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The Farm Bill and Duck Production in the Prairie Pothole Region: Increasing the Benefits

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Abstract

The Food Security Act of 1985 contained provisions that affected wildlife conservation nationwide. Two provisions that most benefited waterfowl populations in the Prairie Pothole Region (PPR) were the Conservation Reserve Program (CRP) and "Swampbuster" (wetland conservation). Permanent cover established under the CRP provides attractive nesting habitat for upland-nesting ducks that is more secure than other major habitats. Swampbuster has prevented drainage of wetlands vital to breeding duck pairs. In 2007 many CRP contracts will expire. Deliberations will begin in late 2006 regarding the next Farm Bill. The United States Department of Agriculture needs sound biological information and scientific analyses to help establish wildlife priorities in the Farm Bill. We used data from breeding duck population and wetland habitat surveys to develop models for 5 species of upland-nesting ducks and applied these models to >2.6 million wetlands in a digital database for the PPR in North and South Dakota, USA. We used geographic information systems techniques to identify locations in the PPR where CRP cover would be accessible to the greatest number of nesting hens. We then summarized distribution of current CRP contracts relative to distribution of upland-breeding ducks. We also used our models to predict change in the breeding duck population (landscape carrying capacity) that might occur if certain wetlands were exempt from the Swampbuster provision. Our analyses showed that 75% of CRP contracts as of July 2005 were in areas accessible to high or medium numbers of breeding ducks and 25% were in areas of low populations. We suggest a method to prioritize CRP extensions and reenrollment of current contracts or target new contracts to maintain or increase duck production. Additionally, our models suggested that if the Swampbuster provision were removed from future Farm Bills and protected wetland were drained, this area of the PPR could experience a 37% decline in the waterfowl populations we studied. (WILDLIFE SOCIETY BULLETIN 34(4):963–974; 2006)

Key words

Conservation Reserve Program, duck, Farm Bill, Prairie Pothole Region, Swampbuster, United States Department of Agriculture.

Reduced duck nest success throughout the Prairie Pothole Region (PPR) since approximately 1935 (Beauchamp et al. 1996) has been implicated as a major factor in declining duck populations. Klett et al. (1988) concluded that duck nest success throughout much of the United States PPR was insufficient to maintain population levels for mallards (*Anas platyrhynchos*) and northern pintails (*A. acuta*) at that time, and Hoekman et al. (2002) concluded that nest success was the most important factor influencing population growth rates of mid-continent mallard populations. The decline in duck nest success in the PPR generally has coincided with the continuing conversion of grasslands to cropland in the region and Greenwood et al. (1995) found that duck nest success in Prairie Canada was negatively related to the proportion of study area landscapes annually cultivated. As grassland cover diminishes, ducks concentrate their nests in remaining perennial cover where predators such as red fox (*Vulpes vulpes*), striped skunk (*Mephitis mephitis*), and American badger (*Taxidea taxus*) focus their foraging efforts. Wildlife managers have recognized the importance of grassland cover to waterfowl for many years, and the protection and restoration of grassland cover has been a major thrust for waterfowl management on lands managed by the United States Fish and Wildlife Service (USFWS) in the PPR.

Continued declining duck populations during the early 1980s led to the development and implementation of the North American Waterfowl Management Plan between the United States and Canada (Environment Canada, Canadian Wildlife Service and United States Department of Interior, Fish and Wildlife Service 1986) and subsequently with Mexico. This plan identified wetland and grassland losses in the Prairie Pothole Region (PPR) of North America as a major cause of waterfowl population declines. Wetland loss, primarily due to drainage for conversion to cropland, has been estimated at 35% and 49% in the PPR of South Dakota and North Dakota, USA, respectively (Dahl 1990). The plan emphasized the need to develop innovative habitat management strategies that would result in changing contemporary land uses and agricultural practices.

In 1985 Congress passed the Food Security Act (the Act; Public Law 99–198) which contained 2 important components relative to waterfowl conservation in the PPR: 1) the Conservation Reserve Program (CRP) and 2) the "Swampbuster" (wetlands conservation) provision. The Act, administered by the United States Department of Agriculture (USDA), had objectives to reduce soil erosion, reduce crop surpluses, and improve wildlife habitat. Under the CRP

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landowners contracted with USDA to convert cropland to undisturbed perennial cover such as grass in exchange for annual payments, usually for a period of 10 years. By 1992 there were about 1.9 million ha of CRP cover in the PPR of North Dakota, South Dakota, and northeastern Montana, USA, where the greatest number of breeding ducks occur in the conterminous states. The CRP and Swampbuster were reauthorized with each subsequent Farm Bill. In 1996 CRP underwent major revisions in eligibility and scoring criteria. Since then the area enrolled in the CRP has increased in the PPR of North Dakota (+0.23 million ha) and decreased in the PPR of South Dakota (–0.10 million ha).

Reynolds et al. (2001) studied the impact of CRP on duck production in the PPR of North Dakota, South Dakota, and northeastern Montana during 1992–1997. They found that CRP cover was preferred nesting habitat for 5 species of upland-nesting ducks (mallard, gadwall [*A. strepera*], blue-winged teal [*A. discors*], northern shoveler [*A. clypeata*], northern pintail). The permanent cover established under CRP exhibited higher nest success than other major cover types. Furthermore, nest success was positively related to the total amount of perennial grass cover on their 10.4-km^2 study sites. They also found that nest success in other cover types was higher during the period when CRP cover was available compared with the period just prior to the CRP. They concluded that CRP cover had a positive landscape effect on duck nest success.

Reynolds et al. (2001) estimated that the CRP was responsible for 2.1 million additional ducks produced annually in the PPR during the period 1992–1997. Reynolds (2005) extrapolated the results from the earlier study to years 1998–2003, using period-specific distribution of CRP and duck population estimates derived from operational surveys conducted annually by the USFWS. The updated assessment estimated that 2.2 million additional ducks were produced annually during the period 1998–2003 bringing the total incremental increase in production to 25.7 million ducks for the period 1992–2003.

Clearly, the CRP benefited upland duck production in the United States PPR since 1985. However, as with any conservation program, the magnitude of the benefit is related to program delivery. Since 1997 changes occurred in the amount and distribution of CRP in the PPR, mostly as a result of changes in the Environmental Benefit Index (EBI) used by USDA to rank parcels for enrollment. Conservation Reserve Program acres in eastern South Dakota declined from about 0.5 million ha prior to 1997 to 0.4 million ha after 1997. In North Dakota there was an increase in CRP from 0.9 million ha prior to 1997 to about 1.1 million ha after 1997. However, the increase of CRP in North Dakota does not necessarily equate to additional benefit to ducks because the added contracts may not be distributed in areas where cover is available to the most hens. To maximize the effect on duck production, CRP cover should be targeted to areas near wetland communities where cover will be accessible to moderate to high numbers of nesting hens.

The Swampbuster provision of the 1985 and subsequent Farm Bills also benefited waterfowl in the PPR. Under this provision agricultural operators who enroll lands in the federal farm program may not be eligible for certain program benefits if they drain or fill wetlands that are subject to Swampbuster. Disincentives associated with Swampbuster are believed to have reduced the rate of loss of freshwater emergent wetlands (Dahl 2006), thus protecting breeding duck carrying capacity in the PPR. Conversely, some agriculture groups have argued that many wetlands covered by Swampbuster interfere with cultivation and crop planting (Brady 2005) and may place an unnecessary burden on operators. The North Dakota Farm Bureau recommended that lands in North Dakota that have been farmed as few as 2 out of 10 years and temporary bodies of water $\leq$4.0 ha be exempt from state and federal regulations (North Dakota Farm Bureau 2006).

In 2007 approximately 1 million ha of CRP contracts in North Dakota and South Dakota will expire, and by 2010 only about 13% of the current CRP area will remain unless reauthorized or extended (Barbarika et al. 2005). The Farm Security and Rural Investment Act of 2002 authorized CRP of up to 15.9 million ha nationwide under 10- to 15-year contracts. This will generate many challenges for deciding which contracts will be enrolled, extended, reenrolled or allowed to expire. Wetland conservation provisions of the next Farm Bill also may be an issue. We believe decisions can best be made when appropriate data and scientific methods are used to target conservation treatments.

