draft** BACA NATIONAL WILDLIFE REFUGE **draft

Task I. Document vegetation condition and bird species-habitat relationships in meadows at Baca National Wildlife Refuge in the San Luis Valley, Colorado

Technical Assistance Plan – 2008 Report

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EXECUTIVE SUMMARY

Baca National Wildlife Refuge was established in the arid San Luis Valley of south central Colorado in 2000. Intermittently to seasonally flooded meadows dominated by Baltic rush and sedges cover about 13% of the 37,500-ha (93,000-ac) refuge and may compose one of the most biologically significant resources in the region. For the past century, the meadows mostly have been managed by flood-irrigation in spring followed by hay harvest in late summer then grazing during fall and early winter. The current condition and wildlife use of meadows should be documented to help assess the appropriateness of this traditional management for supporting the refuge's proposed mission of conserving habitat for native biota especially migratory birds. Coinciding changes in surface water area, general structure and composition of vegetation, and occurrence of breeding species of migratory birds were measured on 140 3.1-ha (7.8-ac) circular plots distributed randomly across meadows during late spring through early summer 2008. The assessment was intended principally as an inventory and in most cases did not incorporate replication needed for formal statistical comparisons. Thus, descriptive statistics and principle components analyses (PCA) were main tools used for summarizing data and conclusions generally were tentative.

Roughly 85% of meadow habitat on plots was dry in late May but about one-half was slightly flooded to covered by shallow (i.e., to 30 cm [12 in] deep) water by late June. Plots had a considerable though highly variable amount of edge (mean $\pm$ 95% CI: 303.3 m $\pm$ 98.3), represented mainly by an abrupt transition with upland shrub (rabbitbrush and greasewood), tall graminoid cover along lateral irrigation ditches, and boundaries between hayed and unhayed areas.

Compared to idle plots (i.e., those covered mainly by meadow that had not been hayed or grazed in the previous year or years), hay-graze plots (i.e., those in which hay had been harvested and cattle had grazed in the previous year) were characterized by: 1) less plant litter during mid-May through June and shorter vegetation height and density in mid-May; 2) greater likelihood of being flooded; 3) having more area of meadow in the surrounding landscape; and 4) a tendency for less interspersed upland especially grass types. A PCA suggested that nearly half of the variation in habitat among plots in late May was driven by a trend from short, sparse herbaceous vegetation with little litter to dense, tall vegetation with much litter, plus a trend from no upland shrub to much shrub. Variation in habitat in June was similarly explained except that the short, sparse vegetation was covered by shallow (to 30-cm [12-in] deep) water.

Twenty-seven species of breeding birds were detected. Common species (i.e., detected on at least 10% of plots) included Wilson's snipe, Wilson's phalarope, horned lark, Brewer's sparrow, vesper sparrow, Savannah sparrow, red-winged blackbird, western meadowlark, and brown-headed cowbird. Based on PCAs, there was much overlap in use of habitat among most of these species in late May when meadows still were relatively dry; most of the bird species were associated with average conditions of litter depth and vegetation height-density and with little or no shrub. When much

meadow flooded in June, however, differences in habitat used by the species became apparent. Wilson's snipe became associated with wet, short, sparse, meadow vegetation and not with shrub; it was detected almost exclusively at hay-graze plots. Savannah sparrow remained consistently associated with average conditions and occurred 25-50% more frequently in hay-graze plots than in idle plots. Wilson's phalarope, red-winged blackbird, and brown-headed cowbird closely overlapped, shifting distinctly to flooded, short-sparse meadow vegetation in early and late June; all three species occurred far more frequently in hay-graze plots than in idle plots. Horned lark and western meadowlark shifted from average conditions in late May to dry, denser, taller meadow vegetation and more shrub in early and late June; both seemed to occur more frequently in idle plots than in hay-graze plots. Brewer's sparrow and vesper sparrow were associated with meadow vegetation of average structure and overlapped much in their affinities for shrub in late May. In June they shifted to dry, dense, tall meadow vegetation while remaining distinctly shrub-associated; the two sparrows mostly used idle plots, somewhat overlapping in habitat with horned lark and western meadowlark.

Mean species richness of breeding birds per plot was 4.1 ± 0.2. Richness appeared less on idle plots than on hay-graze plots. A positive relationship between species richness and area of wet meadow in the landscape was evident on hay-graze plots. Plots on which Wilson's snipe, Savannah sparrow, red-winged blackbird, or brown-headed cowbird occurred had more area of meadow in the landscape than did plots where the respective species did not occur, while the converse was true for Brewer's sparrow and vesper sparrow.

Relatively few wetland-dependent species of birds were common in this assessment, probably because the peak in runoff from snowmelt in nearby mountains was later than usual in 2008. Regardless, data from this modest inventory effort suggest that traditional management of meadows tends to favor short-sparse, intermittently to seasonally flooded, herbaceous vegetation with little shrub, in relatively large, contiguous areas. Conversely, relatively small or narrow meadows tend to have tall-dense, less frequently flooded vegetation interspersed with upland shrub and grass. A pattern of frequent flooding, haying, and grazing in large meadows may favor Wilson's snipe, Wilson's phalarope, Savannah sparrow, red-winged blackbird, brown-headed cowbird, and overall species richness. Increased area of relatively dry, idle meadow may favor Brewer's sparrow and vesper sparrow.

A critical gap in knowledge is the value of large areas of flooded meadow that in the previous year were either idle or were fall-grazed but not hayed. Few such areas were available for this assessment and may pose opportunities for enhancing the habitat and species diversity of birds. A more finely scaled, information-theoretic assessment that includes multiple management approaches across representative years of spring runoff seems warranted. Regardless, approaches considered should account for control of introduced plant species and direct and indirect influences of historic ecosystem processes on native plant diversity.

INTRODUCTION

Wetlands likely are the most diverse and unique biological communities of the 21,000-km^2 (8,100 mi^2) San Luis Valley in south central Colorado and north central New Mexico. Although their total area may cover a relatively minor part of the landscape, wetlands provide crucial habitat for most species of migratory birds that nest, migrate through, or overwinter in this vast, high elevation (2300 m [~7500 ft]), intermountain valley. Conservation of migratory birds is the principal emphasis of national wildlife refuges (NWRs) in the valley. Thus, management of wetlands is the focus of goals on two of the refuges (U.S. Fish and Wildlife Service 2003). The third refuge, Baca NWR, was created recently (2000). Although its official goals are not yet established, the proposed mission of the refuge emphasizes conservation of migratory birds and native habitats. Short-term goals focus on improving knowledge of the refuge's natural resources and ecological processes, to support long term planning and objective setting for optimally managing the area.

Of all habitats found on Baca NWR, wetlands, especially sedge-Baltic rush meadows (scientific names of biota are listed in Appendix A), lend themselves most readily to active management. Indeed, throughout the past century, meadows have been the most actively manipulated habitat, primarily through flood irrigation in spring via structures in creeks and major drainage ditches that divert water to shallow (0.5 m deep [1.6 ft]) ditches. Flooding typically has been followed by hay harvest in late summer and grazing by cattle in fall to early winter. Because management of meadow habitat typically is frequent (annually or nearly so) and relatively unvaried among years, there may be consequences to consider, e.g., possible shifts in plant species composition, alteration of the structure of vegetation preferred by nesting and foraging birds, or changes in production of invertebrate and plant foods for birds.

