Factors Associated with Duck Use of Impounded and Natural Wetlands in Western South Dakota

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ABSTRACT -- Many wetlands in the northern Great Plains west of the Missouri River are stock ponds, created by impoundment of natural drainages or excavation of existing wetlands to provide water for livestock or improve habitat for waterfowl. We evaluated factors influencing use of wetlands by breeding duck pairs and broods relative to modification, water regime, size, and hydrological location on United States Forest Service lands within the Grand River National Grassland in northern South Dakota (2003 and 2004). Responses for both indicated pairs and broods were related positively to wet area, total wetland area within 4 km, emergent edge cover, and shoreline development index, and related negatively to basin cover (proportion of basin area with emergent cover). Duck responses were higher for in-stream than for isolated wetlands. Wetland type (water regime and modification) was a critical factor related to number of indicated pairs and probability of mallard (*Anas platyrhyncos*) use in late May. The negative response of indicated pairs to basin cover in May is associated with the high use of modified semipermanent wetlands, where wetland morphology and water depths limit emergent cover to the perimeter. Emergent edge cover was a critical factor for indicated pairs in May and for probability of use by broods in early July. The influence of wetland size and proximity to other wetlands was evident in five of eight models for pairs and all three brood models. The complexity of and variability among our models demonstrated the seasonal complexities of wetland conditions and waterfowl life history and habitat needs.

Key words: *Anas acuta*, *Anas discors*, *Anas platyrhynchos*, habitat use, impoundment, South Dakota, national grasslands, waterfowl.

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The Badlands and Prairies of the northern Great Plains (Bird Conservation Region 17; Fig. 1) is considered one of 67 areas of continental significance to North American waterfowl (North American Waterfowl Management Plan 2004). The region lies west of the Missouri River and is characterized by an arid to semi-arid landscape of flat to moderately rolling hills intercepted by intermittent streams, river breaks, and large expanses of prairie, with some areas of buttes and mountains (Pool and Austin 2006). Breeding population estimates for western Dakotas and southern Montana for 1986 through 2005 averaged 1,296,427 breeding ducks (United States Fish and Wildlife Service, unpublished data). Wetland habitat available for waterfowl, however, can be extremely variable because of high annual, seasonal, and spatial variability in precipitation. Natural wetland habitats are primarily riverine pools or palustrine wetlands along intermittent streams that might be temporarily to semipermanently flooded. To increase water permanency or depth for livestock watering or waterfowl, a large proportion of wetlands have been altered or created, primarily by building dams within intermittent drainages or excavating existing wetlands. These modified wetlands provide valuable seasonally, semipermanently, or permanently flooded wetland habitat for migrating and breeding waterfowl. In the region west of the Missouri River, impoundments accounted for 42% and excavated wetlands accounted for 8% of total wetland numbers (excluding basin-like pools in riverine systems; Rieger et al. 2006). When those palustrine pools along riverine systems are included, the estimates can be much higher. In the Little Missouri National Grassland in western North Dakota, which has long been managed for grazing, 83% of all palustrine wetlands, and 98% of semipermanently flooded palustrine wetlands, have been so modified (Euliss and Mushet 2004). The large proportion of modified wetlands therefore has altered dramatically the characteristics of wetland habitat available to waterfowl in this region.

The value of modified wetlands for breeding waterfowl in the Badlands and Prairies has long been the subject of study. Many investigators (Bue et al. 1952, Lokemoen 1973, Ruwaldt et al. 1979, Rumble and Flake 1983, Svingen and Anderson 1998) have described the characteristics of impounded wetlands used by waterfowl. However, most of these studies have focused on site-specific characteristics of impounded, semipermanently flooded wetlands, such as water area, emergent and submergent vegetation, and water clarity. Fewer studies have considered the value of modified wetlands in the context of other wetland types and landscape features (Lokemoen 1973, Flake et al. 1977, Mack and Flake 1980), which would help target development of new wetland projects. One characteristic feature of the region is the abundance of small (≤ 2 ha), often unmodified wetlands located within drainages of intermittent streams. These wetlands often are clustered or more regularly spaced along the length of a drainage (e.g., every 0.2 - 0.4 km) like a beaded chain and might be valuable for water-dependent biota, including ducks, because of their hydrological and spatial connectivity. Unmodified in-stream

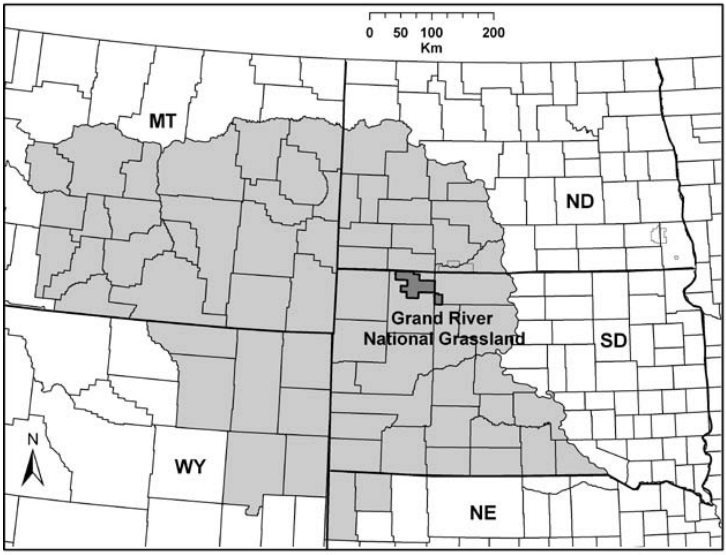

Figure 1. Locations of Grand River National Grassland within Bird Conservation Area 17 (shaded counties).

wetlands have not been considered in waterfowl studies in the northern Great Plains (but see Lokemoen 1973) and might be excluded from regional wetland summaries (Rieger et al. 2006). Also, the value of seasonally flooded wetlands to breeding pairs and broods has been examined infrequently in Prairie Badlands Region (Lokemoen 1973, Naugle et al. 1999) although their value to waterfowl in the Prairie Pothole Region is well documented (Stewart and Kantrud 1974, Swanson and Duebbert 1989, Krapu et al. 2006).

Managers planning to protect, restore, or develop wetlands in the northern Great Plains need reliable information on factors influencing waterfowl use such as water regime, placement in the landscape, size, and shape. We designed a study to evaluate duck use of wetlands that were classified as unmodified or modified (impounded or excavated) and isolated or in-stream (located within 50 m of a drainage) on a large grassland area in northwestern South Dakota. This area was selected for study because it was representative of grassland-dominated landscapes in the Badlands and Prairies that are managed for grazing. In addition, the United States Forest Service (USFS) sought current information about waterfowl habitat and use relative for planning of grazing management. Our objectives were

to 1) evaluate duck use of different wetland types (seasonal or semipermanent, modified or unmodified, and isolated or in-stream), and 2) relate numbers of indicated breeding pairs, or probability of use by breeding pairs or broods, to wetland and landscape characteristics of palustrine wetlands within the area. Based on earlier studies in the region and elsewhere, we hypothesized that pair and brood use would be greater in wetlands that had greater water permanency, more complex shoreline, greater cover of emergent vegetation, greater proportion of vegetative cover along wetland edge, and larger size. We discussed results relative to management and creation of wetlands within the larger landscape for waterfowl and grazing.

