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Agricultural Set-aside Programs and Grassland Birds: Insights from Broad-scale Population Trends

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Abstract

The Conservation Reserve Program (CRP) is a voluntary set-aside program in the United States designed to ameliorate soil erosion, control crop overproduction, enhance water quality, and provide wildlife habitat by replacing crops with other forms of land cover. Because CRP includes primarily grass habitats, it has great potential to benefit declining North American grassland bird populations. We looked at the change in national and state population trends of grassland birds and related changes to cover-specific CRP variables (previous research grouped all CRP practices). Changes in national trends after the initiation of the CRP were inconclusive, but we observed signficant bird-CRP relations at the state level. Most bird-CRP relations were positive, except for some species associated with habitats that CRP replaced. Practice- and configuration-specific CRP variables were related to grassland bird trends, rather than a generic measure of all CRP types combined. Considering all CRP land as a single, distinct habitat type may obscure actual relations between birds and set-aside characteristics. Understanding and predicting the effects of set-aside programs (like CRP or agri-environment schemes) on grassland birds is complex and difficult. Because available broad-scale datasets are less than adequate, studies should be conducted at a variety of spatial and temporal scales.

Keywords:

agricultural landscapes, conservation reserve program, farm bill, grassland birds, set-aside, USA

1 Introduction

The ability of set-aside programs to produce wildlife benefits at landscape and regional scales has been widely documented both internationally (see Van Buskirk & Willi 2004 for review and also Kleijn & Baldi 2005, Van Buskirk & Willi 2005) and specifically for the Conservation Reserve Program (CRP) in the United States (Hohman & Halloum 2000, Haufler 2005). The CRP was initiated as part of the Food Security Act of 1985 (Hohman & Halloum 2000). The CRP provides a variety of financial incentives (rental agreements, cost sharing, etc.) for landowners in the United States to convert cropland in environmentally sensitive areas to grassland, forest, and other forms of land cover (see Suppl. A for available conservation practices, termed CPs) through voluntary contracts with the United States Department of Agriculture (USDA). Originally designed as a set-aside program to control agricultural production, the CRP has been expanded by subsequent legislative modification. Environmental benefits and creation of wildlife habitat are now primary objectives of the CRP (Hohman & Halloum 2000). Currently, approximately 14 million hectares of potential wildlife habitat are enrolled under a CRP contract (USDA 2004). This represents both a substantial addition of potential wildlife habitat and a substantial landscape modification (Weber et al. 2002 and see Fig. 1 below). Thus, CRP land may be an important contributor to changes in the composition and configuration of agricultural landscapes in the United States.

Evaluation of the CRP has focused on grassland birds for two reasons. First, ≈ 81% of the total CRP lands are enrolled in grass-based conservation practices (USDA 2004), although other cover types and practices are available (e.g., trees, woody shelterbreaks and windbreaks, etc.). The CRP has substantially increased the amount of potential grassland habitat for birds that breed in grasslands of the continental US. Second, almost 60% of North American grassland breeding bird species are declining (Sauer et al. 2004), the most consistently negative trends of any group of North American birds in recent decades (Vickery & Herkert 2001, Brennan & Kuvlesky 2005). These declines have largely been attributed to conversion of native grassland to cropland, rangeland, and other human landuses (Brennan & Kuvlesky 2005). Thus, grassland birds should respond to the types of landscape changes resulting from the CRP (Riffell et al. 2008).

Many different types of evidence may be used to evaluate the effects of set-aside programs on grassland birds

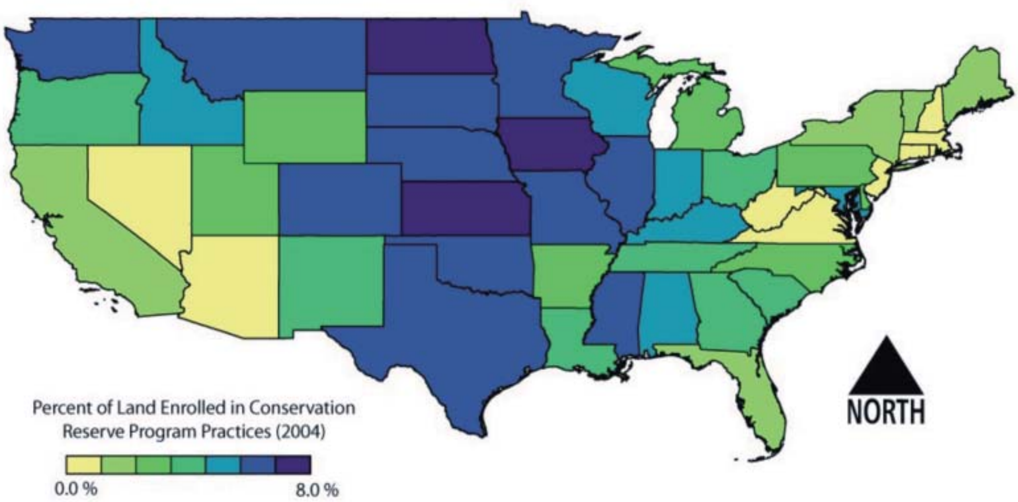

Figure 1. Percent of land enrolled in the Conservation Reserve Program in 2004 (data from USDA Farm Service Agency).