Land managers must be better equipped to anticipate outcomes of various approaches for conserving meadows and ascertain whether the current approach is most appropriate for resources of major interest, especially migratory birds, native plant communities, and local to regional hydrology. For example, contemporary management of the refuge's "hay meadows" may play an important role in control of invasive,

introduced species of plants (R. Garcia, U.S. Fish and Wildlife Service, personal communication). Changes to improve meadow habitat for certain species of birds could limit the ability to control such plants; the converse may be true. Various strategies for managing irrigation flows likely have direct consequences for groundwater recharge and for periodic flooding of playa basins in the western part of the refuge.

The intent of this 1-year, preliminary work was to inventory birds and bird habitat resources in meadows in such a way that current conditions could be characterized and specific management questions could be formulated and refined for study in subsequent years in the context of adaptive resource management ("learn while doing," *sensu* Walters 1986). Information from this technical assistance plan should help support development of habitat goals and objectives for the refuge's Comprehensive Conservation Plan (Gergely et al. 1997). Main goals of this work were to: 1) quantify coinciding changes in water area, vegetation dynamics, and bird use of meadows during late spring and early summer at Baca NWR; and 2) begin to develop basic predictive models to help managers anticipate the response of vegetation and bird species in meadows to flooding-hay harvest-grazing, or rest from such disturbance.

Primary Objectives

(1) Document the occurrence, abundance, and distribution of breeding species of birds in meadows (mid-May through early July)

(2) Document temporal shifts in habitat conditions: measure vegetation structure and the extent and depth of surface water or of saturated soil every 2 weeks during May through early July.

(3) Document vegetation composition and assess the role of major plant species or groups of species in temporal shifts in structural heterogeneity of meadow habitat during May through early July.
(this objective was addressed in only a cursory, general way in 2008)

(4) Quantify relationships between occurrence of common species of birds and: a) vegetation structure; b) class of water-cover condition; c) plant species composition; and d) composition of vegetation types in the landscape.
(part c was addressed in only a cursory, general way in 2008)

Secondary Objectives

(5) Compare vegetation structure in irrigated meadows in May and in June among three classes of management:
a) hay was harvested but no livestock grazing occurred in 2007
b) hay was harvested and livestock grazing occurred in 2007 ("hay-graze" areas)
c) no hay harvest or livestock grazing occurred in 2007 ("idle" areas)
(part a could not be addressed because little such area was available in 2008)

(6) Determine relative abundances and general habitat associations of migrant species of birds in meadows during early fall (August and September).
(this objective was not addressed in 2008)

(7) Establish permanent survey plots and complete a detailed draft protocol for rapid assessment of vegetation structure and general composition in meadows.
(no plots were established but a classification and protocol were drafted)

STUDY AREA

Baca NWR covers 37,500-ha (~93,000-ac) of Saquache and Alamosa counties in south central Colorado (Fig. 1). The refuge is part of a contiguous, 2,000-km^2 (~775 mi^2) block of land managed by federal, state, and private entities for conservation purposes. Roughly 75% of the refuge is upland covered by various mixtures of rabbitbrush, greasewood, and grasses. Intermittently to seasonally flooded meadows dominated by Baltic rush and sedges cover about 14% (U.S. Fish and Wildlife Service 2005). Mean daily minimum and maximum temperatures range from -13 and 2^oC in January to 10 and 28^oC in July (9 and 36^oF to 50 and 83^oF). Annual precipitation on the

valley floor averages roughly 25 cm (10 in). However, an average of up to 75 cm (30 in) falls, mostly as snow, in the adjoining Sangre de Cristo Mountains, and much of this ultimately drains into the valley. Elevation from east to west across the refuge ranges from about 2400 m (7900 ft) to 2300 m (7550 ft), but little topographic relief occurs within the refuge.

Disturbances vary spatially and temporally across meadows on what now is Baca NWR. These disturbances probably have important implications for bird communities. A brief summary of these disturbances follows (see photos that follow this section for examples of habitat conditions).

Flooding. – Runoff from snowmelt in the Sangre de Cristo Mountains varies in extent and duration from spring to spring, and peak runoff may occur any time from late May to mid-June. Water depth on flooded meadows typically reaches 5-40 cm (2-16 in) at peak runoff and gradually declines through about mid-July. Some meadows may be covered largely by open water for perhaps a week, but plant growth is rapid such that areas of open water scarcely are evident 3-4 weeks after runoff begins.

Hay Harvest. – Meadows flooded in spring typically are dry by late summer. Hay is cut and baled in late summer and early fall, and bales are removed by mid-fall. After harvest, stubble height generally is 10-15 cm (4-6 in).

Grazing. – Cattle graze meadows during fall and early winter, with stocking rates and grazing periods depending on growing season moisture and thus forage availability. Most hayed meadows are grazed by cattle in a typical year. Stocking rates are adjusted to a target of removing about 50% of vegetation that remains after hay harvest. Some meadows that are not hayed in late summer also are grazed by cattle. Elk (*Cervus elaphus*) on the refuge tend to graze upland graminoids during late fall through winter (R. Garcia, personal communication), but in most years graze hayed meadows in late winter and early spring. Meadows in the north central part of the refuge that have been hayed then grazed by cattle typically are especially heavily grazed by elk.

Rest of Meadows (i.e., idle condition). – Some refuge meadows are treated infrequently to rarely by hay harvest. These appear to be smaller, narrower patches of meadow than those where hay frequently (i.e., almost annually) is harvested. Thus, meadows that usually are idle, at least from hay-harvest, may have greater interspersion

of shrub i.e., shrub communities and other "upland" plant associations, which occur on slight elevations of only about 0.5 m (1.6 ft). The difference in frequency of hay harvest probably relates mostly to the greater ease of operating machinery in larger, more contiguous meadows. Accompanying this contrast in management is the likelihood that meadows less frequently hayed are less often flood-irrigated than meadows that are hayed regularly. Moreover, some meadows that are rested from hay-harvest also may be grazed infrequently by cattle.

These differences, yet unmeasured, probably would have implications for the structure of habitat for migratory birds that nest in meadows or use them during migration. Much less plant litter (i.e., mulch, or duff) may accumulate in meadows where hay-harvest and cattle grazing occur than in those that are idle. This contrast seems obvious for standing dead vegetation that is available in spring, when nesting birds are selecting breeding territories.

Creation of Habitat Edge. – Distinct vertical edges are created by disturbances associated with hay harvesting and cattle grazing. Chief among these are the abrupt edge between hayed and unhayed meadow vegetation, lateral ditches bordered by excavated soil, and a circa 1-m (3.1-ft) wide border of idle meadow vegetation along lateral ditches in hayed meadows. Additionally, a distinct, natural edge is formed along meadows by the shrub community. In hayed meadows, there often is a 2-5-m wide zone of idle cover between hayed vegetation and these shrubs.

Microtopography. – Within some meadows, subtle topographical rises and depressions of 0.1-0.5 m (0.3-1.6 ft) appear to contribute heterogeneity that could be important to migratory birds by supporting a slightly different mix of species and vegetation structure. Such microtopography may be more pronounced in idle meadows. In meadows that are hayed and grazed almost annually, heavy drags are routinely pulled by tractors over the terrain to maintain level ground for haying equipment.

Photo 1. Dry hay-graze meadow, late May.

Photo 2. Dry idle meadow, early June.

Photo 3. Edge between hay-graze and idle, early June.

Photo 4. Flooded idle meadow, late June.

Photo 5. Lateral ditch passing water to flooded hay-graze meadow, early June.

Photo 6. Hay-graze meadow bordered by rabbitbrush-greasewood shrub, with newly cut lateral ditch in foreground, late May.

Photo 7. Transition from hay-graze to idle to shrub, late May.

Photo 8. Shallow hay-graze meadow, early June.

