Trends in Important Bird Habitats of the Playa Lakes Joint Venture Region: A Synthesis of the Literature and Expert Knowledge

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Front cover photo: A dryland cropping system of wheat-corn-fallow in Sterling, Colorado. Photo originally appeared in Peterson et al. (2002; see Literature Cited and Additional References section for full citation).

EXECUTIVE SUMMARY

To enhance avian conservation planning, the Playa Lakes Joint Venture (PLJV) seeks to understand changes in land use that affect avian habitats. Literature searches and interviews with land-use experts reveal several recent changes affecting, or potentially affecting, the amount and/or characteristics of avian habitats in the PLJV. The land-use change currently affecting the greatest area of cropland habitat is the intensification of crop production in dryland cropping systems. Traditionally, these systems entailed planting one wheat crop every two years (i.e. a 2-year wheat-fallow rotation). Economics, however, are driving farmers to grow dryland corn or other row crops between wheat crops, thus intensifying production within the same 2-year period. In some cases, crop rotations are lengthened to produce more crops (e.g., wheat-corn-forage hay-fallow) between fallow periods. As a result, acreages of fallow and winter wheat are decreasing, and land-management regimes are changing (e.g., greater reliance on herbicides). In turn, spatio-temporal distributions and types of avian cover and food resources are changing. In addition, various factors are driving irrigation farmers into dryland farming, thereby diminishing food and cover provided by irrigated crops and semi-permanent wetlands sustained by irrigation runoff. Within the Conservation Reserve Program (CRP), acreage of native (reintroduced) grasses and forbs is increasing, albeit limited by the long intervals between CRP signup periods, the difficulty and cost of removing non-native plantings, and the fact that many PLJV counties have reached their cap on CRP acreage. Few acres of previously untilled grassland or shrubland are being converted to cropland, primarily because most of the PLJV region's arable land is already in crop production. However, changing land uses continue to fragment and degrade both grasslands and shrublands. Changing land ownerships due to recreation real estate sales are a concern—especially in the southern PLJV region, where large ranches are being broken up. In turn, there may be changes in land management that promote woody vegetation and other fragmenting processes. Invasive species, as well as infrastructures and activities associated with growth in the energy industry, also continue to fragment and degrade both grassland and wetland habitats in the PLJV region. An Extended Summary of trends in the PLJV region follows.

EXTENDED SUMMARY

AGRICULTURAL HABITATS

- Since the mid-1970s, cropland increased by ~3 million acres, although that figure does not account for CRP acreage; most arable land in PLJV states, however, has been cultivated and conversion is now rare.

- Economics and development of drought- and herbicide-tolerant crops are driving production intensification in dryland cropping systems. Conservation of soil and soil moisture encourage conservation tillage that may diminish nest failure and chick mortality, but they also encourage increasing reliance on herbicides, which is reducing cover and food resources for granivores and insectivores.

- Winter wheat (see Appendix 1 for scientific names of organisms used in this document) and wheat fallow croplands are decreasing (fallow reduced $\geq$3 months/2-year rotation), and stubble height of wheat in fallow is decreasing. Loss of winter wheat may be having negative impacts on migrating/overwintering waterfowl that forage on sprouting wheat, and decreasing stubble height is diminishing winter cover. Loss of fallow may be negatively impacting spring migrants, nesting grassland birds, and overwintering birds.

- Most secondary crops used to intensify production between wheat crops in dryland rotations are increasing (especially corn, sorghum, and soybeans, but also sunflower and other oilseeds, cotton, specialty grains, peanuts, and forage hays)—most likely replacing wheat and wheat fallow. Soybean production in the mixed grass region of Kansas quadrupled from 1980-2000. Cranes and waterfowl avoid foraging in soybean croplands; the same is probably true for other avian species. Although oilseed sunflower is consumed by many avian species during fall migration, sunflower stubble provides poor cover.

- From 1978 to 1998, post-harvest waste corn in fallow fields of the central Platte River valley in Nebraska decreased by nearly half due to improvements in machinery and altered crop genetics (e.g., shorter wheat), diminishing food resources for migrating waterfowl and cranes.

- Irrigated croplands are decreasing (1-million acre decline in PLJV states from mid-1990s to 2002), particularly corn and other cereal grains, possibly reducing overall food resources for migrating/wintering waterfowl and cranes. Decreases in irrigated cropland are greatest in the Southern High Plains, northeastern Colorado, and sw. Nebraska. Previously irrigated cropland may be converted back to intensive dryland farming, grassland (ranchland, CRP), or pasture.

- Since the mid-1980s, the greatest overall change in agricultural land use has been the enrollment of croplands in the CRP. From 2001-2004, CRP acreage in the PLJV states increased nearly 1 million acres; however, many PLJV counties have reached their 25% cap on CRP enrollment.

- Possible funding cuts and/or changes to the Environmental Benefits Index could result in lower prices paid per acre and fewer acres eligible for re-enrollment/first-time enrollment in CRP. In Kansas, 33-50% of original CRP enrollees have reverted back to rangeland or hay cropping when their contracts expired; contracts for 6.8 million acres of CRP in the PLJV states are due to expire in 2007.

- Monocultures of introduced grasses and/or vegetation that has become rank/invaded by woody vegetation or invasives in CRP are having negligible or even negative impacts on some species; in PLJV states, however, CRP plantings have been predominantly native species, and many grassland birds benefit from CRP. Sericea lespedeza is invading unmanaged CRP habitats in parts of Kansas.

- Direct avian mortality due to insecticides is declining, largely due to integrated pest management techniques and safer products; however, manufacturers rapidly develop new products, making it difficult to predict future insecticide types, uses, or environmental impacts.

- By the mid-1990s, herbicides used to control weeds in corn fields composed 47% of all agricultural pesticides used in the U.S. Atrazine (commonly used in corn fields) has been linked to demasculinization in frogs, and recent research links glyphosates with significant amphibian mortality; effects on avian survivorship and productivity, however, remain unknown. Use of atrazine and glyphosates continues in the PLJV—glyphosates are increasing as crops are genetically engineered to tolerate this chemical.

- Urban/ex-urban growth is subsuming cropland around major urban centers/corridors and along interstate corridors as aging or economically stressed farmers sell their land for 'ranchette' development; this is resulting in fragmentation of remaining croplands.

GRASSLAND HABITATS

- Primarily due to cropland conversion, Texas has lost >79% of its shortgrass and >30% of its mixed grass habitat; Colorado has lost 59% of its shortgrass habitat; Kansas has lost >48% of its [primarily] grassland; overall, rangeland of the PLJV states decreased by 5.04 million acres from 1982-1997.

- The condition of many remaining grasslands continues to deteriorate due to infrastructure development (communications towers, petroleum well pads, powerlines, wind farms, etc.), overgrazing, fire suppression, invasions of exotic species (or unsuppressed native species), including eastern red cedar and species of mesquite. Grassland birds (gallinaceous birds, raptors, songbirds) can be negatively impacted by the habitat degradation and fragmentation caused by these factors, particularly area sensitive species and/or those that avoid anthropogenic/vertical structures.

- Shortgrass prairie is considered relatively resistant to invasive species; however, yellow sweetclover, Japanese brome, downy brome, and hoary cress can form significant stands in PLJV grasslands and exclude native plant species that provide important grassland bird habitat.

- Many ranchlands (primarily grasslands) in/around major river corridors are being sold for hunting recreation, particularly in/near the Canadian, Red, Arkansas, and Platte river drainage systems. Changes in land ownership are resulting in habitat fragmentation as new landowners develop infrastructures and allow encroachment of woody vegetation to benefit game species. Many ranchers still holding onto their lands are also allowing brush to encroach on 30-40% of their land so they can attract hunters willing to pay for access to their land.

- Urban/ex-urban growth is subsuming significant acreage of grassland/rangeland around major urban centers/corridors and along interstate corridors, especially within 100 miles (east) of the Colorado Front Range.

- Increasing prices for cattle have improved the outlook for ranchers. However, most Farm Bill provisions do not benefit to ranchers; the Grassland Reserve Program has had negligible appropriations (no improvement predicted), and the Sodbuster provision has been relatively ineffective at discouraging landowners from tilling native grassland.

- Management of existing rangelands is improving through reduced overgrazing, post-grazing recovery, and patch burning/grazing (where burning is practical) to create shifting mosaics of habitat that may benefit the lesser prairie-chicken, mountain plover, killdeer, upland sandpiper, chestnut-collared longspur, and other shortgrass/mixed grassland species.

SHRUBLAND HABITATS

- Shinnery oak and sand sagebrush are declining due to herbicidal and mechanical control, cropland conversion, and overgrazing; 27% of the original sand sagebrush habitat has been lost in the Kansas counties of Finney, Kearny, and Hamilton.

- Nesting success and/or population densities of lesser prairie-chicken, northern bobwhite, scaled quail, Brewer's sparrow, and other shrub-steppe passerines are declining where reductions of sand sagebrush, shinnery oak, and/or shrubland understories of forbs and grasses have been significant (>50-80%). In some local areas, sand sagebrush and shinnery oak have become too dense and/or tall to provide suitable habitat for grassland birds.

- Fragmentation/degradation of remaining shinnery oak and sand sagebrush habitats continue. Infrastructures associated with Energy development/extraction are fragmenting/degrading shrubland habitats in southeastern New Mexico, the Texas and Oklahoma panhandles, and eastern Colorado; more development has been proposed for western Kansas and eastern Colorado. Rising fuel prices may result in redeveloping New Mexico oil/gas fields previously considered 'dry.' Most proposals/reports of impacts from energy developments address only direct impacts of infrastructures, but the fragmented area is much greater.

- Most PLJV areas with high potential for oil/gas development overlap some part of the lesser prairie-chicken's range. Prairie-chicken populations are negatively impacted by fragmentation, vertical structures, and general changes in the landscape; nesting success is lower where buffer distances between nesting habitat and anthropogenic structures are <0.62 mi (1 km).

- Avian collisions with wind turbines have been reduced due to changes in turbine technology and siting guidelines, but collisions still occur, and raptors, prairie grouse, and other area-sensitive and open-country species may avoid vertical structures in their habitats. The U.S. Fish and Wildlife Service recommends a 5-mile buffer between prairie grouse leks and wind turbines.

AQUATIC HABITATS

- 'Wet outside pit' and 'wet pit only' playa habitats are decreasing (exception: wet outside pit playas are stable in New Mexico), primarily due to siltation, tillage, modification, overgrazing, and declines in irrigation. At least locally, waterfowl are decreasing as playas dry up. Many remaining playas may have significantly diminished water-holding capability due to sedimentation (particularly playas embedded in croplands); this may have been exacerbated by the recent drought, during which macropores may have formed in many playa basins.

- River channels, warmwater sloughs, and floodplain marshes are decreasing due to dewatering and invasions of exotic plants, especially saltcedar and Russian olive. Significant saltcedar infestation has reduced native riverine habitat in the Arkansas, Cimarron, and Platte river drainages; the Pecos River drainage on the PLJV's southwestern border is heavily infested as well. Saltcedar is also invading moist pastures, grasslands, CRP, and other upland habitats that accumulate precipitation runoff and have high water tables. Irrigation ditches are contributing to saltcedar's range expansion, as it easily sprouts from root fragments carried downstream during floods. Russian olive is most common in riparian areas, but it is also invading uplands, including CRP fields where control of woody vegetation is lacking. Eastern red cedar is invading riparian corridors as well as grasslands.

- In Colorado, the area infested by saltcedar and Russian olive is estimated at 42,000 and 15,000 acres, respectively. (The estimated amount of water used by that much saltcedar and Russian olive is 170,000 acre-feet per year.) The annual rate of increase for saltcedar in Colorado is 1-2.5%; unchecked, this rate would allow 90,000-200,000 acres to become infested by 2050.

- Saltcedar, Russian olive, and eastern red cedar often form monocultures, thus outcompeting native plants and significantly altering vegetative communities. All three species tap into water tables and contribute to decreasing water resources. Saltcedar's rate of evapotranspiration is especially high, and it exudes high levels of salt onto the soil surface—further degrading the habitat for native species.

- Purple loosestrife recently invaded Colorado wetlands, but an aggressive eradication program has reduced its range. Similar efforts to control loosestrife are taking place in Kansas and Nebraska.

- Teasel, perennial pepperweed, and hoary cress (the latter two commonly known as ‘whitetop’) are increasing. Teasel has invaded some wetlands and borrow ditches along the Front Range, where its rosettes carpet shorelines and outcompete other species. Perennial pepperweed has invaded many Colorado wetlands; the South Platte River corridor in Arapaho County is one such ‘hot spot.’ Hoary cress is invading wetlands and (during wet springs on relatively alkaline soils) CRP fields and fallow fields. Both whitetops can form dense monocultures, and neither is believed useful to wildlife.

- Common reed (commonly known as phragmites) and cattails can form monocultures that completely choke wetland habitats and preclude most waterbirds. Many land managers regularly have to spend significant personnel time/funds to contain and reduce infestations. Common reed is a major problem in Kansas wetlands, and cattails are fairly ubiquitous.

- Invasive species in wetlands are likely having adverse effects on waterfowl, cranes, shorebirds, and other waterbirds that feed along shorelines and/or in littoral zones of riverine and other wetland habitats; they also result in diminished food resources, winter cover, and/or nesting substrates for passerine birds.

PURPOSE and INTRODUCTION

To achieve habitat objectives for all-bird conservation planning, it is important to understand land-use trends that affect the distribution and quality of important avian habitats. In accordance with its Implementation Planning Guide (Playa Lakes Joint Venture 2004), the Playa Lakes Joint Venture (PLJV) is seeking this understanding through several approaches, including inventories and mapping of natural resources, monitoring of avian habitats and populations, data analyses, and syntheses of existing information. This report's primary purpose is to synthesize information on trends in important avian habitats—or changes in land use that likely give rise to trends—within the PLJV region (Fig. 1). This information is needed to assist the PLJV with developing Area Implementation Plans (AIPs) called for in the Implementation Planning Guide (Playa Lakes Joint Venture 2004).

Ultimately, the PLJV would like to understand trends in avian habitats at three spatial scales: (1) the entire PLJV, (2) Bird Conservation Regions (BCRs) within the PLJV, and (3) state portions of BCRs within the PLJV. This will require in-depth analyses of large datasets (e.g., National Agricultural Statistics Survey and Natural Resources Inventory) and geographic modeling efforts that overlay avian population distributions with habitats undergoing change. In the meantime, the PLJV sought information describing the more salient, recent trends in avian habitats (or changing land uses that imply habitat trends) within the PLJV. To that end, this report serves to alert PLJV staff and associates about important land-use changes, and the habitats or general areas within the PLJV where these changes are probably having the greatest effect. The detailed, quantitative habitat-trajectory models proposed by the PLJV will flesh out the habitat-trend snapshots provided herein.