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(e.g., increased abundance or improved breeding success). Most studies of CRP effects have been conducted at small (local) spatial and short temporal scales, but Ryan (2000) suggested that the strongest evidence of CRP benefits would be positive population trend changes after the initiation of the CRP. The few existing regional-scale assessments of avian response to the CRP have short-comings. First, most have been restricted to single species and/or a single region (e.g., Roseberry & David 1994). Second, studies that have assessed CRP over an entire species' range (e.g., Herkert 1998) or a large region (e.g., Murphy 2003) have treated all CRP-enrolled lands as a single habitat type (but see Riffell et al. 2008). However, different CRP practices may vary greatly in habitat quality for grassland birds. In the southeastern U.S., tree plantings (CP3, CP11, etc.) comprise over 60% of CRP-enrolled acres (Burger 2000). Even within various grass cover practices, there are important differences (Johnson & Schwartz 1993). For example, native warm-season grasses (CP2) may provide better habitat value than cool-season grasses (CP1) for some species (Delisle & Savidge 1997, McCoy et al. 2001a). Similarly, birds do not equally use all types of practices used in European agri-environment schemes (Henderson et al., 2000; Bracken & Bolger, 2006) which vary from country to country (Kleijn & Sutherland, 2003; Kleijn et al. 2006). Third, the shape of the grassland patches may influence habitat quality. Nests in linear strips (e.g., grass waterways, field borders) may experience greater predation rates than larger patches created by enrolling whole fields (Best 2000 and references therein) and thus may be of lower quality.

Our overall hypothesis was that if CRP has been effective at improving landscape conditions for grassland songbirds, then this effect should leave a signal in population trends of grassland birds at broad scales. We conducted two analyses of CRP effects on grassland bird population trends, testing two specific hypotheses. First, we hypothesized that national population trends after the initiation of the CRP should be more positive (or less negative) than national population trends prior to the CRP. To test this, we tabulated the number of grassland bird species that exhibited changes in overall national population trends after the initiation of the CRP. Second, we hypothesized that states with the most land area in the CRP should have the largest, most positive changes in grassland bird trends. To differentiate effects of different CRP conservation cover types (e.g., native vs. exotic, linear vs. block habitats), we calculated pre- and post-CRP population trends for each state (a state-level analysis) and related the magnitude of trend changes (Δ trends) to the amount of different conservation practices within each state. Finally, we discuss the value and limitations of using regional and national trends as indicators of landscape change.

2 Methods

2.1 Trends of Grassland Breeding Birds

We used the North American Breeding Bird Survey (BBS) to calculate population trends for obligate and facultative grassland breeding birds in the continental US (breeding designations according to Vickery et al. 1999). The BBS is a long-term monitoring program initiated in 1966 (Robbins et al. 1986, Sauer et al. 2004). Currently, over 4,000 routes in North America are surveyed annually during the breeding season (summer). Each 39.4-km route follows secondary roads and consists of 50 stops at 0.8-km intervals. At each stop, trained observer(s) record all birds detected by sight or sound during a 3-minute period (Robbins et al. 1986, Sauer et al. 2004). The wide distribution of these routes across the continental U.S. and the temporal frame (1966 – present) make the Survey appropriate for assessing broad-scale effects of CRP on grassland bird populations.

We calculated national and state population trends via estimating equations (Link & Sauer 1994) using the web-based analytical tools provided by the Breeding Bird Survey (Sauer et al. 2004). This approach adjusts trend estimates for potential sources of variation by weighting individual routes based on variability of counts along that route, missing counts (years), and observer effects (Sauer et al. 2004). We calculated both national trends (continental US) and state-specific trends for each grassland bird species for two time periods:

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Table 1. CRP variables used in state trend vs. CRP regressions.

Variable Name	Variable Definition
Landscape Change Variables	
Δ Pasture	% Change in pastureland
Δ Cropland	% Change in cropland
Δ Forest	% Change in forestland
Δ Housing	% Change in housing density
CRP Variables (% of state land area)	
Total CRP	Total acres of CRP
Exotic Grass	Total CP1 plantings
Native Grass	Total CP2 plantings
Total Grass	Total acres of grass practices = CP1 + CP2 + CP10
Native Ratio	% of all grass plantings (CP1 + CP2) that are CP2
Grass Strips	Total acres of grassy strip practices
Woody Strips	Total acres of woody strip practices

(a) 1966 – 1986, the time period from the beginning of the BBS to the inception of the Conservation Reserve Program (hereafter referred to as pre-CRP); and (b) 1987 – 2003, the time period from the beginning of the CRP to the most recent available data (post-CRP). Although the CRP was officially initiated in 1985 through legislation, we used 1987 as the starting date because that is when the first CRP contracts (and hence the first land cover conversions) were planted. One potential problem is that BBS routes may have underrepresented some land cover types. While this may be true for some land cover types, BBS routes generally provide adequate representation across most environmental variables within states (Lawler & O'Conner 2004).

2.2 Landscape Change Variables

Because CRP variables could have been confounded with other landscape changes over the time period of the CRP, we calculated the rate of change from 1987 – 2002 for pasture (pastureland and rangeland), crops, forest, and housing density (Tab. 1) for each state using Census of Agriculture data (http://www.nass.usda.gov/Data_and_Statistics/index.asp). Our assumption is that these four variables would capture major landscape changes occurring in each state over that time period.

