwall pairs were positively associated with trampled and bare-soil shorelines.

In this study we found that gadwall and American wigeon pairs tended to use ponds with more of the shoreline grazed than did northern shovelers. Gadwall and American wigeon pairs were less abundant on ponds with a dense peripheral band of emergents.

Mallard and pintail pairs were less abundant on stock ponds where the periphery was grazed more intensely. Pairs of these species were more abundant on ponds in ungrazed or only lightly grazed pastures. Over-grazing is detrimental to breeding waterfowl use of stock ponds. Salyer (1962) and Kirsch (1969) have observed more pairs on wetlands on ungrazed land than on grazed land. Bue et al. (1964) concluded that over-grazing of stock ponds not only reduced the occurrence of desirable nesting cover species but also reduced the density-height conditions necessary to nesting waterfowl. Duebbert and Kantrud (1974) have shown that the type of cover available to dabbling duck hens at the beginning of nesting was an important factor in nest site selection. Jahn and Hunt (1964) have observed that breeding mallard pairs in Wisconsin were most abundant on wetlands where adjacent nesting cover was abundant. Smith (1971) found that mallards did not use the heavily grazed open shorelines if other areas were available.

Emergent vegetation height was positively associated with all species of breeding pairs except American wigeons. Mallard pairs were more abundant on ponds with taller emergents. Blue-winged and green-winged teal tended not to use ponds which had shorter emergent vegetation.

Keith (1961) noted that presence of residual upland cover from previous years may be extremely important to early nesting pairs. Gjersing (1975) observed that pair populations seemed to respond positively to increased residual vegetation resulting from rest rotation grazing. Kadlec (1962) noted that residual vegetation must be present in early spring for maximum breeding pair use. He also observed that residual vegetation collected snow in winter which resulted in thinner ice and earlier spring thawing. Early thawing provided open water for early arriving pairs which influenced selection of breeding areas. Mundinger (1976) found that greater pair use occurred in years following a rest period from grazing on pastures which he felt was due to increased residual vegetation.

Wetland association

A variety of wetlands in the home range may be necessary to provide all the breeding habitat requirements of pairs (Dzubin 1969a).

We found that the number of wetland classes on the plot was an important variable associated with breeding pair use of stock ponds. Pintail, gadwall, and American wigeon pairs may require greater wetland diversity to satisfy a greater variety of specific breeding habitat needs. Characteristically larger home range sizes for these species may be the result of the need for greater wetland diversity. Blue-winged teal and northern shoveler pairs may have needs which are met on one or two ponds and do not require a diversity of wetlands. No literature evidence could be found to support this hypothesis.

Mallard pairs were inversely correlated (r) with numbers and areas of artificial wetlands on the plot and with wetland diversity. Mallard and American wigeon pairs were not correlated (r) with numbers or areas of surface water of natural wetlands on the plot. Mallard pairs may prefer more isolated ponds (Evans and Black 1956). Stock ponds associated with the least number of other wetlands would offer the least chance of interspecific disturbance. A large number of other wetlands with open water on the plot could negatively influence mallard pair use of stock ponds located in the same area. Conversely, it is possible that mallard pairs use more isolated ponds because of their larger home range size (Lokemoen 1973). Out-lying ponds would tend to be used more by those species with larger home ranges.

At least two other explanations are possible. More mallard pairs may be using isolated ponds because pairs were being crowded onto the available water areas. Also, fewer mallard pairs may use stock ponds when pairs could disperse onto many associated natural wetlands.

located nearby. Evidence to support these explanations is lacking.

Too many man-made wetlands on the plot may negatively influence pair use on a particular stock pond. The number and surface area of the other stock ponds and dugouts on the study plot were negatively correlated (r) with mallard, blue-winged teal, gadwall, northern shoveler, and American wigeon pairs. It was also possible that as the number of other artificial basins on the plot increased, pairs spaced themselves (territoriality) on all available ponds such that use of any given pond decreased. Numbers or surface areas of natural wetlands were positively correlated (r) with pintail, blue-winged teal, gadwall, and northern shoveler pairs on stock ponds. Natural ponds may provide some pair requirements not available on man-made ponds.

Northern shoveler pairs may prefer stock ponds associated with a few large natural wetlands rather than many small wetlands. Surface water area of natural wetlands on the plot was positively correlated with numbers of northern shoveler pairs but pairs tended to be present on ponds located on the plots with fewer natural wetlands. Larger ponds definitely have the advantage in being more permanent, thus offering more brood security. It was also possible that a greater number of natural wetlands on the plot allowed northern shoveler pairs to be more dispersed with fewer numbers being present on a stock pond at any given time. Fewer but larger natural wetlands on the plot would be used less with more pairs using the stock pond. I could find no evidence to support either explanation.

Numbers of dry basins associated with breeding pairs may indicate crowding on stock ponds as a result of pairs homing to dry wetlands or crowding on stock ponds as a result of other wetlands drying up. Pintails, gadwalls, and green-winged teal were positively correlated (r) with number of dry basins on the plot. Pintail pairs were more abundant on ponds associated with more dry basins. Sowls (1955) found highest percentages of returning hens to Delta, Manitoba, for pintails, gadwalls, and northern shovelers while smallest percentages were for blue-winged teal and mallards. Gates (1962) calculated high homing rates for gadwall hens to Ogden Bay, Utah. Thus, the pintail and gadwall pairs observed on stock ponds in this study may have been forced to use stock ponds when basins they were homing to became dry.

Physiographic strata

Some geographic preference by breeding waterfowl has been noted in South Dakota (Ruwaldt 1975, Brewster et al. 1976). Edminster (1964) observed that stock ponds located in the traditional flyway of waterfowl were more likely to be used than ponds located outside the original range. In this study, geographic location of stock ponds was an important variable associated with use by different species. All pairs except American wigeons and green-winged teal were more common on stock ponds in the Missouri Coteau. The Missouri Coteau, by nature of its location in the Prairie Pothole Region, has more natural glacial wetlands and a more integrated wetland system than the west-river strata. Pairs could prefer stock ponds located in this stratum because of the complex of associated natural wetlands.

However, numbers and types of wetlands on the plot with stock ponds should have accounted for most of this variation but usually entered the regression and discriminant functions after the strata variables. This indicated that other variables not measured in this study influenced the geographic distribution of pairs on stock ponds.