STUDY AREA

Grand River National Grassland (62,726 ha; hereafter Grand River) was located in Perkins County, northwestern South Dakota, near Lemmon (Fig. 1). The area was characterized by rolling hills, river breaks, and some badland-type areas and was dominated by large tracts of contiguous mixed-grass prairie. Blocks of Forest Service lands were interspersed among other public lands and private land-holdings. Landscape characteristics and land use on private lands were very similar to those of Forest Service lands except for small areas of cultivated fields, which were dispersed through the area. The entire national grassland was situated in the Missouri Plateau ecoregion, an unglaciated topography characterized by moderately dissected level to rolling plains with isolated sandstone buttes (Bryce et al. 1998). Wetlands on the federal lands were largely a mix of unmodified (natural) and modified (stock dams) wetlands; excavated wetlands (dugouts) were uncommon (Table 1; Austin and Buhl 2005). Overall, 30% of wetlands had temporary, 43% seasonal, and 27% semipermanent water regimes (Cowardin et al. 1979). Palustrine wetlands were dominated by unmodified in-stream seasonal and temporary wetlands and modified in-stream semipermanent wetlands; overall, 39% were modified. On federal lands, total density of palustrine wetlands was 0.697 wetlands/100 ha, and total area of palustrine wetlands was 156.2 ha. All wetlands on federal lands were embedded within large grassland tracts.

The area experienced a semi-arid continental climate, with hot, dry summers (average maximum temperature of 28°C) and very cold winters (average temperature of -7°C). Precipitation was heaviest in late spring and early summer. This study coincided with a multi-year drought in the area, starting 2002, when annual precipitation was 23.7 cm below the long-term average annual precipitation of 44.9 ± 9.5 [SD] cm (Lemmon, South Dakota; National Climate Data Center 2004). During our study, annual precipitation at Lemmon was 39.6 cm in 2003 (5.4 cm below average) and 28.5 cm in 2004 (16.4 cm below average; National Climate Data Center 2003, 2004). In 2003, the area experienced 10 cm precipitation during May but

Table 1. Numbers and percentage of palustrine wetland basins, by NWI water regime and modifier, on United States Forest Service lands at Grand River National Grassland, South Dakota. Percentages indicate percent of wetlands in that regime. No wetlands were classified as intermittently exposed, or modified by partial drainage or American beaver (*Castor canadensis*).

				Modified			
	Total	Unmodified		Impounded		Excavated	
Water regime	N	N	%	N	%	N	%
Temporary	115	102	88.7	12	10.4	1	0.9
Seasonal	166	132	79.5	24	14.5	10	6.0
Semipermanent	107	1	0.9	85	79.4	21	19.6
All	*388*	*235*	*60.6*	*121*	*31.2*	*32*	*8.2*

below-average precipitation during July and August. In 2004, precipitation was markedly below average during late winter and early spring, and most rain (9 cm) occurred in early July.

MATERIALS and METHODS

GIS development and wetland descriptions

Spatial data from National Wetlands Inventory (NWI), USFS, and other sources were merged in a GIS by using Map and Image Processing software (version 7.0; MicroImages, Inc., Lincoln, Nebraska). Other spatial data layers in the GIS included digital orthophotoquads, ownership (USFS or non-USFS), and roads and trails (USFS). All wetland data presented here represent only palustrine wetlands on federally owned national grasslands; wetlands on private, state, or national park land were excluded. We did not include wetlands classified as riverine, lacustrine, or permanently flooded palustrine. We defined wetland basins as wetlands digitized as polygons (nonlinear) in NWI data (distinct from linear wetlands such as roadside ditches). NWI polygons representing water regimes (Cowardin et al. 1979) were merged into wetlands by using standard protocol that had been developed for the Prairie Pothole Region (Cowardin et al. 1995, Johnson and Higgins 1997), and individual wetlands were labeled with unique identifying numbers. The most permanent water regime of the merged polygons defined the wetland. Hereafter, we refer to temporarily, seasonally, and semipermanently flooded wetlands as temporary, seasonal, and semipermanent wetlands, respec-

tively. Wetlands were considered modified if the NWI classification indicated it was impounded (h), excavated (x), or partly drained (d). We determined wetland area from the total size of the wetland polygon as determined from the NWI data, which were based on aerial imagery from 1979 through 1990. For each wetland, we also calculated the shoreline development index (SDI; Lind 1974), which is the ratio of shore length to circumference of a circle of equal area. A SDI of 1.0 indicates a circular wetland, and larger values indicate a more complex shape.

We assumed that a wetland would be hydrologically influenced by any drainage (permanent or intermittent stream) within 50 m. We therefore classified wetlands as isolated if their centroid was greater than 50 m from a linear drainage and in-stream if their centroid was less than or equal to 50 m of the drainage.

We determined the total area of seasonal and semipermanent wetlands within 4 km of the centroid of each wetland (this area included wetlands outside the national grassland). Because of varying size and shape of wetlands, this estimate might be imprecise, but it does provide an index to wetland area in the proximity of each wetland. Four kilometers represents the average maximum distance in the home range of mallard (*Anas platyrhyncos*) females in prairie pothole habitat (Dwyer et al. 1979). We ignored temporary wetlands because we expected many of those wetlands to quickly dry out each spring and thus would be unavailable for waterfowl.

Importantly, the wetland data were developed from NWI data, which were based on aerial photographs obtained during 1979 through 1990; hence they did not include more recent wetland projects, such as those conducted during the 1990's that created or altered some wetlands via impoundment. Therefore, the results from our study do not fully reflect the more recent wetland restorations or creations, and wetlands created after about 1990 were not included in surveys or summaries. Our results are based on wetlands that have been modified for greater than 10 years.

Study design

In developing the study design, we considered factors of biological relevance, based on information from other studies examining duck use of wetlands in both the Badlands and Prairies and Prairie Pothole Region. We recognized four factors that were most likely to influence duck pair or brood use of wetlands and therefore were key to our sampling design: 1) water regime (seasonal or semipermanent), 2) modification (unmodified or modified), 3) hydrological location (within a stream drainage [in-stream] or isolated), and 4) size (<0.2 ha, 0.2-2.0 ha, or 2.0-5.0 ha). We refer to the combinations of these four factors as wetland strata. The use of seasonal wetlands by breeding pairs and brood is well documented (e.g., Stewart and Kantrud 1974, Swanson and Duebbert 1989, Krapu et al. 2006). Duck use of semipermanent wetlands has been documented in many studies,

although in the western Dakotas most studies have focused solely on semipermanent wetlands, largely because they are most likely to retain water throughout the breeding season. Similarly, pond size has a strong positive effect on duck numbers and probability of use (e.g., Lokemoen 1973, Kaminski and Weller 1992, Cowardin et al. 1995). Modification and hydrological location were specific issues of interest to our study because of management implications for wetland creation and restoration as well as grazing management.