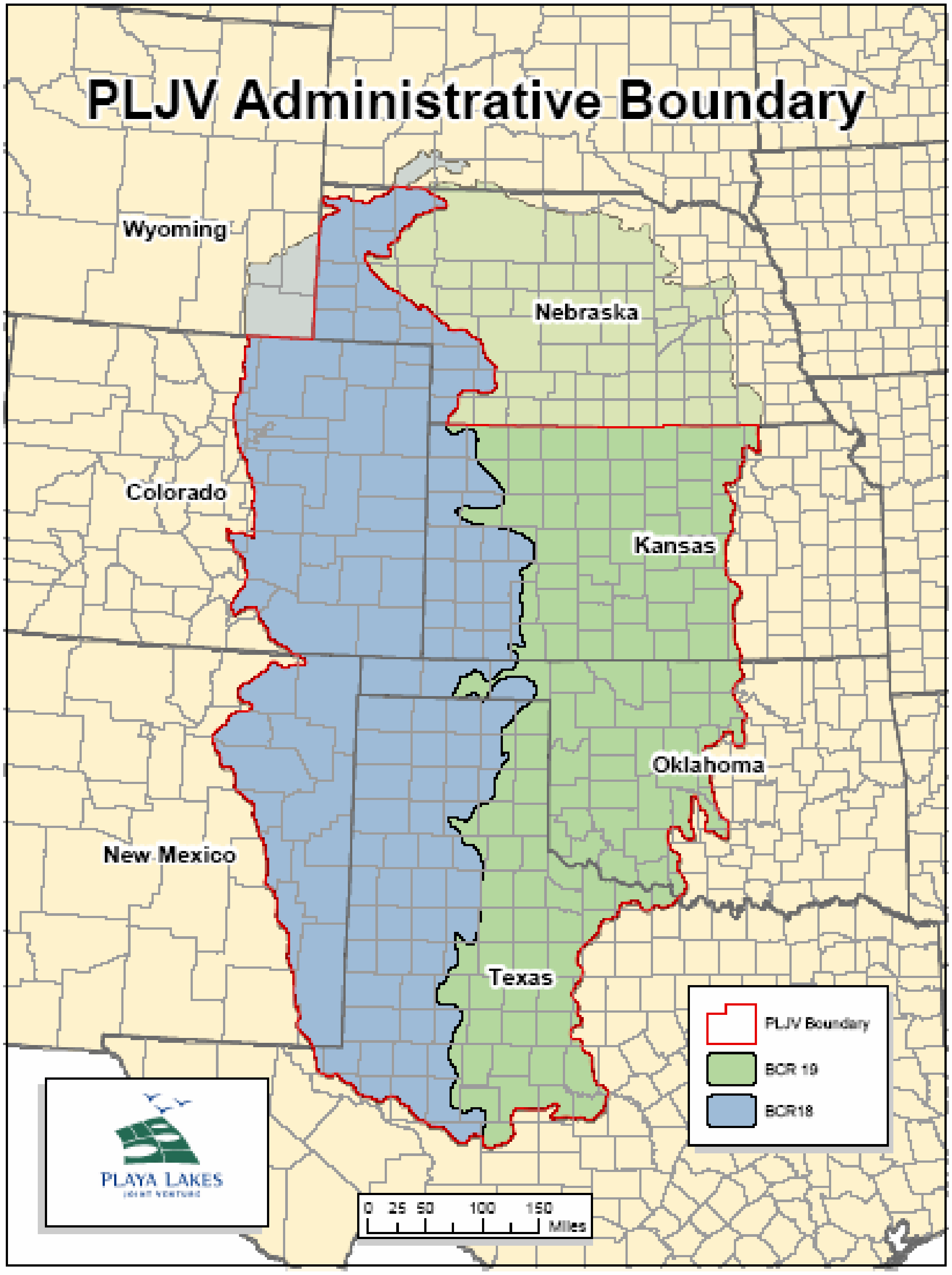

Figure 1. Map of the Playa Lakes Joint Venture region, which encompasses most of Bird Conservation Regions (BCR) 18 and 19. (BCRs form an important basis for bird-conservation planning in North America.)

METHODS

Various datasets were searched for published literature regarding changes in land use and trends that may be affecting avian habitats (explicit or implicit) within, and immediately surrounding, the PLJV region. Effects of land-use changes on bird populations and habitats in other regions also were considered if they provided insight into possible trends in the PLJV. The datasets searched included Agricola, Cambridge Scientific Abstracts, Wildlife Worldwide, and others. Information was obtained from peer-reviewed literature, unpublished reports, the World Wide Web, and through phone interviews with researchers, land managers, agency personnel, policy-makers, and others familiar with changing land uses and related trends. Whereas trend data are useful for understanding changes in the recent past (i.e., relatively current), expert knowledge was often valuable for identifying possible future changes and trends.

Ultimately, the PLJV seeks trend information specific to habitat types (i.e., those defined in the PLJV's habitat association classification scheme; Playa Lakes Joint Venture 2004). There are few quantitative data, however, on habitat trends. Therefore, discussions in this report focus on changing land uses and management practices likely effecting avian habitats. To corroborate some of the more qualitative and speculative discussions with quantitative information, the National Agricultural Statistics Service (NASS) and Natural Resource Inventory (NRI) datasets were queried to determine, roughly, changes in acreage among certain habitat types within PLJV states. Discussions on changes in land use and habitat trends are organized in the text by the habitat 'type,' 'association,' and/or 'condition'—as defined by the PLJV's habitat association classification scheme. To minimize redundancies, changes likely affecting more than one habitat category are detailed under the category apparently affected most by that change. Changes in land ownership are impacting croplands and rangelands, but for somewhat different reasons and with differing effects; therefore, this change is addressed under both habitat categories.

Most literature/databases on land use report in English units of measure (i.e., acres, miles); thus, English units of measure are reported herein. Appendix 1 lists scientific names of organisms used in this document. Appendix 2 summarizes habitat trends, by PLJV's association classification scheme for BCRs 18 and 19.

RESULTS & DISCUSSION

Several recent, current, and predicted land-use and land-management changes have affected, or have the potential for affecting, significant areas of avian habitat within the PLJV region. Agricultural intensification is probably directly affecting more cropland than any other land-use change. Also impacting avian habitats are declines in irrigated agriculture, changes in land-ownership patterns, growth in the energy industry, and range expansions of invasive/exotic plants.

Efforts to model changes in land use and/or characterize habitat trends, both within the PLJV region and in adjacent regions, are underway. For example, Geographic Information System (GIS) data layers are being used to graphically model trends in land-ownership patterns in Texas and the ways in which wildlife habitat may be influenced by those changes (Wilkins et al. 2003). Egbert et al. (2001) and Peterson et al. (2004) compared remotely sensed land-cover maps to historical land-cover maps as a means of detecting land-cover changes in Kansas (see <http://mackinaw.kgs.ku.edu/kgcc/catalog/catalog.cfm> for details). Conner et al. (2001) recently analyzed NRI and Major Land Use (MLU) datasets to assess trends in U.S. grasslands (with focal analyses on several states, including Colorado and Texas) and the economic and biological trends affecting them (Colorado summary in Seidl et al. 2001). In northeastern Colorado, researchers have initiated a study on the uptake of nutrients (carbon, nitrogen, and water) in lands reverted from CRP to grazing or minimum-till agriculture (Hanan et al. 2003); results of such research may help predict effects of CRP reversions to cropland in the PLJV. In Colorado, there is an excellent Weed Mapping Program underway, which could help identify areas of concern (Colorado Department of Agriculture 2005). Ahn et al. (2001), Higgins et al. (2002), and Finch et al. (2004) have also characterized land-use changes and/or grassland conditions in nearby regions: the southeast, northern Great Plains, and desert southwest, respectively. These studies have potential implications and applicability to changes/trends in the PLJV region, as well. Overall, these and other research teams could become valuable collaborators in future quantitative assessments of PLJV's avian habitats.

AGRICULTURAL HABITATS

Although the total acreage of cropland in PLJV states increased by only 3% (~3 million acres) from 1974-2002 (National Agricultural Statistics Service 2002), that figure masks significant acreage placed into CRP beginning in the mid-1980s (i.e., the PLJV classifies CRP as an agricultural habitat, but the National Agricultural Statistics Service does not include CRP). However, conversion of previously untilled grassland to cropland in PLJV states appears to have reached a virtual limit—as most arable lands have already been tilled. Interviewees for this project generally agreed that grassland conversion to cropland is no longer a significant factor affecting habitats in most portions of the PLJV region (J.R. Bell [pers. comm.] for the Texas panhandle; R.F. Meyer [pers. comm.] for east-central Colorado; R.D. Rodgers, [pers. comm.] for Kansas).

Wheat-Fallow Croplands

There is mounting evidence that agricultural intensification is leading to declines in bird populations in agricultural landscapes (e.g., Freemark et al. 1991, Lokemoen and Beiser 1997, Rodgers 1999, Brickle et al. 2000, Chamberlain et al. 2000, Donald et al. 2001, Jobin et al. 2001, Berendse et al. 2004, Gregory et al. 2005). Agricultural intensification includes increased dependence on insecticides, herbicides, and synthetic fertilizers; cropping on a greater percentage of a given landscape; eliminating hedgerows/fencerows and weedy field margins/corners; landscape-level monocultures; diminished heights in post-harvest wheat stubble and declining amounts of waste grain; changes in crop genetics; increasing the number of crops produced within a given rotation period; and diminished fallow periods. In the PLJV, intensified crop rotations, decreasing fallow periods, and the concomitant increased reliance on herbicides in traditional dryland wheat-fallow (herein, ‘wheat’ refers to ‘winter wheat’) systems are probably affecting more avian habitat area than other changes currently taking place. The ultimate factor driving these changes is economics; the proximal factor, however, is the switch from wheat-fallow rotations to wheat-alternative crop-fallow rotations.

Traditionally, mono-cropping in dryland wheat-fallow systems in most sectors of the PLJV region entails tilling the ground prior to planting, planting winter wheat during the fall, and harvesting the crop in the subsequent summer. In most years, soil moisture is too limiting to allow another crop to be planted immediately post-harvest. Therefore, the land rests in fallow—generally with up to five episodes of tillage (more in rainy years) to control weeds—until the following fall, when the next wheat crop is planted (G.A. Peterson, pers. comm.). In other words, for a given piece of land, one crop of winter wheat is harvested every other year, and the land rests in fallow for about 14 months between crops (i.e., a 2-year wheat-fallow rotation). During fallow periods, weeds are periodically controlled by mechanical means. In many traditionally managed fallow fields, weed control was not conducted until spring, thus leaving crop stubble and a diversity of forbs and other plants that provide important food and cover resources for numerous avian species (e.g., Rodgers 1999). However, many of those forbs (at least in Colorado, and most likely elsewhere) are considered weeds by farmers, and some are classified as noxious weeds (D.B. Bosley, pers. comm.). Because winter wheat also provides relatively high-quality forage, some farmers (mostly south of I-70, where the spring season is longer) grow winter wheat for the dual purpose of harvesting grain and providing pasture for livestock, whereby livestock graze the wheat in fall/winter months (see <http://www.ars.usda.gov/Business/docs.htm?docid=6556>). In Oklahoma, for example, two-thirds of the wheat planted in fall 1995 was intended for both livestock pasture and grain harvest (True et al. 2001).

Intensified rotations within dryland cropping systems, however, entail planting a secondary crop between wheat crops in a 3- to 5-year wheat-alternative crop-fallow rotation (Economic Research Service 2004; e.g., Norwood and Dhuyvetter 1993; R.D. Rodgers, pers. comm.). Conserving soil moisture, nutrients, and organic matter—the primary factors that make intensified cropping rotations possible in semi-arid regions like the PLJV—can be achieved by minimizing soil disturbance and leaving crop residues on the soil surface (Tanaka and Anderson 1997, Bordovsky et al. 1998, Peterson et al. 1998, Rodgers 2006). No-till (NT) practices—recommended widely as the best means of minimizing soil disturbance—entails drilling seed directly into the ground without prior tilling or removing stubble/residues of the previous crop. To further minimize soil disturbance, NT farmers generally rely on herbicides instead of mechanical means for controlling weeds during fallow periods (Jones et al. 1985, Johnson et al. 1986, Rodgers 1983, Lin et al. 1995, Baumhardt and Lascano 1999, Knezevic Cassman 2003). Combined use of NT and herbicides allows farmers in the High Plains to produce additional crops between wheat crops (Economic Research Service 2004). For example, intensified cropping in a 3-year rotation might entail wheat-corn-fallow. That is, the secondary crop (dryland corn in this case) is planted in the spring after the wheat is harvested and is subsequently harvested that fall before the next 14-month fallow period begins (R.F. Meyer, pers. comm.).

In eight counties of eastern Colorado alone (Adams, Kit Carson, Logan, Morgan, Phillips, Sedgwick, Washington, Yuma), the acreage of dryland corn increased from 28,000 in 1989 to 290,000 in 1999 (Peterson et al. 2002), probably largely at the expense of fallow land and wheat crops. Besides dryland corn, secondary crops being used with increasing frequency within the PLJV region include proso millet, grain sorghum (also commonly known as "milo"), and annual forage crops (e.g., sudan hay [i.e., hay sorghum] or hay millet; Croissant et al. 2004). In New Mexico, grain sorghum is often double-cropped (i.e., two crops planted in the same year) with wheat, peanuts, and/or cotton (D.M. Davis, pers. comm.). In Texas, grain sorghum and cotton are often inter-cropped with wheat (Bordovsky et al. 1998, Baumhardt and Lascano 1999). In Kansas, soybean production has increased dramatically (National Agricultural Statistics Service 2005), most likely at the expense of fallow land and wheat. Sunflower (generally black oilseed), safflower, and other oilseed crops also have become popular as secondary crops in High Plains cropping systems (Johnston et al. 2002; L. Pruett, pers. comm.). For example, in the eight-county region of Colorado mentioned above, the area of sunflower increased from 63,000 acres in 1991 to 270,000 acres in 1999 (Peterson et al. 2002), again probably at the expense of fallow land and wheat production. In some cases, farmers are undertaking somewhat longer rotation periods while producing even more crops (e.g., wheat-corn-millet-annual forage-fallow in a 5-year rotation; Croissant et al. 2004). Overall, the secondary crops planted, as well as possible rotation regimes, largely depend on latitude/longitude, elevation, land-management practices, and other factors (e.g., soils) that affect growing conditions. In Colorado, for example, dryland corn and millet are recommended for more-northern areas (i.e., north of Cheyenne Wells), whereas grain sorghum is recommended for areas farther south (Croissant et al. 2004).