In this paper we identify areas where CRP cover will provide the greatest benefits for duck production and address the importance of Swampbuster in conserving waterfowl breeding populations. We used spatially explicit models developed from wetland and breeding duck surveys and digital wetland habitat data to estimate the long-term population size and distribution of 5 duck species on approximately 2.6 million wetlands in the PPR of the Dakotas. This approach provides a method to identify areas where grass cover such as CRP will be accessible to the greatest number of upland-nesting ducks in the region. These data are presented in map formats that can be provided at different scales for use by field personnel.

We also simulate the impact of converting to cropland certain wetlands classified as temporary or seasonal water regime (Cowardin et al. 1979) or are $\leq$0.40 ha in area. We assume that wetlands in these classes that are embedded in croplands could be farmed the majority of years and, therefore, are the most likely wetlands to be drained and converted to cropland in the absence of protective programs.

Study Area

Our study area included the portion of Dakotas that lies east or north of the Missouri River (Fig. 1). This area approximated the combined geographical regions of these states known as the glaciated PPR (Kantrud and Stewart 1977) and glacial Lake Agassiz plain (Bluemle 1991). We refer to this area as the PPR. The area contained $\geq$2.6 million depression wetland basins, most of which were not integrated with natural surface drainage connections. The area was characterized by having the highest density of breeding dabbling ducks in the United States (Bellrose 1976). Agriculture was the predominant land use in the PPR, with cattle-production operations most common in the western area, and small-grain and row-crop production generally increasingly dominant from west to east.

Methods

Wetland Data

We obtained digital data of wetlands in our study area, classified according to Cowardin et al. (1979), from the USFWS National Wetlands Inventory (NWI) office, St. Petersburg, Florida, USA. The NWI classified numerous wetland zones or areas within some wetland basins (see Cowardin 1982). However, our breeding duck surveys were conducted on a sample of wetlands in which the entire basin was classified based on the deepest water zone, similar to that described by Stewart and Kantrud (1971). To maintain consistency between wetland classes used in our waterfowl survey sample and wetlands used to extrapolate across our entire study area, we translated NWI wetlands into basin classes using the procedures described by Cowardin et al. (1995) and Johnson and Higgins (1997). For palustrine system wetlands, this process essentially dissolved the interior wetland polygons of complex basin wetlands and reclassified each wetland by the deepest water regime. Lacustrine system wetlands were combined with wetlands containing intermittently exposed and permanently flooded water regime polygons and redefined as lakes. We also separated riverine system wetlands from the other classes. Our final wetland classes were temporary, seasonal, semipermanent, lake, and riverine. We determined the area of each wetland basin (*BASINAREA*) by summing the areas of individual polygons composing the basin.

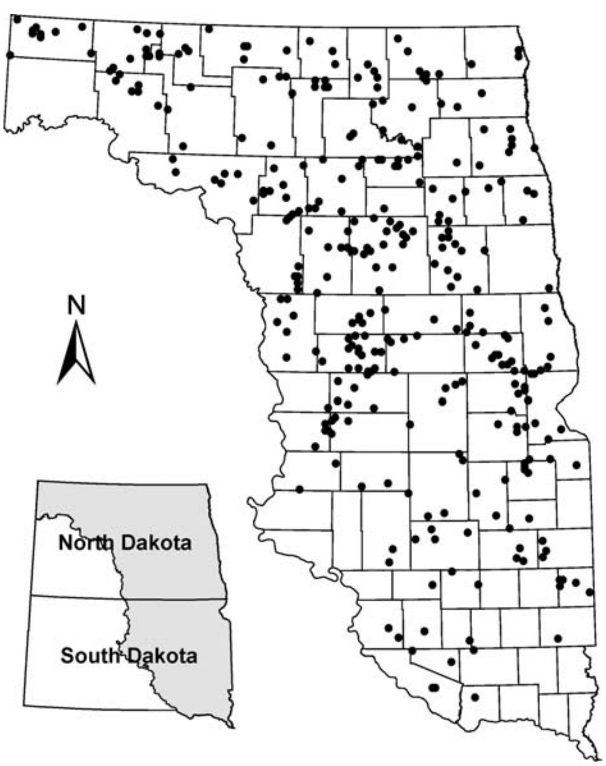

Figure 1. Locations of 335 10.4-km^2 sample blocks used to survey duck populations and wetland habitat in the Prairie Pothole Region of North Dakota and South Dakota, USA, 1987–1998.

Sample Design for Wetland and Breeding Duck Surveys

Basin wetlands.—Primary sampling units for breeding duck surveys on basin wetlands were 335 10.4-km^2 blocks (Fig. 1), selected using a stratified random process as described by Cowardin et al. (1995). We used ARC/INFO (1997) geographic information systems (GIS) software to overlay our sample blocks with the wetland basin layer described above. We then randomly selected approximately 2,800 wetland basin polygons from our sample blocks with the following distribution: 15% temporary, 45% seasonal, 35% semipermanent, and 5% lake. This provided an optimal allocation for a stratified random sample that treated wetland basin classes as strata and avoided oversampling the more numerous temporary basins that are dry more frequently than other classes.

Riverine wetlands.—Less than 0.03% of the wetlands in our study area were classified as riverine, and, because these wetlands are not the principal habitat for ducks in our study area (Kantrud and Stewart 1977), we did not include them in our survey design. However, we believed riverine wetlands provided important duck habitat in some areas, so we included them in our assessment. We obtained duck-pair data for riverine wetlands from surveys conducted on 338 stream sample miles in the PPR area of North Dakota during May 1983–1986 (United States Fish and Wildlife Service, unpublished report). We translated results from these surveys into pairs per hectare of riverine wetland class as mallard = 0.304, gadwall = 0.085, blue-winged teal = 0.354, northern shoveler = 0.069, and northern pintail = 0.015, and treated them as constants in our estimation procedure.

Breeding Pair and Wetland Habitat Surveys

Each year during 1987–1998, survey personnel visited each sample wetland basin once during the period 1 May–15 May and again during the period 20 May–5 June to record the occurrence of all mallard, gadwall, blue-winged teal, northern shoveler, and northern pintail. Two surveys were necessary to match the timing of data collection with the peak occurrence of each species. We used methods described by Cowardin et al. (1995) to conduct surveys and followed the methods described by Hammond (1969) and Dzubin (1969) to record duck population data. Distinctive pairs (1 M and 1 F) and each male in groups of 1–5 were calculated as pairs, except northern shoveler for which only distinctive pairs were considered. All other groupings were considered as migrants or nonbreeding ducks and were not used to calculate pairs (Cowardin et al. 1995). We used data from the first count to calculate breeding pairs for mallard and northern pintail, from the second count for gadwall and blue-winged teal, and from the count nearest May 15 for northern shoveler.

Observers carried maps with boundaries of all ponds surveyed, and, by comparing the extent of water observed in wetlands at the time they were surveyed with the mapped wetland boundary, observers made visual estimates of the percentage of surface area of each wetland basin covered by water. We recorded this percent full estimate (*PFULL*) on the field data form and used it to calculate the surface area of water for each wetland visited during the survey. Some wetland basins extended beyond the boundaries of our sample plots and, therefore, were not completely surveyed. When this occurred we expanded both the percent full and duck population data to the entire wetland basin area.

Duck-Pair Regression Models

We developed regression models relating duck pairs to wetland and spatial variables using PROC MIXED (SAS Institute 1997). Because we intended to apply our models to all wetland basins (approx. 2.6 million) in our study area, we considered only predictor variables that could be measured for all wetlands. Cowardin et al. (1988) found a nonlinear relationship between duck pairs and wetland size for the 4 classes of basin wetlands in our sample. Their best-fitting models included wet area and square root of wet area. On large wetlands dabbling ducks tend to occur more frequently along the shallow water (shoreline) zone than in the deepwater zone (Kantrud and Stewart 1977). We used the square root of wet area as a proxy for shoreline length.

