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## IMPACT OF THE CONSERVATION RESERVE PROGRAM ON DUCK RECRUITMENT IN THE U.S. PRAIRIE POTHOLE REGION

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**Abstract:** The U.S. Department of Agriculture (USDA)'s Conservation Reserve Program (CRP) resulted in the conversion of about 1.9 million ha of cropland to perennial grass cover in the Prairie Pothole Region of North Dakota, South Dakota, and northeastern Montana by 1992. Many wildlife managers believed this cover would provide benefits to wildlife, including upland nesting ducks. During 1992–1995, we evaluated success of 5 duck species nesting in CRP fields and nearby Waterfowl Production Areas (WPA) throughout the region. We examined relationships between daily survival rates (DSR) of duck nests in CRP cover and landscape-level habitat and population parameters. We computed DSR of duck nests in other major cover types in our study area from data collected during 1980–1984 (pre-CRP) and 1990–1994 (CRP) periods. We then applied recruitment models to estimate duck production in our study area during peak CRP years (1992–1997) and compared these results with those that simulated the scenario in which cropland was in place of CRP cover (i.e., the CRP had not occurred). DSR were higher in all habitats combined during the CRP period compared to the pre-CRP period. Regressions of DSR in CRP cover on the percent of each study plot in perennial cover and geographic location were significant ( $P < 0.01$ ) for 4 of 5 duck (*Anas* spp.) species. Estimated nest success and recruitment rates for the 5 species combined during 1992–1997 were 46% and 30% higher, respectively, with CRP cover on the landscape compared to a scenario where we simulated cropland in place of CRP. Our model estimated an additional 12.4 million recruits from our study area to the fall flight as a consequence of the CRP during 1992–1997. Our results document benefits to 5 duck species in the northern plains associated with a farm program that provided financial incentives to landowners for planting undisturbed grass cover as an alternative to annual crops.

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**Key words:** *Anas acuta*, *Anas clypeata*, *Anas discors*, *Anas platyrhynchos*, *Anas strepera*, blue-winged teal, Conservation Reserve Program, CRP, ducks, gadwall, mallard, nest success, northern pintail, northern shoveler, Prairie Pothole Region, recruitment.

During 1985–1992, mallard (*Anas platyrhynchos*), blue-winged teal (*A. discors*), and northern pintail (*A. acuta*) breeding populations reached their lowest levels since annual surveys began in 1955 (Dubovsky et al. 1997). Long-term population declines for these species coincided with large-scale declines in nest success throughout the Prairie Pothole Region of the United States (see Fig. 1 for area map) and Canada (Beauchamp et al. 1996). Sargeant and Raveling (1992) concluded that predation was the primary cause of duck nest loss in the Prairie Pothole Region. Klett et al. (1988) concluded that during 1980–1984, nest success was inadequate to maintain populations of mallards and northern pintails in most areas of North Dakota, South Dakota,

and Minnesota and of gadwalls (*A. strepera*) and blue-winged teal in North Dakota and Minnesota. Long-term changes in predator demographics and lower nest success of ducks have coincided with the conversion of perennial grassland to cropland in the Prairie Pothole Region (Sargeant et al. 1993, Beauchamp et al. 1996). In North Dakota 67%, South Dakota 53%, and Montana 50% of grasslands have been converted, mostly to cropland, since settlement (U.S. Department of Agriculture [USDA] 1994). As grassland cover was converted to cropland, ducks increased their use of the remaining areas of cover for nesting, where predators such as red fox (*Vulpes vulpes*), striped skunk (*Mephitis mephitis*), and badger (*Taxidea taxus*) forage (Cowardin et al. 1983). Greenwood et al. (1995) found that duck nest success on study areas in prairie Canada was negatively correlated with the proportion of land

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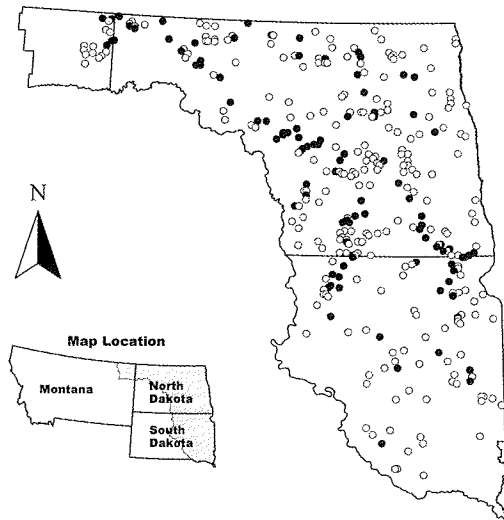


Fig. 1. Study area for assessing the impact of the Conservation Reserve Program (CRP) on duck recruitment in the Prairie Pothole Region of North Dakota, South Dakota, and northeast Montana, USA. Circles represent 335 randomly selected 10.4-km<sup>2</sup> sample plots from Cowardin et al. (1995) where duck breeding population and habitat data were collected during 1992–1997 for input into productivity models. Dark shaded circles show the subsample of 98 study plots from which data were collected to estimate nest daily survival rates for 5 species of ducks nesting in CRP cover and planted cover on Waterfowl Production Areas, 1992–1995.

annually cultivated and suggested that nests located in small blocks of nesting habitat were more likely to be destroyed by predators than those located in large contiguous blocks that were not fragmented by cultivation. Ball et al. (1995) reported high duck production rates on study blocks in north-central Montana where large areas of grass remained intact.

Efforts by the U.S. Fish and Wildlife Service (USFWS) to protect and increase grassland cover in the U.S. Prairie Pothole Region include purchasing nearly 112,000 ha of uplands on WPA (Cowardin et al. 1995) that are managed primarily for nesting ducks. Many of these WPA and adjacent private lands have high densities of wetlands that attract breeding ducks. However, studies have documented low nest success on some of these WPA (Klett et al. 1988, Sargeant et al. 1995), possibly due to their isolation in landscapes dominated by cropland. In 1985, Congress authorized the CRP as part of the Food Security Act (Public Law 99-198). The CRP is a national program administered by the USDA with objectives to reduce soil loss on highly erodible land,

reduce crop surpluses, and improve wildlife habitat. Landowners contracted with USDA to convert cropland to perennial cover—such as grass or trees, usually for a period of 10 years—in return for annual payments. Enrollment began in 1986 and continued with periodic enrollments through 1995 when 14.7 million ha had been enrolled nationwide.

During 1992, North Dakota had 0.9 million ha and South Dakota and Montana each had 0.5 million ha enrolled in the CRP within the Prairie Pothole Region (USDA, Natural Resources Conservation Service, Bismarck, North Dakota, unpublished data). This land represented 98% of the final enrollment in these areas. Enrolled fields (hereafter CRP cover) in our study area were predominantly planted to a mix of grasses and legumes composed of wheatgrasses (*Agropyron* spp.), smooth brome (*Bromis inermis*), alfalfa (*Medicago sativa*), and sweetclover (*Melilotus* spp.). CRP cover planted to trees (approx. 1000 ha, [Moulton 1994]) was not included in our study. Haying, grazing, or other commercial uses of CRP plantings were not allowed unless authorized by the Secretary of Agriculture in response to drought or other agricultural emergency. Studies have shown that undisturbed cover of this type is attractive to nesting ducks (Duebber and Lokemoen 1976, Reynolds et al. 1994, Greenwood et al. 1995, Renner et al. 1995). Klett et al. (1988) reported duck nest success in planted cover (plant composition similar to CRP cover) to be about average compared to other available common habitats. Other studies provided evidence that nest success in planted cover (including CRP cover) is high compared with other cover types (Duebber 1969, Duebber and Lokemoen 1976, Kantrud 1993, Reynolds et al. 1994). These findings led to speculation that the CRP would benefit upland nesting ducks.