Although NT and other conservation tillage systems have been promoted for decades to protect/improve soils and conserve soil moisture (Mannering and Burwell 1968, Mannering and Fenster 1983, Johnson et al. 1986, Jones at al. 1985), farmers have been reluctant to try these new methods. This reluctance is due not only to tradition, but to the costs associated with purchasing new machinery (or retooling old machinery) to accommodate changes in practices often required for growing secondary crops (R.D. Rodgers, pers. comm.). Furthermore, recommendations for cropping systems often change as new research results are released, which may add to farmer concern over investing in changes that may soon become outdated. For example, there is considerable debate as to which tillage system is most economical and under which cropping regimes (e.g., Crabtree et al. 1986, Bordovsky et al. 1998, Janosky et al. 2002, Peterson et al. 2002, Rodgers 2006).

Recently, however, continued declines in commodity prices combined with sharply increasing production costs and changes in market demands (i.e., growing demand for oilseeds and specialty grains) are leaving farmers with little choice but to change their cropping systems and land-management practices or to find non-farming means of making an income from their land. In addition, many researchers now consider traditional wheat-fallow systems to be not only economically unsustainable, but also environmentally unsustainable due to soil erosion, diminished nutrients/organic matter, and depauperate communities of soil microbes (Becker 1999, Peterson et al. 2002). Further driving the changes in cropping systems are genetic changes (i.e., development of drought- and herbicide-tolerant crops, shorter varieties of wheat). Overall, these changes have led to significant agricultural intensification, with secondary crops replacing much of the fallow period in traditional wheat-fallow systems all across the Great Plains (Derksen et al. 2002; Economic Research Service 2004; J.R. Bell, D.B. Bosley, pers. comm.).

Clearly, the intended result of agricultural intensification is greater crop yields (Johnson et al. 1986, Peterson et al. 1998) and, presumably, greater profitability to farmers (but see Crabtree et al. 1986, Bordovsky et al. 1998, Janosky et al. 2002, Buman et al. 2005, Rodgers 2006). However, depending on the type of secondary crop planted, it can effectively reduce the total fallow period by 3-6 months (generally during avian breeding seasons) for each secondary crop added to a given rotation. In some cases, farmers are eliminating fallow periods altogether (Becker 1999). Cropping intensification, genetic changes, and low prices are also discouraging farmers from planting wheat. Consequently, overall wheat acreage is decreasing (Economic Research Service 2004). For example, from 1980 to 2005 in Kansas, the annual acreage of ‘non-irrigated’ winter wheat planted ‘after summer fallow’ declined from 6.2 million acres to 4 million acres (National Agricultural Statistics Service 2004), most likely due to agricultural intensification in wheat-fallow systems. As mentioned earlier, reduced fallow, ‘chemical farming’ (herbicide use in particular), and other forms of agricultural intensification have been implicated as major contributing factors in declines of grassland/farmland birds in North America and western Europe.

Studies indicate that avian responses to agricultural intensification are mixed—depending on the bird species considered, the crop types grown, how/when the land is managed, the landscape context, and how the edges of crop fields are managed (Lokemoen and Beiser 1997, Rodgers 1999, Best et al. 2001, Kirk et al. 2001, Vickery et al. 2002). In Britain, for example, the spatial relationships between distributions of granivorous birds and agriculture in lowland farming regions indicate that responses of birds to agriculture are species specific; overall, however, avian frequencies are low in landscapes dominated by wheat (Siriwardena et al. 2000). Yet, aside from research involving game birds, little has been published on which, or how, avian species have used and fared in wheat-fallow systems—particularly in the Great Plains. This lack of information makes it difficult to predict species-specific impacts of intensified cropping systems, declines in wheat production, and increasing reliance on herbicides.

Much of the fallow time being eliminated by agricultural intensification in the Great Plains coincides with the breeding season of grassland birds, and typically it is fallow fields that receive the greatest avian use in agricultural landscapes. Lokemoen and Beiser (1997) found that breeding species diversity and nesting densities in North Dakota were greater in minimum-tillage fallow fields than in crop fields (sunflower, wheat). In a study on foraging patterns of vesper sparrows nesting in Iowa croplands, Rodenhouse and Best (1994) concluded that the birds foraged principally in, or near, uncropped areas (such as fencerows) or weedy areas within the crop fields. When vesper sparrows fed in croplands, they did so primarily where crop residues (usually corn) were most plentiful (Rodenhouse and Best 1994). In England, summer abundances of birds (all functional groups) were greater in set-side land (i.e., similar to the CRP) and rotational set-aside land (i.e., similar to fallow) than in winter-planted cereal croplands or grasslands (Henderson et al. 2000). Henderson et al. (2000) also found that rotational set-aside land was used more than non-rotational set-aside land, indicating that the plant communities regenerating naturally in rotational set-aside land provided better foraging opportunities than the more structurally uniform composition in non-rotational set-aside lands.

Significant avian use of fallow land also has been reported in non-breeding seasons. In North Dakota, for example, Lokemoen and Beiser (1997) found greater densities of spring migrants in minimum-tillage fallow fields than in croplands due to the greater availability of food and cover resources in fallow fields. In eastern Kansas, red-tailed hawks, northern harriers, and American kestrels used fallow fields more than rangelands (Williams et al. 2000). In western Kansas, ring-necked pheasants declined by 65% from 1966-1975 to 1986-1995, primarily due to the loss of suitable cover and forage in fallow fields of dryland wheat-fallow systems (Rodgers 1999). Contributing to this loss is diminished heights of wheat stubble (the result of improved harvest machinery and shorter strains of wheat), which compromises the quality of winter cover. Use of herbicides further diminishes habitat structure and food resources.

Krapu et al. (2004) found that post-harvest waste corn (primarily ears) in fallow fields declined in the central Platte River valley of Nebraska by up to 47% from 1978 to 1998, largely due to improvements in machinery and crop genetics. Because both resident and migratory birds—migrating waterfowl and cranes in particular—benefit significantly from the high-energy content of waste corn in landscapes now largely devoid of natural food resources, this represents a considerable reduction in food resources. Krapu et al. (2004) also reported that sandhill cranes and waterfowl appear to avoid foraging on soybeans. This is significant in that many acres of corn within the PLJV are likely being replaced by soybeans, particularly where soil moisture is greater or irrigation remains feasible, and it is likely that other avian species make little use of soybeans as well. In Kansas—where soybean production has increased more dramatically than anywhere else in the PLJV—the area of soybeans (for all counties entirely encompassed by the Bird Conservation Region [BCR] 19 portion of Kansas) doubled from 178,000 to 363,000 acres from 1980 to 1990; in the subsequent decade it doubled again to 765,000 acres (National Agricultural Statistics Service 2005). From 2000 and 2004, however, the same region had added only another 11,300 acres of soybeans (National Agricultural Statistics Service 2005), indicating that the growth in soybean cropping may be reaching a limit in Kansas. In the BCR 18 portion of Kansas, soybean acreage has tripled since 1980, although the acreage was relatively minimal to begin with (20,500 acres in 1980 to 85,000 acres in 2004; National Agricultural Statistics Service 2005), probably because soybeans require more moisture than what is available in BCR 18.

In general, species that require a relatively specific vegetation structure or food resource during a certain time in their annual cycle are also likely to be impacted (whether negatively or positively) if the vegetation structure of intensified cropping rotations varies significantly from that of wheat-fallow rotations. For example, mountain plovers and horned larks commonly nest in bare, or nearly bare, fallow fields (i.e., little or no stubble; Beason 1995, Shackford et al.

1999), as these habitats appear superficially similar to their native nesting habitats (i.e., heavily grazed grasslands; Knopf 1996). The single-brooded plover typically nests in bare agricultural fields before significant emergence of most spring-planted crops (F.L. Knopf, pers. comm.), a situation much like that in shortgrass habitats, wherein the grasses remain dormant until after plover nesting is completed (Knopf and Miller 1994). Therefore, the growth of secondary crops in what used to be fallow fields may not reduce plover nesting habitat, per se. Horned larks, however, produce two to three broods (i.e., they nest later into the season; Beason 1995); therefore, the emergence and growth of secondary crops in what otherwise would have been fallow could eliminate significant amounts of horned lark nesting habitat. Indeed, the Breeding Bird Survey results indicate highly significant declines in horned lark populations in the High Plains, Rolling Red Plains, and Staked Plains strata, which compose most of the PLJV region (see Sauer et al. 2005). Also causing concern is the effects of herbicides, which not only kill non-target plants (Freemark and Boutin 1995), they greatly reduce the seed resources required by granivorous grassland bird species (Rodenhouse and Best 1994, Brickle and Harper 2002, Rodgers 2002). Herbicides also deplete the broad-leaved habitats required by most invertebrate prey (Chiverton and Sotherton 1991, Freemark and Boutin 1995, Burel et al. 2004) upon which insectivorous birds and the broods of granivorous species depend (Rodenhouse and Best 1994, Beason 1995, Knopf 1996).

On the other hand, the no-till (or delayed minimum till) practices accompanying agricultural intensification in what had been wheat-fallow croplands may result in less nest destruction than what is typical in tilled fields. In turn, this could mitigate, to some extent, the decline in food and cover resources resulting from herbicide use in intensified cropping systems. Traditional fallowed wheat fields were tilled up to five or more times per growing season to control weeds, but in fields planted to secondary crops the number of passes is much lower and generally does not entail tilling (D.B. Bosley, pers. comm.). For example, Shackford et al. (1999) found that 70% of mountain plover nests in fallow fields were destroyed by farm machinery. Similarly, Rodgers (1983) reported that surface tillage for weed control in traditional wheat-fallow systems of Kansas caused nearly 100% nesting failure and mortality to the flightless young of ring-necked pheasants, northern bobwhites, mourning doves, and songbirds. Additionally, many farmers remove weeds even when there is not a significant weed problem in their fields, thus compounding the already-high mortality rates in fallow fields. This so-called ‘recreational mowing’ is performed primarily for aesthetic reasons when farmers have few other demands on their time (A.W. Allen, pers. comm.). Although unnecessary field management continues today, the recent sharp increases in fuel costs (and the ongoing increases in herbicide costs) are likely to begin discouraging any unnecessary field management (A.W. Allen, pers. comm.). Overall, nest survival of grassland birds may improve among avian species using those fields. Furthermore, researchers continue improving land-management techniques and equipment to benefit wildlife. For example, Rodgers (1999) found that 53% of the nests in a fallow field would survive mechanical weed control if undercutters (subsurface tillage) without mulch treaders were used instead of surface tillage.

Research on avian use of ‘decoy’ sunflower fields in North Dakota to diminish avian depredation in sunflower crops (Linz et al. 2004) provides a more positive insight into potential effects of producing secondary crops (as it pertains to sunflowers and, probably, other oilseed and small-grain crops). Preliminary data indicate that 49 non-blackbird species were detected in or near sunflower fields from late August to mid-October. Of the species detected in (or on the edges of) sunflower fields, 74% were granivores, including several species of conservation concern (grasshopper, LeConte’s, and sharp-tailed sparrows, and Smith’s longspur; Linz et al. 2004). This research indicates the possibility that increased acreage of sunflower crops on the PLJV landscape could potentially mitigate losses of food resources formerly obtained in weedy wheat-fallow habitats by granivorous birds during fall migration, and by some resident species. However, there are significant structural differences between sunflower and traditional wheat-fallow fields; thus, cover—winter cover in particular—is likely to diminish where post-harvest sunflower replaces wheat fallow (A.W. Allen, pers. comm.). Overall, if secondary crops in dryland cropping systems provide suitable, or even better, replacements for traditional wheat-fallow in terms of cover and food resources for nesting birds, broods, or migrants, and if alternative tillage methods (e.g., delayed minimum till) are used as a means of reducing weeds in place of herbicides, then more intensive cropping in dryland systems may benefit some species at some times of year. However, the possibility that overall populations of PLJV birds that use croplands will benefit via agricultural intensification is dubious (R.D. Rodgers, pers. comm.).

The studies discussed above provide only partial insights into how agricultural intensification may be affecting avian community structures, population trends, and local distributions in the PLJV region. Clearly, numerous passes with farm machinery to control weeds in traditionally tilled dryland cropping systems negatively impacts avian nesting success due to direct mortality of eggs or broods. Increasing reliance on herbicides in the intense cropping rotations implemented more recently, however, may be negatively impacting avian species indirectly via loss of invertebrate, seed, and cover resources (Rodgers 1999, McCarty and LaReesa Wolfenbarger 2005). The extent to which adding oilseed and small, specialty-grain crops to dryland rotations mitigates the loss of seed-bearing forbs for avian granivores is uncertain. Ultimately, there are many unanswered questions regarding avian use of croplands, and more research is needed to determine the extent to which any one species or guild would benefit from, or decline due to, multi-cropping and other factors associated with agricultural intensification, the crops replacing wheat, and the associated increased reliance on herbicides (see Freemark and Boutin 1995). Factors that need consideration include definition of avian response to changes in the overall landscape, patch size, timing of use, timing and type of land-management practices associated with multi-cropping systems, different rotation regimes, and the types of secondary crops planted. Because many multi-cropping rotations are already in place, there may be ample opportunities for research and to answer these questions within a relatively short period of time.

Irrigated Croplands

In the arid west, agricultural irrigation arrived in the late 1800s, although it did not increase significantly until after World War II (Mac 1998). In Colorado, the acreage of irrigated croplands increased 27% from 1960-1980 (Colorado Department of Agriculture 1980). Similar trends were seen elsewhere within the region encompassed by the PLJV, where playas filled by irrigation tailwater were considered crucial habitat for waterfowl and other birds (Nelson et al. 1983*a*, 1983*b*). Irrigation in the PLJV region also supported cereal grains, especially corn and grain sorghum, important to foraging waterfowl and cranes (Nelson et al. 1983*b*). However, it soon became clear that the existing levels of groundwater mining for irrigation were unsustainable.

In 1980, the Colorado Department of Agriculture reported that water levels in Colorado portions of the Ogallala Aquifer would decline seriously by 1995 (Colorado Department of Agriculture 1980). The same problem was projected for much of the PLJV region, as the Ogallala Aquifer underlies almost the entire area (Luckey et al. 1988). As predicted, wells began to dry up during the 1990s in a number of Ogallala regions. Until then, the acreage of irrigated cropland in all PLJV states increased, and then it began to decline (20.3 million acres in 1997, 19.3 million acres in 2002; Natural Resources Inventory 2002). Coupled with a recent period of prolonged and intense drought, increasing demands on water for industrial and residential development, and sharp increases in energy costs, irrigation farming in much of the PLJV has become economically unsustainable for many operators (S. Amosson, J.R. Bell, pers. comm.).