Upland habitat

Upland habitat variables were not as highly correlated with breeding pairs using stock ponds as wetland association variables. Mallard pairs were less abundant on ponds located on plots with a large area of fallow but were positively associated with area of small grain on the plot. Pintail pairs were most abundant on ponds adjacent to large amounts of pasture. Northern shoveler pairs were more abundant on ponds with upland areas in small grain. American wigeon pairs tended to use ponds located on plots with treeland.

Stoudt (1971) found that mallard pairs at Redvers, Saskatchewan, were more abundant on ponds in cultivated land as opposed to pasture where pintail, blue-winged teal, and canvasback were more abundant. Smith (1971) found that American wigeon pairs were more abundant on natural ponds surrounded by hayland and ungrazed woodland. Similar results for mallard, pintail, and American wigeon pairs were found in this study.

Disturbance

Roads located on the plot did not appear to adversely disturb breeding pairs. In fact, pintail pairs were positively correlated (r) with hectares of roadside. Gadwall pairs tended to use ponds located on plots with more roadside area. Mallard pairs were more abundant on stock ponds located near roads. Roadsides may be important nesting cover for all dabbling duck species (Smith 1971). Milonski (1958) has shown that roadsides were preferred nesting cover for pintail pairs.

Disturbance due to human activity around farmsteads may negatively influence pairs of some breeding species. Gadwall and American wigeon pairs tended to use ponds located further from occupied farmsteads than did northern shovelers, green-winged teal, and blue-winged teal. Gadwall pairs were more abundant on ponds located further from farmsteads. Mallard pairs were more likely to use ponds located further from farmsteads than were pintail pairs. This would indicate that mallards, gadwalls, and American wigeons preferred stock ponds isolated from farmsteads while pintails, northern shovelers, blue-winged teal, and green-winged teal were less affected.

Time and temperature

Mallard pair use of stock ponds increased with increasing pond age but pair use declined after about 16 years. Lokemoen (1973) found that mallard pairs using stock ponds in North Dakota were positively related to pond age with ponds less than five years old being used less by pairs. He suggested that removal of vegetation and lack of nutrients following construction caused younger ponds to be used less.

Time of day may also be an important factor influencing use by pairs. Lulls and peaks of use by mallard pairs occurred at times when pairs were likely to be returning from or going to feeding areas. Mallard pairs may have been going to fields to feed or nest from 600 to 900 CDT and from 1800 to 2100 CDT.

Hochbaum (1955), Bossenmaier and Marshall (1958), and Winner (1959) observed that ducks feeding in upland areas tended to concentrate their feeding flights into two daily periods, one during early morning and the other during late afternoon or evening. Dzubin (1969a) observed that pairs left census ponds in early morning to fly to nesting cover. He observed that mallards, pintails, and American wigeons were not observed on study ponds in evening and morning because they fed on grain stubble at these times. Mallards and pintails were especially prone to leave ponds after 1800 hours.

Blue-winged teal pairs were more abundant on stock ponds during mid-day. Drewien (1968) found that blue-winged teal hens left the nest in afternoons for as much as four hours to feed and rest before returning in the evening. Klett and Kirsch (1976) found that mid-day counts of blue-winged teal were lower than during early morning and evening. However, the number of lone drakes observed at mid-day increased as the breeding season progressed. Lacy (1959) found greatest differences between morning and mid-day pairs per unit of artificial water area early in the season when pairs were selecting nesting sites. Later in the season when nests were initiated, lone drakes and pairs remained longer on man-made ponds though peak occupancy still remained in early morning.

More mobile species were less abundant on ponds when temperatures were higher. More pintail and mallard pairs were observed on ponds early in the day when temperatures were cooler. Green-winged teal, blue-winged teal, and northern shovelers used ponds when or where temperatures were higher than did gadwalls and American wigeons. Maximum use of the stock pond at different period of the day would allow maximum coexistence by the various species with least amount of interspecific disturbance. Sowls (1955) has observed that two or more pairs may use the same loafing spots at different times of the day.

Management suggestions

The following management suggestions are made:

1. Stock ponds between 0.5 ha and 2.0 ha in surface area are recommended for construction for breeding dabbling duck species except northern shovelers. Northern shoveler pairs may require larger ponds. Ponds smaller than 0.5 ha of surface water may dry up during the brood rearing season and are not a reliable source of livestock drinking water. Larger ponds are less efficient. Breeding pair densities decrease with increasing surface area. Ponds larger than 2.0 ha should be constructed in preference to ponds less than 0.5 ha. A cash incentive program to share an additional 10 percent of the cost of construction of stock ponds favorable to breeding pairs and broods would be beneficial.

2. Ponds should be constructed with the maximum possible amount of shoreline per unit of surface area. Stock ponds with at least twice as much shoreline as would be necessary to just enclose the surface water area are recommended for construction. Minimum shoreline distance should range from 300 m for ponds with 0.5 ha of surface water to 1000 m for ponds with 2.0 ha of surface water. Ponds constructed in gentle topography at the confluence of several draws or with islands would have long irregular shorelines.

3. Heavy grazing should be discouraged because it adversely affects pair use. Light grazing may control dense peripheral stands of emergents and allow higher duck use, particularly for pintails, American wigeons, northern shovelers, and green-winged teal.

4. Recently constructed ponds should be protected from grazing to allow emergents to become established. Ponds with emergents scattered in dense patches or diffuse open stands appear to be important for pairs of mallards, pintails, blue-winged teal, gadwalls, and American wigeons.

5. Spacing of stock ponds to distribute grazing pressure appears to be good for breeding pairs. More stock ponds should be constructed, especially in areas having lowest stock pond densities.

6. Ponds should be constructed and managed for species preferring the particular stratum. Development of stock ponds in a stratum for species which avoid that stratum would give poorer results

than if the ponds had been planned and managed for species preferring the stratum.

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APPENDICES

APPENDIX A. Stock pond density

There are an estimated 92,000 stock ponds in the Missouri Coteau, Northern Plateau, Pierre Hills, and Southern Plateau of South Dakota (Table 1). Ponds were sufficiently represented in these four strata to allow statistical analysis (Table 2). The Pierre Hills stratum has five times as many stock ponds as each of the other strata. Density of stock ponds per square kilometer were greatest in the Pierre Hills (0.92) and least in the Missouri Coteau (0.22). Hectares of stock pond basin per square kilometer are greatest in the Pierre Hills (2.24) and least in the Northern Plateau (0.81). The Northern Plateau had approximately four times as many ponds per land unit as the Missouri Coteau but stock pond basin area per land unit was nearly equal. This was due to the larger basin size of stock ponds in the Missouri Coteau.