We also included in our design other factors that have been shown to influence duck use of wetlands during the breeding season (see review by Kaminski and Weller 1992). Within wetlands, cover of emergent vegetation often has been shown to be a critical influence on duck use, with greatest duck use when the ratio of open water to emergent cover is 50:50 (e.g., Weller and Fredrickson 1974, Lokemoen 1973, Flake et al. 1977, Murkin et al. 1997). Duck use also often is related positively to shoreline length or complexity (Roberson 1977, Leschisin et al. 1992, Svingen and Anderson 1998, Brown et al. 1996). Water conductivity influences wetland function, including the communities and productivity of submergent vegetation and aquatic invertebrates (Swanson and Duebbert 1989, Euliss and Mushet 2004), which in turn influences food resources and hence attractiveness of wetlands to waterfowl. Most duck species in the region are dabbling ducks that nest on uplands in close proximity to water; hence condition of upland cover around individual wetlands might serve as a factor attracting nesting pairs. Finally, from a landscape perspective, availability of a diversity of wetlands can be critical in fulfilling physiological and behavior requirements of ducks over the course of the breeding season (Kaminski and Weller 1992). One reflection of this aspect, wetland densities or total wetland area in the landscape around a wetland, has been shown to influence waterfowl use (Lokemoen 1973, Brown and Dinsmore 1986, Fairbairn and Dinsmore 2001, Naugle et al. 2001). We recognize that other factors, such as water depth, submerged aquatic vegetation, and abundance of macroinvertebrates also can influence duck use, but were unable to address these factors due to logistical constraints.

We randomly selected 60 palustrine wetlands for sampling each year. All wetlands were within extensive grassland tracts and were not bordered by cultivated lands. There was only one unmodified semipermanent wetland available (Table 1), so this wetland and stratum was dropped from the study. The single larger basin (8.6 ha) in the study area was excluded because it was not representative of the wetland population. We anticipated wetlands would become dry during the season, and we wanted to maintain 60 wet wetlands during each of the five surveys as an adequate sample for ducks. Therefore, we set up a system to replace with alternates any wetlands that were dry when first visited in early May (Survey One), or that went dry by Survey Three (mid-June) or Survey Four (late June-early July). If a wetland was dry when visited during the first survey, it was replaced immediately with the next alternate wetland on the list (selected and

listed in random order) of the same stratum (regime-modification-isolation-size classification). If an alternate wetland matching that specific stratum was not available, then the next alternate wetland available for the next group up (e.g., different size class) was selected as the replacement. Wet wetlands surveyed in Survey One also were surveyed in Survey Two, regardless of water condition in that survey, so that we would use the same wetlands to determine numbers of breeding pairs (see below). Similarly, wet wetlands surveyed in Survey Four were surveyed in Survey Five, regardless of water condition in that survey, so that we had the same wetlands for early and late broods.

Field procedures

Field observers conducted surveys on selected wetlands at Grand River during 2003 and 2004 to determine wetland characteristics and waterfowl use. Five surveys were conducted between the first week of May and 1 August. The first two surveys (May) were intended to record indicated breeding pairs, the third survey (mid-June) to record late-breeding birds and earliest broods, and the final two surveys (July) to record later broods.

At each wet wetland and survey, observers recorded wetland characteristics, birds observed, and the location of the wetland by using a geographic positioning system receiver to verify wetland identification. Wetland data included percent full (visually estimated based on surface area and imagery from digital orthophotoquads); percent emergent cover of entire wetland (basin cover; 0%, 1-10%, 11-66%, and >66%); percent of shoreline edge with emergent cover (emergent edge cover; nearest 10%); water conductivity (1-3999 µs/cm; Hanna Instruments, Inc., Model HI991301); and average height of upland vegetation within 200 m of the wetland edge (low [<4 cm], moderate [4-10 cm], and high [>10 cm]), indicative of nesting cover available. Ranked measures of vegetation were those used by the USFS for monitoring (United States Forest Service 2003).

Birds on each wetland were observed first at a distance with binoculars or spotting scope and again from the wetland edge. Observers walked the perimeter of larger wetlands to flush birds from emergent vegetation; during the brood-rearing period they walked the perimeter of each wetland. Observers recorded numbers and social groups of waterfowl (Dzubin 1969), number of waterfowl broods, and brood size and age (Gollop and Marshall 1954). Surveys were conducted throughout the day, but observers avoided surveys on large marshes before 0900 hr or after 1700 hr. Surveys were not conducted during periods with strong wind (>30 - 40 km/h) or moderate to heavy rain. We do not think visibility negatively affected our counts of pairs and broods because of the small size and minimal shoreline complexity of the wetlands, low density and coverage of emergent vegetation, and the techniques used (observations from good vantage points, and walking the wetland perimeter). However, we recognize that at least a few broods likely escaped detection entirely and, hence, we might have underestimated brood use.

Data analysis

We examined the relationship of 10 explanatory variables with the number of indicated breeding pairs (all species combined) and the probability of wetland use by pairs (individual species), or by broods (all species combined), by using generalized linear models (Myers et al. 2002; generalized linear models procedure [PROC GENMOD], SAS Institute 2004). We computed the number of indicated pairs for each wetland based on the number of ducks and size of groups observed, following the criteria of Dzubin (1969). For May (surveys One and Two), we used negative binomial regression models (Allison 1999, Pedan 2001) to model the relationship of the explanatory variables with the number of indicated pairs of all species combined. Negative binomial regression is a generalized form of Poisson regression (Allison 1999). We used logistic regression models (SAS Institute, Inc. 1995, Allison 1999, Hosmer and Lemeshow 2000) to separately model probability of wetland use by mallard, gadwall (*Anas strepera*), and blue-winged teal (*Anas discors*) pairs in Surveys One and Two. Logistic regression models were used for analyses of individual species, rather than negative binomial regression models, because most counts, by species, were either 0 or 1 with very few counts larger than 1. We also used logistic regression models to model probability of wetland use by broods for mid-June (Survey Three) and July (Surveys Four and Five). As an exploratory method, we used backwards elimination (SAS Institute, Inc. 1995, Hosmer and Lemeshow 2000) to determine which explanatory variables had a significant relationship with the response variable (number of indicated pairs or probability of wetland use), with the significance level set at 0.05. The following explanatory variables were considered: 1) year, 2) wetland type (unmodified seasonal, modified seasonal, and modified semipermanent wetland), 3) hydrological location, 4) wet area (wetland area [ha] x percent full), 5) total wetland area within 4 km of the wetland, 6) SDI, 7) emergent edge cover, 8) water conductivity, 9) numeric score for basin cover, and 10) numeric score for average upland cover. Although basin cover was recorded as a rank (0 = 0%, 1 = 1-10%, 2 = 11-66%, and 3 = 67-100%), we converted this variable to a numeric by replacing each rank with the midpoint of the percentages covered by the rank (0, 5.5, 38.5, and 83.5). Average height of upland cover was also recorded as a rank (L, M, or H), but level H was an open-ended level so midpoints could not be computed. So, for this variable we treated the ranks as a simple numeric value (L = 1, M = 2, and H = 3).