2.3 Conservation Reserve Program Variables

We used practice-specific summaries of contract acreage (as of 2004) from the USDA Farm Service Agency (USDA 2004) aggregated at the state level. We calculated several variables potentially relevant to the ecology and management of grassland songbirds in North America (Tab. 1). Total CRP was the % of total state land area enrolled in CRP (all practices) in 2004. Exotic Grass, Native Grass, and Total Grass were the % of each state's land area enrolled in CP1 (Introduced grasses and legumes – new plantings), CP2 (Native grasses and legumes – new plantings), and CP1 + CP2 + CP10 (Existing grasses and legumes), respectively. To represent the relative importance of native practices to state agencies (which actually administer the conservation practices), we also calculated Native Ratio, which was the % of all new grass plantings that were native (CP2 / [CP1 + CP2]). To address potential effects of linear strip habitat, we calculated two variables. Grass

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Strips was the % of each state's land area enrolled in grassy strip practices: CP8 (Grass waterways) + CP13A, C (Filter strips – grass) + CP15 (Contour grass strips) + CP21 (Filter strips). Woody Strips was the % of each state's land area enrolled in woody strip practices: CP4A, B (Wildlife habitat corridor) + CP5 (Field windbreaks) + CP13B, D (Filter strips – trees) + CP16 (Shelterbelts) + CP22 (Riparian buffers). Grass and woody strip practices are often established adjacent to each other (e.g., CP21 filter strips are often placed adjacent to CP22 riparian forest buffers). Because CRP data with this level of detail is not available, this could have confounded constrasts between grass strips and woody strips in unknown ways. However, our main objective is to contrast linear strip practices with other practices that are often established in large blocks (e.g., CP1 and CP2).

2.4 Statistical Analysis

I. **National trends**. We retained only those species with data available from at least 10 BBS routes in both time periods (Sauer et al. 2004). To test for possible effects of CRP on bird trends, we calculated the difference in national trends before (1966 – 1986) and after (1987 – 2003) the initiation of the CRP such that:

$$\Delta \text{ trend} = \text{trend}_{\text{post-CRP}} - \text{trend}_{\text{pre-CRP}}.$$

We standardized Δ trends by dividing the difference by the square root of the sum of the variances of the individual trends (Link & Sauer 1994). We considered any Δ trend with $|z| > 1.654$ ($\alpha < 0.10$) as significantly improved or worsened. We used a χ^2-square test of independence to determine if the distribution of trend changes was predominantly positive. To guard against high levels of Type II errors (not detecting real effects) that can occur with avian count data (Thompson & Schwalbach 1995), we used $\alpha < 0.10$ (rather than $\alpha <$ 0.05) for these and all other analyses we conducted (see Westmoreland & Best 1985).

II. State trends. Our motivation for conducting state-level analysis was to circumvent some inherent problems of relying solely on national trend changes (see above). First, even if other factors had caused significant negative changes in a national population trend, the magnitude of this change should be smaller in states with greater participation in CRP. Second, by using states as our sampling unit, we were able to partition CRP land cover into different cover types. Finally, although CRP only comprises approximately 2 – 3% of the United States' land area, 5 – 7% of many states are enrolled in the CRP (Fig. 2), which increases the potential for the CRP to produce observable effects (Herkert 1998) and less likely that CRP effects would be swamped by other factors (Peterjohn 2003).

We used individual states as the observational unit for these analyses. For each state, our dependent variable was the difference in population trend before and after the implementation of the CRP standardized to z-scores. We retained only those state-level species trends that were based on at least 10 routes (in a particular state) in both time periods and only those species for which we were able to calculate Δ trends in at least 10 states.

Using state Δ trends as a dependent variable, we first evaluated all models containing 1 – 4 of the landscape change variables to account for broad landscape change. For each bird species, we retained the model that explained the most variation in our dependent variable, with the criteria that all landscape change variables had $\alpha <$ 0.10. Then, we built a regression model for each grassland species where the state-level Δ trend (z-scores) for a particular species was regressed against each of our CRP variables separately (each model also contained the retained landscape change variables). Because of limited sample size, we were not able to examine models that contained multiple CRP variables (Morrison et al. 1998). CRP variables were retained in the model if $\alpha < 0.10$. We inspected bivariate plots to insure that statistical significance was not due to single data points. When multiple CRP variables were significant for an individual species, we present them as competing models and ranked them according to model R^2.

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3 Results

3.1 National Trends

We estimated national population trends for 28 obligate and 46 facultative grassland breeding birds (Fig. 2, Suppl. B). Twenty-eight percent of the obligate species improved ($z > 1.645$, $P < 0.10$) after the initiation of the CRP, and 18% worsened ($z < -1.645$, $P < 0.10$). Of the facultative species, 19% improved and 25% worsened. Proportions of improving species did not differ from the proportion of worsening species, nor did the proportion of improving species differ between obligate and facultative species (P = 0.372 – 0.572).

3.2 State-level Trends

I. **Landscape change variables.** Eighteen species were related to landscape change variables, and these relations were primarily positive for cropland, pasture, and forest (Tab. 2; Suppl. C). Change in pasture was positively related to change in trends Bobolink, Turkey Vulture, Western Kingbird, Common Yellowthroat, and Brewer's Blackbird, but negatively related to Upland Sandpiper and Horned Lark (scientific names listed in Suppl. B). Change in cropland was positively related to change in trends of American Kestrel, Ring-necked Pheasant, Mourning Dove, Loggerhead Shrike and negatively related to only Savannah Sparrow. Change in forest was positively related to American Kestrel, Red-winged Blackbird, and Brown-headed Cowbird and negatively related to only Killdeer. In contrast, change in housing density was negatively related to Western Meadowlark, Turkey Vulture, Killdeer, Loggerhead Shrike, and Red-winged Blackbird, but positively related to only Common Nighthawk (Tab. 2; Suppl. C).