Table 1. Distribution and estimated numbers, hectares, and densities of stock pond basins among four major physiographic strata in South Dakota, 1976.

Major Physiographic Region	Area of Strata (Km^2)	Percent of Area Sampled	Number of Ponds		Hectares of Ponds	
			Total (in thousands)	Per Km^2	Total (in thousands)	Per Km^2
Missouri Coteau	27,995	0.18	6.3	0.22	24.1	0.86
Northern Plateau	30,093	0.15	24.5	0.82	24.5	0.81
Pierre Hills	52,821	0.11	51.4	0.97	118.7	2.24
Southern Plateau	20,813	0.17	9.7	0.47	21.7	1.04
Total	131,722	0.15	91.9	0.70	188.6	1.43

Table 2. Numbers of stock ponds containing surface water by physiographs strata for May and June, 1973 - 1976.

Physiographic strata	1973		1974		1975		1976		Total	
	May	June	May	June	May	June	May	June	May	June
Missouri Coteau	14	14	13	12	12	13	8	6	47	45
Northern Plateau	24	23	19	18	30	28	21	17	94	86
Pierre Hills	49	50	38	38	54	51	41	35	182	174
Southern Plateau	14	14	14	14	14	16	14	9	56	53
Total	101	91	84	82	110	108	84	67	379	358

APPENDIX B. Precipitation and pond surface water area

Breeding pair use of wetlands may not only reflect water conditions on the immediate ponds but also water conditions over the entire breeding grounds (Dzubin 1969). Precipitation records, obtained from the National Weather Service at Brookings, South Dakota, were averaged over all stations within each stratum to explore the relationships between pairs using stock ponds, pond surface water area, and regional precipitation.

Deteriorating water conditions over the four year period are evident in the declining 12 month precipitation (Table 1). Precipitation in all strata in 1972-73 was well above average for the four year study period. Twelve month precipitation was lower in 1974-75 and 1975-76 than in the first two years. The four year drying trend resulted in a drought over much of South Dakota in 1976.

This drying trend was also evident in the reduction of stock pond surface water area over the four year period (Table 2). Total surface water area available to breeding pairs during the May and June censuses decreased in all strata from 1973 to 1974 and from 1975 to 1976. Greatest decreases occurred in the Missouri Coteau and smallest decreases occurred in the Northern Plateau.

Pond water conditions during a critical period of time in spring migration influences use of breeding habitat (Drewien and Springer 1969). This critical period probably occurs in April and May in South Dakota when peak migrations of dabbling ducks occur. Precipitation

Table 1. Average annual precipitation from May through April and average precipitation during March and April (in parenthesis) by year and physiographic strata.

Physiographic Strata	Average precipitation (cm) 72-73	73-74	74-75	75-76	4-year Average
Missouri Coteau	57.38 (4.92)	45.19 (3.30)	39.50 (4.26)	41.35 (2.87)	45.85 (3.84)
Northern Plateau	47.93 (4.02)	41.30 (2.96)	38.30 (5.83)	37.26 (2.49)	41.22 (3.83)
Pierre Hills	51.54 (4.63)	42.72 (3.10)	36.30 (4.07)	35.03 (2.30)	41.40 (3.53)
Southern Plateau	55.73 (3.84)	49.35 (2.91)	34.34 (4.80)	35.88 (2.30)	43.66 (3.46)
Strata Average	53.14 (4.35)	44.68 (3.07)	37.11 (4.74)	37.24 (2.49)	43.05 (3.66)

Table 2. Hectares of stock pond surface water by physiographic strata from May (in parenthesis) and June breeding pair counts, 1973 - 1976.

Strata	1973	1974	1975	1976
Missouri Coteau	(12.02) 13.98	(10.26) 12.22	(10.71) 10.57	(5.24) 2.00)
Northern Plateau	(15.07) 13.70	(9.70) 9.21	(13.85) 12.54	(11.34) 9.73
Pierre Hills	(46.09) 42.86	(34.74) 39.44	(46.27) 45.16	(25.97) 22.11
Southern Plateau	(15.05) 15.38	(11.46) 12.21	(14.64) 13.69	(11.63) 9.91
Total	(88.23) 85.93	(66.16) 73.08	(85.47) 81.97	(54.18) 43.75

prior to this period may have an important influence on stock pond surface water area available to breeding pairs during that critical period. Pospahala et al. (1974) concluded that precipitation during the 12 months prior to the May U.S. Fish and Wildlife Service Waterfowl Survey was an important variable influencing the number of natural ponds present in Alberta, Saskatchewan, and Manitoba. Precipitation during April and May was of minor importance compared to the cumulative effect of several months on the number of ponds.

Twelve month precipitation, averaged from 1 May through 30 April was compared with stock pond surface water area in May to see if there was a positive relationship. Average 12 month precipitation for each stratum did not follow the trend in either May or June total pond surface area (Tables 1 and 2). Lack of congruence was especially evident in 1975. May pond surface water area had increased 29 percent but precipitation over the previous 12 months decreased by 16 percent.

The relationship between precipitation and surface water area is complicated by a host of interacting factors including evaporation, transpiration, seepage, humidity, temperature, wind, basin area, soil type, soil moisture, pond depth, and consumption by cattle (Eisenlohr and Sloan 1968, Stoudt 1969, Rundquist 1973). Apparently these factors and possibly others caused the discrepancy in trends between surface area and 12 month precipitation.

While it is possible for pond surface water area to increase in years of decreasing precipitation due to seepage inflow, it is much more plausible that the increase in total surface area of stock ponds in 1975 was due to above average precipitation falling in a short period of time. Eisenlohr (1969) concluded that annual precipitation was not related to water replenishment in natural ponds in North Dakota because soil moisture and the magnitude of the storm were the effective controls over the amount of precipitation that became basin inflow. Precipitation on the water surface was the major source of water supply. Runoff only became an important source when the ground was either frozen or saturated (Eisenlohr and Sloan 1968). Accumulated snowfall was effective in supplying water if it melted rapidly while the ground remained frozen. Rain was an important source of runoff only if a large amount fell within a short period of time regardless of whether it was a dry or wet year. Stoudt (1969) believed that precipitation in May or June had a greater influence on raising and maintaining water levels of natural ponds and lakes in Saskatchewan than precipitation occurring later in the season.