Stewart and Kantrud (1973) found that ducks were not distributed equally throughout the biotic regions of the PPR in North Dakota. Therefore, we calculated the location of each wetland in our sample using Universal Transverse Mercator (UTM) coordinates.

We developed pair–wetland regression models ($n = 20$) for each combination of wetland class ($n = 4$) and duck species ($n = 5$). We used backward stepwise procedures to fit each model, deleting terms with $P > 0.05$ in each step. Explanatory variables in the most complex model for each analysis included 1) area covered by water for each sample basin measured in May of each year 1987–1998 (*WETAREA*), 2) $\sqrt{WETAREA}$, 3) $WETAREA \times \sqrt{WETAREA}$, 4) $\sqrt{WETAREA} \times$ UTM easting ($UTME$), 5) $\sqrt{WETAREA} \times$ UTM northing ($UTMN$), and 6) $\sqrt{WETAREA} \times UTME \times UTMN$. Because the same ponds were surveyed each year, we accounted for lack of independence among repeated measures using a repeated statement, with ponds as subjects. We maintained a Toeplitz structure among repeated measures because extensive evaluation indicated that this structure was most appropriate. We weighted each observation by the product of the proportion of each pond counted multiplied by $1/\sqrt{WETAREA}$. The first term in the weighting factor reflected our reduced confidence in pair counts from partially surveyed ponds, and the second term was necessary because the variance in number of pairs increased in proportion to $\sqrt{WETAREA}$.

We used cross-validation (Snee 1977) to evaluate the predictive ability of each model. The cross-validation procedure consisted of estimating the coefficients of the model from randomly selected subsets (80%) of ponds and applying the model to the remaining 20% of the ponds. We then computed the mean square error between predicted and observed number of pairs to assess the predictive ability of the model. We repeated this process 1,000 times for each model. We also computed R^2 values based on predicting total numbers of pairs occupying wetlands on landscapes of approximately 41.6 km^2.

Incorporating Hydrologic Variation into Models

The area of individual wetlands inundated by water in May varies both temporally and spatially. To apply our breeding-pair regression models to wetlands other than those surveyed each year required an estimate of *WETAREA* for every wetland in our study area. We did not directly account for temporal variation in *WETAREA* but instead based our analyses on the average value among years ($\overline{WETAREA}$). We made use of the relationship $\overline{WETAREA} = \overline{PFULL} \times BASINAREA$ and accounted for spatial variation in $\overline{WETAREA}$ by developing a model in which $\overline{PFULL}$ varied spatially. We averaged values of *PFULL* across years (1987–1998) and used multiple regression to relate $\overline{PFULL}$ to 1) *BASINAREA*, 2) *UTME*, 3) *UTMN*, and 4) $UTME \times UTMN$. We transformed all predictor variables using a natural log function (ln) to reduce skewness and stabilize variance in the residuals. We developed separate models for each wetland class and selected models that contained predictor variables that were significant ($P < 0.01$) and had lowest mean square error. We used a similar approach to model $\overline{\sqrt{PFULL}}$ and to estimate $\overline{\sqrt{WETAREA}}$ for use in our breeding-pair regression models. Because the relation between $\overline{\sqrt{PFULL}}$ and $\overline{PFULL}$ was very strong for lakes ($R^2 = 0.98$), we used a cubic polynomial regression model to estimate $\overline{\sqrt{PFULL}}$ from $\overline{PFULL}$.

The above procedure was effective in accounting for large-scale spatial variation in wetness conditions. However, when we examined the residuals from the above regression models, we found evidence of spatial correlations: wetlands near one another tended to have similar residuals compared to wetlands farther apart. This was true for all wetland classes except lake and suggested that predictions could be improved by developing a "kriging" model for the residuals. A kriging estimate for any given point is a weighted average of the points surrounding it; weights typically decrease with increasing distance based on a variogram function that is estimated from the data. We used PROC VARIOGRAM (SAS Institute 1996) to estimate the variogram functions, and then used PROC KRIGE2D (SAS Institute 1996) to generate predictions of residuals from our models for uniformly spaced points on a 5-km grid. We used search radii of 105 km, 140 km, and 120 km, respectively, for temporary, seasonal, and semipermanent wetlands. The choice of search radius generally is not critical as long as the value is large enough to capture most of the spatial correlation. We verified that predicted values were not sensitive to our choice of search radius by trying different values. Estimates of $\overline{PFULL}$ and $\sqrt{\overline{PFULL}}$ from the regression models then were adjusted based on results of the kriging exercise to obtain final estimates. Final estimators were

$$\overline{PFULL}: \left[e^{b_0+b_1\times\ln(x)+b_2\times\ln(y)+b_3\times\ln(x)\times\ln(y)+b_4\times\ln(BASINSIZE)}\right] - 0.5 + \hat{Z} \quad (1)$$

$$\sqrt{\overline{PFULL}}: \left[e^{c_0+c_1\times\ln(x)+c_2\times\ln(y)+c_3\times\ln(x)\times\ln(y)+c_4\times\ln(BASINSIZE)}\right] - 0.5 + \hat{W} \quad (2)$$

where b_0–b_4 and c_0–c_4 were parameter estimates, x and y were UTM easting and northing for the centroid of each wetland, and $\hat{Z}$ and $\hat{W}$ were estimates of small-scale spatial variation from the kriging models.

Incorporating Accessibility into Models

Ducks are known to use nesting cover that is distant from core wetlands used for feeding and resting (Coulter and Miller 1968, Duebbert et al. 1983). Therefore, the proximity of CRP cover to breeding pairs is an important consideration in determining how many breeding hens will have access to that cover for nesting and potentially capitalize on its benefits. We used published data on home range characteristics for the 5 species studied (Table 1) and created additional models that measured potential accessibility by female ducks to specific land units within our study area. Accessibility models, also referred to as gravity models and spatial interaction models, are based on principles of Newtonian physics and have been used by social scientists for over a century to measure human social phenomena such as market areas (Carey 1858) and more recently to measure access to health care facilities (University of New Mexico 2004). Newton's hypothesis states that the interaction between 2 objects is directly proportional to the mass of the objects and inversely proportional to the distance between the 2 objects (Thrall and del Valle 1997). In our models land-area units were the first-order objects with constant area (mass) of 390 × 390 m (15.2 ha), and the population of breeding duck pairs is the second-order object with mass determined by the density of breeding duck pairs estimated to occupy the community of wetlands within a finite distance from the land unit. Distance was classed as proximity zones (Laurini and Thompson 1992) based on home-range metrics for each of the 5 duck species (Table 1). We calculated potential accessibility to land units for each species (PA_s) as

$$PA_s = \sum_{i=1}^{n_d} pop_i / a_d, \quad (3)$$

where pop_i was the number of pairs predicted to occur on wetland i, a_d is the area (km^2) of the proximity zone calculated by buffering each land area unit by distance d (distance that hens will travel from core wetlands to nesting sites; Table 1), and n_d was the number of wetland basins $\leq d$ km from the land unit. We scaled pop_i by a_d because the size of proximity zones varied among species, and we wanted a common metric (density) to project our results. The total potential accessibility index (PA) for breeding hens for land units in our study area was derived by summing PA_s for the 5 species we studied. We divided our entire study area into a 390 × 390-m grid (approx. 1.4 million units) and used GIS techniques to solve equation 3 for each unit. We assumed all breeding hens within a species' proximity zone had equal access to that particular unit. Because the distance across proximity zones was always greater than the distance across land units, all breeding hens in our analysis (and in nature) had access to >1 unit. This did not affect the usefulness of our results because we were interested in the relative differences in accessibility among land units.

Table 1. Distances used to determine proximity zones for calculating the number of duck pairs (5 species) that could access any 15.2-ha land unit in the Prairie Pothole Region of North Dakota and South Dakota, USA. Distances were derived from home-range studies.