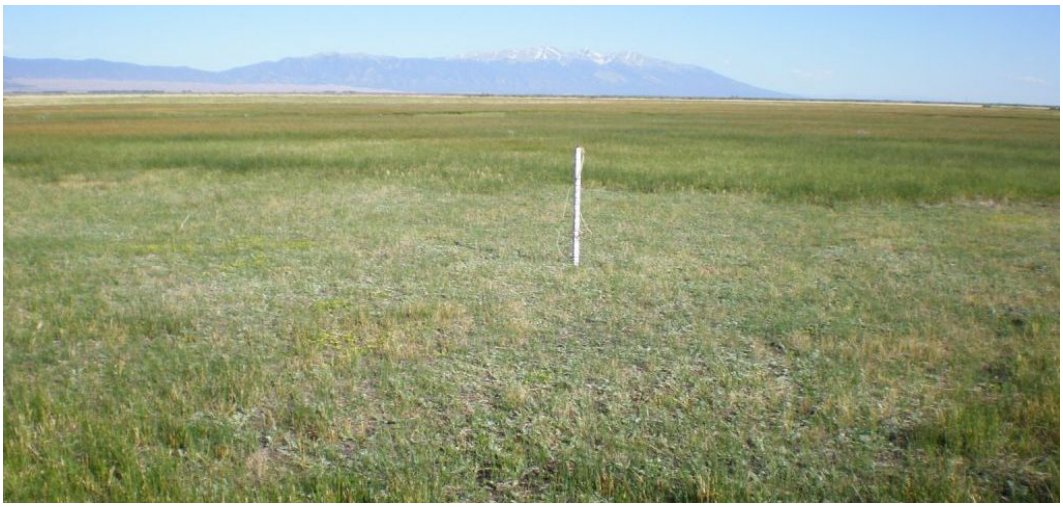

Photo 9. Low, sedge-dominated, microtopographical site surrounded by meadow vegetation dominated by Baltic rush, in hay-graze meadow, early June.

METHODS

Sampling. – A random-systematic approach was used to establish survey points in the refuge's meadows (Photo 10). Using ArcGIS (ESRI 2007), north-south transects were randomly placed on east-west intervals across wet meadows delineated on a digitized map of refuge vegetation types (M. Artmann, U.S. Fish and Wildlife Service, Denver, CO). Along a given transect, a sampling point was selected at a random distance between 0 and 100 m (325 ft) from the north boundary of the meadow, i.e., where wet meadow was the dominant habitat within 100 m. Subsequent points were placed every 300 m from the first point, until reaching another wet meadow boundary; most transects had three points (range, one to six). Each point was separated from others by at least 300 m. Points that were within 100 m of buildings or developed roads (i.e., those with raised, graveled roadbeds) were rejected. One hundred and forty sampling points were thus established, without regard to management history. Points were distributed throughout nearly all meadow habitat on the refuge and represented continua from: relatively dry to wet conditions (i.e., in early spring); hay-harvested and grazed, or idled (some few were not hayed but had been grazed); relatively small and narrow (100-200 m wide) and interspersed with other vegetation types e.g., shrub; to extensive and broad (i.e., more than1 km [0.6 mi] wide), and monotypic in vegetation composition, structure, and microtopography.

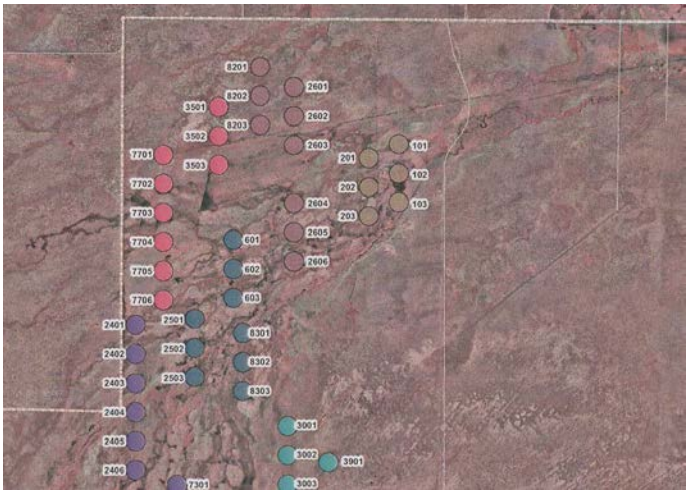

Photo 10. Example of distribution of survey plots.

Bird surveys.— A 100-m (325-ft) radius, circular plot was centered on each point, covering 3.1 ha (7.8 ac). Birds were surveyed on each plot by using 8-min point counts (Hutto et al. 1986). Plot boundaries were at least 100 m apart to maintain statistical independence for measuring birds and habitat. Every singing male or indicated pair that may breed in meadows of the area (Appendix B) was tallied when first detected within a given plot. Paired birds exhibited behaviors such as threat calls or food carrying. Laser rangefinders were used to record distances ($\pm$ 0.5 m) to birds where first were detected, to look for evidence of detection bias among species. Birds that persistently called and displayed in flight over plots were tallied as indicated pairs, such as Wilson's phalarope and Wilson's snipe. For brown-headed cowbirds, only detections females were used in summaries and analyses. Birds flying high overhead and not appearing to use meadows were disregarded, although unusual species were noted.

Birds were surveyed from about 0.5 hours before sunrise until 2 hours after sunrise on mornings when weather did not impede detection of birds especially of singing males (i.e., no rain; wind less than 20 km/h). Every plot was surveyed once during each of three periods: 15-25 May (mid-spring), 1-15 June (late spring), and 16-30 June (early summer). The field crew practiced surveys together during 10 days of preparations before data collection began, to ensure methods were consistent.

Habitat and vegetation conditions.—Each plot was visited in each survey period to categorize and delineate boundaries of habitat types and water conditions on color infrared, aerial photographs (1:1725; Photo 11). Global positioning receivers and laser rangefinders were used to verify habitat boundaries in the field. Area (ha) of each category subsequently was calculated; categories are described in Appendix C.

Edge was defined as an abrupt change in vertical structure of vegetation, created by disturbances such as hay harvest or by marked change in plant species composition; categories are described in Appendix C. Examples were the boundary between mowed and unmowed, herbaceous vegetation, and the border of herbaceous meadow vegetation and the shrub community. Edges were identified in the field and total distance of each type was determined.

Height-density indices of vegetation in dry meadow were collected in mid-May (i.e., before greenup) and late June by recording visual obstruction of a white, 3.5-cm

(1.5-in) wide density board (Robel et al. 1970). The board was broken into 0.5-dm (2-in) increments except the lowest dm was in 0.25-dm increments. The increment nearest the point where the board was 100% obscured by vegetation was recorded; the pole was viewed from 1 m (3.3 ft) high and 4 m away. Height-density indices were recorded at a given plot in locations determined by blind tossing of a plastic disc. At each location, litter depth also was recorded by dropping a 1.5-cm (0.6-in) diameter x 50-cm log PVC pipe vertically from 0.5 m (1.6 ft) above the soil surface into the vegetation, then measuring (to nearest cm) the distance from the end of the dowel to the soil. The mean of four to five height-density readings and litter depths were recorded for each of dry idle meadow and dry hay-graze meadow, on a given plot where both types were common (i.e., paired samples). Relatively few records (10 to 12 plots) were needed to characterize the structure of meadow vegetation because it was relatively monotypic, especially the hay-graze type. Structure of vegetation in flooded areas of meadows was not recorded.