We did not include interaction terms in the models, nor did we include any quadratic effects. We computed Hosmer and Lemeshow's (2000) goodness-of-fit tests for the final logistic regression models. We computed least squares means (LSMEANS) for all categorical explanatory variables included in the final models. We constructed plots to graphically show the relationships of significant continuous explanatory variables with the response variable (number of indicated

pairs or probability of use), while holding other continuous variables constant at their median values and averaging across levels of the categorical variables.

For some models (mainly the brood data), there were "zero cells" present in the data, which cause convergence problems in logistic regression models (Allison 1999, Hosmer and Lemeshow 2000). "Zero cells" means that for some of the categorical variables, wetlands within a given category were either all used or all not used. For example, no wetlands with basin cover greater than 66% were used by ducks in either Survey One or Two, and isolated wetlands were never used by broods. One way of eliminating the "zero cell" problem is to treat categorical variables as numeric. This method worked for basin cover and average upland cover where both variables had some "zero cells," were ordinal variables, and could easily be converted to numeric. Two other variables that had "zero cells" were hydrological location and wetland type. To eliminate the "zero cell" problem with these two variables, we excluded observations for the category with the "zero cells" from the analysis. For example, isolated wetlands were not used by broods, so isolated wetlands were dropped from the analysis and hydrological location was not included as a possible explanatory variable in the model. For the category with the "zero cell," the response can be predicted perfectly and there is no reason to include these observations in the model. Therefore, the resulting model from the backwards elimination will be the "best" model for predicting use of wetlands for the remaining categories.

Conductivity data were missing for a number of observations due to temporary malfunction of the instrument. There usually were six or fewer observations per survey that had missing values, so any observation with conductivity missing was excluded from the analysis. One exception to this was Survey Four of 2003, where 43% of observations lacked conductivity data due to instrument malfunction. Instead of excluding that many observations, conductivity was excluded as a potential explanatory variable for Survey Four.

RESULTS

We surveyed a total of 128 wetlands at Grand River in 2003 (37 unmodified and 91 modified), 99 wetlands in 2004 (38 unmodified and 61 modified). We recorded duck and wetland data for 45 to 61 wet wetlands in each survey.

Water conditions at Grand River were poor in both years. In 2003, 20% of seasonal wetlands and 17% of semipermanent wetlands visited during early May (Survey 1) were dry; by late July (Survey 5), 62% of all seasonal wetlands and 51% of all semipermanent wetlands that had been visited during the course of the year were dry. In 2004, 28% of seasonal wetlands and 27% of semipermanent wetlands visited in early May were dry; by late July, 58% of all seasonal wetlands and 47% of all semipermanent wetlands visited were dry.

We observed 12 duck species on surveyed wetlands: mallard, gadwall, blue-winged teal, northern shoveler (*Anas clypeata*), northern pintail (*Anas acuta*), American wigeon (*Anas americana*), green-winged teal (*Anas crecca*), canvasback (*Aythya valisineria*), ruddy duck (*Oxyura jamaicensis*), hooded merganser (*Lophodytes cucullatus*), ring-necked duck (*Aythya collaris*), and lesser scaup (*Aythya affinis*). Mallard, blue-winged teal, and gadwall were the most commonly observed species. Peak numbers of indicated pairs observed were 94 pairs in 2003 and 121 pairs in 2004. Numerically, ducks were observed most commonly on semipermanent wetlands as expected, reflecting the larger size and greater water permanence of these wetlands. Overall, we consistently observed the largest proportion of indicated pairs in May on modified semipermanent wetlands (77% and 81% in early and late May, 2003, respectively; 60% and 66% in early and late May, 2004).

Total number of broods was highest in late July. During late July 2003, gadwall (48%) and mallard (21%) broods were observed most commonly, with fewer broods of American wigeon (12%), blue-winged teal (12%), northern pintail (5%), and northern shoveler (2%). In late July 2004, gadwall (47%) and blue-winged teal (27%) broods were observed most commonly, with fewer broods of northern pintail (9%), mallard (7%), northern shoveler (7%), and American wigeon (4%). Broods were observed most often on modified in-stream semipermanent wetlands, as anticipated, but they also were observed on other wetland strata, particularly those located in-stream. Broods were never observed on isolated wetlands.

We examined correlations among explanatory variables. The explanatory variables that showed the highest correlations were wetland area and SDI (Pearson correlation coefficient = 0.503-0.710 across the 5 surveys). The second strongest correlation was between basin cover and emergent edge (Kendall's tau correlation coefficients = 0.284-0.494). No other correlation was consistently greater than 0.25 across the surveys. However, during the last 2 surveys, emergent edge was correlated with basin cover (0.494 and 0.403) and average upland cover (0.266 and 0.289), which was likely indicative of a combination of grazing influences, basin morphology, and wetland productivity.

Relating duck abundance or use to landscape and wetland variables

Number of indicated pairs. The models for the number of indicated pairs varied between early (Survey 1) and late May (Survey 2) (Table 2). Wetland type, hydrological location, and basin cover were variables included for both May surveys. During early May, estimated number of indicated pairs differed among wetland types and was lowest for unmodified seasonal wetlands, intermediate for modified seasonal wetlands, and highest for modified semipermanent wetlands (Table 3). During late May, estimated number of indicated pairs was again lowest on unmodified seasonal wetlands but did not differ between modified seasonal and

Table 2. Response variables, sample sizes, and explanatory variables included in final models for number of or use by indicated pairs for Grand River National Grassland (2003 and 2004) during Surveys One (early May) and Two (late May). N indicates sample size (number of wetlands). Plus or minus sign in parenthesis indicates direction of relationship with response variable; see associated figures for graphical representation.