Species	Distance (km)	Source
Mallard	3.62	Dwyer et al. 1979, Lokemoen et al. 1984, Cowardin et al. 1985
Gadwall	1.61	Gates 1962
Blue-winged teal	1.61	Dzubin 1955
Northern shoveler	1.21	Poston 1974
Northern pintail	4.03	Derrickson 1975

Applying Models to Wetlands and Land Units

We used ARC/INFO (1997) GIS software to apply spatially explicit models to wetlands and land units within our study area. We first estimated $\overline{WETAREA}$ and $\sqrt{\overline{WETAREA}}$ for every wetland basin in our study area from equations 1 and 2. We then used these estimates as inputs to the pair–wetland regression models. This gave us estimates of the long-term average breeding duck population associated with every wetland mapped by NWI in our study area. Finally, we incorporated accessibility into our models by applying proximity models (equation 3) to determine PA for every 390-m^2 grid cell in our study area. Large values for PA indicated cells that had the most potential for increased duck production resulting from nesting cover provided by the CRP.

Identifying Priority Areas for CRP

We assigned each 390-m^2 grid cell to a low-, medium-, or high-priority zone based on the value of PA. These priority zones can be considered as areas where the application or retention of CRP cover will result in different levels of benefit for duck production. The CRP tracts located in priority 1 areas (high pair accessibility) provide the greatest benefit for duck production, whereas CRP tracts in priority 3 areas (low pair accessibility) provide the least benefit. We

Table 2. Regression models used to estimate the average number of breeding pairs of 5 duck species on wetlands of 4 classes in the Prairie Pothole Region of North Dakota and South Dakota, USA, 1987–1998.

	Variable[a]					
Wetland Class	$\overline{WETAREA}$	$\sqrt{\overline{WETAREA}}$	$\overline{WETAREA} \times \sqrt{\overline{WETAREA}}$	$\sqrt{\overline{WETAREA}} \times UTME$	$\sqrt{\overline{WETAREA}} \times UTMN$	$\sqrt{\overline{WETAREA}} \times UTME \times UTMN$
Mallard						
Temporary	−0.3039	35.4917		−0.0520	−0.0063	0.0936×10^{-4}
Seasonal	0.1420	7.3974		−0.0022	−0.0011	
Semipermanent	0.0090	0.9034		−0.0019	−0.0080	
Lake		2.9136		−0.0037		
Gadwall						
Temporary		48.5631		−0.7706	−0.0089	0.0141×10^{-3}
Seasonal	0.1632	36.6815		−0.0528	−0.0066	0.0946×10^{-4}
Semipermanent	0.0171	6.7852		−0.3815	−0.0083	
Lake		4.0219		−0.0052		
Blue-winged teal						
Temporary		91.1876		−0.1497	−0.0168	0.0274×10^{-3}
Seasonal	0.3363	89.6838	−0.0187	−0.1366	−0.0164	0.0251×10^{-3}
Semipermanent	0.0111	52.5978	0.0339×10^{-2}	−0.0774	−0.0094	0.0140×10^{-3}
Lake	0.0248	70.8958	-0.0186×10^{-2}	−0.1146	−0.0127	0.0208×10^{-3}
Northern shoveler						
Temporary		16.1481		−0.0238	−0.0028	0.0419×10^{-4}
Seasonal	0.0637	19.4071	0.0064	−0.0289	−0.0035	0.0517×10^{-4}
Semipermanent	0.0076	4.6515	-0.0546×10^{-3}	−0.0022	-0.0621×10^{-2}	
Lake		8.9331		−0.0039	−0.0013	
Northern pintail						
Temporary		61.7667		−0.0950	−0.0112	0.0173×10^{-3}
Seasonal	0.0269	24.5180		−0.0342	−0.0044	0.0601×10^{-4}
Semipermanent		5.0446		−0.0023	-0.0694×10^{-2}	
Lake		1.4730		−0.0022		

[a] WETAREA indicates area covered by water; UTME, Universal Transverse Mercator easting; UTMN, Universal Transverse Mercator northing.

used GIS techniques to determine how much current (ca. Jul 2005) CRP occurred in each of the 3 priority zones within the PPR of North and South Dakota. We obtained certified digital data for CRP fields in our study area for all but 6 counties in North Dakota from the USDA Farm Service Agency (FSA). For the remaining 6 counties, we used preliminary digital data obtained from the FSA.

Assessing the Impact of Removing Wetland Protection

We examined the potential impact on duck breeding populations from removing wetland protection on small and shallow wetlands as provided by the Swampbuster provision of the Farm Bill. To accomplish this we developed criteria to identify wetlands at-risk to drainage defined as any wetland 1) of temporary or seasonal class, or <0.40 ha, 2) partially or totally embedded in cropland, and 3) not protected by USFWS ownership or perpetual easement. Wetlands meeting these criteria are virtually all on privately owned lands used for crop production, and >90% are enrolled in federal farm support programs (D. Campbell and B. Natwick, Farm Service Agency, personal communication). To identify wetlands that met the above criteria, we used GIS techniques and combined 3 layers of digital data for our entire study area as follows: 1) basin wetland data, 2) cropland classified from Earth Resources Observation and Science LANDSAT satellite imagery, and 3) lands protected by the USFWS (national wildlife refuge lands and perpetual easements). We then used the results from our pair–wetland regression models to simulate the impact of drainage on duck populations by removing at-risk wetlands from the database.

Results

During 1987–1998 we visited an average of 2,600 wetland basins twice each year and recorded 115,012 duck pairs on 18,148 wet pond-years. Species composition was 25% mallard, 21% gadwall, 35% blue-winged teal, 10% northern shoveler, and 9% northern pintail. Pair–wetland regression models indicated that pairs per wet area generally increased from south to north and from east to west for all wetland classes (Table 2). Predicted number of pairs increased with wetland size nonlinearly, indicating higher pair densities on smaller wetlands. Cross-validation indicated these models performed substantially better than models that did not account for spatial variation or nonlinearity. Although R^2 values for predicting pairs on individual wetlands were low (approx. 0.30), the value based on predicting total numbers of pairs occupying wetlands (n = approx. 1,000) on landscapes of 41.6 km^2 was 0.88.

Regression models for wetness (i.e., $\overline{PFULL}$ and $\sqrt{\overline{PFULL}}$; Table 3) indicated that wetness varied spatially and with basin size. In general, wetness increased from northwest to southeast and with basin size. In addition to the large-scale spatial variation, kriging models for residuals revealed smaller scale variation in wetness patterns. Kriging

Table 3. Regression coefficients used to estimate the percentage of the surface area of a wetland basin covered by water (*PFULL*; equation 1) and $\sqrt{PFULL}$ (equation 2) for 4 classes of wetlands in the Prairie Pothole Region of North Dakota and South Dakota, USA, 1987–1998.

	Predictor variable				
Wetland class	***Constant***	***Easting***[a]	***Northing***[a]	***Easting***[a] × ***Northing***[a]	***BASINAREA***
Temporary					
PFULL	21.794	0	−2.587	0	0.024
$\sqrt{PFULL}$	18.973	0	−2.246	0	0.030
Seasonal					
PFULL	10.369	0.114	−1.305	0	0.047
$\sqrt{PFULL}$	8.633	0.952	−1.080	0	0.043
Semipermanent					
PFULL	−119.705	18.953	13.821	−2.186	0
$\sqrt{PFULL}$	−114.634	18.225	13.267	−2.106	0
Lake					
PFULL	23.698	0	−2.756	0	0.029
$\sqrt{PFULL}$[b]					

[a] Easting and northing values were divided by 1,000 and transformed by taking the natural log.
[b] $\sqrt{PFULL} = 0.150236 + 0.550644(PFULL) + 1.042858(PFULL)^2 - 0.748504(PFULL)^3$.

reduced the mean square prediction error by approximately 50% for each wetland class.

We applied the above basin wetness and pair–wetland models to 2,634,262 basin wetlands and applied ratio estimators to 7,766 riverine wetlands to estimate the mean number of breeding duck pairs occurring on each wetland in our study area during the period 1987–1998. The estimated number of breeding pairs (averaged for the period 1987–1998) for 5 duck species in our study area was as follows: mallard = 928,517; gadwall = 672,774; blue-winged teal = 1,471,187; northern shoveler = 372,471; northern pintail = 469,244; and total = 3,914,193. Pair density for all species combined, by wetland class, was temporary = 2.57/ha, seasonal = 2.72/ha, semipermanent = 1.43/ha, lake = 0.42/ha, and riverine = 0.83/ha.