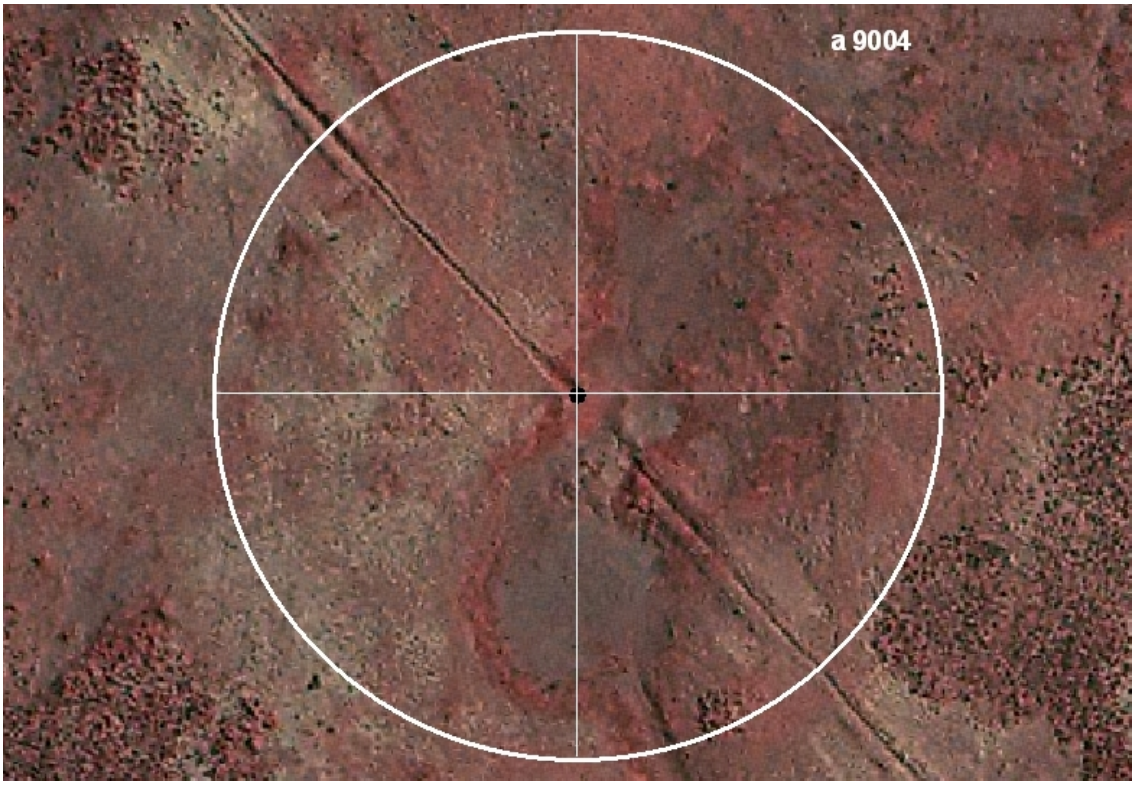

Photo 11. Example of color infrared image of survey plot, used in the field to verify habitat boundaries and document changes in surface water conditions.

Relationship between area of meadow in landscape and occurrence of individual species and mean species richness. – Total area (ha) of meadow within 500 m of each sampling point was determined by using ArcGIS and an existing digital map of the refuge vegetation (M. Artmann, U.S. Fish and Wildlife Service, Denver, CO). A relatively local scale was used because area needs of many species of open-country passerines seem modest and probably fall within this value, while the area sensitivity of most species of wetland birds generally is unknown (Johnson 2001, Johnson and Igl 2001, others). Area of meadow was compared to mean species richness and occurrence of individual species. To calculate mean species richness, the total number of species detected among all survey periods was determined for each plot. Then, the number of species detected was averaged across plots.

Data analyses.—For each survey period, occurrence for a given species of bird was determined by calculating the percentage of plots at which it was detected. Relative abundance of a given species was defined as the mean number of detections per ha. Total abundance was the sum of relative abundances of all species. Species richness was the total number of species observed.

The sampling unit of interest in this assessment was the 100-m radius plot. Most summary analyses consisted of simple bar graphs that indicated central tendency (mean $\pm$ 95% confidence intervals) for a given category of plot type. Comparisons were made for exploratory purposes, as this assessment was designed principally as an inventory and in most cases did not incorporate replication of treatments necessary to support more formal comparisons. Categories of management were assigned to plots after plots were selected. Plots were categorized coarsely as either idle, hay-graze, graze only, or hay only, based on whichever category described most of the plot, per on-site reconnaissance and information from refuge staff. Thus, comparisons between or among plots of different management categories were crude and tentative. Moreover, many habitat data were not normally distributed and no attempts were made to transform such.

Principal components (PC) analysis is commonly used to identify main factors that underlie variation in biological phenomena. The tool was used to explore relationships between occurrence of individual species of birds and habitat variables, i.e.,

vegetation type, water condition, and habitat edge. PC analysis was used because many habitat variables were correlated and subjective attempts to reduce variables seemed presumptuous or arbitrary. Bird species that were detected on less than 10% of survey plots in all survey periods were omitted from the analysis, as were any vegetation type, water condition, or edge variables that were observed on less than 3% of plots. Data for each survey period were analyzed separately. First, a PC analysis of habitat variables was used to determine the most important gradients in habitat i.e., those that explained most variation in habitat across meadows. Then, habitat data from points at which a given species of bird was detected were plotted on PC 1 and PC 2 axes derived from the initial analysis. Finally, plots of all species used in the analysis for a given survey period were overlaid. Resulting graphs depicted each species' relative location on gradients of habitat in each of late May, early June, and late June. PC analyses were performed on SPSS (v. 16.0), using varimax autorotation and principle components analysis as the extraction method.

RESULTS

Habitat

Vegetation structure. – At the beginning of the bird breeding season in mid-May, there was significantly more litter in idle meadows than in hay-graze meadows (Fig. 2). Hay-graze meadows consistently had almost no litter.

Vegetation height-density was greater in idle meadows than in hay-graze meadows, both in mid-May and late June, and was unchanged in idle meadows between these periods (Fig. 3). An apparent increase in height-density of vegetation in hay-graze meadows from mid-May to late June was obscured by increased structural heterogeneity, in part associated with the shortage of plant litter in that type.

Habitat composition. – On average, nearly two-thirds of the area on sample plots and roughly 85% of meadow habitat on the plots was comprised by dry meadow habitat in late May (Fig. 4). By late June, however, about one-half of the area covered by meadow habitat was slightly flooded or covered by shallow water. When major management categories of plots were considered (Fig. 5), the mean area of meadow

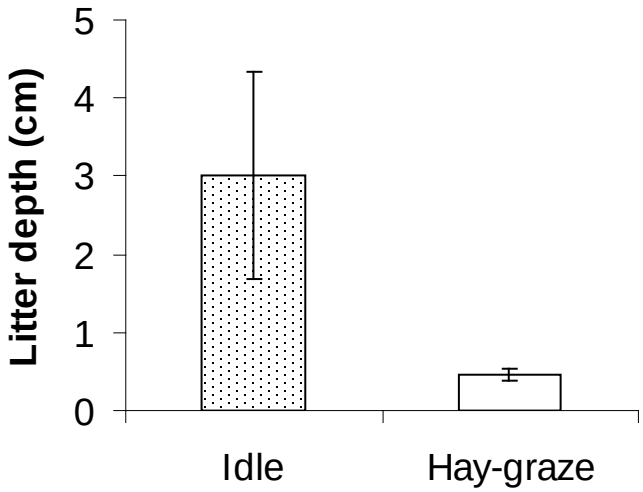

Figure 2. Mean depth of plant litter in adjoining idle and hay-graze vegetation in meadows at the beginning of the bird breeding season (mid-May) at Baca National Wildlife Refuge, south central Colorado, 2008. Four to five paired measures of litter depth were averaged on each of 10 3.1-ha (7.8-ac) circular plots. Idle vegetation had not been treated by hay harvest or cattle grazing in at least the previous year and adjoining haye-graze vegetation had been treated by hay harvest then cattle grazing in the previous late summer and fall. Meadow vegetation was dominated by Baltic rush and sedges. Error bars represent 95% confidence intervals.