Stock pond surface water area seems to depend more on amount and duration of precipitation than do natural ponds. Stock ponds located at the bottom of drainage basins receive more runoff than natural ponds in poor drainage glacial areas. Rundquist (1973) found that the direction and extent of weekly fluctuations in water levels of eastern Montana stock ponds were highly correlated with total weekly precipitation ($r = 0.86$). Bue (1956) observed that some similarity existed between water levels of 50 stock ponds in the Pierre Hills stratum and monthly precipitation as recorded in Pierre, S.D., in 1950 and 1951. The only deviations in water levels from this pattern could be explained by the occurrence of local heavy rains which were not recorded in Pierre.

In this study, May pond surface water area followed both the direction and extent of change in combined March and April precipitation. Above average precipitation during these two months and rapid melting resulted in heavy runoff in 1975 and increased surface water area.

Further evidence that stock pond surface water area was dependent on the amount of precipitation in March and April, was seen in the changes of total number of basins and surface area of each of the four years (Table 3). All wetland classes had greater percentages of basins wet both in number and area in 1973 and 1975 than in the other two years. These were years of above average March and April precipitation. A greater percentage of stock ponds had surface water in 1975, the year of greatest March and April precipitation, than any other year. In 1974 and 1976 when March and April precipitation was least, fewer stock ponds contained water and held less water.

Stock pond surface water area appeared to be more influenced by March and April precipitation than natural wetlands on the same plots. Stock ponds decreased less in surface area in 1974 and 1976 but increased more in surface area in 1975 than natural wetlands. Intermittent streams and dugouts showed the same direction and extent of change in percentages of basins wet and percentages of surface area with March and April precipitation as did stock ponds. Surface water area of streams, dugouts, and stock ponds depended more on surface runoff than natural ponds and lakes in the same area.

Table 3. Percent of total number of basins with surface water and percent of total basin area with surface water () for selected wetland classes located on quarter sections with stock ponds for May and June, 1973 - 1976.

Wetland class[a]	1973		1974		1975		1976	
	May	June	May	June	May	June	May	June
Ephemeral	29 (4)	0 (0)			25 (38)	17 (3)		
Temporary			86 (60)	14 (7)	100 (57)	100 (86)		
Seasonal	50 (63)	25 (62)	33 (4)	0 (0)	33 (21)	67 (25)	6 (1)	0 (0)
Semi-permanent	100 (83)	88 (79)	82 (56)	88 (53)	89 (37)	78 (33)	38 (6)	0 (0)
Intermittent stream	80 (70)	88 (63)	47 (39)	36 (26)	77 (55)	59 (47)	50 (38)	24 (12)
Dugout	100 (79)	100 (81)	57 (49)	86 (83)	88 (68)	75 (63)	70 (58)	40 (28)
Stock pond	88 (83)	88 (80)	73 (60)	71 (66)	93 (83)	92 (80)	72 (53)	58 (43)

[a]natural pond classification according to Stewart and Kantrud (1971).

The importance of stock ponds in drought years as permanent water sources has been noted by other researchers. Keith (1961) concluded that the value of dammed and reflooded natural wetlands was greatest in water critical years when the natural ponds dried up in June and July. Stewart and Kantrud (1974) observed in 1968, a dry year in North Dakota, that the value of man-made wetlands (stock ponds and dugouts) increased over natural basins for breeding waterfowl. Bue et al. (1964) and Ruwaldt (1975) made similar observations in South Dakota. Stoudt (1971) observed that stock ponds were the most permanent water bodies during drought at Redvers, Saskatchewan.

In this study, stock ponds were found to be more permanent in total numbers of wet basins and total surface water area than natural wetlands in the same area during drought years. Stock ponds increased more in percentages of basins wet and total basin areas containing water in 1975, a wet year, than natural wetlands and decreased less in the same percentages during dry years. In 1976, the driest year, a greater percentage of stock ponds had surface water and had a greater proportion of the total basin area covered by water than any natural wetland class except permanent streams.

Pond surface area appeared to respond more to decreases in precipitation than to increases. The decrease in surface water area from 1973 to 1974 and from 1975 to 1976 was nearly proportional to decreases in March and April precipitation. However, pond surface water area did not increase proportionally to increased precipitation. Surface water area increased only 29 percent across all strata in

1975 when precipitation increased 54 percent. March and April precipitation was highest in 1975 but surface water area was less than in 1973. It was possible that as the drying trend intensified in 1975 due to below average annual precipitation, soil moisture content had greatly decreased. When precipitation did come in March and April of 1975, a much greater proportion of it was retained in the soil.

Trends in pond surface water area in the Missouri Coteau were least like trends in March and April precipitation. Surface water area increased less than would be expected by examining increased precipitation. June pond surface area in the Missouri Coteau dropped 82 percent from 1973 to 1976 while study ponds in the other strata dropped less than 50 percent over the same period of time. Surface water area also dropped more than would have been expected by decreased precipitation in 1976. This was probably due to the poorer drainage and more porous quality of eastern glacial loams as compared to good drainage and impermeable quality of western clay soils. Bue (1956) believed that study ponds in the Pierre Hills stratum were rapidly filled by heavy rains and good snow runoff because of the large drainage basins and the inability of Pierre soils to rapidly absorb moisture.

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APPENDIX C. Breeding pairs and surface water

Mallards, blue-winged teal, and pintails were the most abundant species using stock ponds each of the four years (Table 1). These three species made up 81 percent of the total number of indicated pairs on study ponds over the period. Similar percentages for these three species using stock ponds were found by Bue (1956) in western South Dakota, Swanson (1959) in eastern South Dakota, and Smith (1953) in eastern Montana. Numbers of pairs per pond and numbers of pairs per hectare of surface water compare with densities obtained from studies of natural ponds and lakes (Table 2). Densities obtained on stock ponds were greater than those recorded for studies on natural wetlands. However, those densities could not be compared too literally as the census methods varied between studies.

Decreasing numbers of pairs using stock ponds over the four year period corresponded well with decreasing surface water area and decreasing March and April precipitation. Blue-winged teal pairs corresponded more with fluctuations in surface water area and March and April precipitation than any other species. Numbers of pairs were highest in 1973 when total pond surface area was greatest. Numbers of pairs increased in 1975 when March through April precipitation and surface water area increased. Bellrose (1976) stated that blue-winged teal were more flexible in their homing behavior which enabled them to make adjustments to drought.

The fact that waterfowl breeding populations are influenced

Table 1. The distribution of indicated breeding pairs on South Dakota stock ponds in the Missouri Coteau and west-river strata combined, 1973 - 1976.