Distribution of CRP Contracts Relative to Distribution of Ducks

We applied accessibility models using results from our pair models for the entire study area and then assigned grid cells to priority zones as follows: priority 1, areas with >19 pairs/km^2 (high accessibility); priority 2, areas with 10–19 pairs/km^2 (medium accessibility); and priority 3, areas with <10 pairs/km^2 (low accessibility; Fig. 2). We overlaid digital data for existing CRP contracts in North and South Dakota to identify the amount of CRP area in the different priority areas. Results from this analysis showed that in both states approximately 75% of CRP acres were in the combined areas of priority 1 (high duck accessibility) and priority 2 (medium duck accessibility) zones, and approximately 25% of CRP acres were in the lowest priority (low duck accessibility) zone (Table 4).

Swampbuster and Breeding Duck Populations

From our analyses we identified 1,371,388 (52% of all basin wetlands in our study area) wetlands that fit our criteria for being at-risk to drainage in the absence of protection. These wetlands supported an average breeding population of 1,434,911 pairs during the period 1987–1998. The results suggest that if all at-risk wetlands were drained, the average breeding duck population would decline by 37% in the PPR of North Dakota and South Dakota (Fig. 3a,b). All species studied showed substantial potential decline in populations due to wetland drainage, but northern pintail suffered the greatest decline (−41%) and gadwall the smallest decline (−33%; Table 5).

Discussion

The PPR of the United States supports some of the highest breeding duck populations in the nation, particularly some of the most heavily harvested species such as mallard, blue-winged teal, and gadwall (*Preliminary Estimates of Waterfowl Harvest and Hunter Activity in the United States during the 2003 and 2004 Hunting Season*; U.S. Fish and Wildlife Service 2005). The PPR of North and South Dakota makes up about 7% of the traditional waterfowl survey area (Cowardin and Blohm 1992) that is the principal breeding area for ducks in North America. Yet, during the last decade (1996–2005), 20% of breeding ducks from the entire survey area occurred in the PPR of the Dakotas (United States Fish and Wildlife Service, Trends in Duck Breeding Populations, unpublished reports, 1996–2005). Undoubtedly Farm Bill conservation provisions since 1985, particularly CRP and Swampbuster, have provided substantial benefits to continental waterfowl populations. Reynolds (2005) estimated that CRP was responsible for 25.7 million additional ducks produced in the United States PPR during 1992–2003 compared to the production expected in the absence of the CRP. In addition, Reynolds (2005) presented evidence that wetlands in CRP fields attracted more breeding duck pairs than similar wetlands in crop fields.

The wetland conservation (Swampbuster) provision of the Farm Bill is another component that we believe has benefited breeding duck populations in the United States PPR. Brady (2005) reported that wetland loss nationwide has declined in recent years, partly as a result of Swampbuster. Swampbuster may be particularly important in light of the 2001 decision by the United States Supreme Court (*Solid Waste Agency of Northern Cook County v. United States*

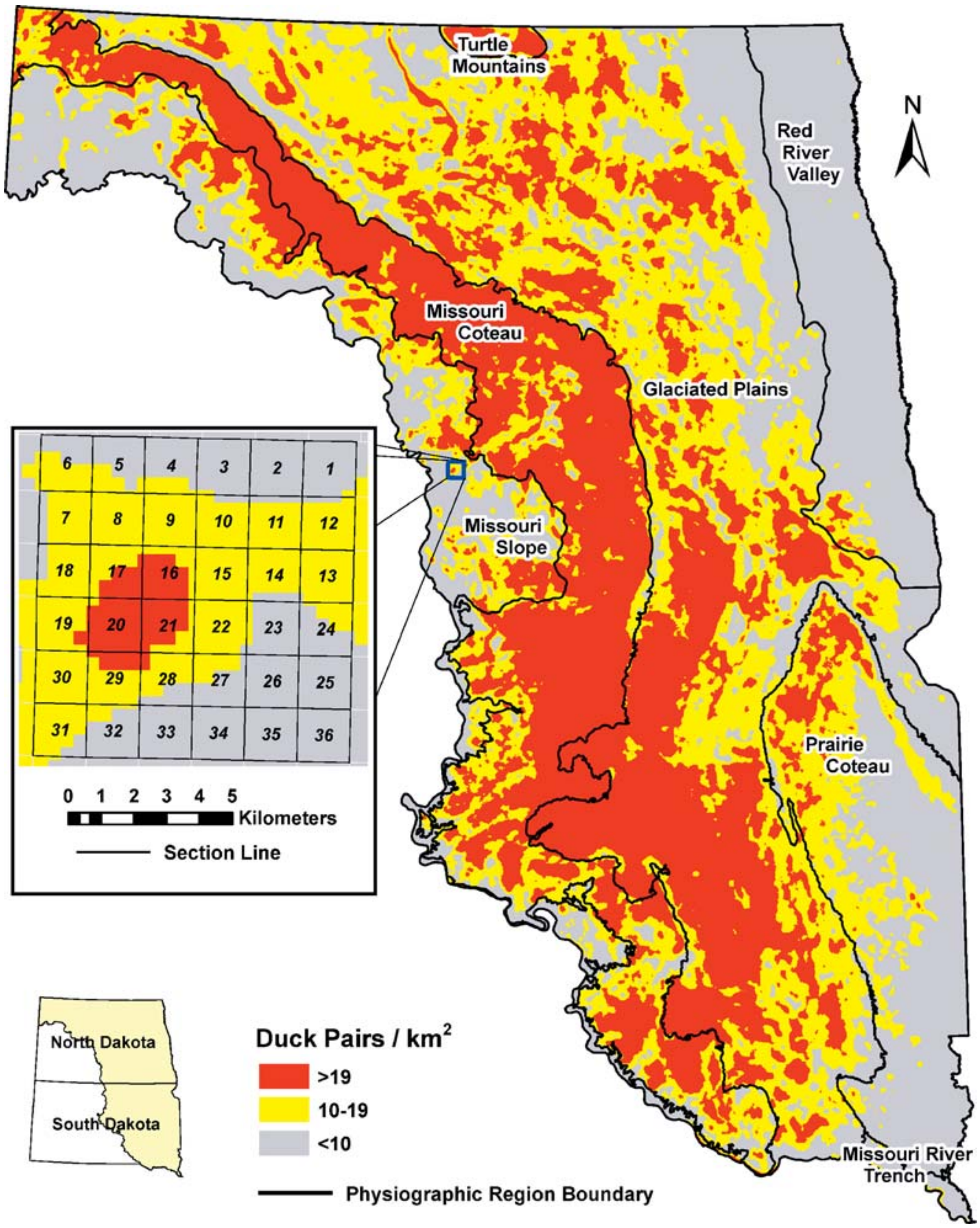

Figure 2. Results of applying duck pair–wetland regression models to 2,634,262 basin wetlands, pair ratio models to 7,766 riverine wetlands and accessibility models to 1,473,661 390 × 390-m (15.2-ha) land units in the Prairie Pothole Region of North Dakota and South Dakota, USA. This map shows which land units would be accessible to different densities of nesting hens and, thus, where Conservation Reserve Program cover would provide the greatest benefits to duck production. Results are presented as pairs/km^2 for proximity zones around each land unit, where the area of proximity for each of 5 upland-nesting duck species (mallard, gadwall, blue-winged teal, northern shoveler, and northern pintail) was the approximate distance hens have been known to travel from core wetlands to nesting cover. Enlarged area shows how this information can be displayed at a larger scale to rank areas of 15.2 ha projected on common land-survey grid blocks (i.e., range, township, section).

Army Corp of Engineers) that may reduce the protection of isolated wetlands under Section 404 of the Clean Water Act.