II. CRP relations. We analyzed the relationship between state Δ trends and CRP variables for 31 species, and this resulted in 217 regression models (summary in Tab. 3, details in Suppl. C). Eight species were positively related to CRP variables, whereas 6 species were negatively related to CRP variables. Two species were positively related to some CRP variables but negatively related to other CRP variables. Only Horned Lark was related to Total CRP. All others were related to more specific descriptions of practice (habitat) type and/or configuration.

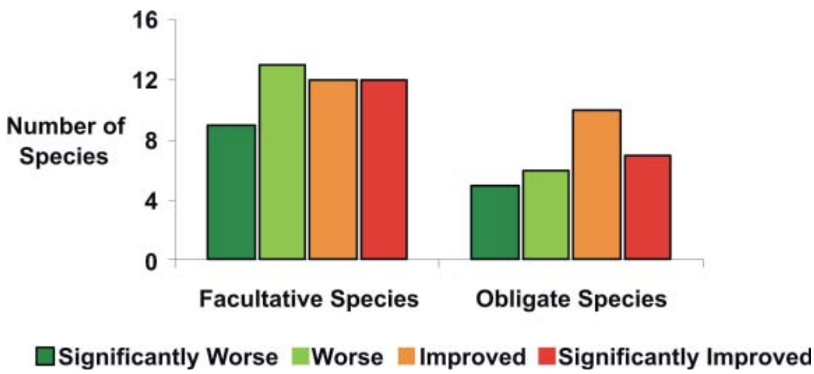

Figure 2. Summary of changes (Δ trend) in national Breeding Bird Survey (BBS) trends following the start of the Conservation Reserve Program (CRP) for 28 obligate and 46 facultative grassland species in the conterminous United States.

Table 2. Summary of bird relations with landscape change variables.

Landscape Variable	# of positive relations	# of negative relations
Δ Pasture	5	2
Δ Cropland	4	1
Δ Forest	3	1
Δ Housing	1	5

4 Discussion

4.1 National Trends

Approximately the same number of grassland birds had national trends that worsened post-CRP (25%) as had improving trends (25%). This suggests that at the national scale, habitat created by CRP may benefit some species whereas other species may suffer as agricultural lands are taken out of production. We caution, however, that negative changes in the national trends after initiation of the CRP do not necessarily indicate a lack of CRP benefits, nor do positive changes necessarily indicate widespread benefits. Changes in national trends (which lack controls) may be confounded with other factors. For example, processes on a migratory species' wintering ground or changes in climate (Sauer & Droege 1990, Igl & Johnson 1999) may cause changes in the national population trend that override, mask, or confound effects of CRP. Thus, factors other than CRP and agricultural land-use changes may be responsible for some national trends despite demonstrable benefits of CRP at smaller scales.

Interpretation of national trend changes is further complicated because offsetting effects in state-to-state differences in the primary CRP practices may "cancel out" locally positive and negative effects. In our results, Eastern Meadowlark and Eastern Kingbird suggest this very phenomenon (Suppl. C). Both species exhibited worsening national trends but were positively related to one or more CRP variables in our state-level analyses. These species exhibited worsening national trends (accelerated declines) after initiation of the CRP. However, this was likely caused by unmeasured factor(s) because the change in trend was most negative in states with little land in the CRP. So, these worsening national declines might be mitigated in states with greater participation in CRP.

4.2 State-level Trends

I. **Landscape change variables.** We included landscape change variables primarily to account for variation due to landscape change to improve our ability to detect bird-CRP relations, and an indepth discussion of these relations is beyond the scope of this paper. However, the relations we observed with landscape change variables were generally consistent with what is know about the species' ecology. Relations with changes in cropland, pasture, and forest were primarily positive, reflecting species responding favorably to an increase in habitat. For example, species with an affinity for pasture like Upland Sandpiper (Houston & Bowen 2001) were positively related to pasture, and species with an affinity for croplands like Mourning Dove (Ryan et al. 1998) were positively related to cropland (presumably because of food resources). Relations with change in housing density were primarily negative, further underscoring the negative impacts of urban development on birds in agricultural landscapes (e.g., Bock et al. 1999). The only exception was Common Nighthawk, which has a known affinity for urban habitats (Poulin et al. 1996).

II. General CRP relations. Eight species were positively associated with state-level CRP variables (Tab. 3, first column from left), and these species nest in grass-

Table 3. Summary of national trend changes (pre- vs. post-CRP) and state-level relationships to CRP variables for species that were involved in the state-level analyses.