We assessed duck use and nest success in CRP cover and planted cover on WPA (hereafter WPA cover) in the Prairie Pothole Region of North Dakota, South Dakota, and northeast Montana during 1992–1995. We chose planted cover on WPA as a reference cover because plant composition and structure were similar to CRP, historical nest success data are available for this cover (Cowardin et al. 1988, Klett et al. 1988), and WPA are present throughout our study area. Nest success in WPA cover provided a benchmark for comparing our findings from duck nests found in CRP cover. These results and other nest success and habitat data were used to estimate duck pro-

duction in our study area under conditions with and without CRP on the landscape. Our objectives were to (1) compare DSR in CRP cover and WPA cover for 1992–1995; (2) explain variation in DSR in CRP cover using characteristics of surrounding landscapes (i.e., percent perennial cover, breeding duck population, number and area of ponds, indices of red fox and coyote [*Canis latrans*] abundance, and geographic location of study areas); (3) estimate average DSR for CRP cover and other major cover types during 1992–1995 (CRP period) in our study area and compare with estimates for 1980–1984 (pre-CRP); and (4) estimate duck recruitment and other population parameters in our study area during 1992–1997 and compare with predictions from models that simulated a scenario in which cropland had never been converted to CRP.

To address objective 4, the primary purpose of our study, we used habitat–production models to account for the distribution of CRP cover relative to geographic and temporal distributions of other habitats and duck populations.

## STUDY AREA AND SELECTION OF STUDY SITES

Our study area was the portion of North Dakota and South Dakota east and north of the Missouri River, and Daniels, Roosevelt, and Sheridan counties in northeast Montana (Fig. 1). This area approximates the Prairie Pothole Region of these states (Stewart and Kantrud 1973), which is the primary breeding area for many duck species (Batt et al. 1989). The area is a glacially influenced landscape (Bluemle 1991) characterized by numerous wetland basins that attract many breeding pairs when wetland conditions are favorable (Cowardin et al. 1995). Cowardin et al. (1995) identified a stratified random sample of 335 10.4-km<sup>2</sup> plots in our study area (Fig. 1). Those 335 plots (hereafter sample plots) constituted the pool from which we selected study plots for data collection (selection described below) and were the basis for production modeling.

## METHODS

### Habitat Classification and Mapping

For each of the 335 sample plots, we identified and mapped upland and wetland habitats according to the classification described by Cowardin et al. (1988). Upland classes were grassland (i.e., pastureland), idle grassland, hayland, cropland, woodland, scrubland, planted cover, road and

railroad rights-of-way, barren land, and other (e.g., rockpiles, shelter belts, etc.). For use in models, we combined woodland, scrubland, and other classes into a single odd area class (Klett et al. 1988). Planted cover was separated further into CRP, WPA, and Waterbank Program, all of which had similar vegetative characteristics but were established through different programs. Upland habitat areas were delineated at the scale of 12.5 cm/km on hard-copy maps, which were georeferenced and digitized using ARC/INFO (Environmental Systems Research Institute, Redlands, California, USA) Geographic Information Systems (GIS) software. We obtained digital wetland data for each plot from the USFWS, National Wetlands Inventory, St. Petersburg, Florida, USA. These data were derived from high-altitude (1:63,360), color-infrared photography acquired during the late 1970s and early 1980s. We combined this wetland data layer with our digital upland data layer to form a complete land classification coverage for each of the 335 sample plots. We also calculated the Universal Transverse Mercator easting and northing coordinates, projected in zone 14, for the center of each plot.

### Wetland Assessment

Each year during May, we measured the number and wet area of all wetland basins that contained water on all sample plots. We derived wetland information from aerial videography taken vertically at an altitude of approximately 4,100 m above ground from small, fixed-wing aircraft. Video imagery was later replayed, and a fixed scene was captured into a computer (equipped with a video capture card) and then saved as a Raster Vector CAD file into Map and Image Processing System (MIPS; MicroImages, Lincoln, Nebraska, USA) GIS software. Captured video scenes were then overlaid with digital wetland polygon data obtained from the USFWS, National Wetlands Inventory, St. Petersburg, Florida, USA. Using the original video as a reference, we delineated wet areas  $\geq 0.008$  ha for all wetland basins on our sample plots.

### Estimation of Numbers of Breeding Pairs

We annually estimated numbers of breeding mallard, gadwall, blue-winged teal, northern shoveler (*A. clypeata*), and northern pintail pairs on each sample plot. We derived these estimates from a survey conducted annually on the 335 sample plots to estimate breeding duck pairs and production for the USFWS, Region 6 portion of the Prairie Pothole Joint Venture, North American

Waterfowl Management Plan (Cowardin et al. 1995). We used aerial videography, as described above, to determine the wet area of all wetland basins on each sample plot, and we conducted ground counts of breeding duck pairs on a sub-sample of those wetland basins. These data were used in regression-ratio models (Cowardin et al. 1995) to estimate breeding duck pairs on each sample plot in our study area. The regression-ratio estimator was

$$\hat{Y}_R = \gamma \left( \sum_{p=1}^N f(a_p) \right), \quad (1)$$

where  $\gamma$  corrected for annual and geographic variation,  $a_p$  was the area of pond  $p$ ,  $N$  was the number of ponds on a sample plot, and  $f(a_p)$  was the uncorrected estimate of breeding population,  $f(a_p) = A \times (a_p) + B \times \sqrt{a_p}$ . For  $A$  and  $B$ , we used regression coefficients provided by Cowardin et al. (1995:7). We computed the correction factor " $\gamma$ " for each USFWS, Wetland Management District (Cowardin et al. 1995) in our study area each year as

$$\gamma = \frac{\sum_{p=1}^n y_p}{\sum_{p=1}^n f(a_p)}, \quad (2)$$

where  $y_p$  was the number of breeding ducks counted on pond  $p$ , and  $n$  was the number of ponds surveyed.

### Selection of Plots for Nest Data Collection

Two-hundred-fifteen of the 335 sample plots contained  $\geq 1$  CRP field. We considered in final selection only those sample plots that had  $\geq 16.2$  ha of CRP and contained sufficient wetland basins to support  $\geq 20$  mallard breeding pairs during average wet conditions, as determined from the pair-wetland regression model described by Cowardin et al. (1988). These criteria were established to increase the chance of locating adequate numbers of nests to estimate nest success on individual plots. One-hundred-thirty-eight plots met our criteria (hereafter study plots). For each of the 138 study plots, we identified the nearest WPA containing  $\geq 16.2$  ha of planted cover that had plant species composition and structure similar to CRP cover.

We generated cover maps for the 138 study plots using MIPS GIS software. Each year, we selected a sample of plots to be studied from the 138 study plots. We refer to a study plot and its neighboring WPA as a replicate. To maximize the number of

replicates that could be searched for duck nests, we limited the amount of cover to be searched on each replicate. Each year, we selected replicates from the pool and randomly chose fields of CRP cover and WPA cover until the last field selected reached or exceeded 81 ha for each cover type on that replicate. On replicates with  $\leq 81$  ha of a specific cover, we selected all fields of that cover type.