Waterfowl species	Indicated breeding pairs 1973	1974	1975	1976	Total
Mallard	100	63	65	66	294
Pintail	38	28	32	27	125
Blue-winged teal	114	50	55	47	266
Gadwall	25	22	21	13	81
American wigeon	15	7	6	6	34
Northern shoveler	11	3	2	5	21
Green-winged teal	6	2	5	5	18
Lesser scaup		4	1	1	6
Ruddy duck	3				3
Total	312	170	187	170	848

Table 2. Comparison of numbers of breeding pairs per hectare (pr/ha) of surface water and per pond (pr/pd) between stock ponds and natural ponds and lakes, all breeding species combined.

Study	Year	Location	Stock ponds pr/ha	Stock ponds pr/pd	Natural ponds pr/ha	Natural ponds pr/pd
Evans and Black (1956)	1950-53	S.D.			1.7	
Farmes (1956)		Minn.			3.9	
Bue (1956:137)	1950-51	S.D.	6.2	5.5		
Keith (1961:75)		Alberta			2.9	
Jahn and Hunt (1964)		Wis.			0.8	
Kruse (1972:21)	1967	N.D.	7.4	7.8	3.0	2.9
	1968		8.7	9.0	2.5	2.6
	1969		4.5	5.2	1.5	1.7
Duebbert (1972)	1968	S.D.		4.7		
	1969			7.9		
Lokemoen (1973:180)	1967-70	N.D.	4.5			
Rundquist (1973:42)	1971-72	Mont.	4.6-5.2			
Gjersing (1975:38)	1969	Mont.		2.9		
	1970			3.4		
MeEnroe (1976:22)	1973-74	S.D.			2.9	4.3
This study[a]	1973-76	S.D.	2.9	2.3		

[a]combined early and late pair counts

by spring water conditions is well documented in the literature. Krapu et al. (1970) believed that size of the mallard population was a function of the water conditions in late March and early April when mallard pairs were establishing territories. Mendall (1958) found that water levels during a short period before nesting were of major importance in determining breeding population levels of black and ring-necked ducks in Maine. Salyer (1962) stated that breeding pair populations in North Dakota tended to fluctuate with the number of available water areas. Evans and Black (1956) and Jenni (1956) have observed the same relationship on natural ponds in South Dakota. Drewien and Springer (1969) concluded that annual breeding populations at Waubay refuge were determined by local water conditions and that pair density fluctuations resulted from changes in water conditions during a critical period in the spring.

Pairs may be quite sensitive to initial and substantial drops in surface water area and spring precipitation. Numbers of pairs of all species combined dropped 56 percent from 1973 to 1974 (Table 1). This decline in numbers was more extreme than the drop in surface water area available (Table 2, Appendix B). Smith (1969) observed the same phenomenon for mallards on his study area. He conjectured that mallard pairs may have suffered a psychological and possibly a physiological shock when they returned to dry breeding grounds.

Breeding pairs may not immediately recover from this decline. In 1975, numbers of pairs did not increase to 1973 population levels even though surface area available was nearly equal both years.

Dzubin (1969) observed that in a good water year preceded by a year of drought and poor production, the breeding population did not make immediate use of the additional water area. There was a lower pair per pond ratio following the year of drought than during the drought year. He believed that the time lag of one to two years occurred while homing pairs reoccupied the available wetlands and production increased. Stoudt (1971) and Smith (1971) have made similar observations in Saskatchewan and Alberta, respectively.

Trends in densities of all species combined did not follow the trend in surface water area (Table 3). After the initial drop in surface area and number of pairs from 1973 to 1974, densities were influenced more by changes in surface area than changes in numbers of pairs. Surface water area decreased drastically in 1976 but densities of breeding pairs actually increased. Mallard, pintail, and blue-winged teal pairs may have crowded onto the available water areas during the severe drought year. Stoudt (1971) has observed crowding of ducks into marginal habitat during drought.

Total numbers of pairs decreased over the four years in all strata except the Northern Plateau (Table 4). Greatest decreases occurred in the Missouri Coteau and Southern Plateau which were the two strata having greatest decreases in total surface water area. Numbers of pairs in the Northern Plateau from 1973 to 1974 remained stable despite greater drops in surface water area than any other stratum.

Greatest fluctuations in numbers and densities of pairs were for

Table 3. Numbers of waterfowl indicated pairs per pond (in parenthesis) and per hectare of surface water of stock ponds averaged over physiographic strata, 1973 - 1976.

Waterfowl species	1973	1974	1975	1976	Average
Mallard	(0.99) 1.13	(0.75) 0.95	(0.59) 0.76	(0.77) 1.20	(0.78) 1.01
Pintail	(0.38) 0.43	(0.31) 0.39	(0.29) 0.37	(0.32) 0.50	(0.33) 0.42
Blue-winged teal	(1.10) 1.29	(0.60) 0.67	(0.51) 0.67	(0.70) 1.07	(0.73) 0.93
Gadwall	(0.25) 0.29	(0.27) 0.30	(0.19) 0.26	(0.19) 0.30	(0.23) 0.29
American wigeon	(0.15) 0.17	(0.09) 0.10	(0.06) 0.07	(0.09) 0.14	(0.10) 0.12
Northern shoveler	(0.11) 0.13	(0.04) 0.04	(0.02) 0.02	(0.07) 0.11	(0.06) 0.08
Green-winged teal	(0.05) 0.06	(0.02) 0.03	(0.05) 0.06	(0.07) 0.11	(0.06) 0.07
Early-nesting pairs	(1.37) 1.56	(1.06) 1.34	(0.88) 1.13	(1.09) 1.70	(1.10) 1.43
Late-nesting pairs	(1.66) 1.94	(1.02) 1.14	(0.83) 1.08	(1.12) 1.73	(1.16) 1.47
Total[a]	(3.03) 3.50	(2.08) 2.48	(1.71) 2.21	(2.21) 3.43	(2.26) 2.91

[a]sum of early and late pair counts

Table 4. The distribution of indicated breeding pairs on stock ponds by physiographic strata and year, 1973 - 1976.