We believe the future of ducks in the United States PPR likely will depend heavily on the future of federal farm programs. More than one-half of the total CRP area (approx. 1 million ha) in North Dakota and South Dakota is due to expire in 2007, and by 2010 only about 13% of the current CRP area will remain unless reauthorized or extended (Barbarika et al. 2005). If the CRP is reauthorized, changes may need to be made in the EBI used to determine which CRP contracts are accepted by USDA, if waterfowl are selected as a priority wildlife group for conservation purposes. These criteria have changed considerably since general signups in 1997–2000 when most of the CRP currently in the PPR was approved. The criteria for general signups during 1997–2000 included points for offers in the PPR National Conservation Priority Area, proximity to wetlands (including potholes), and proximity to state water-, air-, or wildlife-quality priority areas (Barbarika et al. 2005)

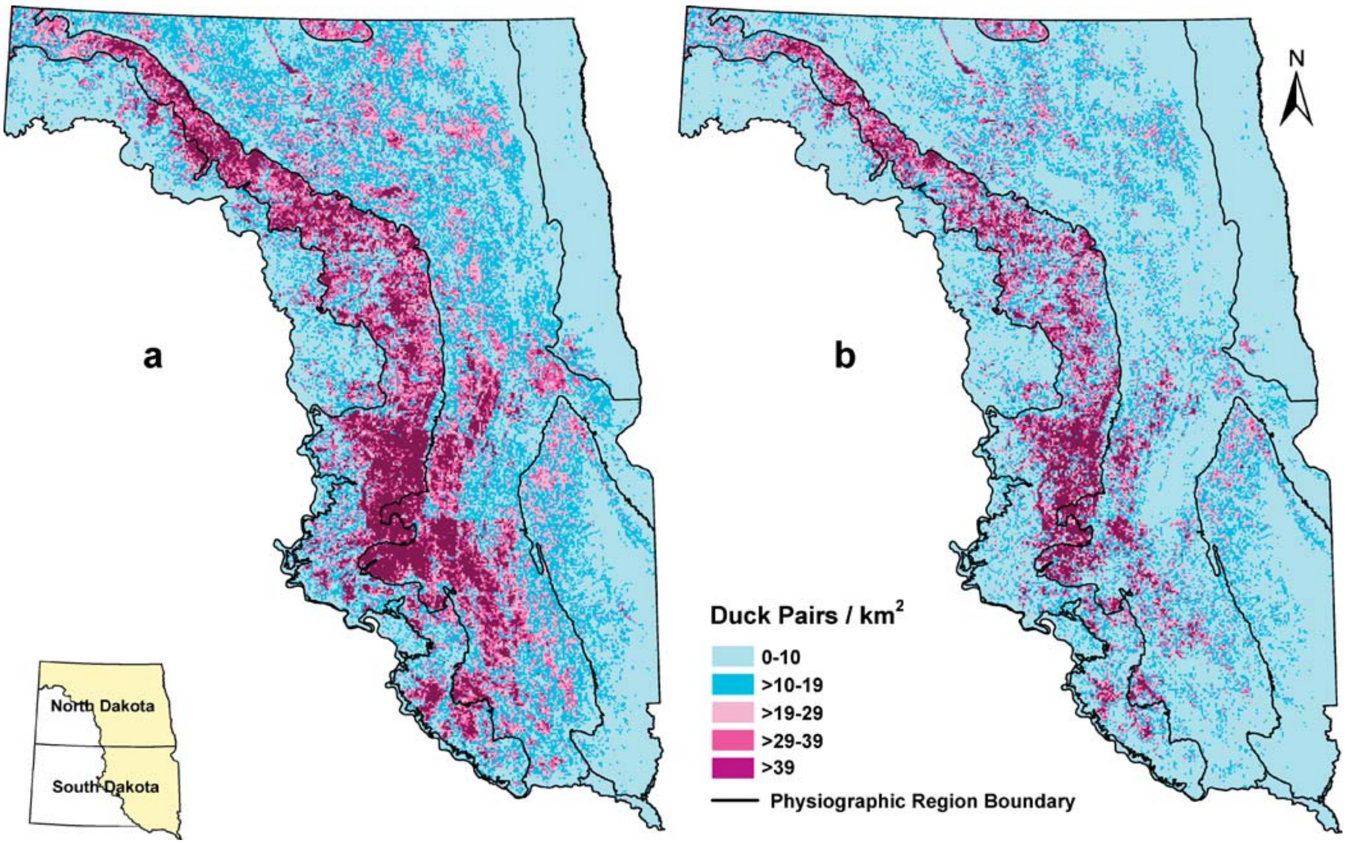

Figure 3. Average (1987–1998) size and distribution (a) of breeding ducks (mallard, gadwall, blue-winged teal, northern shoveler, and northern pintail combined) in the Prairie Pothole Region of North Dakota and South Dakota, USA, and the predicted change (b) if drainage occurred on approximately 1.37 million at-risk wetlands protected by the Swampbuster provision of the Farm Bill. (a) represents approximately 3.91 million duck pairs, and (b) represents approximately 2.48 million duck pairs (a decline of 37% from [a]). At-risk wetlands are defined as temporary or seasonal class or $<$0.40 ha in area, and totally or partially embedded in cropland, and not protected by United States Fish and Wildlife Service ownership or perpetual easement.

such as USFWS Waterfowl Production Areas. After 2000 the EBI criteria for most signups no longer included points for these location and proximity factors. As a result of EBI changes, since 2000 only 19% (43,518 ha) of 230,717 ha offered from North Dakota and South Dakota were accepted during signups 26 and 29, the most recent general signups (United States Department of Agriculture, Farm Service Agency news release 2004), compared to the nationwide acceptance rate of 55% for these signups (United States Department of Agriculture, unpublished reports). Since 2000 the EBI for most signups has emphasized field windbreaks, grass waterways, riparian buffers, shelterbelts, wind-trap strips, and trees.

These latest EBI criteria may provide some conservation

Table 4. Percent distribution of Conservation Reserve Program (CRP) cover (ca. 2005), average breeding duck populations for 5 combined species[a] 1987–1998 and geographic area relative to 3 priority zones[b] in the Prairie Pothole Region of North Dakota and South Dakota, USA.

	% distribution		
Priority zone	CRP cover	Breeding duck pairs	Area
North Dakota			
1 (high)	36	61	31
2 (medium)	39	30	33
3 (low)	25	9	36
South Dakota			
1 (high)	44	72	40
2 (medium)	31	21	30
3 (low)	25	7	29

[a] Mallard, gadwall, blue-winged teal, northern shoveler, and northern pintail.
[b] Priority 1 area $>$19 pairs/km^2, priority 2 area 10–19 pairs/km^2, and priority 3 area $<$10 pairs/km^2.

Table 5. Predicted change in average number of breeding duck pairs of 5 species resulting from draining at-risk[a] wetland basins in the Prairie Pothole Region of North Dakota and South Dakota, USA, using survey data 1987–1998.

Species	Estimate (1987–1998 average)	Predicted (postdrainage)	% change
Mallard	928,517	573,109	−38
Gadwall	672,774	447,562	−33
Blue-winged teal	1,471,187	941,541	−36
Northern shoveler	372,471	239,567	−36
Northern pintail	469,244	277,503	−41

[a] At-risk wetland basins were defined as temporary or seasonal class (Cowardin et al. 1979) or $<$0.40 ha in area, totally or partially embedded in cropland, and not protected by United States Fish and Wildlife Service ownership or perpetual easement.

benefits (Hyberg 2005) but are incompatible with the nesting-habitat requirements of upland-nesting ducks. For example, idle grass plantings in strips and buffers are similar to road rights-of-way and other fragmented habitats described by Cowardin et al. (1988). Although these may be attractive to nesting hens, they also exhibit high depredation rates (Klett et al. 1988, Reynolds et al. 2001). Conversely, landscapes associated with high nest success tend to have large (≥32-ha) blocks of CRP associated with other perennial grass cover, including other CRP cover. Whole-field enrollments have been demonstrated to meet the productivity requirements of upland-nesting ducks (Reynolds et al. 2001).