During 1992, we selected 14 replicates (7 in North Dakota and 7 in South Dakota) to be searched by field crews. Our goal for the first year was to gather data to determine the number of replicates needed to meet our first objective. We assumed that if we had enough replicates to address objective 1, other objectives would also be met. For objective 1, we set  $\alpha = 0.10$ ,  $\beta = 0.20$ , and  $\delta = 0.03$  for assessing differences (2-tailed test) in DSR between CRP and WPA cover. Variance estimates for the species examined (mallard, gadwall, blue-winged teal, northern shoveler, and northern pintail) in 1992 ranged from 0.05–0.15. Because drought conditions prevailed in our study area during the pilot year that resulted in reduced nesting effort, we believed variances of  $\leq 0.08$  were attainable under more favorable conditions. With a variance of 0.08, about 100 replicates would be needed to meet our study objectives. Therefore, we developed a minimum goal of 35 replicates per year for 1993–1995.

Ideally, we would have selected replicates randomly from our pool of study plots each year. However, due to the distribution of replicates and logistics, this was not feasible. Instead, we first delineated crew-areas, defined as geographic areas with  $\geq 7$  replicates that were  $\leq 161$  km apart. The 7 replicates and distance criterion were based on what we judged as logistically feasible for a field crew to collect data under the study design. Eleven crew-areas covered our entire study area, and we were able to work in 7–8 crew-areas each year (1993–1995). Klett et al. (1988) found regional differences in duck nest success among eastern and central North Dakota and eastern and central South Dakota. Thus, to optimize spatio-temporal variation, each year (except 1992) we included  $\geq 1$  crew area in each of the regions described by Klett et al. (1988). We selected replicates  $\geq 2$  times from each of the 11 crew-areas during the period of study. Each year, 3–8 replicates were chosen at random from those available in selected crew-areas.

### Predator Indices

We did not collect predator abundance data on study plots. Instead, we obtained annual indices

of coyote and red fox abundance for counties in North Dakota where we had study plots (S. H. Allen, North Dakota Game and Fish Department, unpublished data). We had no indices of coyote or red fox abundance in South Dakota or Montana.

### Field Methods

*Nest Searching.*—In spring–summer 1992–1995, we located duck nests in CRP and WPA cover following methods of Klett et al. (1986). A nest was defined as  $\geq 1$  egg tended by a hen when found (Klett et al. 1986). Each field selected for study was searched 3 times at approximate 21-day intervals between 1 May and about 2 July of a particular year. Standard procedures were followed for marking nests and recording location and nest site data (Klett et al. 1986), and stage of incubation was determined for each nest following Weller (1956). Nests were revisited on subsequent searches or more frequently to determine fate (hatched, destroyed, or abandoned). Nests that appeared to have been abandoned on the day of discovery were considered failed due to investigator influence.

### Analytical Procedures

*Duck Nesting Study.*—We estimated DSR using the methods of Mayfield (1961, 1975) and Johnson (1979). We excluded nests that were terminated when found, those that showed evidence of egg depredation or that contained eggs laid by nest parasites when found, and all nests that likely were abandoned due to investigator influence or that contained eggs broken by investigators. DSR were calculated for CRP and WPA cover on each replicate for each of 5 principal duck species: mallard, gadwall, blue-winged teal, northern shoveler, and northern pintail. Statistical analyses were conducted on DSR. Nest success (probability that  $\geq 1$  egg in a clutch hatched) was derived exponentially from DSR and laying and incubation periods (Klett et al. 1986) for presentation in portions of the results and discussion.

We developed models of DSR to identify sources of variability in observed DSR and to improve estimates of DSR in CRP and WPA cover on our study plots and to extrapolate to sample plots not studied. We used correlation analysis and stepwise regression (SAS Institute 1989) to identify variables that best explained variation in observed DSR. Explanatory variables considered for inclusion in our models were: (1) indicated breeding pairs (BPOP); (2) number of wet ponds (WETPOND); (3) area of wet ponds (WETAREA);

(4) percent perennial grass cover (PGRASS); (5) indices to coyote (COYINDEX) and red fox (FOXINDEX) abundance in the spring, measured at the county level in North Dakota; and (6) location corresponding to Universal Transverse Mercator coordinates for the center of each study plot or sample plot (i.e., easting [EAST], northing [NORTH] and their product [E  $\times$  N]). The last 3 variables were treated as a variable subset (LOC), meaning that all 3 variables were either included in or excluded from a particular model. Because of large numbers of missing values for FOXINDEX and COYINDEX (Montana and South Dakota study plots), we fitted a second suite of regression models after excluding those 2 variables from the group of predictors. Significance levels for adding new variables or variable subsets and retaining existing ones in our models were both  $P \leq 0.15$ . We used weighted least squares (Snedecor and Cochran 1980), weighted by exposure days (Johnson 1979) to fit the stepwise models.

Prior to conducting stepwise analyses, we examined correlation coefficients among the explanatory variables to check for multicollinearity. Residuals from regression models were plotted against predicted values of DSR and against each explanatory variable and examined for evidence of nonconstant variance or nonlinear relations between DSR and explanatory variables.

Based on results of initial analyses, we fitted regression models for DSR in CRP cover as a function of PGRASS and LOC, by species to increase accuracy of estimating DSR in CRP fields on sample plots not studied. We then used analysis of covariance (ANCOVA), with DSR as the response variable and PGRASS, LOC, and species as explanatory variables, to identify and combine regression coefficients showing nonsignificant species effects. This approach allowed us to preserve species effects that were supported by our data and pool those that could not be statistically separated. We also considered models allowing for effects of nest age and initiation date on DSR (Klett and Johnson 1982, Grand 1995).

*Duck Production Models.*—We used models presented by Cowardin et al. (1995:equations 3–7) and Krapu et al. (2000) to estimate production parameters for the principal species for years 1992–1997 (peak-CRP period) on each of the 335 sample plots. These production models use input data for breeding population size, availability of various nesting habitats, nesting habitat preference, nest success by habitat, wetland condition,

Table 1. Input parameters for duck production models presented by Cowardin et al. (1995), and data sources used in analyses to estimate production for 5 principal duck species in the U.S. Prairie Pothole Region for 1992–1997 under 2 scenarios: (1) actual landscape configuration, and (2) cropland in place of Conservation Reserve Program cover.