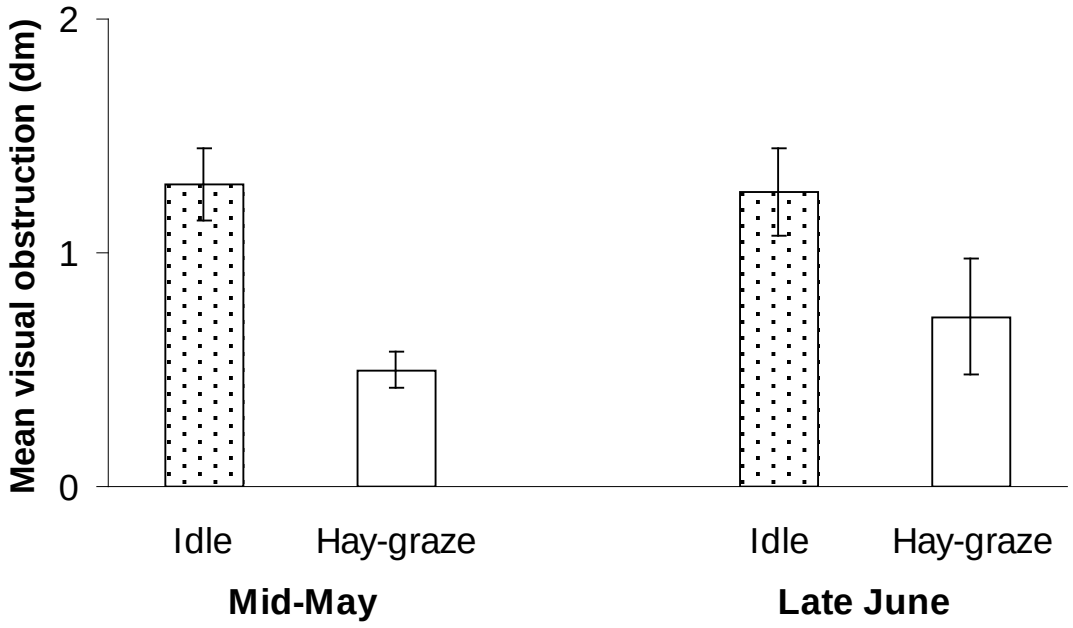

Figure 3. Mean height-density (i.e., a visual obstruction index) of vegetation on dry portions of meadows at Baca National Wildlife Refuge in south central Colorado during mid-May and late June, 2008. Four to five paired measures of height-density were averaged on each of 10 3.1-ha (7.8-ac) circular plots in early spring and on 13 plots in late spring. Each pair was represented by 1) vegetation that had not been treated by hay harvest or cattle grazing in the previous year, and 2) adjoining vegetation that had been treated. Baltic rush and sedges were the dominant plant cover in meadows. Error bars are 95% confidence intervals.

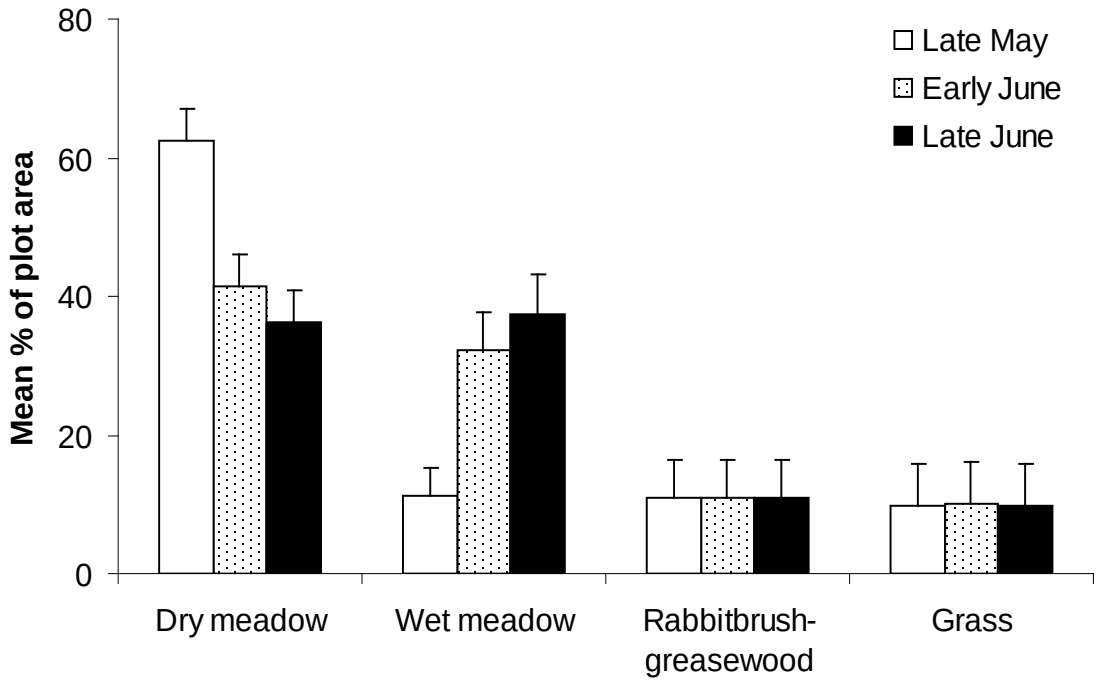

Figure 4. Composition of major habitat classes and surface water conditions in meadows at Baca National Wildlife Refuge, south central Colorado, from late May through late June 2008. Data were from 140 3.1-ha (7.8-ac) circular plots that were selected randomly without regard to management history. Rabbitbrush-greasewood shrub and grass communities were in upland sites that were interspersed with or on edges of meadows. Meadow classes were dominated by Baltic rush and sedges. Dry meadow had dry to slightly moist soils. Wet meadow consisted of slightly flooded sites and shallow sites, defined (respectively) as soil completely saturated to surface water less than 10 cm (4 in) deep, and as water 10-40 cm (4-16 in) deep. Error bars are 95% confidence intervals.