Another change in the qualifying criteria for CRP offers was associated with CRP conservation practice CP23 (wetland CRP) that targeted certain wetlands with a cropping history and required planting a 6:1 ratio of CRP cover-to-wetland area. Because CP23 specifically focused on cropped wetlands, it offered potentially great benefits for waterfowl and other wetland birds. Because most wetlands in the PPR are small (81% ≤0.40 ha), a ratio of at least 6:1 (CRP:wetland) was necessary for entire fields to qualify for enrollment. Also, prior to 2003, farm operators could combine CP23 with other CP practices to enroll entire fields. In April 2002 CP23 accounted for 24% of all CRP in North Dakota and South Dakota. In 2004 CP23 was removed from the general signup and replaced by a new continuous practice, CP23a. Under CP23a, only those wetlands meeting cropping-history criteria and associated uplands up to a 4:1 ratio (upland:wetland) were eligible for that CP practice. The effect of that change in much of the PPR was fragmentation of fields in such a way that farming the non-CRP portion was difficult and, consequently, CP23a was not popular with farm operators as indicated by the low enrollment after this change (Barbarika et al. 2005). This change also caused concern by some wildlife conservation groups because duck nest success in planted cover around wetland edge (similar to CP23a) tends to be low (3–13%; Phillips et al. 2003) compared to that observed in entire fields of CRP (19–27%; Reynolds et al. 2001).

Since 1997 changes in enrollment criteria and the EBI have occurred annually. It is impossible to discuss the collective impacts these changes had on the amount and distribution of CRP enrolled in the PPR of the Dakotas. However, it is evident that in the more recent sign-ups the acceptance rate of CRP offers in the PPR has declined (United States Department of Agriculture, unpublished report). We can only speculate that if the CRP is continued beyond 2007 and recent EBI criteria are retained, CRP area in the PPR will be reduced and duck production will decline.

The other major component of the Farm Bill relating to breeding ducks in the PPR is the Swampbuster provision. Temporary and seasonal wetlands are preferred by the 5 species of breeding ducks we studied, and these wetlands constitute >90% of the wetlands in the PPR. Because of their small size and shallow depth, temporary and seasonal wetlands commonly are tilled (Stewart and Kantrud 1973), and, consequently, these wetlands are most likely to be drained. Our results indicate that for the 5 species of breeding ducks we studied, 37% depend on the nearly 1.4 million wetlands that would be at risk to drainage if Swampbuster protection were removed. We estimated the reduction in the mallard breeding population due to drainage of at-risk wetlands at 38% for the PPR of the Dakotas (Table 5). This potential loss would be sufficient to result in more restrictive duck-hunting regulations than would otherwise occur in 3 of 11 years with all other conditions being comparable to those observed in years 1995–2005 (based on adjustments made to mallard breeding populations 1995–2005 and applied to table 8 in United States Fish and Wildlife Service [2005]).

Management Implications

Since 1985 the CRP and Swampbuster provisions of the USDA Farm Programs have provided substantial benefits to duck populations in the United States PPR by increasing the amount of preferred nesting cover and protecting wetlands vital to breeding ducks. Ducks produced in the PPR are harvested by hunters in every state in the continental United States, plus Canada, Mexico, and several countries in South America (United States Fish and Wildlife Service, unpublished data).

In 2007 contracts on large amounts of CRP nationwide will begin to expire (Johnson and Stephenson 2005). On 4 August 2004, President Bush announced that USDA intends to offer early reenrollment and contract extensions of CRP acreage. It has not yet been determined how the EBI and other criteria will be used to decide which contracts will be prioritized for reenrollment and different periods of extension. It also is likely there will be additional signups in the future to enroll new lands into the program. The USDA, FSA, and Natural Resources Conservation Service have expressed a desire to account for and improve the conservation benefits derived from USDA conservation programs (Hyberg 2005, Kellogg 2005). However, budget constraints and conflicting ideas about which program objectives should be prioritized undoubtedly will impact decisions about the future of the CRP and other conservation components of the Farm Program. We assume that future decisions about Farm Bill conservation programs will rely heavily on science and objective assessments of program results. For example, Congress is looking for quantifiable measures of benefits derived from conservation programs (Hyberg and Lederer 2005), and Johnson and Stephenson (2005) anticipated that GIS would serve an increasingly comprehensive role in the future CRP signup process.

In this study we used GIS techniques, biological data, and models to identify priority areas in the PPR of North Dakota and South Dakota where CRP cover would be accessible to the greatest number of breeding female ducks. This information could be used to help prioritize existing CRP contracts for reenrollment or target additional contracts for future enrollment. Although our study focused on the Dakotas, the USFWS can provide similar data for other areas of the PPR of Minnesota, Iowa, and northeastern Montana, USA. For convenience, USFWS can provide duck-pair accessibility data in digital form that can be used to produce hard copy or computer-based maps of virtually any size and resolution for any area in the PPR. When combined with other readily available digital data (roads, survey grid, ownership) this approach would provide a simple user-friendly method to determine the relative duck accessibility rating for any 15.2-ha (approx. 40-acre) unit in the PPR.

We also quantified the potential consequence on breeding ducks from removing Swampbuster provisions that have been part of the federal Farm Program since 1985. Each year, duck-hunting regulations such as season length and bag limit are determined by USFWS based on the status of duck populations and available wetland habitat (United States Fish and Wildlife Service 2005). When wetland habitat in the PPR is converted to other uses, the landscape carrying capacity for breeding pairs is reduced and, consequently, duck production from those wetlands is lost. This, in turn, can affect the harvest of ducks by hunters throughout North America.

We realize that many factors besides waterfowl will be considered when deciding the future direction of the CRP and other conservation programs administered by USDA. However, due to the national (and international) importance of waterfowl production from the United States PPR, we assume waterfowl will remain a priority wildlife group relative to decisions about the CRP and Swampbuster. Indeed, Reynolds et al. (1994) presented evidence that, by targeting CRP toward areas of high duck density in the PPR of North Dakota, greater conservation of highly erosion-prone lands and wetlands would occur compared to the targeting criteria in place at that time. We conclude that, in order to maintain the current potential of the United States PPR to produce ducks, the CRP and wetland protection components of the farm program must be retained in this area. Furthermore, by targeting CRP cover toward areas identified as high priority for breeding hens, even greater benefits to duck production may be realized.

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Literature Cited

ARC/INFO. 1997. ARC/INFO. Version 7.1.2. Environmental Systems Research Institute, Redlands, California, USA.

Barbarika, A., S. Hyberg, J. Williams, and J. Agapoff. 2005. Conservation Reserve Program overview and enrollment summary. Appendix B. Pages 209–244 *in* A. W. Allen and M. W. Vandever, editors. The Conservation Reserve Program—planting for the future: proceedings of a national conference. U.S. Geological Survey, Biological Resources Discipline, Scientific Investigations Report 2005–5145, Fort Collins, Colorado, USA.

Beauchamp, W. D., R. R. Koford, T. D. Nudds, R. G. Clark, and D. H. Johnson. 1996. Long-term declines in nest success of prairie ducks. Journal of Wildlife Management 60:247–257.

Bellrose, F. C. 1976. Ducks, geese and swans of North America. Wildlife Management Institute. Stackpole, Harrisburg, Pennsylvania, USA.

Bluemle, J. P. 1991. The face of North Dakota. North Dakota Geological Survey Educational Series 21, Bismarck, USA.

Brady, S. J. 2005. Highly erodible land and Swampbuster provisions of the 2002 Farm Act. Pages 5–15 *in* J. B. Haufler, editor. Fish and wildlife benefits of Farm Bill conservation programs: 2000–2005 update. The Wildlife Society Technical Review 05-2, Bethesda, Maryland, USA.

Carey, H. C. 1858. Principles of social science. Lippincott, Philadelphia, Pennsylvania, USA.

Coulter, M. W., and W. R. Miller. 1968. Nesting biology of black ducks and mallards in northern New England. Vermont Fish and Game Bulletin 68–2.

Cowardin, L. M. 1982. Some conceptual and semantic problems in wetland classification and inventory. Wildlife Society Bulletin 10:57–60.

Cowardin, L. M., and R. J. Blohm. 1992. Breeding population inventories and measures of recruitment. Pages 423–445 *in* B. D. J. Batt, A. A. Afton, M. G. Anderson, C. D. Ankney, D. H. Johnson, J. A. Kadlec, and G. L. Krapu, editors. Ecology and management of breeding waterfowl. University of Minnesota, Minneapolis, USA.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service FWS/OBS 79/31, Washington, D.C., USA.