State trends + related to CRP variables	State trends + & related to CRP variables	State trends - related to CRP variables	No relations
Species with improving national trends			
Northern Harrier Bobolink	---	Savannah Sparrow Lark Sparrow	Dickcissel Eastern Bluebird Turkey Vulture Red-winged Blackbird
Species with worsening national trends			
American Kestrel Eastern Meadowlark Eastern Kingbird Common Nighthawk	---	Horned Lark Killdeer	Northern Bobwhite Upland Sandpiper Wilson's Snipe Cattle Egret Western Kingbird
Species with constant national trends			
Mourning Dove Western Meadowlark	Mallard Swainson's Hawk	Loggerhead Shrike Say's Phoebe	Ring-necked Pheasant Grasshopper Sparrow Common Yellowthroat Vesper Sparrow Brewer's Blackbird Brown-headed Cowbird

lands or other open habitats. Other studies corroborate benefit of CRP for Mourning Dove, Eastern/Western Meadowlark, and Bobolink (Reynolds et al. 1994, Johnson & Igl 1995, Patterson & Best 1996, Best et al. 1997, Herkert 1997, Ryan et al. 1998). The habitat relations of Northern Harrier, American Kestrel, and Common Nighthawk, and Eastern Kingbird relative to CRP habitats have not, to our knowledge, been previously investigated, although plausible mechanisms exist. For example, for Northern Harrier and American Kestrel, CRP may provide additional nesting and/or foraging habitat in agriculture- and grassland-dominated landscapes. However, further research is needed to corroborate and understand how the CRP benefits these species.

Six species were negatively associated with state-level CRP variables. Of these species, Horned Lark and Killdeer nest in cultivated fields or in very short-grass habitats with patches of open, bare ground. Others have documented their preference for cultivated lands (see Best et al. 1997, Ryan et al. 1998, Hohman & Halloum 2000 for reviews) and heavily grazed habitats (Saab et al. 1995, Ryan et al. 1998). Thus, as CRP takes fields out of production, these species may lose habitat. Say's Phoebe may also prefer grazed habitats (Saab 1995) over CRP habitat. This is not a serious conservation concern in North America because these species expanded their ranges during the agricultural intensification of the last century, which occurred at the expense of other grassland birds. Other species were negatively related to configuration variables (e.g., Savannah Sparrow and Lark Sparrow), which we discuss below.

Two species were both positively and negatively related to CRP variables. Swainson's Hawks were positively related to native grasses but negatively related to exotic grasses (Tab. 3, Suppl. C). In contrast, Mallard was negatively related to native grasses but positively related to exotic grasses. These species especially illustrate the importance of not lumping all CRP habitat into one cover type.

III. Importance of CRP cover type. Generally, native grass practices were more likely to be associated with more positive (or less negative) trends of grassland birds than were exotic grass practices (Suppl. C). Northern Harrier, Swainson's Hawk, Bobolink, and Mourning Dove were related to the ratio of native to exotic grass, indicating that they benefited from an emphasis on native grass practices in a given state. A potential explanation for the two raptors is that native grass plantings typically provide a variable canopy and vegetative structure that supports more abundant small prey compared to exotic grass (CP1) fields (Burger et al. 1990). This canopy structure may also facilitate foraging by Bobolink and Mourning Dove. In contrast, Mallard and Loggerhead Shrike were negatively related to native grasses. High breeding success in exotic grass plantings has been documented for Mallard (Kantrud 1993), but the relation with Loggerhead Shrike is more difficult to explain. Potentially, native grass practices are correlated with less woody cover, which the shrikes use for perching and nesting.

Clearly, treating all CRP-enrolled land as a single, distinct habitat type may be inappropriate. Not all practices create equivalent (or even appropriate) habitat for all species. If all CRP practices are grouped into one variable, many cover- or practice-specific effects of CRP may go undetected. For example, Swainson's Hawks were positively related to the amount of native grass (CP2) but negatively related to the amount of exotic grass (CP1) in a state. Had we lumped these two types of CRP habitat, we may not have detected these relations. Understanding and evaluating the effects of CRP on grassland birds requires considering the effects of specific practices in the context of species-specific habitat requirements of grassland birds. However, combining all CRP practices may be appropriate for species that respond negatively (e.g., Horned Lark) because they respond to the loss of preferred cultivated and/or grazed habitats caused by participation in the CRP, rather than to the CRP cover type per se. Regardless of the CRP practice implemented, it is still lost habitat for this group of birds.

IV. Importance of configuration. Our results suggest that ignoring configuration of habitats can also obscure bird-CRP relations. Although we were not able to describe fine detail about the configuration of CRP habitat (i.e., mean patch size, distance to nearest neighbor, etc.), we were able to construct two variables that represented linear habitat – grass strips and woody strips. Consistent with our expectations, two area-sensitive species – Savannah Sparrow (Herkert 1994) and Lark Sparrow (Coppedge et al. 2001) – were negatively related to both grass and woody strips (Tab. 3, Suppl. C). Presumably, these species were responding to the increased edge and fragmenation that these types of practices (shelterbreaks, grassed waterways, riparian buffers, etc.) create. Conversely, species that use use woody vegetation for singing perches, nesting substrate. or foraging (e.g., Eastern Kingbird, American Kestrel, Mourning Dove; see Suppl. C) were positively associated with strip practices. Thus, CRP practices that involve linear habitats (i.e., shelterbelts) may improve habitat for these species, but habitat quality for these species may be reduced in areas where CRP is mostly comprised of blocks of grass.

V. Conservation Implications. Lumping all CRP habitat into one habitat has likely limited our understanding of how CRP influences grassland species. We observed many more relations with practice- and configuration-specific measures of CRP habitat than with a generic metric of CRP. Although our analysis was correlative (and involved small sample sizes for some species), our results suggest several ideas that should be tested at a variety of spatial scales. First, native grass practices may be generally more positively related to grassland birds than are exotic grasses. Second, linear strips (vs. block habitats) may benefit some birds, but negatively impact others. Investigations into the effects of configuration should strive to further quantify the configuration of CRP habitat, including clumpiness, mean patch size, and other important landscape metrics. Finally, our results underscore that government-

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subsidized set-aside programs may not be a panacea for all grassland birds because this group of species includes a variety of life-histories and habitat requirements, and the set-aside programs themselves (e.g. CRP, agri-environment schemes) themselves often include a variety of land-cover types. Rather, set-aside programs should be used as part of a comprehensive, regional conservation strategy that strives to create a mosaic of different habitat types and configurations (i.e., a mosaic of large and small patches) in agricultural landscapes.