Response	Survey	N	Variables included in model and relationship
Estimated number of indicated pairs, all species	1	108	Wetland type (Unmod-seasonal < Mod-seasonal < Mod-semipermanent) Hydrological location (Isolated < In-stream) Total wetland area within 4 km (+) Shoreline Development Index (+) Emergent Edge cover (+) Basin cover (−)
	2	101	Wetland type (Unmod-seasonal < Mod-seasonal = Mod-semipermanent) Hydrological location (Isolated < In-stream) Wet area (+) Basin cover (−)
Probability of use by Mallard pairs	1	108	Year (2003 < 2004) Hydrological location (Isolated < In-stream) Shoreline Development Index (+) Basin cover (−)
	2	101	Year (2003 < 2004) Wetland type (Unmod-seasonal = Mod-seasonal < Mod-semipermanent) Basin cover (−)

Table 2, continued.

Response	Survey	N	Variables included in model and relationship
Probability of use by Gadwall pairs	1	108	Shoreline Development Index (+) Emergent Edge cover (+) Basin cover (−)
	2	101	Wetland type (Mod-seasonal < Mod-semipermanent, Mod-seasonal = Unmod-seasonal, Unmod-seasonal = Mod-semipermanent) Wet area (+) Basin cover (−)
Probability of use by Blue-winged teal Pairs	1	108	Wetland type (Unmod-seasonal = Mod-seasonal < Mod-semipermanent) Hydrological location (Isolated < In-stream) Total wetland area within 4 km (+) Shoreline Development Index (+)
	2	101	Hydrological location (Isolated < In-stream) Wet area (+) Basin cover (−)

Table 3. Differences in duck responses among wetland types. Only those response variables and survey periods that had wetland type as a critical explanatory variable in the model are presented. LSM = least squares means, LCI = lower confidence interval, UCI = upper confidence interval. Least squares means in the same row sharing the same letter do not differ statistically (P > 0.05).

		Unmodified Seasonal			Modified seasonal			Modified semipermanent		
Response	Survey	LSM	LCI	UCI	LSM	LCI	UCI	LSM	LCI	UCI
Estimated no. indicated pairs, all species	1	0.195 A	0.093	0.406	0.552 B	0.309	0.988	1.087 C	0.651	1.815
	2	0.302 A	0.136	0.669	0.831 B	0.452	1.527	1.403 B	0.829	2.375
Probability of use, mallard	2	0.132 A	0.046	0.326	0.206 A	0.096	0.387	0.580 B	0.397	0.744
Probability of use, gadwall	2	0.186 AB	0.069	0.413	0.104 A	0.032	0.291	0.435 B	0.249	0.641
Probability of use, blue-winged teal	1	0.014 A	0.002	0.108	0.024 A	0.003	0.153	0.206 B	0.066	0.488

modified semipermanent wetlands. For both May surveys, estimated number of indicated pairs was higher for in-stream wetlands than for isolated wetlands (Table 4) and decreased as basin cover increased (Fig. 2A). The metric representing water conditions included in the models differed between surveys. In early May, estimated number of indicated pairs was related positively to total wetland area within 4 km (Fig. 2B), whereas in late May, the estimated number was related positively to wet area of the wetland (Fig. 2C). Pair numbers were related positively to emergent edge cover (Fig. 2D) and SDI only in early May (Fig. 2E).

Probability of use by indicated pairs by species. The models for wetland use by mallard, gadwall, and blue-winged teal pairs varied with survey and species (Table 2). Probability of mallard use was higher in 2004 than 2003 for both early May (2003: LSMEANS = 0.101, LCI = 0.038, UCI = 0.240; 2004: LSMEANS = 0.279, LCI = 0.139, UCI = 0.481) and late May (2003: LSMEANS = 0.167, LCI = 0.078, UCI = 0.322; 2004: LSMEANS = 0.417, LCI = 0.268, UCI = 0.583). In early May, mallard use was higher on in-stream than isolated wetlands (Table 4), and was related positively to SDI (Fig. 3A). In late May, mallard use was similar on unmodified and modified seasonal wetlands but higher on modified semipermanent wetlands (Table 3). Wetland use by mallard pairs in both early and late May was related negatively to basin cover (Fig. 3B), and the same pattern was found for use by gadwall pairs (Fig. 3B). Wetland use by gadwall pairs during early May was related positively to SDI (Fig. 3A) and emergent edge cover (Fig. 3C). In late May, gadwall use was related positively to wet area (Fig. 3D) and also influenced by wetland type. Gadwall use was similar between unmodified and modified seasonal wetlands, and between unmodified seasonal and modified semipermanent wetlands, but use was

Table 4. Differences in duck responses between isolated and in-stream wetlands. Only those response variables and survey periods that had hydrological location in the model as a critical explanatory variable are presented. LSM = least squares means, LCI = lower confidence interval, UCI = upper confidence interval. Duck response was consistently lower ($P < 0.05$) on isolated wetlands than on in-stream wetlands.

		Isolated			In-stream		
Response	Survey	LSM	LCI	UCI	LSM	LCI	UCI
Estimated no. indicated pairs, all species	1	0.237	0.101	0.556	1.007	0.737	1.377
	2	0.376	0.158	0.896	1.326	0.960	1.832
Probability of use, mallard	1	0.087	0.023	0.278	0.313	0.189	0.470
Probability of use, blue-winged teal	1	0.011	0.001	0.145	0.159	0.081	0.287
	2	0.062	0.008	0.342	0.275	0.177	0.401