In an analysis of irrigation trends from 1992 to 1997, Howell (2001) noted a decline in irrigated acreage throughout much of the Southern High Plains Region (roughly the southern half of the PLJV region), even as irrigation acreage increased elsewhere in the nation. Farmers still using irrigation are trying to maintain production by retooling their irrigation equipment to deliver water more efficiently. For example, 30 years ago furrow and flood irrigation—which results in tremendous evaporative and transport losses—composed the majority of irrigation systems in the Texas High Plains, but today those systems have all but disappeared (J.R. Bell, pers. comm.). The use of sprinklers has also declined. Instead, irrigation farmers are using low-pressure nozzle drips ('microspray' systems, whereby hoses with nozzles that deliver fine mists of water are hung from center-pivot infrastructures to just above the soil surface) or subsurface irrigation (Howell 2001; S. Amosson, J.R. Bell, pers. comm.).

As a consequence of the significant changes in farm machinery and land-management practices usually required for switching to dryland agriculture (J.R. Bell, pers. comm.), the conversion of irrigated to dryland agriculture has been a more recent, and relatively slow, change. Certain events and programs have accelerated (or may accelerate) the conversion in some regions. For example, a dispute over water rights in the case of Colorado vs. Nebraska and Kansas resulted in the Republican River Compact, under which water table declines in the Republican River drainage will be addressed by capping and closing wells in portions of northeastern Colorado—the Burlington area in particular (D.B. Bosley, pers. comm.). The land may be converted back to grassland where soils in the Republican drainage are sandy (D.B. Bosley, pers. comm.), especially south of the South Platte River (D. Alexander, pers. comm.). It is also likely that some farmers impacted by the compact will resort to intensive dryland farming. In New Mexico, some farmers are taking advantage of a Natural Resources Conservation Service (NRCS) program that encourages capping wells and converting irrigated land to native grassland (D.M. Davis, pers. comm.). Most of the few enrollees are in Roosevelt County, although there appears to be some interest within a few nearby counties. Increases in fuel prices may drive up the demand for this program in the near future (D.M. Davis, pers. comm.).

Clearly, land-use changes in some irrigated farmlands are already occurring, but the ultimate fate of most irrigated farmland remains uncertain. In part, this uncertainty is due to the increasing average age of farmers, the ongoing declines in commodity prices, and rising production costs (J.R. Bell, pers. comm.). Some farmers may simply choose to retire. The fate of their lands could include enrollment in Farm Bill programs, although many—if not most—counties in the PLJV have reached their CRP caps (i.e., limited to 25% of a county's cropland; J.R. Bell, D.B. Bosley, and D.M. Davis, pers. comm.). Other retirees may attempt to place conservation easements on their irrigated croplands, although rangelands are generally preferred over farmlands for conservation easements. Furthermore, funds available for purchasing development rights on conservation easements are extremely limiting at this time. Irrigated farmlands that provide habitat for quail, deer, and other game species may be sold as recreation real estate (see discussion below on Grassland Habitats). Another option for farmers is to sell land and water rights to dairy operations. At least in northeastern New Mexico and nearby portions of Texas and Oklahoma, the dairy industry is expected to increase in the near future as some large cheese processing plants are built (S. Amosson, J.R. Bell, D.M. Davis, pers. comm.).

Some farmers opting to remain in the agricultural business may convert their irrigated croplands to rangeland for grazing cattle, although ranching generally requires more acreage than many crop farms encompass, and purchasing additional land is usually economically impossible and/or there are no adjacent lands for sale. Furthermore, limited water availability also limits cattle-ranching opportunities. Thus, the majority will likely to convert to intensive dryland cropping systems, as long the prices of oilseeds, specialty grains, cotton, and corn, soybeans, and sorghum don't fall precipitously. This change in land use is already occurring in the Republican and Platte River drainages of Colorado (D. Alexander, pers. comm.), and, more than likely, 10-20% of irrigated croplands (mostly corn) in the Texas panhandle will see significant conversion to dryland cotton farming over the next 5-10 years (J.R. Bell, pers. comm.).

The ways in which the decline in irrigated lands may affect avian assemblages in the PLJV region remains uncertain. Because most flood and furrow irrigation systems disappeared more than a decade ago (J.R. Bell, pers. comm.), many of the changes to playas and other wetlands that were modified to receive and hold irrigation tailwater have probably already occurred, and avian communities may have already responded accordingly. Post-harvest residues left behind in many irrigated croplands—corn, grain sorghum, peanuts, and sunflowers in particular (e.g., Nelson et al. 1983*a*, Anderson et al. 2000)—historically provided important food resources for geese, ducks, cranes, and gallinaceous birds. To some extent, planting dryland strains of corn, sorghum, and other cereal or oilseed crops in between wheat crops may be mitigating some losses as irrigated lands are phased out. Overall, however, the effect may be one of declining food resources. To some extent, this will be determined by a given crop's nutrient content, palatability, and residual/waste levels in fallow fields (see Krapu et al. 2004).

Historically (where residual cover was adequate), many bird species also used the post-harvest stubble in irrigated croplands of the PLJV region as important winter cover. Thus, conversion from irrigated cereal crops to dryland cotton farming in Texas and other regions of the PLJV does not bode well for most overwintering wildlife, as little to no post-harvest residue is left in cotton fields. If dryland cotton crops are rotated with dryland wheat or grain sorghum, wildlife may still realize some benefits from these fields when stubble of non-cotton crops is left standing (J.R. Bell, pers. comm.). On the other hand, economics may necessitate more cattle grazing on post-harvest fields (J.R. Bell, pers. comm.), which could diminish any food and cover value those fields might otherwise provide. Overall, changes in habitat quality that result from switching to dryland agriculture from irrigated production will depend on the crop types planted and the ways in which they are managed (see discussion above on Wheat-Fallow Croplands).

Conservation Reserve Program Croplands

Probably the single-greatest change in agricultural land use in the PLJV over the last 20 years has been the enrollment of croplands into the CRP (J.R. Bell, pers. comm.). In Kansas alone, 2.9 million acres of cropland have been converted to CRP, which increased the state's total grassland area by 14% (Egbert et al. 2001). Each year since its inception, the number of acres enrolled in the CRP has increased throughout the United States; from 1999-2003 alone, enrollment jumped from 29.8 to 34.1 million acres, and 63% of that increase was due to enrollees in the general sign-up program (Appendix B in Allen and Vandever 2005). In 2001, the number of CRP acres (general and continuous sign-ups combined) in the PLJV states (i.e., includes area outside the PLJV region) was more than 11.6 million acres (Farm Service Agency

2001); by 2004, that figure had grown to more than 12.2 million acres (Allen and Vandever 2005).

General sign-up is the dominant CRP type in the PLJV, and the PLJV appears to encompass one of the nation's two largest contiguous areas of high-density, general sign-up CRP acreage (see page 222 in Allen and Vandever 2005). Indeed, many PLJV counties have reached their 25% cap on CRP enrollment (J.R. Bell for northwestern Texas; D.M. Davis for eastern New Mexico; R.F. Meyer for eastern Colorado; R.D. Rodgers for Kansas). Clearly, CRP has resulted in an enormous increase in the acreage of grassland habitats in the PLJV, and, with notable exceptions, much of the CRP in the PLJV region was originally planted with native grasses.

That the CRP has provided many benefits to grassland birds and other wildlife is widely accepted (see reviews in Heard at al. 2000, Allen and Vandever 2005) and does not need further review herein—except to note that some avian grassland species have benefited more from the CRP than others. Some species have not benefited from CRP planted with monocultures of introduced tall grasses and/or CRP vegetation that has become rank and invaded by woody vegetation due to a lack of disturbance processes that reduce litter and set back succession (see Robel et al. 1998, Johnson 2000). However, paradigms in CRP plantings and management continue to evolve, thus improving the outlook for all grassland species. For example, in 2004, the vast majority (94.25%) of all new grass plantings (~4 million acres) installed in the PLJV states consisted of CP2 (native) as opposed to CP1 (non-native; Farm Service Agency 2004). The U.S Department of Agriculture's increasing emphasis on periodic vegetation management in CRP grasslands also should continue to enhance the abundance, diversity, and timely presence of suitable food and cover resources for a diversity of avian grassland species (see Rodgers 2005, Rodgers and Hoffman 2005).

Because CRP has become an important land use within the PLJV, significant changes in the general sign-up program could represent profound changes to the PLJV's avian habitat. Approximately 6.77 million acres of CRP in the PLJV states are under contracts due to expire in 2007 alone. Currently, there is considerable concern among some land/wildlife managers that a large percentage of CRP in the PLJV will be lost during the next re-enrollment due to funding cuts and/or changes in eligibility (through proposed changes to the Environmental Benefits Index [EBI]; J.R. Bell, S. Briggs, D.M. Davis, R.D. Rodgers, pers. comm.). However, A.W. Allen (pers. comm.), who works directly with the Farm Bill on matters pertaining to wildlife values, indicates that no decisions about future enrollment criteria and standards have been made by the Farm Service Agency at this point. Allen also believes that even if major funding cuts or EBI changes occur, they are more likely to impact continuous sign-up CRP programs as opposed to the general sign-up program (A.W. Allen, pers. comm). Because the vast majority of CRP land encompassed by the PLJV is enrolled under the general sign-up (Appendix B in Allen and Vandever 2005), loss of CRP lands in the PLJV due to programmatic changes is not likely to be significant as far as upland habitats are concerned (the exception could be the playa buffer program, which is just barely underway and falls under the general sign-up program). Furthermore, many farmers enrolled in the CRP have sold their farming equipment, which diminishes the likelihood that (if given a choice) they would dis-enroll from the CRP (A.W. Allen, pers. comm.).

However, both commodity and conservation subsidy programs provided under the U.S. Department of Agriculture's (USDA) Farm Bill are being impacted by significant recent budget cuts ($1.7 billion), and hurricanes Katrina, Rita, and Wilma will generate enormous additional impact to the budget (A.W. Allen, pers. comm.). Thus, prices paid per acre of general sign-up CRP, as well as the amount of land eligible for re-enrollment or enrollment for the first time, may be limited due to budgetary constraints (A.W. Allen, pers. comm.). As agricultural intensification improves the overall economic outlook for dryland farmers, farming could take the economic edge over CRP if prices paid per acre of general sign-up CRP decline (J.R. Bell, R.D. Rodgers, pers. comm.). In Kansas, CRP attrition has already been observed, with 33-50% of CRP land reverting back to rangeland or hay when CRP contracts expire. It remains to be seen how the PLJV's CRP acreage may change in the next few years, but the overall acreage may decline.

Sericea lespedeza—Sericea Lespedeza, commonly known as Chinese bush clover, has been planted for erosion control and as wildlife and livestock forage in the southeastern U.S., where its populations are controlled via livestock foraging (E. Lane, pers. comm.; but see <http://www.r6.fws.gov/pfw/r6pfw15.htm>). For reasons not yet fully understood, however, it appears to be exploding in parts of Kansas (http://www.r6.fws.gov/pfw/r6pfw15.htm), particularly in CRP plantings and rangelands (E. Lane, R.D. Rodgers, pers. comm.). Originally, this phenomenon was seen to the east of the PLJV region, but it has rapidly moved into western

Kansas, Nebraska, and Oklahoma (except the panhandle). Sericea lespedeza also may have entered Colorado but has not yet been detected (E. Lane, pers. comm.). Part of this species' success is the 20-year longevity of its seeds and its ability to tolerate a wide variety of conditions, including drought, shade, and acidic-to-somewhat-alkaline soils (see <http://www.oznet.ksu.edu/ sericea/>). Although some mammalian wildlife species and quail are known to forage on and seek cover under this plant species, the seeds do not contain sufficient energy resources for sustaining quail through winter. Overall, sericea lespedeza has great potential for out-competing native plants once it becomes well established. Burning is believed to further promote its proliferation (by eliminating competition; see <http://www.oznet.ksu.edu/sericea/>); thus burns in CRP and other grasslands must be monitored for invasions of sericea lespedeza.

All Agricultural Habitats

Pesticide use—A factor that affects habitat quality of all non-CRP croplands (and shrublands; see discussion below on Shrubland Habitats) is pesticide use. Overall, however, farmers are becoming better versed in the use and environmental impacts of pesticides (J.R. Bell, pers. comm.). These and other factors, including the economic edge typically realized from using integrated pest management (IPM), are slowly reducing the use of insecticides (R.F. Meyer, pers. comm.). For example, in northern portions of the PLJV, insecticides are being applied in bands (i.e., every other band is sprayed instead of the entire field), particularly where migratory invertebrates (e.g., grasshoppers) are the target pests (Lockwood et al. 2000; J.R. Bell, pers. comm.).

In northern Texas, relay inter-cropping (e.g., strips of cotton interspersed with strips of canola [see note about canola in the heading for Appendix 2], wheat, and/or grain sorghum) has been shown to promote populations of predatory invertebrates that consume cotton aphids, thereby reducing the need to spray for these pests (Parajulee at al. 1997). For avian species that use habitats intercropped with cotton, clearly these are positive trends. However, *Heliothis* spp. (cotton bollworms and budworms) are also major cotton pests (Bohmfalk et al. 1996), and pesticide use is considered necessary to prevent a 50-60% decrease in yield where outbreaks of these pests occur (J.R. Bell, pers. comm.). Therefore, where cotton farming continues and outbreaks of bollworms or budworms occur, significant pesticide use is also likely to occur.

Other alternative practices being implemented to help minimize environmental contamination, wildlife mortality, and/or unnecessary reduction in food and cover resources include establishing no-spray zones between crops and important natural resources (e.g., wetlands; Mickelson et al. 2001) and along the margins of cereal-crop fields (Flickenger et al. 1991, Rodenhouse and Best 1994, Chiverton 1999). The extent to which these practices are being used in the PLJV, however, is not clear. In general, pesticides are also becoming somewhat less dangerous to the environment (e.g., the switch—at least in the U.S.—from organochlorines to organophosphates). Although organophosphates can be highly toxic to wildlife in the short-term (e.g., Flickenger et al. 1991), generally they degrade rapidly; thus, they do not accumulate in the environment to the extent that organochlorines accumulated (e.g., DDT). Today, even organophosphates are being replaced, to some extent, by naturally derived insecticides (e.g., pyrethrin-based compounds), which are less toxic to vertebrate wildlife than organophosphates and degrade quickly (R.F. Meyer, pers. comm.). Pesticides, however, incur high research and development costs, which, in turn, drive up prices and accelerate the development and production of lower-cost generics. Therefore, manufacturers are constantly developing new products, making it difficult to predict future pesticide use with respect to types, typical uses, or impacts on the environment (J.R. Bell, pers. comm.).