5 So what can broad-scale trends really tell us?

When consistent with results from smaller-scale studies, changes broad-scale trends corroborate and add to the weight of existing evidence. When these national trends are consistent with our analyses at the state level and with a body of research at landscape-, farm-, and field-scales (e.g., Best et al. 1995, Patterson & Best 1996, Ryan et al. 1998, Hohman & Halloum 2000), we gain confidence in the conclusions about how CRP set-aside habitat affects these species. However, without corroborating evidence at other scales, changes in broad-scale trends are not reliable evidence for effects of CRP (or lack thereof) on grassland birds because of variation in responses at local scales and confounding with other aspects of environmental change. Although we accounted for some variation due to other changes in the landscape, CRP participation could still be correlated (and hence confounded with) other changes in the landscape that we did not measure. Cause and effect relationships can only be deduced through replicated experiments using data about abundance, breeding success, and population responses at a variety of scales (field, farm, landscape, regional, and national). Thus, large-scale analyses are insufficient by themselves to accurately evaluate the mechanistic effects of CRP on grassland birds (Manel et al. 2000).

A serious limitation to relating broad-scale trends to landscape changes caused by government set-aside programs is that available datasets are not sufficient to model more complex relationships among grassland birds, CRP characteristics and distribution, and other environmental factors. We incorporated more complexity in our analyses than other studies by looking at cover-specific variables, but there are many other factors which could possibly influence grassland birds:

- Over the duration of a CRP contract, ecological succession can affect the suitability of a particular CRP tract for grassland bird species (Millenbah et al. 1996, Coppedge et al. 2001, McCoy et al. 2001b). Thus, management of set-aside lands over the course of a 10- or 15-yr contract can affect the quality of a particular tract for grassland birds (e.g., stripdisking for Northern Bobwhite [Greenfield et al. 2003]).
- Field size is variable, and grassland birds will likely have higher breeding success in large set-aside fields compared to smaller fields (Herkert et al. 2003).
- Landscape context may influence the ability of a particular set-aside tract to provide population benefits. Isolated tracts may have lower nesting density (e.g., Herkert et al. 2003) or nesting success, while clustering tracts together may increase their benefits (e.g., Parkhurst et al. 2002).
- Thresholds may exist. For example, Riley (1995) found that CRP benefited Ring-necked Pheasant only when the amount of cropland in the surrounding landscape was > 50%. Similarly, Herkert (1998) found that Grasshopper Sparrow population trends increased in landscapes with > 3.8 % CRP.
- In a given landscape or region, a suite of these factors may influence how set-aside does (or does not) benefit grassland birds, and fully understanding the effects of set-aside requires that they all be investigated.

Despite these substantial drawbacks, broad-scale evaluations of set-aside programs should continue because broad-scale questions are often politically and socially important to answer and because broad-scale effects can further support conclusions from manipulative experiments conducted at smaller scales. A major hurdle is that the practice-specific, spatially explicit data these analyses would require are not readily available for large regions. Future evaluation of the CRP and other set-aside programs should include smaller, more fo-

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cused studies until detailed, spatially explicit data are available for large-scale analyses (Manel et al. 2000). We encourage scientists conducting research on grassland birds in set-aside to use standard techniques and methodology to facilitate the future use of meta-analysis (e.g., Arnqvist & Wooster 1995) to further explore and understand large-scale effects of CRP on grassland birds.

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Supplement A. List of available conservation practices in the Conservation Reserve Program from 1986 - 2004.

Code	Description	Code	Description
CP1	Introduced Grasses	CP16, 16A	Shelterbelts
CP2	Native Grasses	CP17, 17A	Living Snow Fences
CP3	Softwood Tree Planting	CP18, 18B	Salinity Reducing Vegetation
CP3A	Hardwood Tree Planting	CP18A, 18C	Salt Tolerant Vegetation
CP4, 4D	Wildlife Habitat	CP19	Alley Cropping
CP4A,4B	Wildlife Habitat Corridor	CP20	Alternative Perennials
CP5, 5A	Field Windbreaks	CP21	Filter Strips
CP6	Diversions	CP22	Riparian Buffers
CP7	Erosion Control Structures	CP23, 23A	Wetland Restoration
CP8, 8A	Grass Waterways	CP24	Cross Wind Trap Strips
CP9	Wildlife Water	CP25	Rare and Declining Habitat
CP10	Established Grass	CP26	Sediment Retention Structures
CP11	Established Trees	CP27	Farmable Wetlands - Wetland
CP12	Wildlife Food Plot	CP28	Farmable Wetlands - Upland Buffer
CP13A, 13C	Filter Strips - Grass	CP29	Marginal Pasture - Wildlife Buffer
CP13B, 13D	Filter Strips - Trees	CP30	Marginal Pasture - Wetland Buffer
CP14	Wetland Trees	CP31	Bottomland Hardwood Trees
CP15, 15 A	Contour Grass Strips	Cp32	Expired Hardwood Tree Contracts
CP15 B	Contour Grass Terrace	CP33	Upland Bird Habitat Buffers

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Supplement B. Change in national trend of grassland breeding birds (obligate and facultative species) before and after initiation of the Conservation Reserve Program (CRP).