Input parameter	Data source
Breeding duck pair estimates	This study, following methods of Cowardin et al. (1995)
<i>W</i> , percentage of wetland basins containing water	This study, using aerial videography
$\alpha$ , index to nesting intensity derived from <i>W</i>	Cowardin et al. (1995):equation 6
Nesting habitat preference of female ducks	NPWRC <sup>a</sup> files analyzed for this study following methods of Klett et al. (1988)
Area of available nesting habitat	This study
Duck nest success	
CRP and planted cover	This study
Other nesting cover types (grassland, hayland, cropland, etc.)	NPWRC nest files analyzed for this study following methods of Klett et al. (1988)
<i>Z</i> , survival rate of broods	This study, using model from Krapu et al. (2000)
<i>B</i> , average brood size at fledging	Cowardin et al. (1995)

<sup>a</sup> U.S. Geological Survey, Northern Prairie Wildlife Research Center.

brood survival, and brood size at fledging to estimate duck production from 10.4-km<sup>2</sup> landscapes (size of our sample plots; Table 1). Except for brood survival of gadwall and brood size at fledging for all species, inputs to production models were derived from this study, and analyses of nesting data that were collected during the period of our study. Brood survival for species other than gadwall was estimated for each sample plot using a proportional hazards model for mallard brood survival presented by Krapu et al. (2000) in which brood survival is a function of (1) percent seasonal wetlands with water, (2) hatch date, and (3) precipitation events. We assumed this model was appropriate for blue-winged teal, northern shoveler, and northern pintail. For gadwall, we treated brood survival as a constant (0.84) based on unpublished data collected in our study area (P. J. Pietz, U.S. Geological Survey, personal communication). Brood size at fledging was taken from Cowardin et al. (1995). Principal production parameters estimated for each plot were (1) overall nest success, (2) recruitment rate (number of females fledged/adult female in the breeding population), and (3) recruits (total males and females fledged). We expanded estimates from the sample plots to our entire study area following the methods of Cowardin et al. (1995) and calculated weighted means for some parameters, using weights equal to the breeding populations estimated on sample plots.

We estimated duck production during 1992–1997 under 2 scenarios: (1) assuming actual landscape

configuration (CRP present), and (2) assuming that cropland had never been converted to CRP cover. Northern Prairie Wildlife Research Center (NPWRC) maintains a repository of waterfowl nest records submitted by researchers and managers from numerous independent studies conducted throughout our study area. We used DSR estimates from nest data collected during 1990–1994 and submitted to the NPWRC Waterfowl Nest File for all habitats except CRP and WPA cover to estimate duck production under actual landscape configuration during 1992–1997. The 1990–1994 period is the most recent for which data are available that coincided with the CRP period. Because the nest file did not contain sufficient data from northeast Montana, we used DSR estimates from central North Dakota (see Klett et al. 1988) for sample plots in Montana. We used data collected on our replicates during 1992–1995 to estimate DSR in CRP and WPA cover.

To simulate duck production under the scenario in which cropland had never been converted to CRP cover, we used DSR estimates from the NPWRC Waterfowl Nest File for 1980–1984, the latest 5-year pre-CRP period. We also used the nest file to determine the preference that hens of each species display for different nesting habitats (probability that a hen will select a particular habitat for nesting, given all habitats are equally available). This analysis followed the methods of Klett et al. (1988), except that, in addition to their 1966–1984 data, we included 1985–1994 data. Preference values were derived from data

Table 2. Number of replicates<sup>a</sup>, replicate-year combinations, and area of Conservation Reserve Program (CRP) cover and Waterfowl Production Area (WPA) planted cover that were searched for duck nests in the Prairie Pothole Region of North Dakota, South Dakota, and Montana, USA, 1992–1995.

State	No. of replicates	No. of replicate-year combinations	Area searched (ha)	
			CRP	WPA
Montana	4	7	508	328
North Dakota	71	112	8,770	4,598
South Dakota	23	42	3,121	1,909
Total	98	161	12,399	6,835

<sup>a</sup> Includes CRP cover and WPA cover paired in a study site.

for central North Dakota and were assumed to apply elsewhere in our study area. Preference for CRP, WPA, and Waterbank Program covers were assumed to be the same. Daily survival rates for nests initiated in planted cover enrolled in the USDA Waterbank Program were assumed to be the same as CRP. We used these preference values and availability of habitat types on each sample plot as inputs to our production models.

## RESULTS

### Breeding Pairs and Wetland Habitat

During 1992–1997, numbers of breeding duck pairs in our study area ranged from 1,479,469 (SE = 80,877) in 1992 to 8,020,051 (SE = 381,023) in 1997, and the 6-year mean was 4,751,664 (SE = 182,104). The mean annual estimates of breeding pairs by species were: mallard = 1,091,034 (SE = 38,234);

gadwall = 798,714 (SE = 39,571); blue-winged teal = 1,960,265 (SE = 83,137); northern shoveler = 458,165 (SE = 18,008); and northern pintail = 443,486 (SE = 17,588). Numbers of ponds were lowest in 1992 (659,113; SE = 32,316), moderate in 1993 (1,221,227; SE = 49,120), and unusually high during 1994–1997 (mean = 1,631,037; SE = 69,148).

### Duck Nesting Study

From 1992–1995, we located 10,727 duck nests on 98 study replicates or 161 replicate-year combinations (Table 2). Of these nests, 10,063 were usable for analyses and included 6,945 nests in 12,399 ha of CRP cover and 3,118 nests in 6,835 ha of WPA cover (Tables 2 and 3). Overall, species composition was 31% blue-winged teal, 27% gadwall, 20% mallard, 10% northern shoveler, 10% northern pintail, and 2% other (American wigeon [*A. americana*], green-winged teal [*A. crecca*], redhead [*Aythya americana*], and lesser scaup [*A. affinis*]). We located proportionately fewer nests of blue-winged teal (27% vs. 41%) and proportionately more nests of mallard (22% vs. 14%) in CRP than in WPA cover. Numbers of nests of remaining species were proportionately similar in CRP and WPA cover.

Differences in estimates of DSR between CRP and WPA cover were small, and confidence intervals included zero (Table 4). Survival of nests was highest for blue-winged teal and lowest for northern pintail. Of the unsuccessful clutches, 5,065 (95.2%) were destroyed by predators, 238 (4.5%) were abandoned by the hen (some of these hens may have died while away from the nest), and 18 (0.3%) failed to hatch due to other causes (e.g., flooding, infertile eggs).

Table 3. Number of usable<sup>a</sup> duck nests found in Conservation Reserve Program (CRP) cover and Waterfowl Production Area (WPA) planted cover in the Prairie Pothole Region of North Dakota, South Dakota, and Montana, USA, for estimating nest success for 5 species, 1992–1995.

Year	Mallard		Gadwall		Blue-winged teal		Northern shoveler		Northern pintail		Other <sup>b</sup>		Total	
	CRP	WPA	CRP	WPA	CRP	WPA	CRP	WPA	CRP	WPA	CRP	WPA	CRP	WPA
1992	67	17	65	32	71	123	10	12	11	4	2	1	226	189
1993	168	53	258	114	290	205	87	50	84	14	8	1	895	437
1994	514	145	663	259	600	396	260	141	241	98	75	31	2,353	1,070
1995	795	207	933	348	913	567	305	165	463	108	62	27	3,471	1,422
Total	1,544	422	1,919	753	1,874	1,291	662	368	799	224	147	60	6,945	3,118

<sup>a</sup> Excludes nests that were terminated when found, showed evidence of depredation or parasitically laid eggs when found, or were abandoned or damaged as a result of investigator.

<sup>b</sup> Includes 107 American wigeon, 31 A. green-winged teal, 20 redhead, and 49 lesser scaup nests.



Table 4. Least squares estimates of daily survival rates (DSR) of duck nests in Conservation Reserve Program (CRP) and Waterfowl Production Area (WPA) planted cover, and lower (LCL) and upper (UCL) 95% confidence limits for the DSR differences for 5 species in the Prairie Pothole Region of North Dakota, South Dakota, and Montana, USA, 1992–1995.