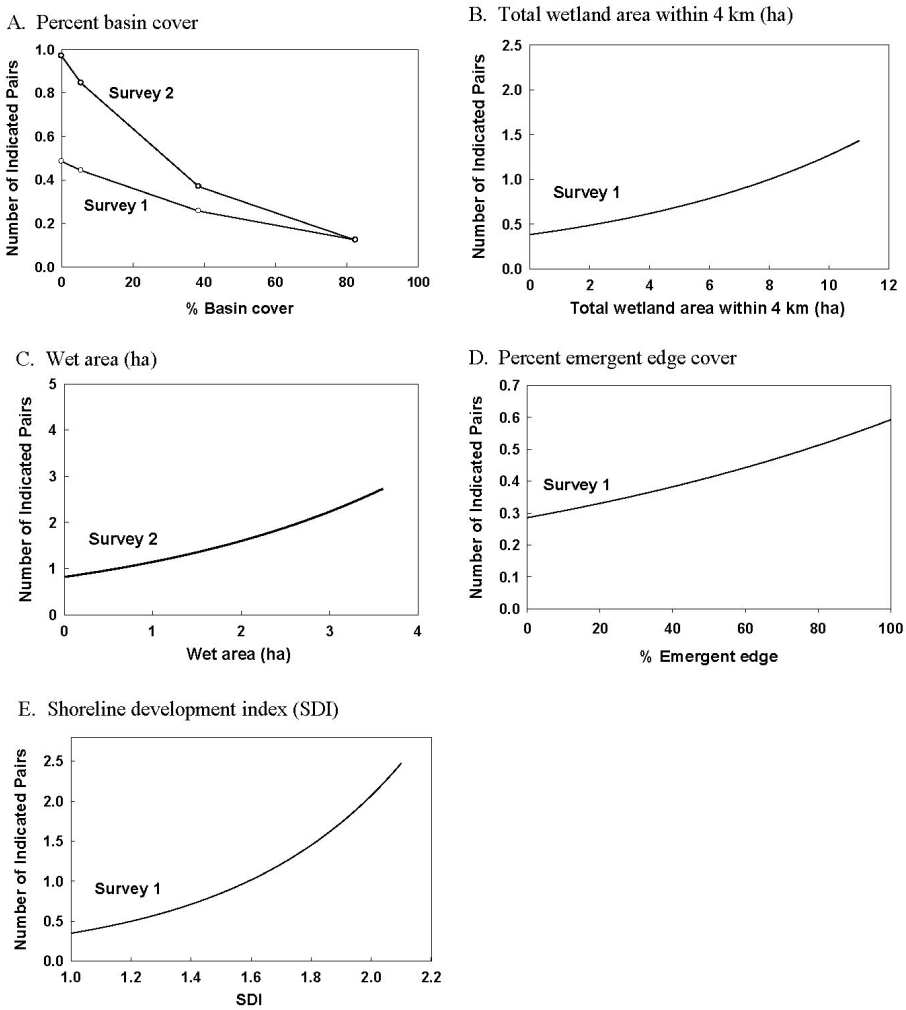

Figure 2. Trends in number of indicated pairs (all species combined) relative to A) percent basin cover, B) total wetland area within 4 km, C) wet area, D) percent emergent edge cover, and E) shoreline development index (SDI) at Grand River National Grassland during Surveys One (early May) and Two (late May) 2003 and 2004.

higher on modified semipermanent than on modified seasonal wetlands (Table 2). For blue-winged teal pairs, probability of use during both surveys was higher for in-stream than isolated wetlands (Table 4). In early May, use by blue-winged teal

pairs also was related positively to SDI (Fig. 3A) and total wetland area within 4 km (Fig. 3E); use was similar between unmodified and modified seasonal but lower than on modified semipermanent wetlands (Table 2). In late May, probability of blue-winged teal use was related positively to wet area (Fig. 3D) but related negatively to basin cover (Fig. 3B). All final models for probability of use by pairs for each species fit well (all $\chi^2 < 8.44$, 8 df, $P > 0.39$).

Probability of use by broods. The models for wetland use by broods (all species combined) varied with survey (Table 5). No broods were found on isolated wetlands in any survey, and none were found on unmodified seasonal wetlands in early July. Therefore, for mid-June (Survey 3) and late July (Survey 5), the first part of the model for predicting the probability of use is: if wetlands were isolated, the probability of use was zero. Then, for in-stream wetlands, the probability of brood use increased with wet area during mid-June and late July (Fig. 4A), and was higher in late July 2003 (LSMEANS = 0.430, LCI = 0.281, UCI = 0.593) than in the same period in 2004 (LSMEANS = 0.197, LCI = 0.093, UCI = 0.370). For early July, the first part of the model is: if the wetland is isolated or unmodified, the probability of use is zero. In the final model for modified in-stream wetlands, the probability of use increased as total area of wetlands within 4 km (Fig. 4B) , SDI (Fig. 4C), and emergent edge cover (Fig. 4D) increased (Fig. 4); use did not differ between modified seasonal and modified semipermanent wetlands ($P > 0.05$). All final models fit reasonably well (all $\chi^2 < 11.62$, 8 df, $P > 0.17$).

DISCUSSION

Factors influencing wetland use by breeding pairs or broods varied across the breeding season. However, our models showed consistent relationships of duck numbers or probability of use across surveys and species for variables and largely supported our original hypotheses.

Many wetlands in the region have been modified or created for the benefit of livestock or waterfowl, largely by impoundment, and their numbers likely have increased substantially the region's waterfowl populations. Impoundment or excavation of wetlands often results in greater water permanency, which in turn supports better development of aquatic vegetation and macroinvertebrates critical to waterfowl in both seasonal and semipermanent wetlands. Hence, modified wetlands should provide better quality duck habitat particularly during the dry conditions we encountered. As anticipated, duck use was often highest in modified semipermanent wetlands and lowest in unmodified seasonal wetlands. Wetland type also occurred as critical for brood use, although only in early July, when we found broods only on modified wetlands. However, in some situations we detected no differences among wetland types (mallard and gadwall pairs in early May, blue-winged teal pairs in late May, broods in mid-June or late July), or no

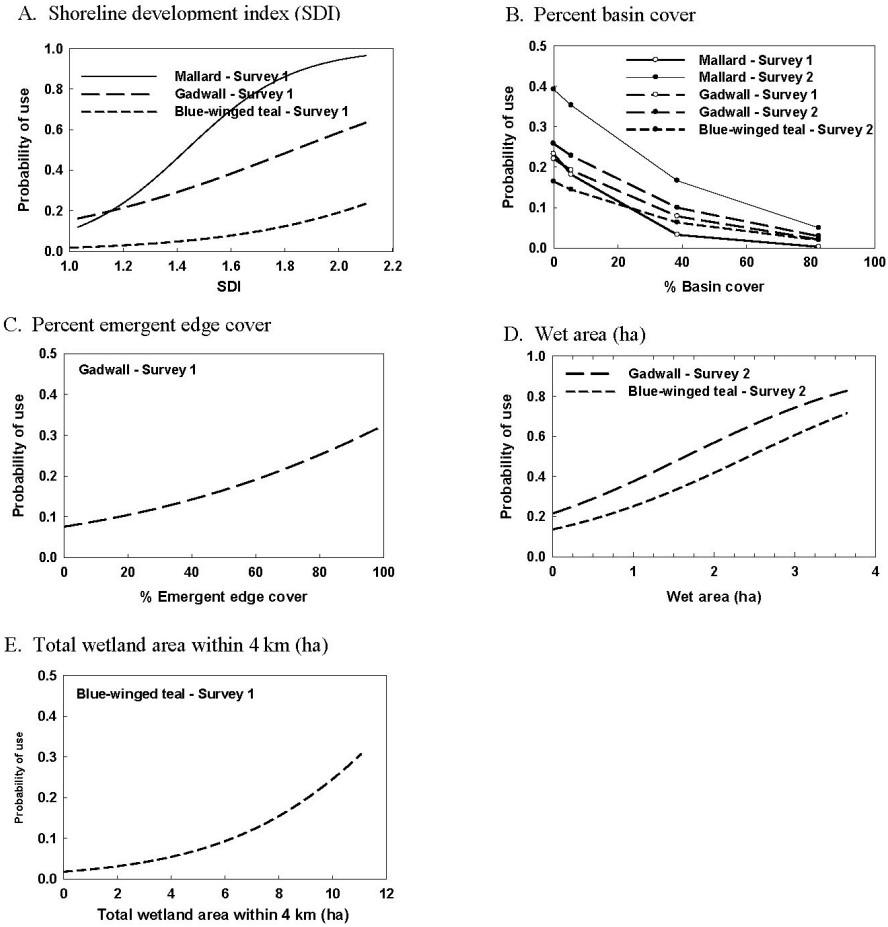

Figure 3. Trends in probability of use for individual duck species relative to A) shoreline development index (SDI), B) percent basin cover, C) percent emergent edge cover, D) wet area, and E) total wetland area within 4 km at Grand River National Grassland during Surveys One (early May) and Two (late May), 2003 and 2004.