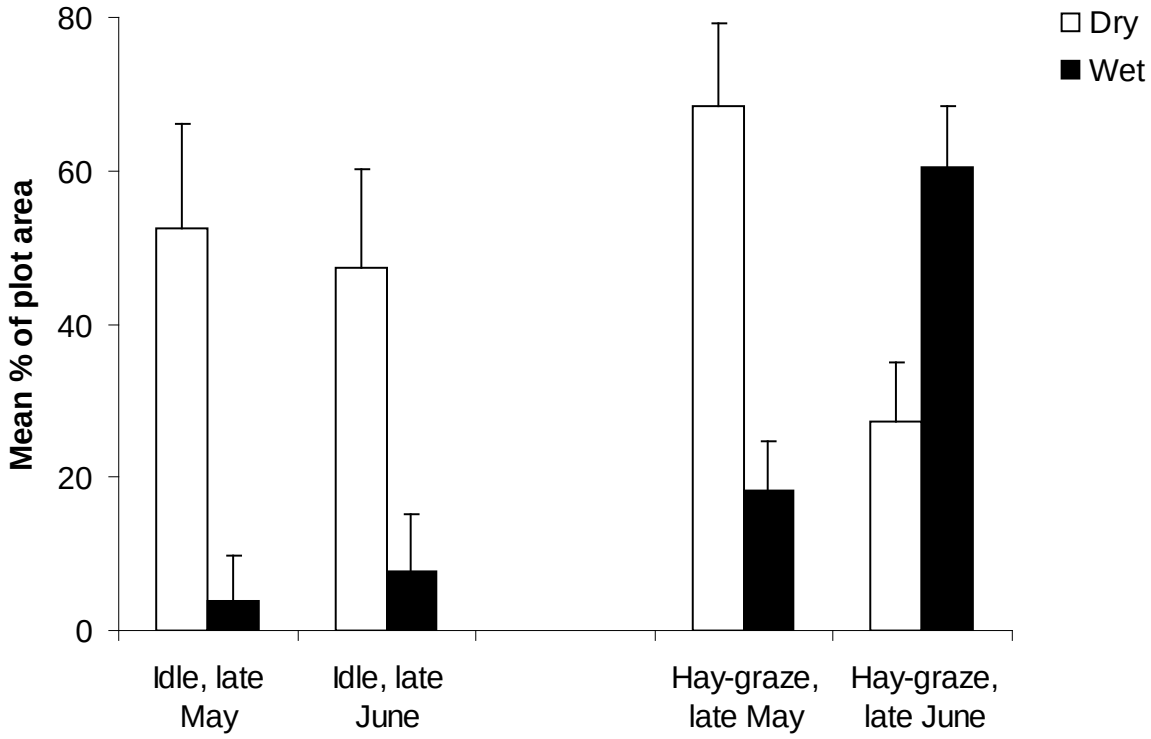

Figure 5. Percentages of the area of idle and hay-graze plots in meadows at Baca National Wildlife Refuge, south central Colorado, that were composed of dry meadow or wet meadow during late May and late June, 2008. Meadow vegetation mainly was Baltic rush and sedges. Dry meadow had dry to slightly moist soils. Wet meadow consisted of slightly flooded sites and shallow sites, defined (respectively) as soil completely saturated to surface water less than 10 cm (4 in) deep, and as water 10-40 cm (4-16 in) deep. The 3.1-ha (7.8-ac) circular plots were selected randomly. In plots categorized as idle (n = 45), no harvesting of hay or grazing by cattle occurred the previous year or years. Hay-graze plots (n = 75) were hay-harvested then grazed by cattle in the previous late summer and fall. Error bars are 95% confidence intervals.

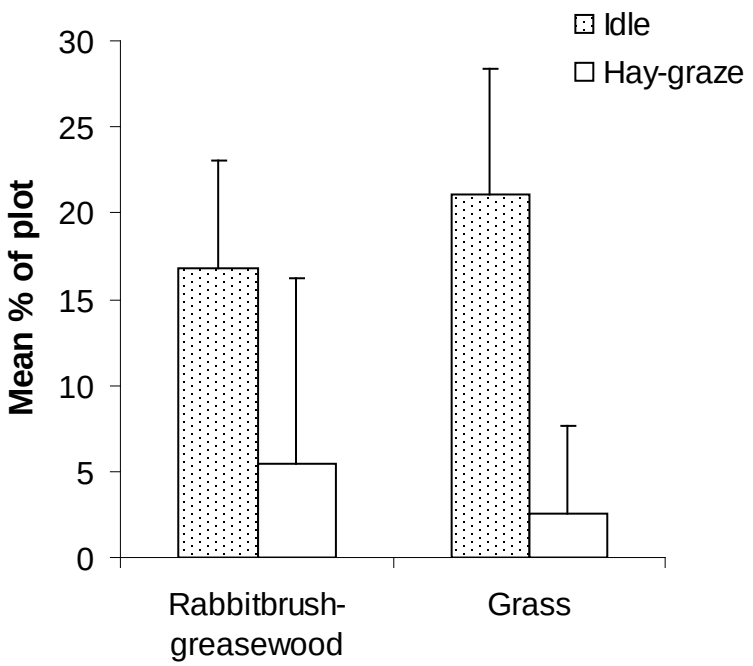

Figure 6. Percentage of 3.1-ha (7.8-ac) circular plots in meadows at Baca National Wildlife Refuge, south central Colorado, dominated by rabbitbrush-greasewood shrub and grass types of upland (i.e., non-meadow) habitat in spring 2008. In plots categorized as idle (n = 45), no harvesting of hay or grazing by cattle occurred the previous year. Hay-graze plots (n = 75) were hay-harvested then grazed by cattle in the previous late summer and fall. Error bars are 95% confidence intervals.

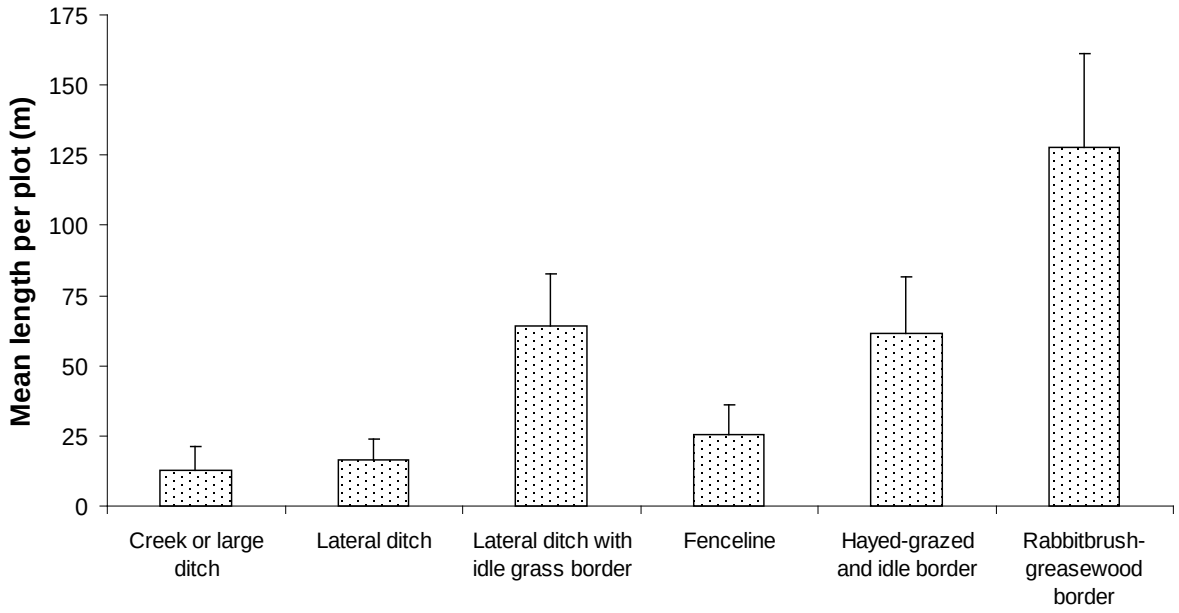

Figure 7. Composition and extent of habitat edges in meadows at Baca National Wildlife Refuge, south central Colorado, spring 2008. Data were from 140 3.1-ha (7.8-ac) circular plots that were selected randomly without regard to management history. Habitat edge was any abrupt change in vertical structure of vegetation, created by disturbances such as hay harvest or by a marked change in plant species composition. For example, a lateral ditch with a grassy border consisted of tall (to 0.5 m) grass about 0.5 m on either side of a 0.3-0.5 m deep ditch in mowed meadows; hayed-unhayed edge was the boundary of mowed and unmowed, herbaceous vegetation; rabbitbrush-greasewood edge was the border of herbaceous meadow vegetation and rabbitbrush-greasewood shrub. Total distance of edge by type was recorded for each plot. Error bars are 95% confidence intervals.

that was inundated by water on hay-graze plots increased during late May through late June but did not on idle plots.