Species	DSR		DSR difference	
	CRP	WPA	LCL	UCL
Mallard	0.9460	0.9431	-0.0068	0.0127
Gadwall	0.9482	0.9482	-0.0095	0.0096
Blue-winged teal	0.9544	0.9534	-0.0077	0.0098
Northern shoveler	0.9438	0.9502	-0.0190	0.0060
Northern pintail	0.9265	0.9313	-0.0227	0.0131

### Variables Affecting Daily Survival Rates

Correlation coefficients among candidate explanatory variables, BPOP, WETPOND, WETAREA, PGRASS, EAST, NORTH, FOXINDEX, and COYINDEX, were all  $\leq 0.5$  in absolute value with 1 exception: EAST and NORTH were negatively correlated ( $r = -0.68$ ;  $n = 142$ ), owing to the south-east–northwest orientation of our study area.

Daily survival rates were positively correlated with BPOP and PGRASS and negatively correlated with EAST and FOXINDEX (Table 5). The highest correlations usually included PGRASS and EAST, but absolute values were  $\leq 0.5$ . Scatter plots of DSR, by species, versus the various explanatory variables did not indicate nonlinear relations or nonconstant variances. In stepwise regression analyses considering all explanatory

variables (study plots in North Dakota), PGRASS was the first variable to enter the model for each species, and the only variable to appear in all models (Table 6, suite 1). PGRASS was also present in 4 of 5 species models that included all study plots, but excluded FOXINDEX and COYINDEX (Table 6, suite 2). Location effects appeared in models for mallard, gadwall, and blue-winged teal. Northern shoveler was the only species to not show an effect of either PGRASS or LOC in suite 2 models. Regression models explained  $\leq 31\%$  of the variability in DSR (Table 6).

### Model for Estimating Daily Survival Rates in CRP

Regressions of DSR on PGRASS and LOC were significant ( $P < 0.01$ ) for all species except northern shoveler (mallard:  $F_{4,137} = 6.9$ ,  $P < 0.001$ ,  $R^2 = 0.17$ ; gadwall:  $F_{4,144} = 4.7$ ,  $P = 0.001$ ,  $R^2 = 0.12$ ; blue-winged teal:  $F_{4,138} = 15.4$ ,  $P < 0.001$ ,  $R^2 = 0.31$ ; northern shoveler:  $F_{4,109} = 2.9$ ,  $P = 0.03$ ,  $R^2 = 0.10$ ; northern pintail:  $F_{4,104} = 4.5$ ,  $P = 0.002$ ,  $R^2 = 0.15$ ). In analyses of residuals from these regressions, we failed to detect a year effect for any species (ANOVA:  $P = 0.04$ – $0.68$ ), nor were we able to detect species differences in regression coefficients for PGRASS, EAST, NORTH, or  $E \times N$  (ANCOVA:  $F_{16,632} = 0.78$ ,  $P = 0.72$ ). We did, however, detect marginally significant differences in the constant terms for individual species (ANCOVA:  $F_{4,648} = 2.73$ ,  $P = 0.03$ ). Our final model was  $DSR = a_i + b_1(\text{PGRASS} \times 10^{-2}) + b_2(\text{EAST} \times 10^{-5}) + b_3(\text{NORTH} \times 10^{-5}) + b_4(\text{E} \times \text{N} \times 10^{-12})$ , where  $a_i$  depended on species (mallard = 1.634, SE =

Table 5. Correlation of daily survival rates of nests for 5 species of ducks with breeding population size, numbers of ponds, area wet, percent of landscape in perennial cover, location (Universal Transverse Mercator easting and northing)<sup>a</sup>, and indices<sup>b</sup> to red fox and coyote abundance. Sample sizes ( $n$ ) are the number of study plot-years in North Dakota, South Dakota, and Montana, USA, 1992–1995.

Variable	Mallard		Gadwall		Blue-winged teal		Northern shoveler		Northern pintail	
	$r$	$n$	$r$	$n$	$r$	$n$	$r$	$n$	$r$	$n$
No. breeding pairs	0.14	141	0.08	148	0.30	142	0.24	113	0.26	109
No. ponds	-0.05	141	0.02	148	0.03	142	-0.04	113	0.01	109
Area wet (ha)	0.06	141	-0.09	148	0.07	142	0.05	113	0.05	109
% perennial cover	0.34	142	0.28	149	0.43	143	0.21	114	0.36	109
Easting (1,000 m)	-0.16	142	-0.21	149	-0.32	143	-0.15	114	-0.07	109
Northing (1,000 m)	-0.05	142	0.05	149	-0.17	143	-0.02	114	-0.06	109
Red fox index <sup>b</sup>	-0.16	95	-0.13	95	-0.12	94	-0.23	75	-0.13	74
Coyote index <sup>b</sup>	0.12	95	-0.14	95	-0.05	94	-0.17	75	0.02	74

<sup>a</sup> UTM coordinates projected in zone 14.

<sup>b</sup> Data from North Dakota Game and Fish Department. Similar data not available for South Dakota and Montana.

Table 6. Results of stepwise regression models using daily survival rates of duck nests in CRP cover by species as the response variable. Two suites of explanatory variables for each study plot were considered: (1) breeding population size (BPOP), number of ponds (WETPOND), area wet (WETAREA), percent of study plot in perennial cover (PGRASS), location (LOC [consisting of Universal Transverse Mercator easting, northing and their arithmetic product]), and indices to red fox (FOXINDX) and coyote (COYINDX) abundance, and (2) the above variables excluding FOXINDX and COYINDX.

Species	Suite (1) <sup>a</sup>			Suite (2) <sup>b</sup>		
	Variables in final model <sup>c</sup>	n <sup>d</sup>	R <sup>2</sup>	Variables in final model <sup>c</sup>	n <sup>d</sup>	R <sup>2</sup>
Mallard	PGRASS, WETPOND	94	0.17	PGRASS, LOC	141	0.17
Gadwall	PGRASS, LOC	94	0.19	PGRASS, LOC	148	0.11
Blue-winged teal	PGRASS	93	0.18	LOC, PGRASS	142	0.31
Northern shoveler	PGRASS, COYINDX	74	0.16	BPOP	113	0.06
Northern pintail	PGRASS, BPOP	74	0.25	PGRASS	109	0.13

<sup>a</sup> Included data from study plots in North Dakota only.

<sup>b</sup> Included data from all study plots in North Dakota, South Dakota, and Montana.

<sup>c</sup> Significance levels for adding variables and retaining existing ones in the models were  $P \leq 0.15$ . Variables in the final models are listed in the order in which they entered the model.

<sup>d</sup> Number of study plot-year combinations.

0.163; gadwall = 1.636, SE = 0.162; blue-winged teal = 1.639, SE = 0.163; northern shoveler = 1.640, SE = 0.163; northern pintail = 1.629, SE = 0.162),  $b_1 = 0.0305$  (SE = 0.0062),  $b_2 = -0.0885$  (SE = 0.0321),  $b_3 = -0.0125$  (SE = 0.0030), and  $b_4 = 0.1529$  (SE = 0.0604).

The model implies that at a given location, DSR would increase linearly as PGRASS was increased (Fig. 2), provided that values of PGRASS were within the range of those observed (5–80%). Daily survival rate increased from east to west and from north to south, but the rate of increase in both

directions varied spatially (Fig. 3). Visually, the contour lines appeared to roughly follow the eastern or northern edge of the Missouri Coteau (Stewart and Kantrud 1973). The rate of increase from north to south was greatest in northeastern Montana and western North Dakota, and that from east to west was most pronounced in South Dakota.