Common Name	Δ trend	*z*-score	P < 0.10
Obligate Grassland Breeding Birds			
Northern Harrier (*Circus cyaneus*)	2.20	2.42	Improving
Swainson's Hawk (*Buteo swainsoni*)	-1.19	-0.88	
Ferruginous Hawk (*Buteo regalis*)	-0.57	-0.30	
Sharp-tailed Grouse (*Tympanuchus phasianellus*)	-7.48	-1.36	
Greater Prairie Chicken (*Tympanuchus cupido*)	-8.17	-0.72	
Mountain Plover (*Charadrius montanus*)	6.92	0.78	
Upland Sandpiper (*Bartramia longicauda*)	-4.87	-4.99	Worsening
Long-billed Curlew (*Numenius americanus*)	-0.15	-0.07	
Marbled Godwit (*Limosa fedoa*)	0.34	0.11	
Burrowing Owl (*Athene cunicularia*)	5.06	1.54	
Short-eared Owl (*Asio flammeus*)	-16.72	-4.10	Worsening
Horned Lark (*Eremophila alpestris*)	-3.02	-4.77	Worsening
Sedge Wren (*Cistothorus platensis*)	-1.47	-0.80	
Sprague's Pipit (*Anthus spragueñ)*	-0.85	-0.16	
Bachman's Sparrow (*Aimophila aestivalis*)	0.61	0.20	
Vesper Sparrow (*Pooecetes gramineus*)	-0.02	-0.04	
Lark Bunting (*Calamospiza melanocorys*)	-0.17	-0.15	
Savannah Sparrow (*Passerculus sandwichensis*)	1.16	2.07	Improving
Grasshopper Sparrow (*Ammodramus savannarum*)	-0.30	-0.26	
Baird's Sparrow (*Ammodramus bairdii*)	-5.99	-1.94	Worsening
Henslow's Sparrow (*Ammodramus henslowii*)	6.12	1.71	Improving
Le Conte's Sparrow (*Ammodramus leconteii*)	4.97	0.78	
McCown's Longspur (*Calcarius mccownii*)	-5.84	-1.98	Worsening
Chestnut-collared. Longspur (*Calcarius ornatus*)	-3.09	-1.70	Worsening
Dickcissel (*Spiza Americana*)	1.69	2.88	Improving
Bobolink *Dolichonyx oryzivorus*)	1.63	2.32	Improving
Eastern Meadowlark (*Sturnella magna*)	-1.32	-3.52	Worsening
Western Meadowlark (*Sturnella neglecta*)	-0.25	-0.51	

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Supplement B. Continued.

Common Name	Δ trend	*z*-score	P < 0.10
Facultative Grassland Breeding Birds			
American Bittern (*Botaurus lentiginosus*)	4.33	2.05	Improving
Cattle Egret (*Bubulcus ibis*)	-5.26	-3.97	Worsening
Turkey Vulture (*Cathartes aura*)	1.62	2.43	Improving
Canada Goose (*Branta canadensis*)	-3.19	-1.30	
Gadwall (*Anas strepera*)	5.66	1.26	
American Widgeon (*Anas americana*)	2.08	0.74	
Mallard (*Anas platyrhynchos*)	0.52	0.48	
Blue-winged Teal (*Anas discors*)	7.69	3.71	Improving
Northern Shoveler (*Anas clypeata*)	14.36	1.16	
Northern Pintail (*Anas acuta*)	2.19	0.71	
Green-winged Teal (*Anas crecca*)	7.38	1.07	
American Kestrel (*Falco sparverius*)	-2.08	-3.03	Worsening
Prairie Falcon (*Falco mexicanus*)	0.85	0.23	
Gray Partridge (*Perdix perdix*)	-16.24	-4.64	Worsening
Ring-necked Pheasant (*Phasianus colchicus*)	0.23	0.41	
Northern Bobwhite (*Colinus virginianus*)	-3.45	-10.70	Worsening
Sandhill Crane (*Grus canadensis*)	-2.84	-1.29	
Killdeer (*Charadrius vociferous*)	-1.86	-5.98	Worsening
Willet (*Catoptrophorus semipalmatus*)	-2.40	-1.60	
Wilson's Snipe (*Gallinago gallinago)*	-2.53	-2.73	Worsening
Wilson's Phalarope (*Phalaropus tricolor*)	1.74	0.32	
Franklin's Gull (*Larus pipixcan*)	81.08	1.68	Improving
Mourning Dove (*Zenaida macroura*)	-0.14	-0.56	
Barn Owl (*Tyto alba*)	-10.27	-2.76	Worsening
Common Nighthawk (*Chordeiles minor*)	-3.66	-4.51	Worsening
Common Poorwill (*Phalaenoptilus nuttallii*)	-8.71	-2.54	Worsening
Say's Phoebe (*Sayornis saya*)	-0.92	-0.88	
Ash-throated Flycatcher (*Myiarchus cinerascens*)	-0.37	-0.56	
Cassin's Kingbird (*Tyrannus vociferans*)	2.07	1.11	
Western Kingbird (*Tyrannus verticalis*)	-1.37	-2.46	Worsening
Eastern Kingbird (*Tyrannus tyrannus*)	-1.58	-4.01	Worsening

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Supplement B. Continued.