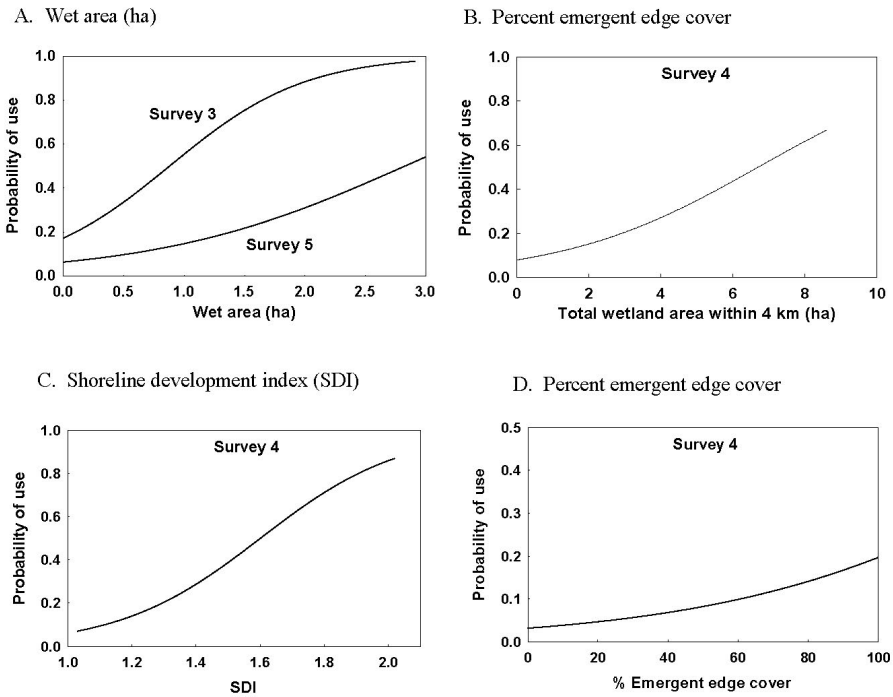

Figure 4. Trends in probability of broods (all species combined) occurring on a wetland basin relative to A) wet area, B) total wetland area within 4 km, C) shoreline development index (SDI), and D) percent emergent edge cover at Grand River National Grasslands during Survey Three (mid-June), Survey Four (early July), and Survey Five (late July), 2003 and 2004.

difference between modified seasonal and modified semipermanent wetlands (total indicated pairs in late May). Our study occurred during an extended drought, which likely resulted in lower use of unmodified seasonal wetlands by pairs because many were dry or too briefly flooded to provide quality habitat for waterfowl. Lokemoen (1973) reported 12% of breeding pairs occurred on natural (unmodified) wetlands in the southern district of the Little Missouri National Grassland during 1967 through 1970, which was a period of average to above average precipitation. In comparison, we observed <10% of breeding pairs on unmodified wetlands at Grand River during two dry years.

Hydrological location of wetlands also was a critical factor for use by waterfowl in this semi-arid region, as demonstrated by greater use of in-stream than

Table 5. Explanatory variables and sample sizes in final models explaining probability of brood use (all species combined) at Grand River National Grassland during Surveys Three (mid-June), Four (early July), and Five (late July) in 2003 and 2004. Plus or minus sign indicates direction of relationship with response variable.

Survey	N	Subset of data used in model	Explanatory variables in final model
3	97	In-stream wetlands only	Wet area (+)
4	69	In-stream and modified wetlands only	Total basin area within 4 km (+)
			Shoreline Development Index (+)
			Emergent edge cover (+)
5	92	In-stream wetlands only	Year (2003 > 2004)
			Wet area (+)

isolated wetlands in five of eight models for breeding pairs, and the restriction of all brood observations to in-stream wetlands. Use of isolated wetlands was low regardless of water regime, particularly later in the year as many isolated seasonal wetlands dried out. Very few isolated wetlands are available at Grand River regardless of water conditions. Both naturally occurring and impounded palustrine wetlands located along intermittent streams often are clustered or regularly spaced along the length of a drainage (e.g., every 0.2 to 0.4 km) like a beaded chain. These in-stream wetlands are valuable for water-dependent biota because of their hydrological and spatial connectivity. Periodic flood events contribute to re-colonization by plants and aquatic invertebrates, and minnows (Dodds et al. 2004) and can flush accumulated nutrients and salts through the wetlands. Small, interconnected in-stream wetlands might be critical to pre-nesting waterfowl because they provide isolation for breeding pairs (Anderson and Titman 1992) and to nesting hens because their distribution would provide access to large areas of upland nesting habitat. During brood-rearing, in-stream wetlands probably provide valuable corridors for brood movements as they move to more permanent waters. Lokemoen (1973) reported 10% of observed broods were on creek pools (in-stream, unmodified wetlands) in the southern district of the Little Missouri National Grassland during 1967 through 1970, a period of good water conditions, which was higher than we found at Grand River (7% of all broods observations in 2003 and 2% in 2004).

Basin cover was a critical factor influencing wetland use by breeding pairs (seven of eight models) but was not critical in brood models. We consistently found that basin cover was related negatively to breeding pairs, with the greatest duck use on wetlands where basin cover was less than or equal to 10%. This relationship seems to be driven by other factors, primarily water regime and wetland size. The preponderance of duck use was in modified semipermanent wetlands, where emergent vegetation is often limited by water depths and wetland morphology along the wetland periphery.

Size was also a confounding factor with basin cover. First, median sizes of wetlands used by pairs (0.19 ha) was nearly twice the size of all sampled wetlands (0.10 ha). Second, the difference in median size of used and unused wetlands was markedly greater for wetlands that had 11 through 66% basin cover (0.60 vs. 0.08 ha, respectively) than for wetlands with 1 to 10% basin cover (0.18 vs. 0.08 ha, respectively). Also, very few wetlands had basin cover greater than 66%, most of these were small seasonal wetlands having wide bands of emergent vegetation along the wetland edge, and only two were used by pairs. The pattern for brood use was less marked: wetlands that had 11 to 66% basin cover (1.64 vs. 0.07 ha for used and unused basins, respectively) than for wetlands with 1 to 10% basin cover (1.24 vs. 0.09 ha, respectively). Given these characteristics and observers' efforts to walk the wetland perimeter to flush birds from edge vegetation, we do not think this response was influenced by visibility. Although greater basin cover and "hemi-marsh" conditions are often cited as the ideal for breeding dabbling ducks, apparent preferences vary among species (Lokemoen 1973, Flake et al. 1977, Roberson 1977, Mack and Flake 1980). Variable results among studies indicate that the value of basin cover on impoundments, at least, varies among species and interacts with other factors such as wetland size and morphometry, water level dynamics, and food resources. Basin cover would be more appropriate as an indicator of habitat quality where basin morphometry is gentle enough to allow development of emergent vegetation across greater than 10% of the wetland.