Despite the increasing awareness of pesticide effects, their rapidly increasing costs, and the wider use/acceptance of IPM and best management practices (BMPs), pesticide use is likely to continue—herbicide use in particular (Lin et al. 1995)—as natural and biological controls are considered too impractical for large-scale use within the region (J.R. Bell, pers. comm.). By the mid-1990s, herbicides used to treat weeds in corn fields composed 47% of all agricultural pesticides used in the U.S., and, in Wisconsin, high levels of atrazine (commonly used in corn fields) in surface and ground water prompted legislative action restricting its use (Wolf and Nowak 1996). Since then, atrazine has been linked to demasculinization in frogs (Hayes et al. 2002), but its use in PLJV states continues (see Croissant et al 2004). There is also recent evidence that glyphosates are causing significant amphibian mortality. Relyea (2005) found that glyphosates reduced overall species richness of aquatic communities by 22%, and tadpoles of several species were either extirpated (two species) or nearly extirpated (one species). The extent to which glyphostate use in surrounding uplands could affect the wetland biota is not clear, although most herbicides are accompanied by cautions against using them in/near wetlands.

The use of glyphosate-based herbicides is increasing as crops are genetically engineered to tolerate this chemical. In much of the PLJV region, glyphosate-tolerant corn is increasingly inter-cropped with (or even replacing) wheat, and it is likely that the concomitant use of glyphosate-based herbicides is increasing; an exception is east-central Colorado, where a decline in the use of this herbicide has occurred (R.F. Meyer, pers. comm.). Although historically glyphosates have been considered relatively "benign" in terms of their effects on terrestrial wildlife, by design they have profound effects on plant communities, which may be resulting in diminished/altered avian food and cover resources. Indeed, many forbs considered weeds (including some state-listed noxious weeds) serve as crucial forage and/or cover resources for both resident and migratory birds. The invertebrate fauna supported by forbs is crucial to young broods and migrating insectivores (Rodenhouse and Best 1994; Lokemoen and Beiser 1997; Rodgers 1999, 2002). Herbicide use in any cropping system or rangeland is almost certainly diminishing food sources and cover for migrating birds throughout the Great Plains region (Rodgers 1999, Linz et al. 2004).

Changes of land-ownership in croplands: human demographics, urban/ex-urban growth—Changing human demographics in rural communities are also contributing to land-use changes across agriculturally dominated landscapes. From 1954-1997, the proportion of farmers aged 55 or older in the U.S. population increased from 37% to 61% (<http://www.ers.usda.gov/Briefing/FarmStructure/Questions/aging.htm>). By 2002, the largest contiguous area in the U.S. populated by the greatest percentage of farmers >65 years old was located primarily within the Southern High Plains (<http://www.noble.org/ Ag/Economics/SuccessionPlanningIsCritical/>). Combined with increasing economic difficulties of farming, many older farmers are retiring and fewer young people are going into farming. Where there is a market for it, some retiring farmers may sell their land for 'ranchette' or other development (D.B. Bosley, pers. comm.), particularly those relatively close to major urban centers and travel corridors. In the Southern High Plains, there is a market for land sought by recreation hunters, but most buyers are seeking ranchlands as opposed to croplands (Byrns 2001; see discussion below on Grassland Habitats); thus, the future of cropland owned by retiring farmers remains uncertain.

Where retiring farmers are unable or not yet ready to sell their lands, some are simply letting their land fallow (D.B. Bosley, pers. comm.). On the other hand, few farmers can afford to keep idle land, in which case some are switching from crop production to ranching cattle. As mentioned earlier, however, many farms do not encompass enough land for profitable ranching, and, even if adjacent lands may be available, the market value may be cost prohibitive to would-be ranchers (D.B. Bosley, pers. comm.). Water is also needed at various locations within a given ranch, although supplies are not always available where needed (see discussion above on Irrigated Croplands). In some cases, nearby successful farmers seeking to increase the sizes of their operations may buy or lease lands from retiring farmers (A.W. Allen, pers. comm.). Although older generations appear somewhat averse to leasing their lands for hunting, younger farmers see it as an opportunity to earn additional income. Wetlands, CRP lands, pasturelands, and (to the extent that they provide foraging opportunities or cover) croplands may be leased to hunters seeking waterfowl and/or upland game birds. Overall, however, there is a great deal of uncertainty about the long-term outcome of most lands now farmed by aging populations in the PLJV region.

Within the PLJV region, another factor affecting cropland habitats in is urban/ex-urban growth. The area undergoing the greatest rate of development over the largest contiguous area is the Front Range corridor of Colorado (Natural Resources Inventory 2001). From 1992-1997, 270,000 acres/year of agricultural land (albeit primarily ranchland as opposed to cropland; detailed below under Grassland Habitats) were lost each year to conversion along the Front Range corridor (Colorado Department of Agriculture, Natural Resources Conservation Service, and Colorado Agricultural Statistics Service 2000). Elsewhere in the PLJV, the increase in developed land from 1982-1997 varied from ~2% to ≥40%, with most of it occurring along interstate routes, around larger towns/cities, and along riparian systems (Table 1). In Nebraska and Kansas, >50% of the land developed from 1982-1997 was cropland (Table 2; although most of Nebraska's conversion likely occurred outside the PLJV region).

Table 1. Percent change in land developed within the Playa Lakes Joint Venture region from 1982-1997 (from Natural Resources Inventory 2001).

State	Area (s) affected most by development	Percent change
Colorado	Along Front Range corridor (northern 1/3)	20-40%
	Along Front Range corridor (central 1/3)	≥40%

Nebraska	Along I-80 corridor	10-20%
Kansas	Along I-70 corridor	10-20%
	Along Cimarron River east of Cimarron National Grassland	10-20%
	Greater Wichita area	≥40%
	Greater Hutchinson area	≥40%
New Mexico	Counties bordering Texas south of Canadian River	10-40%
Oklahoma	Beaver County in the panhandle	10-20%
	Corridor from Lawton to Enid east to PLJV boundary	10-40%
Texas	Along most riparian areas of the western panhandle	10-40%
	Greater Amarillo area to Canadian River corridor	20-40%
	Greater Lubbock area	≥40%
	Greater Odessa/Midland/San Angelo/Abilene area, Colorado River corridor	10-40%

Table 2. Percent of land developed from 1982-1997 that was cropland, rangeland, or pastureland, by state (from Natural Resources Inventory 2001).

State	Cropland (%)	Rangeland (%)	Pastureland (%)
Colorado	27	4	8
Nebraska	68	19	9
Kansas	53	7	14
New Mexico	17	8	4
Oklahoma	19	18	27
Texas	23	11	25

GRASSLAND HABITATS

Before European settlement, most of the area encompassed by the PLJV region was largely covered with short- or mixed-grass prairie (Mac 1998). Since then, the area of native grasslands has declined precipitously, primarily due to cultivation. For example, Texas has lost >79% of its shortgrass and >30% of its mixed grass habitat (Mac 1998). In pre-settlement eastern Colorado, there were approximately 26.5 million acres of grassland—including 21% of the U.S. shortgrass prairie; by 1997, however, only 11.2 million acres of grassland remained, a loss of 59% (Seidl et al. 2001). In Kansas, >48% of the land cover—primarily grassland—has come under cultivation since European settlement (Peterson et al. 2004). Overall, rangeland throughout the PLJV states decreased by 5.04 million acres from 1982-1997, largely due to cultivation (Table 3; see Appendix E at: <http://www.nrcs.usda.gov/programs/Env_assess/GRP/ GRP.html>). However, as mentioned earlier, conversion of previously untilled grassland to cropland in PLJV states appears to have reached a natural limit: most arable land has already been converted. Indeed, it seems likely that factors discouraging today's commodity producers are also discouraging further conversion of grassland to cropland.

Table 3. Change in rangeland acreage, by state, from 1982-1997 (from Natural Resources Inventory 1997).

State	1982 (acres)	1997 (acres)	Change (acres)	% Change
Colorado	25,053,600	24,574,100	-479,500	-1.91
Kansas	16,496,700	15,727,900	-768,800	-4.66
Nebraska	23,585,600	23,089,100	-496,500	-2.11
New Mexico	41,736,100	39,989,500	-1,746,600	-4.18
Oklahoma	14,982,900	14,032,800	-950,100	-6.34
Texas	96,342,900	95,744,700	-598,200	-0.62
Total	218,197,800	213,158,100	-5,039,700	-2.31

Meanwhile, the condition of many grasslands continues to deteriorate due to fragmentation by anthropogenic activities and infrastructures associated with urban/ex-urban development, communications, and the extraction/distribution of energy (details below under Shrubland Habitats). Changes in plant-community structure are due to overgrazing, fire suppression, plantings or native and introduced species, and chemical control (e.g., Weaver et al. 1996). Range expansions of invasive/exotic species further degrade grasslands in some regions, although shortgrass systems are believed to be relatively resistant to invasives (see Low and Lauenroth 2001). In time, however, even shortgrass systems may be found susceptible to invasive species. For example, yellow sweetclover—the seed stock of which is pervasive in many areas of shortgrass prairie—often becomes dominant in disturbed areas during wet years, and there is some speculation that this legume may slowly pave the way in shortgrass systems for other invasive species (E. Lane, pers. comm.). Also of concern is Japanese brome, downy brome (commonly known as cheatgrass) and hoary cress (commonly known as 'whitetop'). Downy brome is generally limited to the Great Basin, although in the PLJV it can form dense stands in disturbed areas; however, Japanese brome—often mistaken for downy brome—is pervasive throughout much of the PLJV region (R.D. Rodgers, pers. comm.). The advance of whitetop in PLJV grasslands is a concern because it can invade moderately moist uplands (<http://www.montana.edu/wwwpb/pubs/ eb138.pdf>; details below on Wetland Habitats). More research is needed to understand the potential of these species to seriously degrade grassland ecosystems in the PLJV region.

Changes of land ownership in grasslands: human demographics, urban/ex-urban growth—It has been well documented that grassland birds can be negatively impacted by habitat fragmentation, particularly those that are area sensitive and/or impacted by vertical structures in their habitats (e.g., Herket 1994, Warner 1994, Coppedge et al. 2001, Pittman et al. 2005). Trend data regarding grassland area (e.g., Table 3), however, do not account for changes in grassland fragmentation or compositional changes, which could represent further decreases—or possible increases (depending on species considered)—in avian habitat (e.g., Coppedge et al. 2001). A relatively recent, potentially significant source of fragmentation and habitat degradation in rangelands of the southern PLJV is a dramatic change in land-ownership patterns (Wilkins et al. 2003). Changing demographics among rural communities and the growth of urban/ex-urban populations are contributing to changes in land-ownership patterns within grassland habitats. As mentioned earlier, the mean age of people engaged in agricultural occupations in the PLJV is increasing. As in farming, economic difficulties associated with ranching continue to increase, which is encouraging many ranchers to retire. Where there is a market for their land, ranchers are selling it for ex-urban (e.g., 'ranchette') development (D.B. Bosley, pers. comm.). This is particularly true within relative proximity to major urban centers and travel corridors. For example, in eastern Colorado, ranchettes are being developed up to 100 miles east of Denver (D. Alexander, pers. comm.).

Over the last 5-10 years, many ranchers in the PLJV—especially in the southern region and around major river corridors—have sold their land for hunting (and some fishing) recreation (J.R. Bell, pers. comm.). Indeed, each year, Sam Middleton—a Lubbock, Texas, figurehead in the sales of rural real estate—is selling several hundred thousand acres of agricultural lands (primarily ranches) in the Southern High Plains (Byrns 2001, Wilkins et al. 2003; R.D. Rodgers, pers. comm.; see <http://www. chassmiddleton.com/ranches-colorado.htm>). These lands are being purchased primarily by new-wealth urbanites seeking hunting opportunities, particularly white-tailed deer and northern bobwhite (J.R. Bell, R.D. Rodgers, pers. comm.). In fact, quail are fast approaching deer in popularity among hunters seeking land for recreation in the region (Byrns 2001).

Several *socioeconomic* factors are driving real estate sales, including increasing concern about post-9/11 foreign travel and the post-Enron perception that land is a relatively stable investment (C.E. Gilliland, pers. comm.). Indeed, some recently purchased ranchlands are speculated to have investment returns of 20% (Byrns 2001). More importantly, however, Texas hunters have long been accustomed to paying for access on private lands; thus, it did not require a major shift in expectation for them to purchase hunting lands. Furthermore, many of these people now have significant disposable income, and they can buy land without the need to make an income from it (Byrns 2001). This, in turn, is driving up assessed values of ranch and farm lands (Wilkins et al. 2003) to the point where ranching and farming are not economically competitive (J.R. Bell, pers. comm.).

An *ecological* factor likely contributing to the trend in real estate sales for recreation land in the southern PLJV region is the negative impact of red imported fire ants on quail populations elsewhere in Texas (Byrns 2001). This invasive exotic is rapidly expanding its range, which abuts (and has begun to overlap) the PLJV's southeastern boundary (distribution trend map available in Gilbert 2004). It remains uncertain whether the fire ants contribute more to quail mortality by killing chicks (Guiliano et al. 1996, Mueller et al. 1999) or by altering chick activity budgets (Pedersen et al. 1996) and competing for food resources (Gilbert 2004). Indeed, fire ants are known to alter the diversity and/or diminish the abundance of certain vertebrates (e.g., Porter and Savignano 1990, Wojcik et al. 2001) and seeds/plants (e.g., Drees at al. 1991, Vinson 1994). In either case, the red imported fire ant is clearly contributing to declines in quail populations (Allen et al. 1995, Guiliano et al. 1996) east and south of the PLJV. In turn, quail hunters are moving north and west to areas where quail populations are still relatively unaffected by fire ants (Byrns 2001), including southern portions of the PLJV region. Fawn recruitment among deer also has been negatively affected by fire ants (Allen at al. 1997), which could be driving additional recreation-land prospectors to the PLJV.

As changes in land ownership occur, land parcels typically decrease in size (Wilkins et al. 2003). In the southern PLJV, significant fragmentation in land ownership could result in considerable landscape fragmentation as buildings, roads, and utilities are developed to serve the new landowners. In addition, owners of recreation lands may encourage (intentionally or not) woody vegetation to encroach into their rangelands. Historically, ranchers controlled woody vegetation on their lands to improve livestock capacity, thus maintaining relatively large blocks of grassland. Whether the new landowners will be willing to conduct brush control is likely to vary widely, depending on their goals. A mosaic of brush cover is generally considered important to the occurrence, nutritional status, and/or survivorship of deer (Darr and Klebenow 1975, Soper et al. 1993) and quail (Williams et al. 2000). As long as these species are perceived to benefit from at least some open area of grassland, new landowners are likely to continue at least some brush control and/or grazing; however, if these activities are perceived to disrupt hunting opportunities, brush control may be discontinued and/or cattle may be removed (C.E. Gilliland, pers. comm.). Even many ranchers still holding onto their lands are allowing brush to develop on 30-40% of their land as a means of attracting deer so they can earn extra income by charging access fees to deer hunters (per acre, hunting land is generally more lucrative than ranchland; Byrns 2001). Either way, it seems reasonable to expect that large blocks of rangeland will continue to diminish due to fragmenting processes.