Common Name	Δ trend	*z*-score	P < 0.10
Scissor-tailed Flycatcher (*Tyrannus forficatusr*)	0.47	0.71	
Loggerhead Shrike (*Lanius ludovicianus*)	0.28	0.40	
Chihuahuan Raven (*Corvus cryptoleucus*)	2.76	0.89	
Eastern Bluebird (*Sialia sialis*)	1.13	1.90	Improving
Western Bluebird (*Sialia mexicana*)	-0.14	-0.10	
Mountain Bluebird (*Sialia currucoides*)	2.00	0.66	
Common Yellowthroat (*Geothlypis trichas*)	-0.37	-1.46	
Canyon Towhee (*Pipilo fuscus*)	1.33	0.89	
Rufous-crowned Sparrow (*Aimophila ruficeps*)	-2.23	-1.33	
Clay-colored Sparrow (*Spizella pallida*)	5.37	4.55	Improving
Lark Sparrow (*Chondestes grammacus*)	2.69	3.73	Improving
Red-winged Blackbird (*Agelaius phoeniceus*)	0.65	2.24	Improving
Brewer's Blackbird (*Euphagus cyanocephalus*)	-0.57	-0.81	
Bronzed Cowbird (*Molothrus aeneus*)	-12.24	-3.72	Worsening
Brown-headed Cowbird (*Molothrus ater*)	-0.46	-1.45	

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Supplement C. Relations between CRP variables and change in state-level trends of grassland breeding birds (obligate and facultative species) before and after initiation of the CRP.

Common Name	N	Model	R^2
Obligate Grassland Breeding Birds			
Northern Harrier	15	– 5.35 + 0.16 Native Ratio*	0.21
Swainson's Hawk	10	– 18.54 + 0.19 Native Ratio****	0.90
		– 11.90 + 9.37 Native Grass**	0.42
		– 30.24 – 0.29 Exotic Grass*	0.32
Upland Sandpiper	11	– 8.15 –1.72 ΔPasture ***	0.62
Horned Lark	31	0.50 – 1.00 ΔPasture – 1.36 Total CRP**	0.25
		1.40 – 0.73 ΔPasture – 2.00 Total Grass**	0.25
		– 1.81 – 1.45 ΔPasture ** – 7.42 Exotic Grass*	0.22
Vesper Sparrow	18	No significant variables	---
Savannah Sparrow	19	0.11 – 6.37 ΔCropland* – 11.56 Grass Strips*	0.41
		– 0.17 – 7.32 ΔCropland ** – 28.77 Woody Strips*	0.37
Grasshopper Sparrow	26	No significant variables	---
Dickcissel	18	No significant variables	---
Bobolink	17	2.55 + 1.19 ΔPasture ** + 0.11 Native Ratio***	0.75
Eastern Meadowlark	34	– 0.45 + 5.47 Grass Strip*	0.10
Western Meadowlark	22	1.78 – 1.06 Housing Change** + 22.23 Woody Strips*	0.47
Facultative Grassland Breeding Birds			
Cattle Egret	10	No significant CRP variables	---
Turkey Vulture	30	9.68 + 2.52 ΔPasture * – 1.73 ΔHousing **	0.18
Mallard	24	– 2.75 + 11.44 Exotic Grass**	0.19
		4.09 – 0.11 Native Ratio**	0.18
American Kestrel	34	– 3.61 + 4.42 ΔCropland ** + 1.10 ΔForest * + 26.64 Woody Strips**	0.33
Ring-necked Pheasant	23	1.29 + 4.84 ΔCropland *	0.15
Northern Bobwhite	27	No significant CRP variables	---
Killdeer	45	0.03 – 0.71ΔForest ** - 0.89 ΔHousing **** – 0.03 Total Grass*	0.33
Wilson's Snip e	14	No significant variables	---
Mourning Dove	46	– 0.81 + 1.27 ΔCropland * + 5.36 Grassy Strips**	0.17
		– 1.67 + 0.90 ΔCropland + 0.03 Native Ratio**	0.16
		– 0.77 + 1.57 ΔCropland ** + 9.84 Woody Strips*	0.15
Common Nighthawk	22	– 5.62 + 1.08 ΔHousing *** + 31.06 Grassy Strips**	0.38
Western Kingbird	16	0.21 + 1.68 ΔPasture *	0.22
Eastern Kingbird	38	– 1.80 + 14.42 Woody Strips*	0.08
Say's Phoebe	11	– 0.13 - 12.72 Exotic Grass**	0.37

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Supplement C. Continued.

Common Name	N	Model	R^2
Loggerhead Shrike	27	4.01 + 3.60 ΔCropland ** – 1.29 ΔHousing *** – 5.42 Native Grass**	0.45
Eastern Bluebird	28	No significant variables	---
Common Yellowthroat	40	2.61 + 0.75 ΔPasture *	0.07
Lark Sparrow	17	2.97 – 66.61 Woody Strips***	0.11
		1.93 – 31.90 Grassy Strips**	0.11
Red-winged Blackbird	45	0.19 + 0.58 ΔForest * - 0.83 ΔHousing**	0.21
Brewer's Blackbird	13	0.11 + 1.56 ΔPasture **	0.34
Brown-headed Cowbird	43	– 2.23 + 0.79 ΔForest**	0.10

* $P < 0.10$; **$P < 0.05$; ***$P < 0.01$; ****$P < 0.001$.

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