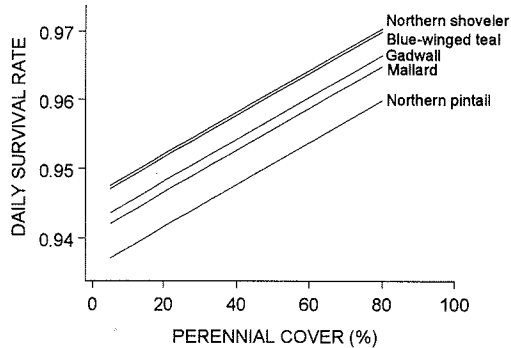


Fig. 2. Relationship between daily survival rate of nests for 5 species of ducks in Conservation Reserve Program cover and percent total perennial cover at an arbitrarily selected location (Universal Transverse Mercator easting =  $4.75 \times 10^5$  and northing =  $52.00 \times 10^5$ ) in the Prairie Pothole Region of North Dakota, USA, 1992–1995. Identical regression slopes with varying intercepts occur at other locations in our study area.

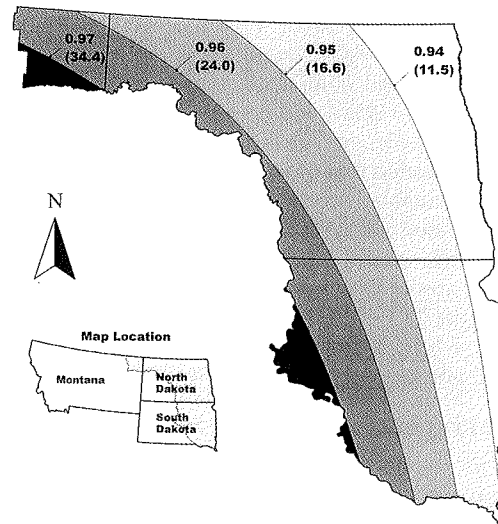


Fig. 3. Geographic variation in daily survival rate and nest success (in parentheses) of mallard nests in Conservation Reserve Program cover assuming that percent of perennial grass cover for the entire Prairie Pothole Region of North Dakota, South Dakota, and Montana, USA, was constant at 35%. Shaded areas represent gradients. Similar relationships were found for gadwall, blue-winged teal, northern shoveler, and northern pintail.

Table 7. Relative preference<sup>a</sup> that 5 species of ducks show for 8 habitats<sup>b</sup> in the Prairie Pothole Region of North Dakota, USA, 1966–1994.

Habitat	Mallard	Gadwall	Blue-winged teal	Northern shoveler	Northern pintail
Cropland	0.004	0.002	0.003	0.004	0.028
Hayland	0.115	0.148	0.153	0.092	0.192
Grassland	0.046	0.053	0.088	0.064	0.055
Idle grassland	0.133	0.087	0.094	0.052	0.059
Planted cover	0.419	0.457	0.382	0.479	0.376
Right-of-way	0.069	0.053	0.066	0.056	0.068
Wetland	0.060	0.051	0.058	0.076	0.042
Odd area	0.154	0.148	0.155	0.176	0.180

<sup>a</sup> Preference for a particular habitat is the probability that a female duck will select that habitat for nesting, given that all habitats are equally available.

<sup>b</sup> Habitats as defined by Klett et al. (1988), except odd area that included other, woodland, and scrubland as defined by Cowardin et al. (1988).

Models that included nest age and initiation date provided evidence of effect for both variables, but differences in DSR between these models and those that did not include age or initiation date effects were small (1–2 percentage points for nest success estimates of most species–PGRASS–LOC combinations). Our objectives included comparing results with those of Klett et al. (1988), and because these authors did not adjust for nest age or initiation date, we chose to use models that did not include these variables.

We estimated average nest success (weighted by population size on each sample plot) in CRP cover for each species using our models. Nest success estimates in CRP were mallard 19.3% (SE = 2.0), gadwall 22.1% (SE = 2.4), blue-winged teal 24.4% (SE = 2.9), northern shoveler 26.5% (SE = 3.0), and northern pintail 22.6% (SE = 2.8).

#### Nesting Habitat Preference and Nest Success

We estimated nesting habitat preference and nest success by habitat, region, period, and species using 26,697 nest records from the NPWRC waterfowl nest file. Species composition was 20% mallard, 24% gadwall, 40% blue-winged teal, 7% northern shoveler, and 8% northern pintail. Planted cover was the most preferred habitat and cropland was least preferred by all species (Table 7). Estimated nest success varied greatly among habitats, regions, species, and periods, but was gener-

ally higher in 1990–1994 (*MED* = 19%, *IQR* [interquartile range; SAS Institute 1990] = 20%, *n* = 160) than in 1980–1984 (*MED* = 15%, *IQR* = 14%, *n* = 160). Habitat rankings, from lowest to highest nest success for all species combined, were right-of-way, wetland, other, grassland, hayland, idle grassland, planted cover (CRP and WPA), and cropland. The relative high nest success ranking of cropland was due to gadwall and blue-winged teal. Nest success in cropland was relatively low for northern pintail and mallard. Species rankings, from lowest to highest nest success, were northern pintail, mallard, northern shoveler, gadwall, and blue-winged teal. Nest success was lowest in eastern North Dakota, followed by eastern South Dakota, central North Dakota, and central South Dakota.

#### Impact of CRP on Duck Production

Estimated nest success and recruitment rates of the 5 principal species combined during 1992–1997 were 46% and 30% higher, respectively, with CRP cover rather than cropland on the landscape. Mallard and blue-winged teal showed the largest (38% and 32%, respectively) and gadwall showed the smallest (21%) gains in recruitment rate between the pre-CRP and CRP periods.

The estimated average annual difference in recruits (fledged male and female ducklings) produced during 1992–1997, with and without CRP, was 37,301 (SE = 65,008) in Montana, 989,727 (SE = 223,882) in North Dakota, 1,043,589 (SE = 354,854) in South Dakota, and 2,070,617 (SE = 424,583) overall. The percent of total recruits that hatched in CRP was 40 (SE = 13), 36 (SE = 3), 21 (SE = 4), and 29 (SE = 3), respectively, for Montana, North Dakota, South Dakota, and overall. For all species combined, predicted nest success was higher in planted cover (CRP cover and WPA cover, 23%, SE = 3%) than in WPA cover only (18%, SE = 4%), when we modeled a scenario to simulate what would have happened if the CRP had not occurred.

#### DISCUSSION

Clark and Nudds (1991) discussed the need for information about the relationships between patch size and composition of managed habitats and duck nest success. They recommended an experimental approach with (1) spatio-temporal replication, (2) measurement of duck nest success in control areas, and (3) 2 or more landscapes that differed in agriculture land use included in the study. As with most wildlife field

studies, our investigation suffered from lack of strict experimental control. However, for our objective to compare duck nest success in CRP versus WPA cover, our study design was appropriate. For investigating the relationship between DSR in CRP and landscape characteristics, we would have preferred to dictate the location and size of CRP plantings. We used planted cover on WPA as a reference for comparing nest DSR in both pre-CRP and CRP periods. Because of the magnitude of the CRP, few landscapes in our study area were not influenced by the CRP; thus our reference areas (WPA cover) could not be considered true controls. Our replicates were numerous and displayed a wide range of spatio-temporal variation in all of the parameters that were estimated or measured, and our results were consistent among species.