The greatest rates of development in the PLJV have been occurring along the Front Range corridor of eastern Colorado (Natural Resources Inventory 2001; see Tables 1 and 2). From 1959-1992, Colorado lost 9.35% (2.5 million acres) of its agricultural land (Colorado Department of Agriculture 1995), primarily grassland habitats (primarily due to development). Recently, rates of loss in Colorado have accelerated. From 1987-1997, the mean loss rate was 141,000 acres/year; however, that rate doubled from 1992-1997 (Colorado Department of Agriculture, Natural Resources Conservation Service and Colorado Agricultural Statistics Service 2000). Undoubtedly, this trend has affected both large and small bocks of grassland habitat.

Other areas of the PLJV where urban/ex-urban development is increasing at the expense of grassland habitats are summarized in Tables 1 and 2. Overall, however, it appears that development is not significant except in relative proximity to major towns/cities and interstate routes. For example, in Wichita, Kansas, the 1990-2000 population growth rate (12.4%) far outstripped that of rural Kansas (3.6%; see <http://webs.wichita.edu/depttools/depttoolsmemberfiles/cedbr/2000CensusTrends. ppt>). In fact, most of western Kansas has seen recent *declines* in human population (R.D. Rodgers, pers. comm.). In Texas, urban growth is occurring primarily in the larger urban areas to the south and east of the PLJV, and along the U.S./Mexico borderlands, with no significant growth predicted to occur elsewhere in the state (see <http://www.bizjournals.com/sanantonio/stories/2003/06/30/editorial3. html>).

Effects of uneven Farm Bill subsidies—The high cost of energy is affecting ranchers as well as farmers, particularly as it relates to providing water for livestock. Recently, increasing prices for cattle have improved the outlook for ranchers, which could encourage them to remain in ranching (R.D. Rodgers, pers. comm.). However, Farm Bill entitlements and provisions are weighted almost entirely toward farmlands, leaving most ranchers at a great disadvantage. At one time, the Grassland Reserve Program (GRP) held great promise for ranchers interested in setting aside their grasslands, but the GRP has realized negligible appropriations, and this problem is not expected to improve in the foreseeable future (A.W. Allen, pers. comm.). Furthermore, the Sodbuster provision of the Farm Bill has done little to discourage landowners from tilling previously untilled grassland (Johnson 2000, Niskanen 2005), as genetically modified crops make it possible to cultivate them where other crops would have failed. Indeed, sodbusting continues even as CRP acreage increases (Johnson 2000). Therefore, some ranchers unable to remain economically viable may convert their operations to, or lease them for, intensive dryland farming, or even high-efficiency irrigation farming (Howell 2001). However, this will probably occur only on a small or local scale, as soil type, climate, and logistical difficulties undoubtedly limit the possibilities for conversion (A.W. Allen, pers. comm.).

Patch burning/grazing: a management technique for improving rangeland condition—Overall, management of existing rangelands continues to improve slowly as ranchers increasingly understand the effects of overgrazing and the need for grasslands to recover after grazing (R.D. Rodgers, pers. comm.). A particularly promising technique for improving rangeland (and CRP) conditions in relatively mesic regions of the PLJV (J.R. Bell, pers. comm.) is patch burning/grazing. This system controls grazing intensity within a given pasture by creating a shifting mosaic of habitats (Robel et al. 1998, Fuhlendorf and Engle 2004; R.D. Rodgers, pers. comm.). The original paradigm was to sustain relatively high cattle-stocking rates by diminishing rangeland variability through even grazing (or burning) across a given pasture (Fuhlendorf and Engle 2001, 2004). Within a patch burn/graze system, however, the aim is to create a constantly shifting mosaic of habitats used differentially by cattle—but at stocking rates similar to those under the old paradigm. Thus, within a given pasture, freshly burned, minimal thatch (recovering from burn), and grass/forb residue (recovered from burn) habitats are created, which, in turn, are used heavily, lightly, and rarely (respectively) by cattle. For example, cattle will spend 75% of their time in the fresh burn to forage on new grasses (see Fuhlendorf and Engle 2001, 2004). Between heavy grazing and trampling in the fresh burn, grasses are suppressed, and once the cattle move on to the next fresh burn, forbs will dominate the recovering burn, thereby increasing plant species diversity (R.D. Rodgers, pers. comm.).

Grassland bird species, such as the mountain plover and chestnut-collared longspur, that evolved with a shifting mosaic of grazed grasslands should benefit from patch burning/ grazing systems implemented within their ranges. Indeed, mountain plovers often nest or forage in recently burned grassland (Knopf 1996, Svingen and Giesen 1999). R.D. Rodgers (pers. comm.) suggested that mountain plovers, upland sandpipers, and killdeer will use recently burned/heavily grazed patches, whereas lesser prairie-chickens with broods have been found foraging in the less grazed/minimal thatch patches. However, changes in traditional ways of ranching and farming almost always take time, and if patch burning/grazing catches on, R.D. Rodgers (pers. comm.) expects that it may be 2-3 decades before 25-35% of the ranchers are using this management technique. Furthermore, patch burning/grazing requires relatively large areas in order for it to be a viable option (A.W. Allen, pers. comm.).

SHRUBLAND HABITATS

While some shrubland types in the PLJV region are increasing, others are decreasing. The primary increasers are invasive, shrub-like trees: eastern red cedar and mesquite. Both of these invasives have been well-documented as encroaching on grasslands throughout much of the PLJV region, largely due to overgrazing and fire suppression (Coppedge et al. 2001, Fuhlendorf et al. 2002; D.M. Davis, pers. comm.). Shinnery oak and sand sagebrush, however, have been declining via herbicidal and mechanical control (Rodgers and Sexson 1990, Olawsky and Smith 1991), cropland conversion, and overgrazing (see reviews in Giesen 1998, Mote et al. 1998, Hagen et al. 2004). In Kansas, 27% of the original Sand Sagebrush habitat has been lost (from 339,645 acres to 214,183 acres) in just Finney, Kearny, and Hamilton counties alone—primarily due to cropland conversion (Robel et al. 2004).

In a study by Coppedge et al. (2001), grassland birds were found to decline along an increasing gradient of woody vegetation (primarily eastern red cedar). Conversely, nesting success and/or population densities of lesser prairie-chickens, northern bobwhites, scaled quail, Brewer's sparrows, and other shrub-steppe passerines can be negatively impacted by significant reductions of sand sagebrush, shinnery oak, and/or shrubland understories of forbs and grasses (see Rodgers and Sexson 1990, Giesen 1998, Pitman et al. 2005). Giesen (1998) indicates that landscapes encompassing <63% native rangeland cannot support lesser prairie-chicken populations, and Pitman et al. (2005) report that shrub cover within native rangeland should be at least 18-20% for lesser prairie-chickens. Thus, it appears that avian species respond differentially to shrub types and structure. There is a threshold above which stands of sand sagebrush and shinnery oak can become too dense and/or tall to provide suitable habitat for birds that use these habitats (R.D. Rodgers, pers. comm.).

Shinnery Oak and Sandsage Shrublands

Cropland conversion probably accounts for more loss of shinnery oak and sand sagebrush habitat than other causes. Fragmentation of remaining shinnery oak and sand sagebrush landscapes continues, however, and is believed to be a significant contributing factor to habitat degradation and declines of prairie grouse. Energy development is occurring throughout much of the PLJV region, and has significant potential to further fragment and degrade shrublands as well as grasslands. In New Mexico, for example, oil and gas development is rapidly expanding in the southeastern region, and rising fuel prices may result in redeveloping fields previously considered 'dry' (i.e., no longer profitable; D.M. Davis, pers. comm.). Oil and gas exploration also has been occurring in the panhandles of Texas and Oklahoma (J.R. Bell, pers. comm.), and applications for oil/gas development have been increasing in east-central Colorado (Melcher et al. 2003). Overall, the PLJV region encompasses significant areas of potential oil/gas development (e.g., Morton et al. 2004 for Colorado potential; <http://www.kgslibrary.com/bulletins/2002/bulletin_2002_Nov-Dec/pg32.html> and <http://www. eti-

geochemistry.com/kansas/> for Kansas potential; <http://www.pttc.org/solutions/413.pdf> for Oklahoma and Texas potential).

Infrastructures and activities related to gas/oil developments—including both the exploration and extraction/distribution phases —generally include well pads, roads, parking lots, powerlines, pipelines, water and disposal wells, evaporation ponds, compressor stations, and gas-processing facilities. Combined, these infrastructures can impact large areas, although most proposals do not account for the resulting landscape fragmentation, which can increase the area of total impact significantly. For example, a proposal to develop a 39,400-well coal bed methane field (in north-central Wyoming) addressed only the 6,660 miles of improved roads, 10,620 miles of 2-track roads, and 5,311 miles of overhead transmission lines related to the project. Overall, the facilities would directly impact at least 331 mi^2 and diminish water levels in the area's wells and surface waters (Powder River Basin Companies and the Bureau of Land Management 2002), but the proposal did not address the indirect effects (i.e., landscape fragmentation) that would result. In another proposal to develop a 365-mi^2 natural gas field (in south-central Wyoming), >9.4 mi^2 would be disturbed (Marathon Oil Company et al. 2004); again, however, effects of fragmentation were not mentioned.

To quantify indirect effects of energy development in the Big Piney-LaBarge gas field of Wyoming's Upper Green River valley, Weller et al. (2002) conducted a landscape-fragmentation analysis. The Big Piney-LaBarge project entailed a 7-mi^2 (as of 1990) core operation area, 1,400 miles of linear features (e.g., roads, powerlines), and 3.8 mi^2 of polygonal features (e.g., well pads, compressor stations, parking lots). Overall, the project was much smaller than the two mentioned above. In the final analysis, however, Weller et al. (2002) found that only 3% of the entire 166-mi^2 study area was >1/4 mile from the nearest infrastructure. In turn, this fragmentation of the landscape was predicted to have deleterious effects on greater sage-grouse (Weller et al. 2002); the same would probably be true for breeding prairie grouse or other area sensitive species that inhabit existing or potential oil/gas fields in the PLJV.

Also increasing significantly throughout the PLJV is the development of wind energy, the effects of which can be similar to those of petroleum extraction/distribution in terms of habitat fragmentation and the effects on avian species that avoid tall structures. Wind farming includes not only the turbines themselves, but also transmission lines, transmission stations, roads, and parking lots. In addition, significant between-turbine spacing is needed for accommodating the turbine rotors (New York State Energy Research & Development Authority 2005). Therefore, when power companies quantify the land required for wind farms, they indicate both the area required for turbine foundations and other structures (i.e., habitat conversion), as well as the total area of land required for the entire wind farm (i.e., indirectly affected habitat). For example, FPL Energy's website indicates that 0.4 acres per megawatt of "installed capacity" are required for turbine and road development in open, flat landscapes (http://www.fplenergy.com/renewable/contents/faqs_wind.shtml>); however, the same source indicates that the total area required for each megawatt of installed capacity is 40 acres. The website of Madison Gas and Electric in Wisconsin indicates that a 17-turbine wind farm (11.22-megawatt capacity) requires 7.4 acres per turbine (i.e., a total of 125.8 acres) for turbine foundations, transformers, and access roads; again, however, significantly more land is leased for the project (i.e., 603 acres for the 17-turbine site, or 86.14 acres per turbine; see <http://www.mge.com/environment/wind/windfarm_facts.htm>). These figures imply that the impacted area of a wind farm is much greater than the area converted by infrastructure development.

The examples provided above indicate that growth in the energy industry—whether based on petroleum or wind—has tremendous potential for severely fragmenting and degrading shrublands, as well as grasslands and wetlands, throughout much of the PLJV region. Because most of the PLJV areas with high potential for oil/gas development overlap at least some part of the lesser prairie-chicken's small, rapidly declining range (see range map in Giesen 1998), the landscape fragmentation associated with energy development is a significant concern. Lesser prairie-chicken populations are negatively impacted by fragmentation (smaller patch sizes, greater edge density), vertical structures, and general changes in the landscape (Fuhlendorf at al. 2002). Pitman et al. (2005) recommend that lesser prairie-chicken nesting habitat (including leks, nesting sites) be buffered from anthropogenic infrastructures (e.g., buildings, improved roads, transmission lines, wellheads) by distances of $\geq$1 km (0.62 mi), as nesting success was lower where buffer distances were smaller.

Although avian collisions with wind turbines have been reduced due to changes in turbine technology and siting guidelines to protect wildlife resources (see Anderson et al. 1999, National Wind Coordinating Committee 2001), the impact of wind turbines and electrical infrastructures on avifauna is an ongoing concern (e.g., Orloff and Flannery 1992, Leddy et al. 1999, Harness and Wilson 2001, Barrios and Rodriguez 2004). Of particular concern is the potential impact to raptors (Harness and Wilson 2001), prairie grouse (Robel et al. 2004), and other area-sensitive species, as well as species of open country not accustomed to encountering vertical structures in their habitats (Leddy et al. 1999, Coppedge et al. 2001). The U.S. Fish and Wildlife Service recently recommended a 5-mile buffer between prairie grouse leks and wind turbines (Manville 2004). While the scope of potential energy extraction in the PLJV region is not clear, it is obvious that landscapes affected by these activities will be impacted significantly, effectively contributing to habitat decline for many species that use those landscapes.

AQUATIC HABITATS

Throughout the PLJV region, many aquatic habitat types are considered stable or increasing. However, both ‘wet outside pit’ and ‘wet pit only’ playa habitats are decreasing (exception: wet outside pit playas are stable in New Mexico; Playa Lakes Joint Venture Waterfowl Team 2005), primarily due to siltation, tillage, modification, overgrazing, and declines in irrigation (see discussion above on Irrigated Croplands; see Melcher and Skagen 2005*a*, *b*). For example, the town of Lamar in east-central Colorado once was known as Colorado’s ‘goose capital,’ but today few geese inhabit the area because the playa wetlands previously filled by irrigation tailwater have dried out with the decline of irrigation in that area (L. Pruett, pers. comm.). Although the hydrologies of these and other tailwater wetlands were altered for human use, they provided important habitat for many waterfowl species, and may have mitigated some losses of natural wetlands elsewhere in the PLJV region.

Exacerbating the outright loss of water in playa wetlands is the functional loss of many remaining playas due to sedimentation (particularly playas embedded in croplands; Melcher and Skagen 2005*a*, *b*). For example, after significant fall and spring rains occurred in the Texas High Plains during 2003-2004, land managers and others noted that the playas in that region did not hold water for long (J.R. Bell, pers. comm), possibly because sediments already had filled much of the potential water-holding volume (see Luo et al. 1997). Alternatively, rapid infiltration may have occurred due to formation of macropores in playa basins during the recent, prolonged drought (J.R. Bell, pers. comm.; also see Melcher and Skagen 2005*a*). If sedimentation has diminished playa water-holding capacity, then wetland wildlife use of playas may continue to decline as well. For functional playas still threatened by sedimentation and other effects of runoff, increased use of Best Management Practices (BMPs; e.g., NT agriculture, installation of grass buffers around playas) should help slow the degradation processes (Melcher and Skagen 2005*a*, 2005*b*), although losses are likely to continue. More research is needed to better understand the hydrological properties of playas, how anthropogenic and other factors may have affected them, and the ways in which birds are responding to these changes.