Cowardin, L. M., D. S. Gilmer, and C. W. Shaiffer. 1985. Mallard recruitment in the agriculture environment of North Dakota. Wildlife Monographs 92.

Cowardin, L. M., D. H. Johnson, T. L. Shaffer, and D. W. Sparling. 1988. Applications of a simulation model to decisions in mallard management. U.S. Department of the Interior, Fish and Wildlife Service Fish and Wildlife Technical Report 17, Washington, D.C., USA.

Cowardin, L. M., T. L. Shaffer, and P. M. Arnold. 1995. Evaluation of duck habitat and estimation of duck population sizes with a remote-sensing-based system. U.S. Department of the Interior, National Biological Service, Biological Science Report 2, Washington, D.C., USA.

Dahl, T. E. 1990. Wetlands losses in the United States 1780s to 1980s. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C., USA.

Dahl, T. E. 2006. Status and trends of wetlands in the conterminous United States 1998 to 2004. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C., USA.

Derrickson, S. R. 1975. Mobility and habitat-use of breeding pintails (*Anas acuta*). Thesis, University of Minnesota, Minneapolis, USA.

Duebbert, H. F., J. T. Lokemoen, and D. E. Sharp. 1983. Concentrated nesting of mallards and gadwalls on Miller Lake Island, North Dakota. Journal of Wildlife Management 47:729–740.

Dwyer, T. J., G. L. Krapu, and D. M. Janke. 1979. Use of prairie pothole habitat by breeding mallards. Journal of Wildlife Management 43: 526–531.

Dzubin, A. 1955. Some evidence of home range in waterfowl. Proceedings of the North American Wildlife and Natural Resource Conference 20:278–296.

Dzubin, A. 1969. Assessing breeding populations of ducks by ground counts. Pages 178–230 *in* Saskatoon wetlands seminar. Canadian Wildlife Service Report Series 6, Ottawa, Ontario, Canada.

Environment Canada, Canadian Wildlife Service, and United States Department of the Interior, Fish and Wildlife Service. 1986. North American Waterfowl Management Plan, Washington, D.C., USA.

Gates, J. M. 1962. Breeding biology of the gadwall in northern Utah. Wilson Bulletin 74:43–67.

Greenwood, R. J., A. B. Sargeant, D. H. Johnson, L. M. Cowardin, and T. L. Shaffer. 1995. Factor associated with duck nest success in the Prairie Pothole Region of Canada. Wildlife Monographs 128.

Hammond, M. C. 1969. Notes on conducting waterfowl breeding population surveys. Pages 238–258 *in* Saskatoon wetlands seminar. Canadian Wildlife Service Report Series 6, Ottawa, Ontario, Canada.

Hoekman, S. T., L. S. Mills, D. W. Howerter, D. J. Devries, and I. J. Ball. 2002. Sensitivity analyses of the life cycle of mid-continent mallards. Journal of Wildlife Management 66:833–900.

Hyberg, S. 2005. The role of science in guiding the Conservation Reserve Program: past and future. Pages 4–10 *in* A. W. Allen and M. W. Vandever, editors. The Conservation Reserve Program—planting for the future: proceedings of a national conference. U.S. Geological Survey, Biological Resources Discipline, Scientific Investigations Report 2005–5145, Fort Collins, Colorado, USA.

Hyberg, S., and T. Lederer. 2005. The view from Capitol Hill: an interpretive summary. Pages 67–68 *in* A. W. Allen and M. W. Vandever, editors. The Conservation Reserve Program—planting for the future: proceedings of a national conference. U.S. Geological Survey, Biological Resources Discipline, Scientific Investigations Report 2005–5145, Fort Collins, Colorado, USA

Johnson, J., and R. Stephenson. 2005. Stakeholders look at the Conservation Reserve Program through different windows. Pages 31–36 *in* A. W. Allen and M. W. Vandever, editors. The Conservation Reserve Program—planting for the future: proceedings of a national conference. U.S. Geological Survey, Biological Resources Discipline, Scientific Investigations Report 2005–5145, Fort Collins, Colorado, USA.

Johnson, R. R., and K. F. Higgins. 1997. Wetland resources of eastern South Dakota. South Dakota State University, Brookings, USA.

Kantrud, H. A., and R. E. Stewart. 1977. Use of natural basin wetlands by breeding waterfowl in North Dakota. Journal of Wildlife Management 41:243–253.

Kellogg, R. L. 2005. Measuring environmental benefits of conservation practices: the Conservation Effects Assessment Project. Pages 22–27 *in* A. W. Allen and M. W. Vandever, editors. The Conservation Reserve Program—planting for the future: proceedings of a national conference. U.S. Geological Survey, Biological Resources Discipline, Scientific Investigations Report 2005–5145, Fort Collins, Colorado, USA.

Klett, A. T., T. L. Shaffer, and D. H. Johnson. 1988. Duck nest success in the Prairie Pothole Region. Journal of Wildlife Management 52: 431–440.

Laurini, R., and D. Thompson. 1992. Fundamentals of spatial information systems. Academic, Harcourt Brace, New York, New York, USA.

Lokemoen, J. T., H. F. Duebbert, and D. E. Sharp. 1984. Nest spacing, habitat selection, and behavior of waterfowl on Miller Lake Island, North Dakota. Journal of Wildlife Management 48:309–321.

North Dakota Farm Bureau. 2006. NDFB home page. <http://www.ndfb.org/2006_NDFB_%20policies.pdf>. Accessed 2006 Jan 1.

Phillips, M. L., W. R. Clark, M. A. Sovada, D. J. Horn, R. R. Koford, and R. J. Greenwood. 2003. Predator selection of prairie landscape features and its relation to duck nest success. Journal of Wildlife Management 67:104–114.

Poston, H. J. 1974. Home range and breeding biology of the shoveler. Canadian Wildlife Service Report Series 25, Ottawa, Ontario, Canada.

Reynolds, R. E. 2005. The Conservation Reserve Program and duck production in the United States' Prairie Pothole Region. Pages 144–148 *in* A. W. Allen and M. W. Vandever, editors. The Conservation Reserve Program—planting for the future: proceedings of a national conference. U.S. Geological Survey, Biological Resources Discipline, Scientific Investigations Report 2005–5145, Fort Collins, Colorado, USA.

Reynolds, R. E., D. R. Cohan, and A. Kruse. 1994. Which cropland to retire: a waterfowl perspective. Pages 110–111 *in* Proceedings of the conference—when Conservation Reserve Program contracts expire: the policy options. Soil and Water Conservation Society, 10–11 February 1994, Arlington, Virginia, USA.

Reynolds, R. E., T. L. Shaffer, R. W. Renner, W. E. Newton, and B. D. J. Batt. 2001. Impact of the Conservation Reserve Program on duck recruitment in the U.S. Prairie Pothole Region. Journal of Wildlife Management 65:765–780.

SAS Institute. 1996. SAS/STAT technical report: spatial prediction using the SAS system. SAS Institute, Cary, North Carolina, USA.

SAS Institute 1997. SAS. Version 6.12. SAS Institute, Cary, North Carolina, USA.

Snee, R. D. 1977. Validation of regression models: methods and examples. Technometrics 19:415–428.

Stewart, R. E., and H. A. Kantrud. 1971. Classification of natural ponds and lakes in the glaciated prairie region. U.S. Department of the Interior, Fish and Wildlife Service Resource Publication 92, Washington, D.C., USA.

Stewart, R. E., and H. A. Kantrud. 1973. Ecological distribution of breeding waterfowl populations in North Dakota. Journal of Wildlife Management 37:39–50.

Thrall, G. I., and J. C. del Valle. 1997. The calculation of retail market areas: the Reilly model. Geo Info Systems (Apr): 46–49.

U.S. Fish and Wildlife Service. 2005. Adaptive harvest management: 2005 hunting season. U.S. Department of the Interior, Washington, D.C., USA.

University of New Mexico. 2004. Health care facilities/provider gravity model. <http://www.unm.edu/~dgrint_grav.html>. Accessed 2004 Apr 24.

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