Emergent cover has been a critical factor influencing duck numbers or use of natural and modified wetlands in the western Dakotas in other studies (Lokemoen 1973, Flake et al. 1977, Roberson 1977, Rumble and Flake 1983) but had a weak showing in our study. Waterfowl numbers and probability of use were related positively to emergent edge cover, as anticipated, but this parameter occurred in only two models for indicated pairs and for one brood model. Moreover, the response curve in the brood model (Fig. 4) suggested only moderate differences in brood use between low and high levels of emergent edge. Emergent cover provides escape cover, shelter from extreme temperatures, and substrate for aquatic invertebrates, and is valuable to minimize shoreline erosion. We suspect our weak results for this factor is complicated by differences in how observers estimated emergent edge cover. In 2003, percent emergent edge cover increased with season, suggesting observer bias related to vegetative growth, whereas in 2004, when observers were better trained to avoid such bias, emergent edge cover was highest during May surveys. In 2004, we determined emergent edge cover to be consistently lowest on modified semipermanent wetlands. This pattern suggested a confounding interaction between emergent cover and wetland type and might be due to basin morphology (steeper slopes along downstream side limiting plant growth) or cattle use patterns.

Many studies have demonstrated that duck numbers and probability of use increases with pond size or water area (e.g., Lokemoen 1973, Flake et al. 1977,

Cowardin et al. 1995, Svingen and Anderson 1998, our study). Larger wetlands also are more likely to have a more diverse waterfowl community (Naugle et al. 1999). Earlier stock-pond studies often recommended creating or focusing on wetlands greater than 1 ha for waterfowl. Our results indicated that smaller wetlands also were critical to breeding pairs. In late May, when wet area was a critical factor in all models for breeding pairs except the mallard, average sizes of wetlands used by ducks at Grand River were 0.77 (2003) and 0.71 ha (2004). These wetland sizes are closer to the recommendations of Lokemoen (1973) for 0.6-ha stock ponds as the most suitable habitat for waterfowl in western North Dakota. Larger wetlands, however, are critical during brood-rearing. Average sizes of wetlands used by broods at Grand River during the three brood surveys in 2003 and 2004 were 0.72 to 2.23 ha, and the median size of wetlands used by broods was 0.96 ha.

Greater shoreline complexity, as represented by SDI, provides more complex shoreline edge to enhance habitat diversity and availability of foraging habitat, loafing sites, and escape cover. It also can provide greater visual isolation among pairs or broods and hence might allow greater duck densities on the same wetland area. Shoreline complexity was critical to breeding pairs (five of eight models), particularly in early May when pairs are likely to be establishing territories or in early nesting efforts, and also to broods during early July, when emergent edge cover also was critical. One might expect duck response to SDI to be confounded with hydrological location, as one would expect that in-stream basins would have higher SDI values because they are located along a drainage and would be more likely to be elongated or have multiple arms rather than a simple round shape as expected for isolated wetlands. However, we discerned no patterns of SDI values relative to basin modification or hydrological location within wetland regimes. Most in-stream wetlands in Grand River are located in a single drainage and hence are most likely to be simple in shape. Only 9% of all basins at Grand River, and 8 to 10% of surveyed basins, have more than one incoming drainage, and these tended to be larger basins ($\bar{x}$ = 1.08 ± 0.05 [SE] ha) with higher SDI values (1.6 ± 0.1).

Beyond the individual wetland, wetland complexes and proximity to other wetlands are critical factors in meeting the needs of breeding waterfowl (Kaminski and Weller 1992). Studies generally have shown a positive relationship between duck or brood use and wetland proximity or density (Lokemoen 1973, Flake et al. 1977, Mack and Flake 1980), although some studies suggested that the mallard is more likely to use isolated ponds (Lokemoen 1973, Roberson 1977, Mack and Flake 1980). Wetlands with greater wetland area nearby would provide more breeding space and isolation, more readily provide access from nest to water, and be more likely to contain a diversity of wetland habitats with suitable water and foraging resources for pairs and broods than those having a small wetland area nearby. Our measure of wetland proximity (total area of seasonal and semipermanent wetlands

within 4 km) was limited to the use of wetland size data derived from GIS, and did not take into account water conditions in each wetland; we did not have the resources to directly measure water conditions at this larger scale. Nevertheless, this imperfect variable proved to be critical to abundance of total breeding pairs and use by blue-winged teal pairs in early May and use by broods in early July. A more comprehensive understanding of the role and use of wetland proximity in this semi-arid landscape should be developed through long-term studies that cover wet and dry years, and through radio-telemetry studies of breeding hens. Movements of breeding pairs and broods among wetlands are largely unknown for western landscapes such as Grand River, where in-stream and modified wetlands predominate and less than 30% of the wetlands are semipermanent wetlands. Moreover, information from such a study would be valuable in understanding the role of wetlands or pools along intermittent streams and their juxtaposition relative to the larger, modified semipermanent wetlands that are obviously key to brood-rearing in this area.

The complexity of and variability among our models demonstrated the seasonal complexities of wetland conditions and waterfowl life history and habitat needs in this semi-arid landscape. Breeding pairs and broods used a variety of wetland types despite dry conditions experienced at Grand River during our study. Modified semipermanent wetlands, and wetlands located along intermittent streams, clearly were critical to both breeding pairs and broods. Impounded wetlands were the key wetland type supporting breeding waterfowl in this semi-arid area across wet and dry years, and might become more critical as climate warms and dry conditions occur more frequently (Johnson et al. 2005). However, unmodified seasonal wetlands also are used by waterfowl and are critical parts of the ecosystem for a range of species (Dodds et al. 2004, Euliss and Mushet 2004).

Studies of waterfowl abundance and habitat use such as ours do not address productivity, a critical aspect of waterfowl conservation. The large intact grasslands of the Badlands and Prairies are thought to have higher nest success rates than the more fragmented grasslands of the Prairie Pothole Region (Pool and Austin 2006). The study by Ball et al. (1995) often used to support this perspective was conducted in extensive grasslands of north-central Montana; their landscape and wetlands, however, were more similar to the Prairie Pothole Region than found in most of the western Dakotas and elsewhere in the Badlands and Prairies. More extensive, long-term studies that assess nest success, pair:brood ratios, and hen and brood survival rates are needed to address the value of this region for waterfowl production.

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