Our results indicate that the CRP provided substantial benefits to upland nesting ducks in the U.S. Prairie Pothole Region during 1992–1997. It would be most simple to infer then, that CRP cover was more attractive to nesting hens and provided greater security from nest predators relative to most other cover types in the study area, as was hypothesized. However, the effect of the CRP on duck recruitment in the Prairie Pothole Region appears to be more complex. One of our objectives was to compare DSR of nests found in CRP cover with that of nests found in WPA cover. Klett et al. (1988) reported nest success rates of 9–12% (for the same species we studied) in WPA cover in North Dakota for 1980–1984. These nest success rates are lower than rates believed necessary for duck population stability in this region (15–20%; Cowardin et al. 1985, Klett et al. 1988). When we initiated our study, we expected to find nest success rates in WPA cover to be similar to those reported by Klett et al. (1988). Kantrud (1993) studied duck nest success in WPA and CRP cover in Minnesota and North Dakota during 1989–1991 and found higher nest success in CRP cover than in WPA cover and nest success in WPA cover was similar to that reported by Klett et al. (1988) for 1980–1984. We did not find a difference in DSR for nests found in CRP cover compared to those found in WPA cover during 1992–1995. In our study, nest success in both types of cover was higher than reported for WPA cover by either Klett et al. (1988) or Kantrud (1993). We believe an explanation for our dissimilar results is related to our finding that DSR in CRP cover was positively related to the percent of perennial grass cover on study plots. Because

WPA cover is similar to CRP cover, DSR in WPA cover presumably also was related to the amount of grass near the fields studied. We could not test this assumption because some WPA were located off the 10.4-km<sup>2</sup> study plots where we did not have land-cover information. However, CRP cover was distributed broadly throughout our study area and presumably contributed to improvements in nest success we observed in WPA cover during the CRP period. We speculate that DSR in many other cover types were influenced by the percent of perennial grass cover in the surrounding area. This is consistent with our findings of higher overall nest success during 1990–1994 (CRP period) than 1980–1984 (pre-CRP period). Greenwood et al. (1995) found that success of upland nesting ducks in grassland areas of prairie Canada (all habitats included) was negatively related to the percent of cropland in the landscape (approximately the inverse of perennial grass). In our study, DSR increased from northeast to southwest for areas of equal PGRASS, or, stated another way, to achieve similar DSR a higher percentage of perennial grass would be necessary in the northeast compared to the southwest.

Several possible explanations may explain why nest success in CRP and WPA cover was higher during our study compared to WPA cover during the pre-CRP period, and why DSR in CRP cover was positively related to PGRASS. Because predation was the principal cause of nest failure in this and other studies in the Prairie Pothole Region (Klett et al. 1988, Sargeant and Raveling 1992), any factor that significantly influences nest success likely influences predator foraging activity. The CRP resulted in the conversion of 1.9 million ha (7% of the total land area) of cropland to undisturbed grass cover in our study area. In some counties, 20–25% of cropland was enrolled in the CRP. Perhaps this large-scale increase in idle grass cover provided nesting ducks and predators with increased nesting and foraging options, respectively, that reduced predator contact with nests. Another factor may be availability of prey other than ducks and duck eggs for predators. CRP cover in the northern plains provides suitable habitat for small mammals such as deer mouse (*Peromyscus maniculatus*), vole (*Microtus* spp.; Lysne 1991), and numerous species of grassland nesting birds (Johnson and Schwartz 1993). Many of the predators that prey on ducks and duck eggs (Sargeant et al. 1993) also prey on small mammals and other birds or their eggs

(McAtee 1935, Jones et al. 1983). Presumably, individual predators are capable of taking a finite number or mass of prey. As prey availability increases, the rate of predation should decline, assuming predator numbers do not increase in response to the increased availability of prey. The availability of food resources has been shown to influence predation rates on waterfowl nests in other areas (Pehrsson 1985, Summers 1986, Crabtree and Wolfe 1988).

With the large amount of perennial grass cover, including CRP, that occurred in some study plots, some fields or partial fields of CRP and WPA cover may not have been frequently visited by predators. These undisturbed conditions may have allowed hens to settle and find security long enough for clutches to hatch. Interestingly, several CRP fields contained high densities of nests (>2.5 nests found/ha searched), while densities in adjacent or nearby fields were much lower. These "hot spots" were usually characterized by intervals of apparently high DSR (i.e., most nests survived to late stages of laying or incubation and/or nest success was high). High densities of duck nests have been observed by others on areas protected from predators, such as islands (Duebber 1982, Duebber et al. 1983) or fenced exclosures (Cowardin et al. 1998).

Our models that included PGRASS and LOC explained only 10–31% of the observed variation in nest DSR. We included a priori other variables (Table 5) in our analyses, which we expected might help explain variability in nest DSR.

Density-dependent recruitment in North American Anatinae has been of interest for some time (Dzubin 1969, Dzubin and Gollop 1972, Pospahala et al. 1974, Weller 1979, Kaminski and Gluesing 1987). Kaminski and Gluesing (1987) reported some compelling evidence for density-dependent recruitment rates in mid-continent mallards. However, their study did not identify the mechanism(s) by which density dependence operates. If density-dependent recruitment exists, it must operate by influencing some component of the reproductive process. The definition of density is a complex issue, and in the past, density has been defined in various ways, such as: (1) breeding pairs/wetland in certain study areas in prairie Canada (Dzubin 1969), (2) breeding population/specified survey area (Kaminski and Gluesing 1987), or (3) breeding population distribution influenced by availability of wetland habitat (Pospahala et al. 1974). We used breeding pairs/10.4-km<sup>2</sup> (BPOP) as a measure of population

density for each species on each study plot-year and included it as an explanatory variable in our stepwise regression analyses of DSR. Daily survival rate consistently was positively correlated with BPOP for the 5 species we studied, but the relationship was not strong enough to retain in 4 of 5 final regression models. Thus, we conclude that nest DSR in CRP cover were not strongly related to breeding population density.

Crissey (1969), Kaminski and Gluesing (1987), and Reynolds (1987) found positive relationships between large-scale indices to mallard production and pond numbers in the Prairie Pothole Region. This implies that some component(s) of productivity is related to wetland conditions on the breeding grounds. Nesting effort (i.e., nests/hen) and nest success are the principal components of hen success (i.e., proportion of hens that produce a brood during the breeding season). Krapu et al. (1983) and Cowardin et al. (1985) found that mallard nesting effort in North Dakota was positively related to abundance of ponds. Greenwood et al. (1995) reported similar relationships for 5 species of upland nesting ducks in prairie Canada. The influence of water conditions on nest success is equivocal. Johnson et al. (1988) reported that predation rates on early-season duck nests in the Prairie Pothole Region of Canada were lower in areas and years in which larger fractions of seasonal wetlands contained water. They found a similar relationship between late-season nests and semipermanent wetlands. Cowardin et al. (1985) found that mallard nests were more successful when ponds were more abundant at the time of nesting. Conversely, Greenwood et al. (1995) included wetland variables in their analyses of duck nest predation rates in the Prairie Pothole Region of Canada and found no effect, and Beauchamp et al. (1996) found no evidence that nest success was associated with conserved soil moisture (index to wetness). WETPOND entered into 1 of 5 species models in suite 1 and none of the species models in suite 2 (Table 6). WETAREA did not enter into any of the models. We conclude that numbers and area of wet basins did not influence nest success in our study plots.