The other major decreases in aquatic habitats are those associated with riparian systems: river channels, warmwater sloughs, and floodplain marshes. These habitats are decreasing due to the depletion of surface water and groundwater via direct and indirect withdrawals (Playa Lakes Joint Venture Waterfowl Team 2005). Also contributing significantly to losses of surface and groundwater, as well as native plant communities, are invasions of exotics plants. Several shrub or shrub-like species are of particular concern (see discussion below). Not only do these invasives adversely affect waterfowl, they affect cranes, shorebirds, and other waterbirds that feed along shorelines or in the littoral zones of riverine and associated habitats. In addition, exotics generally do not provide suitable substitutes in terms of food resources, winter cover, or nesting substrates for passerine birds at any time of year (e.g., McKernan Braden 1999; see summary on pp. 348-351 *in* Dudley et al. 2000). For example, along the lower Colorado River, monocultures of saltcedar have eliminated three avian guilds (frugivores, granivores, cavity nesters) and the insectivore guild has been reduced significantly (Cohan et al. 1979; van Riper III on p. 11 *in* Skagen et al. 2004).

Invasive/exotic species—Range expansions of invasive and exotic species are degrading wetlands throughout the PLJV area. Saltcedar infestation is particularly acute in all types of wetlands. As of 2003, it was estimated to infest up to 1.6 million acres of riparian habitat within the 17 western states, and an estimated 50,000 additional acres are invaded annually (see <http://resourcescommittee.house.gov/archives/108/testimony/jamestate0724.htm>). Currently, the greatest monocultures of this exotic in the PLJV region may be found within/around the Arkansas River drainage (E. Lane, L. Pruett, pers. comm.), including playas and other wetland types in that region (Melcher 2003), and along the Cimarron River drainage (Lynch and Wittwer 2005; R.D. Rodgers, pers. comm.). Saltcedar also has begun to establish significant stands in the North and South Platte river drainages (E. Lane, pers. comm.; see <http://www.r6.fws.gov/pfw/r6pfw15.htm>), and there are heavy infestations in the Pecos River drainage on the PLJV's southwestern border (Hart 2002). In Colorado, the total area estimated to be infested by saltcedar and Russian olive is 42,000 and 15,000 acres, respectively. The estimated amount of water used by that much saltcedar and Russian olive is 170,000 acre-feet per year (<http://cwcb.state.co.us/Resource_Studies/Tamarisk_Study_2003.pdf>), a significant impact on Colorado's limited water resources. Annual rates of increase by saltcedar in Colorado are 1-2.5%, which could enlarge the infested area to somewhere between 90,000 acres to 200,000 acres by 2050 if rigorous control programs are not implemented (<http://cwcb.state.co.us/Resource_Studies/Tamarisk_Study_2003.pdf>). In addition, saltcedar is invading moist pastures, grasslands, CRP, and other upland habitats that accumulate precipitation runoff and have high water tables (Hart 2002, Lynch and Wittwer 2005), where seeds can germinate and quickly send their tap roots down to groundwater resources (E. Lane, pers. comm.). Because irrigation ditches contribute to the expansion of saltcedar (Hart 2002), the PLJV's significant ditch system is undoubtedly serving as a conduit for dispersing saltcedar into new territory. Saltcedar also easily sprouts from root fragments torn away from riparian embankments and carried downstream during floods (E. Lane, pers. comm.).

Also relatively unchecked in the PLJV region—particularly in more northern sectors, such as the Platte River drainage—is the expansion of Russian olive. Although it is most common in riparian areas, Russian olive is also infesting certain uplands, including CRP fields where control of woody vegetation is inadequate (Lynch and Wittwer 2005, R.D. Rodgers, pers. comm.). Eastern red cedar is not only invading grasslands (see discussion above on Shrubland Habitats), it is invading riparian areas as well. Saltcedar, Russian olive, and eastern red cedar (Rodgers 2003) outcompete native plants and often form monocultures, thus changing the vegetative communities they invade. Although all three of these species can lower water tables, saltcedar's high rate of evapotranspiration has a particularly strong effect on water tables; it also takes up significant levels of salt and exudes it onto the soil surface—thereby degrading the habitat for understory species that cannot tolerate salts (Hart 2002).

A number of non-woody plants also threaten wetland habitats in the PLJV region. In Colorado, purple loosestrife recently began to invade wetlands, but aggressive attempts have been successful in eradicating it and minimizing its spread (D. Weber, pers. comm.). Similar efforts to control loosestrife are taking place in Kansas (see <http://www.accesskansas.org/kda/Plantpest/PestManagement/plant-purpleloosestrife.htm>) and Nebraska (see <http://ianrpubs.unl.edu/weeds/ec177.pdf>). Other invasives, however, are gaining footholds in the region, including teasel, perennial pepperweed, and hoary cress (the latter two commonly known as ‘whitetop’; E. Lane, pers. comm.). Teasel has been found in wetlands and borrow ditches along the Front Range, where its rosettes carpet the perimeters of wetlands, thus outcompeting other species (E. Lane, pers. comm.). Although this species seems to remain at the wetland perimeter, it could impact native wetland edge species if it continues to spread. Perennial pepperweed has already invaded much of Colorado, and because it requires significant moisture, it is affecting riparian areas and wetlands most. Currently, the South Platte River corridor in Arapaho County is a ‘hot spot’ for perennial pepperweed (E. Lane, pers. comm.). Hoary cress requires moderate moisture; therefore, it not only invades wetlands, it is also appearing during wet springs along roads where soils are relatively alkaline, in CRP fields, and in fallow croplands. Both whitetop species can form dense monocultures, and neither is believed to provide any value to wildlife (see <http://www.unr.edu/ nevadanews/detail. aspx?id=1075>, <http://www.montana.edu/wwwpb/pubs/eb138.pdf>). Also of concern in wetlands of the PLJV region are common reed (also known as phragmites) and cattails. These species often form dense monocultures that completely choke wetland habitats. Many land managers regularly have to spend significant personnel time and funds to contain these species and reduce infestations (Melcher et al. 2003; H. Hands, pers. comm.; see <http://www.r6.fws.gov/pfw/r6pfw15. htm>).

CONCLUSIONS & ADDITIONAL CONSIDERATIONS

Clearly, major changes in land use are affecting avian habitats within the PLJV region. Among the more-salient changes are agricultural intensification, diminishing acreage of irrigated cropland, and fragmentation due to urban/ex-urban development, expansion in the energy industry, and range expansions of invasive/exotic species. Currently, agricultural intensification is changing more habitat area than any other change in land use. The result is decreasing acreage of winter wheat and wheat fallow, whereas acreages of many secondary dryland crops are increasing, particularly corn, sorghum, cotton, and soybeans; sunflower and other oilseeds, specialty grains, and forage hays are also increasing in some areas. The losses of irrigated corn and sorghum cropland may be partially offset by increases in dryland corn and sorghum, and losses of wheat cropland may be partially offset by the replacement of irrigated crops with dryland wheat. By and large, however, the increasing reliance on herbicides and the elimination of idle lands and weedy areas in agricultural landscapes are not conducive to avian use. Both large and small blocks of grassland and shrubland habitats also continue to be degraded by conversion and fragmentation processes, especially due the breakup of large ranches, ranchette development, and growth in the extraction, production, and distribution of energy. Ongoing invasions of exotic (and some native) plants contribute further to the degradation and fragmentation of grasslands, shrublands, and aquatic habitats.

Overall, however, the effects of land use on avian habitats and populations are highly complex, and many questions about the effects of changing land uses remain unanswered. Furthermore, simply tracking acreages affected by changes in land use do not necessarily reveal the full effects of those trends. Fragmentation by human activities, anthropogenic infrastructures, and invasive species can render large blocks of habitat into habitat sinks, or they may exclude some species altogether. Another important consideration with respect to habitat quality is landscape context. In western Kansas, for example, ring-necked pheasants have declined significantly, despite a significant increase in CRP land throughout the landscape. (Although not a native species, the pheasant is economically and culturally important throughout the Great Plains, and it may serve as an umbrella for a number of declining grassland bird species.) The problem is increasing use of herbicides and shorter post-harvest stubble in adjacent foraging areas, such as fallow wheat fields. In eastern Colorado, Skagen et al. (2005) found that nest survival of lark buntings and horned larks was inversely correlated with patch size, most likely due to the ways in which local predator communities have responded to fragmentation in an otherwise highly fragmented landscape. These findings led the authors to recommend that conservation planners not overlook the potential value of smaller habitat blocks in fragmented landscapes (Skagen et al. 2005).

There are also broader-scale factors (e.g., climate change, altered water and nutrient cycles) that may interact with regional or local changes in land use and their effects on avian habitats. For example, large-scale irrigation has been shown to influence precipitation patterns approximately 90 km downwind of significantly irrigated landscapes in Texas High Plains (Moore and Rojstaczer 2002); thus, loss of irrigated landscapes also may cause losses of wetlands elsewhere. In eastern Colorado, researchers have found that soil organic matter, microbial biomass, and nitrogen/carbon dynamics are greatly diminished by cultivation, and models indicate that it could take 50 years for croplands to recover to pre-cultivation conditions

(Burke at al. 1995). The ways in which any one land-use change may interact with global climate to affect carbon sequestration and nitrogen deposition remain relatively unknown at this point. Overall, it will be important to consider these and other factors when evaluating the potential effects of land-use trends on avian distributions, community structures, and populations. Models and other tools for predicting the interactive effects of local- to broad-scale changes in land use will be increasingly helpful *as more high-quality data become available and the models are refined and validated in the field*. Meanwhile our understanding of how changes in land use may affect entire ecosystems, much less the wildlife species that inhabit those systems, is rudimentary, at best.

RESEARCH & CONSERVATION IMPLICATIONS

Changes within agricultural lands may or may not be entirely detrimental to all species, but research on exactly how, when, and which species use various croplands—and how changes in croplands affect these patterns—has been minimal. This makes it difficult to predict the outcomes of current changes in land use. Thus, additional in-depth research on avian use of agricultural habitats is needed. More information on the effects of wind farms and other fragmenting processes in grassland and shrubland habitats is also needed to improve our understanding of the relationships between patch size, landscape context, and avian population dynamics. Some important research questions (from both ecological and social sciences) are listed below.

- Which croplands are used by which avian species and how/during which season are they used (e.g., foraging, roosting, nesting, winter cover, migration stopover, brood rearing)? How do avian productivity and survivorship vary in different cropping systems (e.g., traditional wheat-fallow vs. more current rotations/crops)? Do different herbicides (and other pesticides currently used broadly throughout the PLJV region) affect avian species differentially, and, if so, how? Do dryland crops provide suitable alternatives to irrigated crops in terms of avian food and cover resources? How do altered genetics, improvements to farm machinery, and other factors affect cropland habitat suitability?

- Which crops and cropland management alternatives would be most beneficial to both farmers and grassland birds native to the central and southern High Plains region, and what are the best approaches for promoting those crops and practices among agricultural communities?

- To what extent are energy developments (and associated infrastructures), urban/ex-urban/rural developments contributing to grassland and shrubland habitat fragmentation, and how do avian species respond? For a given species, at which scales do the effects of fragmentation impact avian populations, and which fragmentation processes are most detrimental? Can these effects be mitigated and, if so, how? At which scale(s) should conservation efforts be implemented?

Because it can take years, if not decades, to procure adequate funds for—much less results from—research, conservation of habitats known to be decreasing or undergoing degradation should continue even in the absence of adequate information. Dynamic conservation planning and adaptive management approaches will allow changes in strategy if future research results indicate that the existing strategies are inappropriate. Because outright loss of habitat due to infrastructure development and agricultural conversion undoubtedly have the most irreversible effects, efforts that focus on precluding further losses are paramount, and the value of small habitat blocks should not be underestimated. Habitats/areas that support the *native*, *endemic* avifaunal communities and/or viable populations of declining species should be prioritized for conservation, including blocks of native grassland and shrubland, playas, riparian systems, and other natural wetland habitats. This will require habitat protection not only through acquisitions or other means of habitat conservation (e.g., conservation easements), but also through public education (e.g., targeted public-education campaigns to encourage public/private funding for land trusts and other entities that fund habitat acquisitions/easements and to encourage the purchase of habitat and duck stamps), policy development (e.g., stringent siting/operational regulations for energy developments, appropriations for the GRP that at least equals CRP funding), and restoration (e.g., exotic/invasive species tracking, mapping, and removal programs).

Where rapid, large-scale removal of invasive plants could threaten endangered or declining avian species currently subsisting in those habitats, removal programs will have to be advanced slowly enough, and in conjunction with vegetation replacement programs, so as not to jeopardize native avian populations. For example, the endangered southwestern willow flycatcher historically inhabited native riparian vegetation, but now it also occurs in monocultures of saltcedar. Although the southwestern willow flycatcher's reproductive success in saltcedar habitat is comparable to that in native vegetative communities (Owen et al. 2005), entire guilds of other avifauna do not occur in monocultures of saltcedar; however, if implemented inappropriately, there is concern that saltcedar removal could exacerbate declines among flycatcher populations. The same phenomenon may apply to avian species within the PLJV region.

The existing published research indicates that birds make significant use of fallow, cereal croplands, and other agricultural situations where foraging opportunities and/or cover are suitable. Thus, conserving croplands with high wildlife value (e.g., corn, sorghum, fallow) is crucial. Most U.S. farmers and ranchers, however, are struggling economically as the global market imposes increasing pressures, fuel costs rise, and water resources become over-tapped; without viable alternatives, many landowners will continue to break up and sell their land, and few young people will recruit into agricultural work—putting agricultural lands at further risk of being fragmented and lost. Furthermore, acceptance of new methods among farming communities can take decades—largely due to cultural traditions and the expenses involved with significant changes in cropping systems and land-management practices; thus, the importance of long-term landowner education and financial assistance programs cannot be underestimated. By the same token, conservation planners need to continue their education on the complex problems facing agricultural landowners. To a great extent, conservation of agricultural lands important to wildlife will require continued improvements to the Farm Bill (e.g., provisions/incentives for crops/practices that support avian populations), development of economically viable farming practices that do not have adverse effects on avian populations, and programs to convene farmers with conservation group/agencies and help them work towards common goals. On certain local levels, this is already happening (e.g., landowner workshops and educational/ logistical resources developed by Rocky Mountain Bird Observatory), but this type of work/education needs to happen on a much larger spatio-temporal scale that includes future (i.e., youth) as well as current landowners. Finally, conservation easements will continue to be crucial means of keeping family farms and ranches intact if funding can be raised to assist the growing number of landowners interested in this alternative. Thus, targeted educational campaigns that encourage public/private funding specifically for this purpose, plus those that encourage the public to purchase habitat and duck stamps, may be one of the most effective means of conserving habitat throughout the PLJV region.