Waterfowl species	Missouri Coteau					Northern Plateau					Pierre Hills					Southern Plateau				
	73	74	75	76	Total	73	74	75	76	Total	73	74	75	76	Total	73	74	75	76	Total
Mallard	20	9	8	13	50	11	15	27	13	66	52	28	26	31	137	17	11	4	8	40
Pintail	18	9	16	13	56	5	5	11	5	26	12	10	3	7	32	3	2	2	2	9
Blue-winged teal	38	13	8	6	65	12	6	10	12	40	42	19	24	18	103	19	11	13	11	54
Gadwall	16	9	4	3	32	4	7	5	5	21	4	5	8	5	22	1	1	4		6
American wigeon	6	1			7	3	4	2	3	12	5	2	3	3	13	1		1		2
Northern shoveler	6	2			8	1		1	3	5	4	1	1	2	8					
Green-winged teal	2	2			4				2	2	3		5	3	11					
Lesser scaup		3	1		4				1	1		1			1					
Ruddy duck						3				3										
Total	106	48	37	35	226	39	37	56	44	176	122	66	70	69	327	41	25	24	21	111

northern shovelers, blue-winged teal, American wigeons, and green-winged teal. Numbers and densities of mallard and pintail pairs fluctuated the least between years. Krapu et al. (1970) found that numbers of mallard pairs remained more stable between years than late-nesting pairs. Early-nesting pairs did not respond to yearly changes as much as late-nesting species. Stoudt (1971) observed that mallard populations were quite stable through drought years. American wigeons were found to have the most stable population levels along with mallards while blue-winged teal were adversely affected by the drought.

Density and numbers of mallard pairs dropped from 1973 to 1975 in all strata except the Northern Plateau (Tables 5 to 8). In the Northern Plateau density and numbers of pairs increased over the same period of time. Mallard pairs appeared to have vacated ponds in the Missouri Coteau, Pierre Hills, and Southern Plateau from 1973 to 1975 and moved northward because densities and numbers increased in the Northern Plateau. Pospahala et al. (1974) have shown that mallard breeding populations in western South Dakota were inversely and significantly ($P<0.05$) correlated with mallard populations of southwest Alberta from 1955 to 1973.

Table 5. Numbers of waterfowl indicated pairs per pond (in parenthesis) and per hectare of surface water of stock ponds in the Missouri Coteau, 1973 - 1976.

Waterfowl species	1973	1974	1975	1976	Average
Mallard	(1.43) 1.66	(0.69) 0.88	(0.67) 0.75	(1.63) 2.48	(1.11) 1.44
Pintail	(1.29) 1.50	(0.69) 0.88	(1.33) 1.49	(1.63) 2.48	(1.24) 1.59
Blue-winged teal	(2.71) 2.72	(1.08) 1.06	(0.62) 0.76	(1.00) 2.99	(1.35) 1.88
Gadwall	(1.14) 1.14	(0.75) 0.74	(0.31) 0.38	(0.50) 1.50	(0.68) 0.94
American wigeon	(0.43) 0.43	(0.08) 0.08			(0.26) 0.26
Northern shoveler	(0.43) 0.43	(0.17) 0.16			(0.30) 0.30
Green-winged teal	(0.14) 0.14	(0.17) 0.16			(0.16) 0.15
Early-nesting pairs	(2.72) 3.16	(1.38) 1.76	(2.00) 2.24	(3.26) 4.96	(2.34) 3.03
Late-nesting pairs	(4.85) 4.86	(2.25) 2.20	(0.93) 1.14	(1.50) 4.49	(2.38) 3.17
Total[a]	(7.57) 8.02	(3.63) 3.96	(2.93) 3.38	(4.76) 9.45	(4.72) 6.20

[a]sum of early and late pair counts

Table 6. Numbers of waterfowl indicated pairs per pond (in parenthesis) and per hectare of surface water of stock ponds in the Northern Plateau, 1973 - 1976.

Waterfowl species	1973	1974	1975	1976	Average
Mallard	(0.46) 0.73	(0.79) 1.55	(0.90) 1.95	(0.62) 1.15	(0.69) 1.36
Pintail	(0.21) 0.33	(0.26) 0.52	(0.37) 0.79	(0.24) 0.44	(0.27) 0.52
Blue-winged teal	(0.52) 0.86	(0.33) 0.65	(0.36) 0.80	(0.71) 1.23	(0.48) 0.89
Gadwall	(0.17) 0.29	(0.39) 0.76	(0.18) 0.40	(0.29) 0.51	(0.26) 0.49
American wigeon	(0.13) 0.22	(0.22) 0.43	(0.07) 0.16	(0.18) 0.31	(0.07) 0.28
Northern shoveler	(0.04) 0.07		(0.04) 0.08	(0.18) 0.31	(0.07) 0.12
Green-winged teal				(0.12) 0.21	(0.12) 0.21
Early-nesting pairs	(0.67) 1.06	(1.05) 2.07	(1.27) 2.74	(0.86) 1.59	(0.96) 1.87
Late-nesting pairs	(0.86) 1.44	(0.94) 1.84	(0.65) 1.44	(1.48) 2.57	(0.98) 1.82
Total[a]	(1.53) 2.50	(1.99) 3.91	(1.92) 4.18	(2.34) 4.16	(1.95) 3.69

[a]sum of early and late pair counts

Table 7. Numbers of waterfowl indicated breeding pairs per pond (in parenthesis) and per hectare of surface water of stock ponds in the Pierre Hills, 1973 - 1976.

Waterfowl species	1973	1974	1975	1976	Average
Mallard	(1.06) 1.13	(0.74) 0.81	(0.48) 0.56	(0.76) 1.19	(0.76) 0.92
Pintail	(0.24) 0.26	(0.26) 0.29	(0.06) 0.06	(0.17) 0.27	(0.18) 0.22
Blue-winged teal	(0.84) 0.98	(0.50) 0.48	(0.47) 0.53	(0.51) 0.81	(0.58) 0.70
Gadwall	(0.08) 0.09	(0.13) 0.13	(0.16) 0.18	(0.14) 0.23	(0.13) 0.16
American wigeon	(0.10) 0.12	(0.05) 0.05	(0.06) 0.07	(0.09) 0.14	(0.08) 0.10
Northern shoveler	(0.08) 0.09	(0.03) 0.03	(0.02) 0.02	(0.06) 0.09	(0.06) 0.06
Green-winged teal	(0.06) 0.07		(0.10) 0.11	(0.09) 0.14	(0.08) 0.08
Early-nesting pairs	(1.30) 1.39	(1.00) 1.10	(0.54) 0.62	(0.93) 1.46	(0.94) 1.14
Late-nesting pairs	(1.16) 1.35	(0.71) 0.69	(0.81) 0.91	(0.89) 1.41	(0.89) 1.09
Total[a]	(2.46) 2.74	(1.71) 1.79	(1.35) 1.53	(1.82) 2.87	(1.84) 2.23

[a]sum of early and late pair counts

Table 8. Numbers of waterfowl indicated breeding pairs per pond (in parenthesis) and per hectare of surface water of stock ponds in the Southern Plateau, 1973 - 1976.