Two upland types, rabbitbrush-greasewood shrub and grass, collectively made up an average of about one-fifth of meadow habitat (Fig. 4). However, grass was more widely represented on idle plots than on hay-graze plots (Fig. 6).

Overall, plots had a mean of 308.3 m of total edge, although this varied much (95% CI = 98.3). Major edge types were lateral ditches with borders of relatively tall grass, borders between hay-graze and idle meadow, and especially borders between shrub and herbaceous meadow vegetation (Fig. 7). Although idle plots had more area of shrub habitat than did hay-graze plots, as reported above, there seemed to be no difference in amount of shrub edge between the two types probably because variation in amount of shrub edge among hay-graze plots was considerable (mean $\pm$ 95% CI: idle, 169.4 + 60.7; hayed-grazed, 80.0 $\pm$ 160.0).

Total area of meadow within 0.5 km of centers of plots averaged 53.4 ha ($\pm$ 2.3 ha, n = 140), or about 68% of the landscape at this relatively proximal scale. The area of meadow within 500 m of centers of idle plots (46.1 $\pm$ 4.0 ha, n = 45) appeared to be less than that in hay-graze plots (59.0 $\pm$ 2.6, n = 75), which supports observations that meadow habitat in hay-graze areas tends to be more extensive and contiguous.

Factor analysis of habitat conditions. – Two PCs had loadings of at least |0.8| for more than two habitat variables across the three sampling periods (Table 1). PC 1 and PC 2 captured about 29% and 16%, respectively, of the total variation in habitat of meadows in each of late May, early June, and late June. In late May, short, sparse herbaceous cover with low amounts of litter loaded negatively and relatively tall, dense herbaceous cover with high amounts of plant litter loaded positively on the first PC axis. Representative plant cover was mostly graminoids especially sedges and Baltic rush. In early and late June, PC 1 remained negatively loaded by short, sparse herbaceous cover with little litter, but the site condition changed from a dry or moist soil to soils that were saturated or covered by water. In early June, the latter condition was characterized by mostly open, 10- to 30-cm deep water with sparse new growth emerging. By late June, there was widespread, new growth of graminoids that extended 15-30 cm above water.

Table 1. Eigenvector loadings for the first two axes in a principal components (PC) analysis of habitat variables in meadows at Baca National Wildlife Refuge, Colorado, 2008. Data were collected during three sampling periods that corresponded to the early, middle, and late parts of the main breeding season of migratory birds in the area. Loadings greater than 0.8 or less than -0.8 (bold numbers) were considered strong drivers of respective PC axes.

	Late May		Early June		Late June	
Variable	PC1	PC2	PC1	PC2	PC1	PC2
dry, hay-graze	**-0.88**	-0.24	-0.23	-0.07	-0.21	0.08
dry, idle	**0.85**	0.00	**0.82**	-0.02	**0.81**	-0.10
wet, hay-graze	-0.06	-0.12	**-0.85**	-0.30	**-0.84**	-0.37
wet, idle	0.04	-0.04	-0.01	0.02	-0.01	0.19
upland shrub	0.07	**0.91**	0.08	**0.91**	0.07	**0.90**
upland grass	0.42	-0.19	0.50	-0.15	0.52	-0.15
ditch, grass edge	-0.53	-0.30	-0.52	-0.30	-0.57	-0.32
hay-graze/idle edge	0.10	-0.15	0.15	-0.14	0.12	-0.16
shrub edge	0.17	**0.88**	0.15	**0.88**	0.16	**0.85**
Eigenvalue	2.57	1.44	2.63	1.44	2.63	1.50
% variance explained	28.54	15.96	29.26	16.01	29.21	16.68
Total variance explained	28.54	44.50	29.26	45.27	29.21	45.89

Thus, PC 1 at first represented a gradient in litter accumulation plus height and density of graminoids, then changed in June to a gradient from shallow water with relatively little plant biomass to dry conditions with much plant biomass. On the second PC axis, shrub and edge (length in m) of this shrub type loaded positively in all three sampling periods (Table 1). Thus, PC 2 represented a gradient in shrubiness.

Birds

Occurrence and abundance of breeding species. – Twenty-seven species known to nest in the San Luis Valley were detected on plots in meadows at Baca NWR during surveys (Fig. 8). Wilson's phalarope, horned lark, Savannah sparrow, red-winged blackbird, and western meadowlark were the common breeding species in meadows; they occurred on at least 20% of plots in one or more survey periods. Species common in at least one survey period included Wilson's snipe, Brewer's sparrow, vesper sparrow, and brown-headed cowbird. Levels of relative abundance of species closely paralleled their respective occurrences (Fig. 9). Mean abundances per plot of all species combined during late May, early June, and late June were 1.2, 1.0, and 1.1 indicated pairs/ha (roughly 0.5 pairs/ac).

Birds and Habitat

Occurrences of common species of breeding birds across PC gradients of habitat conditions are collectively indicated for late May, early June, and late June in Figures 10, 11, and 12, respectively. In late May, there was much overlap in use of habitat among species; most were associated with average conditions of litter depth and vegetation height and density of meadow vegetation and little or no shrub shrub (Fig. 10). When meadows were flooded in early and late June, however, habitat used by species diverged from an average condition and differences among species grew more apparent (Figs. 11 and 12). Following are general patterns of habitat association.

Wilson's snipe. – The snipe's occurrence was too infrequent in late May to discern its general habitat association. In early and late June, it was associated with wet,