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APPENDIX 1. Scientific names of plant (including crops) and animal species mentioned in this document. Species are listed in alphabetic order by common name. **Note:** CANOLA, the acronym for Canada Oil Low Acid, now includes any rapeseed cultivar that produces oil containing <2% erucic acid and meal containing <30 µmol/g of glucosinolates (Grombacher and Nelson 1996); although North American canola cultivation originated in northern sectors of the Great Plains, various cultivars are now being grown in other sectors as well, including the PLJV.

American Kestrel (*Falco sparverius*)
Brewer's Sparrow (*Spizella breweri*)
Canola (*Brassica napus*)
Cattail (*Typha* spp.)
Chestnut-collared Longspur (*Calcarius ornatus*)
Common Reed (*Phragmites australis*)
Corn (*Zea mays*)
Cotton (*Gossypium hirsutum*)
Cotton Aphid (*Aphis gossypii*)
Downy Brome (*Bromus tectorum*)
Eastern Red Cedar (*Juniperous virginiana*)
Grasshopper Sparrow (*Ammodramus savannarum*)
Greater Sage-Grouse (*Centrocercus urophasianus*)
Hoary Cress (*Cardaria draba*)
Horned Lark (*Eremophila alpestris*)
Japanese Brome (*B. japonica*)
Killdeer (*Charadrius vociferus*)
LeConte's Sparrow (*A. leconteii*)
Lesser Prairie-Chicken (*Tympanuchus pallidicinctus*)
Mesquite species (*Prosopis* spp.)
Mountain Plover (*Charadrius montanus*)
Mourning Dove (*Zenaida macroura*)
Northern Bobwhite (*Colinus virginianus*)
Northern Harrier (*Circus cyaneus*)
Peanut (*Arachis hypogaea*)
Perennial Pepperweed (*Lepidium latifolium*)
Proso Millet (*Panicum milaceum*)
Purple Loosestrife (*Lythrum salacria*)
Red Imported Fire Ants (*Solenopsis wagneri*; formerly *S. invicta*)
Red-tailed Hawk (*Buteo jamaicensis*)
Ring-necked Pheasant (*Phasianus colchicus*)
Russian Olive (*Elaeagnus angustifolia*)
Safflower (*Carthamus tinctorius*)
Saltcedar (*Tamarix* spp.)
Sand Sagebrush (*Artemesia filifolia*)
Sandhill Crane (*Grus canadensis*)
Scaled Quail (*Callipepla squamata*)
Sericea Lespedeza (*Lespedeza cuneata*)
Sharp-tailed Sparrow (*Ammodramus nelsoni*; now Nelson's Sharp-tailed Sparrow)
Shinnery Oak (*Quercus havardii*)
Smith's Longspur (*Calcarius pictus*)
Sorghum, Grain; also known as milo (*Sorghum bicolor*)
Sorghum, Hay; also known as Sudan grass or hay millet (*S. bicolor*)
Southwestern Willow Flycatcher (*Empidonax traillii extimus*)
Soybean (*Glycine max*)
Sunflower (*Helianthus annuus*)
Teasel (*Dipsacus* spp.)
Upland Sandpiper (*Bartramia longicauda*)
Vesper Sparrow (*Pooecetes gramineus*)
Weeping Lovegrass (*Eragrostis curvula*)
White-tailed Deer (*Odocoileus virginianus*)
Winter Wheat (*Triticum aestivum*)
Yellow Sweetclover (*Melilotus* spp.)

APPENDIX 2. Habitat trends (known or assumed) resulting from changes in land use and/or land management, by type, association, and/or condition—according to Playa Lakes Joint Venture Planning Implementation Guide (Playa Lakes Joint Venture 2004). To assist readers with identifying where trends are taking place, areas or states impacted (or probably impacted) by a habitat trend are in boldface font. Data pertaining to PLJV states includes the entire area of all six PLJV states (i.e., not limited to the PLJV region).

Type	**Association**	**Condition**	**Trend**
Wetland	Playa	Wet, wet pit	Decreasing throughout **PLJV states** due to continued declines in irrigation (J.R. Bell, pers. comm.) and sedimentation (see Melcher and Skagen 2005*a*, *b*; PLJV Waterfowl Team 2005).
Wetland	Playa	Dry	Decreasing throughout **PLJV sates** due to agricultural intensification, tillage, modification, sedimentation, diminished protection in Clean Water Act (see Melcher and Skagen 2005*a*, *b*; PLJV Waterfowl Team 2005).
Wetland	Riverine	All	Decreasing throughout **PLJV states** due to dewatering of surface/ground water and invasions of Saltcedar, Russian Olive, and other invasives (PLJV Waterfowl Team 2005; Eric Lane, pers. comm.); area infested by Saltcedar and Russian Olive in Colorado estimated at 42,000 and 15,000 acres, respectively; annual rates of increase by Saltcedar in Colorado are 1-2.5%, which could result in 90,000 to 200,000 acres becoming infested by 2050 (http://cwcb.state.co.us/Resource_Studies/Tamarisk_Study_2003.pdf).
Agricultural	Cropland	Corn (dryland)	Increasing (e.g., in Adams, Kit Carson, Logan, Morgan, Phillips, Sedgwick, Washington, Yuma counties of **e. Colorado**, the acreage increased from 28,000 in 1989 to 290,000 in 1999; Peterson et al. 2002). From 1978-1998, post-harvest waste corn (primarily ears) in fallow fields declined in the central Platte River valley of Nebraska by 47% due to improvements in machinery and in crop genetics (Krapu et al. 2004).
Agricultural	Cropland	Corn (irrigated)	Decreasing in **all PLJV states** (NASS 2002). See note above re: 47% decline in post-harvest waste corn.
Agricultural	Cropland	Fallow	Decreasing significantly in **all PLJV states** (NASS 2005). From 1980 to 2005, dryland winter wheat in **Kansas** (greatest wheat-producing state) planted after summer fallow declined from 6,200,000 to 4,000,000 acres (NASS 2005).
Agricultural	Cropland	Hay	No specific trend data provided by NASS (2002). (See section below on grass sorghum.)
Agricultural	Cropland	Millet	No trend data provided by NASS (2002); 800,000-1,000,000 acres currently grown in Central Plains (Baltensperger, et al. 2004); probably decreasing overall, but may be increasing locally, including some parts of **e. Colorado** (Croissant et al. 2004).
Agricultural	Cropland	Sorghum	Grain sorghum (*Sorghum bicolor;* commonly called milo) decreased **in PLJV** states by nearly 50% (5.3 million acres) from 1974-2002 (NASS 2002); however, it is probably increasing in parts of **e. Colorado** (Croissant et al. 2004) and it continues to be an important crop in **Kansas**, where grain sorghum is often grown for ethanol production and could increase if ethanol demands increase (see http://www.ksgrains.com/sorghum/MiloMania04.pdf).

Type	Association	Condition	Trend
			Grass sorghum (Sudan hay), grown as a forage or silage crop, is being used in some dryland rotations with winter wheat and corn, thus it may be increasing locally, including the **Southern High Plains** (http://www.ksgrains.com/sorghum/MiloMania04.pdf) and parts of **e. Colorado** (Croissant et al. 2004).
Agricultural	Cropland	Soybean	Increased nearly 4× (~2 million to 7.5 million) in **PLJV states** from 1974-2002 (NASS 2002); in all **Kansas** counties entirely encompassed by BCR 19, soybeans increased from 178,000-765,000 acres from 1980-2005, but the increase from 2000-2004 was only 11,300 acres, indicating that soybean cropping in that area may have reached a limit (NASS 2005); in all counties entirely encompassed by BCR 18 in **Kansas**, soybean acreage increased from 20,500-85,000 acres from 1980-2004 (NASS 2005).
Agricultural	Cropland	Sunflower	NASS sunflower data too recent to determine overall trend in **PLJV states** (NASS 2005), but increasing throughout most PLJV states; however, from sunflower increased from 63,000 to 270,000 acres during 1991-1999 in Adams, Kit Carson, Logan, Morgan, Phillips, Sedgwick, Washington, Yuma counties of **e. Colorado** (Peterson et al. 2002); from 1998-2000, sunflower planted increased from 68,000 to 100,000 acres in **Nebraska** (http://www.ipmcenters.org/cropprofiles/docs/NEsunflowers.html); **Kansas** is a major sunflower-producing state and grew 70,000 acres in 1991; also being grown in Texas (http://www.cyberspaceag.com/kansascrops/sunflowers/sunflowerhistory.htm) (http://muextension.missouri.edu/xplor/agguides/ crops/g04290.htm) (http://www.agmrc.org/agmrc/commodity/grainsoilseeds/sunflower/sunflowerprofile.htm).
Agricultural	Cropland	Wheat (dryland, winter)	Decreased ~33% in **PLJV states** from 23.3 million in 1974 to 17.7 million acres in 2002 (NASS 2002); from 1980 to 2005 in **Kansas** alone, the annual acreage of 'non-irrigated' winter wheat planted 'after summer fallow' declined from 6,224,000 to 3,975,000 acres (NASS 2004).
Agricultural	Cropland	Peanut	Possibly increasing locally in parts of **New Mexico** (D.M. Davis, pers. comm); declines in **Texas** and **Oklahoma**, presumably due, in part, to some aspect of the Farm Bill (http://www.fws.gov/refuges/profiles/index.cfm?id=21660).
Agricultural	Cropland	Pasture	Increased slightly from 1982-1997 in **Colorado, Kansas, Oklahoma, New Mexico;** however total for all **PLJV states** combined decreased by 360,000 acres (Natural Resources Inventory 1997).
Agricultural	Cropland	Cotton	Decreased in 4% from 5.1 million acres in 1974 to 4.9 million acres in 2002 (NASS 2002); expected to increase in **Texas panhandle** (S. Amosson, pers. comm.) by 10-20% in next 5+ years (J.R. Bell, pers. comm.).
Agricultural	CRP large & small blocks	Native grass	Overall CRP grasslands (all sign-ups, native and non-native) in all **PLJV states** increased from 11.6 million acres (Farm Service Agency 2001) to 12.2 million acres (Allen and Vandever 2005); in **Kansas**, 2.9 million cropland acres have been converted to CRP (probably mostly native grasses); native grasses likely increasing throughout **PLJV states**: in 2004, 3.97 million acres of CP2 (native) were installed (Farm Service Agency 2004).
Agricultural	CRP large & small blocks	Non-native grass	Probably increasing at least locally throughout **PLJV states** due to invasive characteristics of some non-natives (e.g., Weeping Lovegrass in **New Mexico**) (A.W. Allen, J.R. Bell, pers. comm.), although in 2004 only 250,000 acres of CP1 (non-native grasses/legumes) were installed, and only 5.75% of all new grass

Type	Association	Condition	Trend
			plantings in the general CRP sign-up were non-natives (Farm Service Agency 2004); for overall CRP trend (see note above for native grasses).
Other	Other	Urban/ suburban	Increasing from 2 to ≥40% around larger urban areas and along highway corridors in all **PLJV states**; greatest area and rates of development in eastern **Colorado** up to 100 miles east of Front Range (see Table 1 in body of text).
Other	Other	Road	Likely increasing in regions where large ranches are becoming broken into smaller parcels—especially in the **Southern High Plains** and **major riparian corridors in southern and northern sectors of the PLJV region** (Natural Resources Inventory 2001; Wilkins et al. 2002, 2003).
Grassland	Tallgrass large & small blocks	All	Probably decreasing significantly (Colorado Department of Agriculture 1980, Colorado Department of Agriculture, Natural Resources Conservation Service, and Colorado Agricultural Statistics Service 2000, Conner et al. 2001); along the **Front Range** and in **riparian regions**, tallgrass may be declining at a faster rate due to the aesthetic appeal of these areas to new landowners (see note below for shortgrass large & small blocks).
Grassland	Mixed grass large & small blocks	All	Decreasing (Colorado Department of Agriculture 1980, Colorado Department of Agriculture, Natural Resources Conservation Service, and Colorado Agricultural Statistics Service 2000, Conner et al. 2001); since European settlement, mixed grass habitat has declined 30.5% in **Texas** (from 34.8 million to 24.2 million acres), 75.3% in **Nebraska** (from 19,000,000 to 4,700,000 acres) (p. 439 in Mac 1998). Overall, the PLJV states lost 5.04 million acres of rangeland (including mixed grass) from 1982-1997; see Tables 1-3 above for additional information.
Grassland	Shortgrass large & small blocks	All	Decreasing (Colorado Department of Agriculture 1980, Colorado Department of Agriculture, Natural Resources Conservation Service, and Colorado Agricultural Statistics Service 2000, Conner et al. 2001); since European settlement, shortgrass habitat has declined 79.5% in **Texas** (from 19.3 million to 4 million acres) (Mac 1998) and 59% in **Colorado** (from 26.5 million to 11.2 million acres) (Conner et al. 2001, Seidl et al. 2001); in **Kansas**, ~48% of grasslands (i.e., shortgrass and mixed grass) have been lost (Peterson et al. 2004). Overall, the PLJV states lost 5.04 million acres of rangeland (including mixed grass) from 1982-1997; see Tables 1-3 above for additional information.
Shrubland	Mesquite Savannah	All	Probably increasing throughout **Southern High Plains** due to overgrazing and fire suppression (Fuhlendorf et al. 2002; D.M. Davis, pers. comm.).
Shrubland	Shinnery Oak large & small blocks	Burned	Probably decreasing throughout its range in the Southern High Plains (**w. Oklahoma and Texas**, **e. New Mexico**) due to fire suppression and because burning is often used to eliminate woody vegetation on rangelands; also, Shinnery Oak re-grows extremely slowly (see review of burning effects on Shinnery Oak, pages 73-74 in Hagen et al. 2004).
Shrubland	Shinnery Oak large & small blocks	Not burned	Possibly decreasing throughout its range in the Southern High Plains (**w. Oklahoma and Texas**, **e. New Mexico**) due to cropland conversion and herbicide treatments (see reviews in Mote et al. 1998).
Shrubland	Sand sage	All	Probably decreasing throughout its range (**w. Oklahoma and Texas panhandles**, **e. New Mexico and**

Type	Association	Condition	Trend
	large & small blocks		**Colorado, sw. corner and panhandle of Nebraska**) due to development, use of herbicides (Rodgers and Sexson 1990), and cropland conversion (Pitman et al. 2005); 27% has been lost (from 340,000 to 214,000 acres) in Finney, Kearny, and Hamilton counties of Kansas (Robel et al. 2004).