Waterfowl species	1973	1974	1975	1976	Average
Mallard	(1.21) 1.13	(0.79) 0.96	(0.29) 0.27	(0.57) 0.69	(0.72) 0.76
Pintail	(0.21) 0.20	(0.14) 0.17	(0.14) 0.14	(0.14) 0.17	(0.16) 0.17
Blue-winged teal	(1.36) 1.24	(0.79) 0.90	(0.81) 0.95	(1.22) 1.11	(1.05) 1.05
Gadwall	(0.07) 0.07	(0.07) 0.08	(0.25) 0.29		(0.13) 0.15
American wigeon	(0.07) 0.07		(0.06) 0.07		(0.07) 0.07
Early-nesting pairs	(1.42) 1.33	(0.93) 1.13	(0.43) 0.41	(0.71) 0.86	(0.87) 0.93
Late-nesting pairs	(1.50) 1.38	(0.86) 0.98	(1.12) 1.31	(1.22) 1.11	(1.18) 1.20
Total[a]	(2.92) 2.71	(1.79) 2.11	(1.55) 1.72	(1.93) 1.97	(2.05) 2.13

[a]sum of early and late pair counts

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APPENDIX D: Correlation matrix of significant (r > 0.106 at 0.05 level) and highly significant (r > 0.1[illegible] at 0.01 level) simple correlation coefficients between independent variables and indicated breeding pairs by species, 1973-1975.

Independent Variable	Dependent Variable (Waterfowl Species) Mallard	Pintail	Blue-winged Teal	Gadwall	American Wigeon	Northern Shoveler	Green-winged Teal
HPB	0.2977	0.3001	0.5214	0.1747		0.3512	0.2052
HPSW	0.2414	0.2046	0.5372	0.1669		0.3298	0.1718
HPOW	0.2705	0.2440	0.5002	0.2701	0.1120	0.3029	0.1750
PSW			0.1463				
POW			-0.2496				
SLDI	0.3845	0.2580	0.5666	0.2026		0.2894	0.1723
VEGH	0.2436	0.1123	0.3779	0.1374		0.1922	0.1319
CRAT2	0.1544	0.1673	0.2185	0.1452	0.1139		
CRAT3			0.1911				
CRAT1			0.1117				
CRAT4			-0.1171				
SINT	-0.1243						
HSMG	0.1335						
HFARM	0.2367						
HROAD		0.1070					
SCF							0.1968
SCS	0.2046	0.1517	0.3507	0.1912	0.2118	0.2270	0.2026
TYP	0.2172		0.1636			0.1542	0.1065
CAR			0.2698	0.3587	0.2183	0.3224	
NWC	-0.1115	0.2245		0.1777			
HOB		0.2126		0.1467			
NASW	-0.1667		-0.1412	-0.1104	-0.1272	-0.1074	
HSWA	-0.1454		-0.1127		-0.1169		
NNSW		0.1101		0.1041			
HSWN		0.1336	0.1927	0.1175		0.1892	
NOW	-0.1069						
HOWB	-0.1631						
NDB		0.2817		0.2512			0.1213
TSLD	-0.1198						
DNRMC	-0.1367		-0.1682				
OOFMC			-0.1617				
D4		0.2867	0.1189	0.2153		0.1453	
D5					0.1111		
D6		-0.1501		-0.1325			
WIND					0.1068		

APPENDIX E: Correlation matrix of highly significant (P 0.01; Ho:γ = 0) simple correlations coefficients between independent variables.

	Wetland habitat variables													Dominant emergents					
	HPSW	HPOW	PSW	POW	SPGI	VEGH	CRAT2	CRAT3	DRAT1	DRAT3	DRAT4	DRAT5	PGR	ELE	SCF	SCS	TYP	CAR	POL
HPE	0.34[a]	0.89		-0.31	0.87	0.36	0.20	0.19							0.20	0.27	0.36		
	0.92[b]	0.85		-0.27	0.87	0.40	0.24								0.17	0.26	0.34		
HPSW		0.91	0.16	-0.33	0.87	0.35	0.24	0.16							0.22	0.33	0.37		
		0.92	0.18	-0.39	0.88	0.41	0.15	0.23							0.17	0.32	0.36		
HPOW			0.21	0.21	0.88	0.31	0.18	0.16							0.19	0.31	0.33		
			0.23	-0.1[illegible]	0.90	0.37		0.23	0.18		-0.17					0.33	0.32		
PSW					0.24	0.15	0.18		0.22	-0.46	-0.66		0.24	0.23		0.20			
					0.25	0.23	0.14	0.14	0.16	-0.47	-0.65		0.19	0.23		0.20			
POW					-0.36	-0.52	-0.41	-0.26		0.14				-0.17	-0.21	-0.31	-0.36		
					-0.30	-0.56	-0.40	-0.31						-0.19		-0.26	-0.41		
SPGI						0.38	0.26	0.24		-0.18	-0.15				0.15	0.33	0.42		
						0.48	0.17	0.32	0.17	-0.15	-0.19					0.36	0.38		
VEGH							0.36	0.39	0.14	-0.14				0.17		0.46	0.56		
							0.34	0.50		-0.16				0.14	0.18	0.50	0.58	0.15	0.14
CRAT2														0.34		0.30	0.17		
								-0.14						0.28		0.25	0.14		
CRAT3																0.14	0.41		
																0.28	0.37		
DRAT1														0.18		0.14			
											-0.18								0.15
DRAT3											-0.19			0.16		-0.16			
DRAT4													-0.19						
													-0.17						
DRAT5													-0.17			0.16			0.23
PGR																	-0.18		
															-0.24				
ELE																0.15			
																0.21			
SCS																	0.22		
																	0.19	0.21	0.15
CAR																			
POL																			0.19

APPENDIX E. (Continued)