Because predation was the primary cause of duck nest failure, the number of individuals and species composition of the predator community on or near our study plots could have influenced nest success. Red foxes have been identified as the most important duck nest predator in much of the Prairie Pothole Region (Johnson and

Sargeant 1977, Johnson et al. 1988, Higgins et al. 1992, Sargeant et al. 1993). Coyotes also are a predator of duck nests (Sargeant et al. 1993) but are considered to pose less of a threat to nests than red foxes. Sovada et al. (1995) found that nest success of upland nesting ducks was about 15 percentage points higher on study areas where coyote was the dominant canid predator compared to areas where red fox dominated. In general, red fox abundance likely decreased and coyote abundance increased from east to west across our study area (Sargeant et al. 1993). For these reasons, we included indices to red fox and coyote abundance in our analyses of nest DSR for study plots in North Dakota. We found no evidence of a relationship between DSR and red fox abundance after other variables were considered and little influence of coyote abundance (Table 6). However, our indices of abundance were crude and were based on county-scale survey data as opposed to more preferred study-plot survey data.

We acknowledge that factors other than the CRP may have been responsible, at least in part, for the increase in duck nest success observed between the pre- and post-CRP periods. Sovada (1993) provided evidence that coyote populations expanded in much of our study area during a time partly coinciding with our study. If so, an argument could be made that increased nest success should be expected even if no change in the landscape had occurred. However, our finding that nest DSR was positively related to the percent of grass cover on our study plots supports the premise that the increase in CRP cover was at least partly responsible for the increase in nest success between the pre-CRP and CRP periods. In an attempt to check the logic of this finding, we used our regression models to estimate the average nest success in WPA cover for the combined 5 duck species using cover compositions that existed on our sample plots during the pre-CRP period (1980–1984). We then compared these expected nest success estimates with the observed nest success for that same cover type and period. Our expected nest success estimate was 17.26 (SE = 4.06) compared to the observed 17.53 (SE = 4.44). This finding supports our conclusion that the relationship between PGRASS and nest success is legitimate. Furthermore, in a 3-year (1992–1994) study of duck nest success in planted nesting cover in southern Saskatchewan (McKinnon and Duncan 1999), nest success was lower than we found in CRP and WPA planted cover but similar to that reported by Klett et al.

(1988) for planted cover in our study area during pre-CRP periods. Canada does not have a landscape-level program similar to the CRP; therefore, McKinnon and Duncan's (1999) results might reflect expectations of nest success in planted cover in the absence of such a program.

We conclude that the CRP has significantly benefitted populations of upland nesting ducks in the Prairie Pothole Region of the U.S. by providing attractive, secure nesting cover that is available to a large portion of nesting hens in the region. Johnson et al. (1992) concluded that nest success was the most important component of the reproductive process for mallards and other dabbling ducks in the Prairie Pothole Region. We estimated that 30% of the recruits hatched in our study area were from nests in CRP cover, and our results suggested that hatch rates in other cover types improved because CRP increased the amount of perennial cover in the landscape. Overall, we estimated that 12.4 million additional ducks (average of 2.07 million per year) were produced in our study area during 1992–1997 with CRP cover on the landscape compared with predicted production which simulated cropland in place of CRP cover. For the 5 common duck species, nest success in our study area for all nesting habitats combined was above levels considered necessary for population stability (Klett et al. 1988). During the pre-CRP period, we estimated that average nest success was below maintenance level for all species except gadwall. The combined impact of high nest success and a strong nesting effort due to ample availability of ponds across most of our study area in most years resulted in high production during the 1992–1997 period. Beauchamp et al. (1996) presented evidence that a widespread decline in duck nest success had occurred across the Prairie Pothole Region between 1935 and 1992, and suggested that a large-scale solution would be required to reverse the trend. We believe that the CRP contributed substantially to such a solution for the U.S. portion of the region.

#### MANAGEMENT IMPLICATIONS

Our results support the premise that large-scale conversion of cropland to undisturbed perennial grass cover will result in increased nest success and productivity for upland nesting ducks in the Prairie Pothole Region of the United States. The positive relationship we detected between DSR in CRP cover and the percent of landscape in perennial grass (PGRASS) suggests that the influ-

ence of planting additional grass extends beyond the bounds of those planted fields. Our results also support the idea that landscape-level programs such as the CRP are more meaningful than actions that focus only on increasing nesting habitat patch size. For example, Sovada et al. (2000) found little evidence that nest success in CRP fields was related to cover patch size.

The USDA Conservation Reserve Program converted 1.9 million ha of cropland to undisturbed grass cover between 1986 and 1992 in the Prairie Pothole Region of North Dakota, South Dakota, and Montana. Many of these contracts have expired, and nearly all will expire by 2002. In 1996, the 104th U.S. Congress passed the Federal Agriculture Improvement and Reform Act that reauthorized the CRP with a national upper limit equal to the 1995 Act (14.7 million ha). The 1996 Farm Bill did not provide for extending contracts that were accepted under the 1985 and 1990 Farm Bills, and all bids submitted for contract under the new CRP were evaluated based on an environmental benefit and cost index. The USDA designated the U.S. Prairie Pothole Region as 1 of 4 National Conservation Priority Areas for purposes of scoring CRP bids under the 1996 Farm Bill. As of October 1999, about 2.2 million ha had been enrolled under the latest CRP in the Prairie Pothole Region of North Dakota, South Dakota, and Montana. An additional 0.18 million ha was enrolled in the Prairie Pothole Region of Minnesota and Iowa. Future enrollment opportunities may be available. Our study indicates that these actions should result in benefits to upland nesting ducks. The CRP is the latest national agricultural land-retirement program. From 1956–1972, the USDA administered a program under the Soil Bank Act of 1956 which converted up to 11.6 million ha of cropland to perennial cover nationally (Berg 1994). The Food and Agriculture Act of 1965 established the Cropland Adjustment Program that set a national goal to shift 16.2 million ha of cropland to idle cover (Duebber 1969). Land-retirement programs likely will be part of USDA's conservation efforts in the future. We believe nationally funded programs should yield widespread benefits; our study results can provide guidance in developing these programs. Ducks from populations in the U.S. Prairie Pothole Region migrate to  $\geq 44$  of the continental states (Munro and Kimball 1982). Consequently, hunters, birdwatchers, and outdoor recreationists nationwide have benefited from the CRP in the northern plains.

Other programs exist that convert cropland to undisturbed grass cover in the Prairie Pothole Region. The Small Wetlands Acquisition Program (USFWS) has set aside 112,000 ha of grass cover on WPA in the Region since 1960 (Cowardin et al. 1995). This program is funded primarily by the sale of Duck Stamps. Models incorporating our results could assist managers in determining the size and locations of future land purchases to achieve a desired level of nest success.

Finally, our results demonstrate the need to protect remaining grasslands in the Prairie Pothole Region, particularly in those areas where numerous wetlands attract high densities of breeding ducks. By combining programs that protect existing grasslands and wetlands with those that restore grass cover, significant benefits to waterfowl populations can be achieved.

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