	WETLAND ASSOCIATION VARIABLES									PHYSIOGRAPHIC STRATA		
	NWC	NASW	NSWA	NOSW	HSWN	NOW	HOWB	NDB	TSLD	DWBMC	D4	D5	D6
HCP													
HPSW													
HPOW													
				0.17									
[illegible]SW	-0.14		0.18				0.18	-0.21		-0.17	-0.22	0.17	
			0.20	0.16		0.17	0.23	-0.22	0.23	-0.18	-0.18		
[illegible]OW				-0.18					-0.15				
													0.14
SLPI		-0.14											
				0.18									
[illegible]GH				0.14								0.15	
				0.26					-0.15				
CPAT2													
				0.15									
CRAT3	0.15			0.16									
FCATI				0.15								0.32	-0.16
				0.21		0.15							
[illegible]RAT3				-0.14		-0.16	-0.16		-0.25	0.20			
							-0.16		-0.15				
PRAT4	0.15							0.18			0.17		
								0.14					
PRAT5													
								0.17					
PGR													
													-0.14
ELE												0.23	-0.20
											-0.15	0.17	
SCF					0.16								
					0.18								
SCS		-0.14		0.17									
		-0.19	-0.14				-0.16						
TYP													
			0.16								-0.16		
CAP	0.17			0.22	0.22			0.14	0.14	-0.14	0.17		-0.16
											[illegible]		

APPENDIX F: (Continued)

	UPLAND HABITAT VARIABLES									DISTURBANCE			TIME AND WEATHER			
	GIST	HSTC	HFARM	HPAS	HEALO	HROAD	HTREE	HCOR	HALF	HHAY	DNFMC	DOFMC	TIME	WIND	TEMP	RAIN
[illegible]			0.41			0.15					-0.24	-0.20				
	0.14		0.42								-0.29	-0.23				
[illegible]	0.13		0.19								-0.23	-0.18				
	[illegible]										-0.30	-0.20		0.14		0.15
[illegible]	0.16		0.13								-0.18					
	0.16		0.13								-0.26	-0.14				0.14
[illegible]				[illegible]	-0.18									-0.18		
									-0.14				0.18		-0.16	
[illegible]				0.15						-0.16	0.20	0.25				
				0.17		-0.22				-0.30	0.15	0.29				
[illegible]			0.35	-0.17							-0.22	-0.20				
			0.30	0.14							-0.37	-0.23				
[illegible]			0.15	-0.14	0.14						-0.19	-0.18				
			0.23	-0.20	0.20						-0.21	-0.19				
[illegible]AT2																
						0.14						-0.14				
[illegible]AT3		0.22	0.18	-0.17							-0.19					
		0.14	0.17	-0.16							-0.17					
[illegible]AT1																
				-0.14	0.20							-0.17			-0.20	
[illegible]AT4				-0.22	0.24	0.18		0.14			-0.16	-0.21				
	-0.14			-0.15	0.16				0.17				-0.19			
[illegible]AT5		0.19		0.15	0.21											
[illegible]	0.66	-0.38		0.59	-0.38	-0.19			-0.34	-0.31	0.21					
	0.67	-0.30		0.61	-0.39	-0.19			-0.40	-0.25						
[illegible]																
	-0.19			-0.18	-0.14											
[illegible]				-0.32	0.19						-0.24	-0.22				
		0.28	0.15	-0.20	0.18						-0.22	-0.14				
[illegible]												-0.25				
		0.22														
POL																
									0.22							

APPENDIX E: (Continued)

	WETLAND ASSOCIATION VARIABLES									PHYSIOGRAPHIC STRATA		
	NW	NASW	HSWA	NSSW	HSWB	NOW	HOWB	NOB	TSLD	DWBHC	D4	D5	D6
NW		0.41 0.37		0.55 0.45	0.29 0.22	0.59 0.54	0.22 0.17	0.61 0.62	0.36 0.33	-0.51 -0.47	0.43 0.43		-0.41 -0.41
NASW			0.58 0.53			0.68 0.69	0.57 0.58		0.27 0.32	-0.39 -0.44		-0.14 -0.16	
HSWA						0.35 0.35	0.89 0.91		0.29 0.33	-0.30			-0.15
NSSW					0.43 0.41	0.76 0.76	0.19 0.19		0.54 0.58	-0.45 -0.48	0.18	0.28 0.28	-0.37 -0.36
HSWB						0.27 0.29	0.32 0.23		0.32 0.32	-0.22	0.32		-0.26
NOW							0.49 0.51		0.53 0.62	-0.58 -0.60			-0.25 -0.24
HOWB									0.47 0.51	-0.40			
NOB											0.42 0.40		-0.29 -0.29
TSLD										-0.51 -0.56		0.25 0.26	-0.26 -0.25
DWBHC												-0.28	0.32
D4												-0.22 -0.22	-0.40 -0.40
D5													-0.54 -0.53
D6													

APPENDIX E: (Continued)

	UPLAND HABITAT VARIABLES										DISTURBANCE		TIME AND WEATHER			
	GINT	HSNG	HFARM	HPAS	HFALO	HROAD	HTREE	HCOR	HALF	HHAY	DWRMC	DOFMC	TIME	WIND	TEMP	RAIN
GINT		-0.24 -0.25		0.38 0.44	-0.23 -0.27	-0.15 -0.19			-0.25 -0.27	-0.26 -0.23	0.16 0.14					
HSNG				-0.54 -0.53						0.14 	 -0.21	 -0.13				
HFARM																
HPAS					-0.43 -0.45	-0.47 -0.47	-0.18 -0.19	-0.26 -0.26	-0.48 -0.48	-0.55 -0.55	0.25 0.24	0.35 0.37				
HFALO											-0.14 -0.17			0.17 	-0.15 	
HROAD									0.32 0.31	0.51 0.53	-0.37 -0.31	-0.43 -0.41				
HTREE												-0.17 -0.18				
HCOR									0.18 0.18		 -0.16					
HALF										0.14 0.15			 -0.18			
HHAY												-0.28 -0.28				
TIME															0.26 0.17	
WIND															-0.23 	 0.27
TEMP																-0.26 -0.23

APPENDIX E: (Continued)

	WETLAND ASSOCIATION VARIABLES										PHYSIOGRAPHIC STRATA		
	HWC	HASW	HSWA	HNSW	HSWN	NOW	HOWB	NDB	TSLD	DWBMC	D4	D5	D6
GINT		0.14	0.16				0.14						
HSWG													
HFARM													
HPAS	-0.15 -0.15										-0.14		
HFALO													
HROAD	0.27 0.25							0.17 0.18		-0.17 -0.16	0.22 0.21		-0.15
HTREE													
HCOR											0.21		
HALF													
HHAY													
DRFMC													
DOFMC	-0.30 -0.26			-0.30 -0.28	-0.15	-0.19 -0.20		-0.20	-0.21 -0.17		-0.18 -0.15		0.22 0.20
TIME													
WIND													
TEMP				-0.19		-0.17			-0.16		0.21	0.17 0.14	
RAIN													

[a]simple correlation for May census

[b]simple correlation for June census