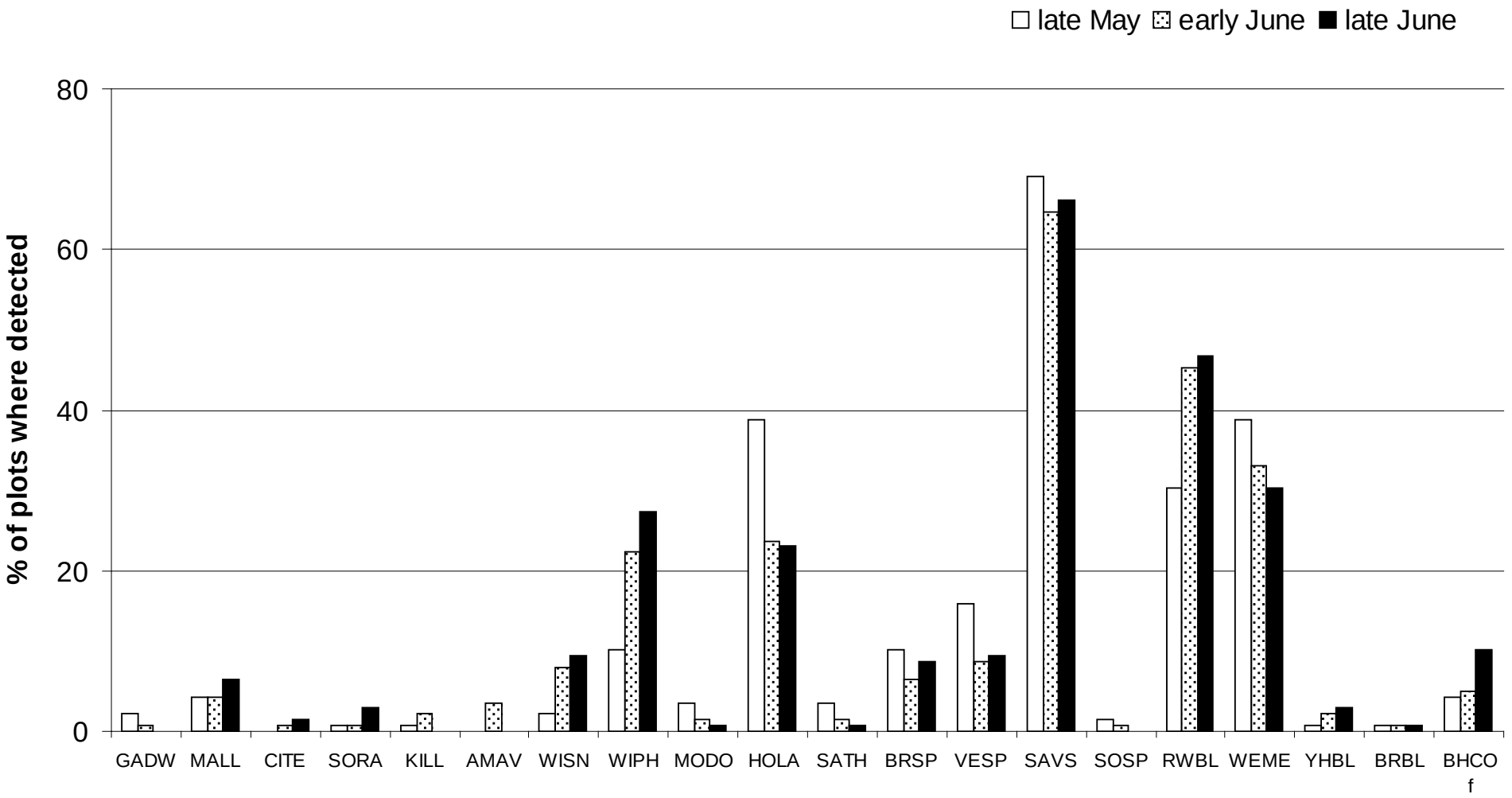

Figure 8. Frequency of occurrence of breeding species of birds in meadows at Baca National Wildlife Refuge, Colorado, during late spring and early summer, 2008. Birds were surveyed by using 8-minute, fixed-radius point counts on 140 randomly placed, 3.1-ha (7-8 ac) circular plots. Species included gadwall (GADW), mallard (MALL), cinnamon teal (CITE), sora (SORA), killdeer (KILL), American avocet (AMAV), Wilson's snipe (WISN), Wilson's phalarope (WIPH), mourning dove (MODO), horned lark (HOLA), sage thrasher (SATH), Brewer's sparrow (BRSP), vesper sparrow (VESP), Savannah sparrow (SAVS), song sparrow (SOSP), red-winged blackbird (RWBL), western meadowlark (WEME), yellow-headed blackbird (YHBL), Brewer's blackbird (BRBL), and brown-headed cowbird (BHCO; females only). Not included are seven species that were detected only once (i.e., at < 1% of plots) during any of three surveys: American bittern, northern pintail, northern harrier, Virginia rail, burrowing owl, black-billed magpie, and yellow warbler. Sandhill crane also was detected (1 individual on 1 plot), but probably did not represent a breeding species.

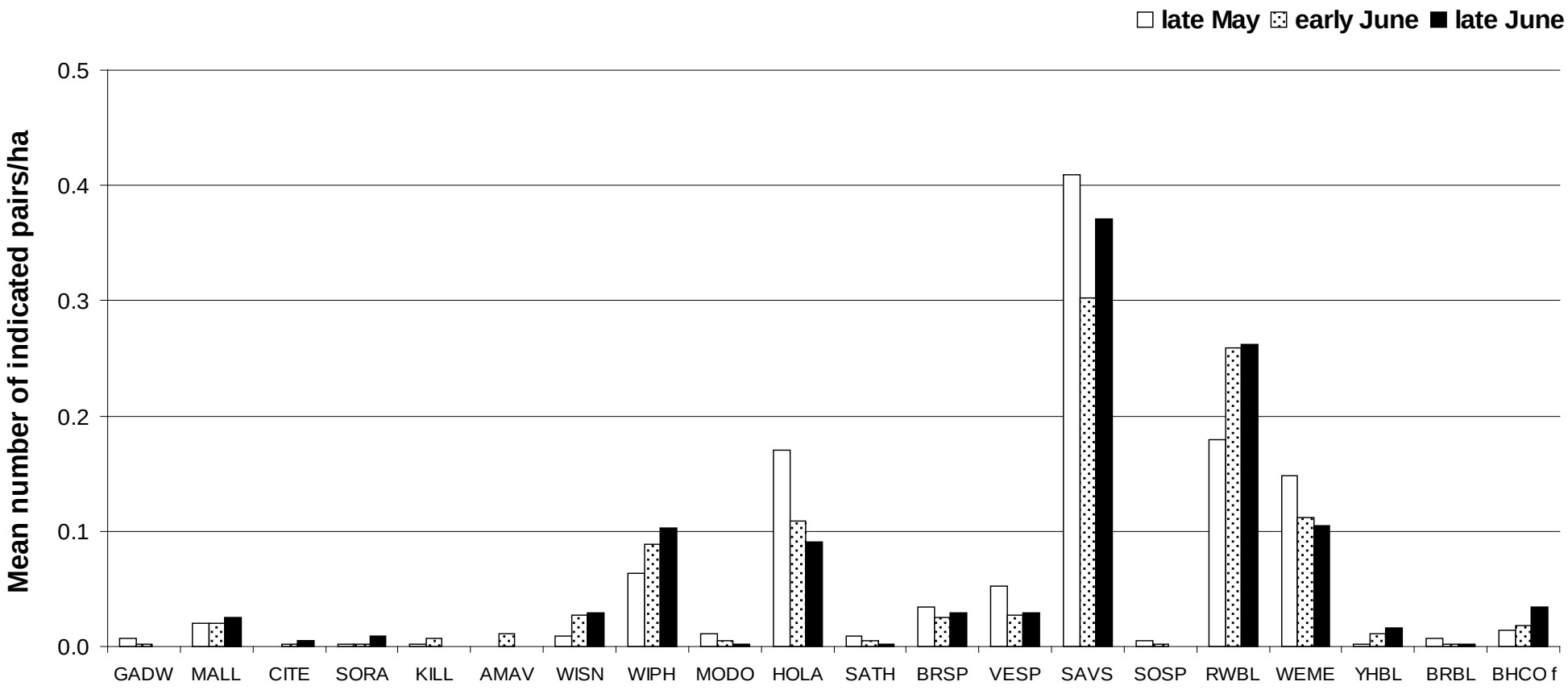

Figure 9. Abundance of individual species of breeding birds in meadows at Baca National Wildlife Refuge, Colorado, during late spring and early summer, 2008. Abundance of each species is expressed as the mean number of indicated pairs per hectare (i.e., per 2.5 ac). Means are derived from surveys of 140 3.1-ha (7.8-ac) circular plots during each of late May, early June, and late June. Species included gadwall (GADW), mallard (MALL), cinnamon teal (CITE), sora (SORA), killdeer (KILL), American avocet (AMAV), Wilson's snipe (WISN), Wilson's phalarope (WIPH), mourning dove (MODO), horned lark (HOLA), sage thrasher (SATH), Brewer's sparrow (BRSP), vesper sparrow (VESP), Savannah sparrow (SAVS), song sparrow (SOSP), red-winged blackbird (RWBL), western meadowlark (WEME), yellow-headed blackbird (YHBL), Brewer's blackbird (BRBL), and brown-headed cowbird (BHCO; females only). Not included are seven species that were detected only once (i.e., at < 1% of plots) during any of three surveys: American bittern, northern pintail, northern harrier, Virginia rail, burrowing owl, black-billed magpie, and yellow warbler. Sandhill crane also was detected (1 individual on 1 plot), but probably did not represent a breeding species. Abundance of less common species is shown collectively; these included American bittern, northern pintail, northern harrier, Virginia rail, burrowing owl, black-billed magpie, and yellow warbler.

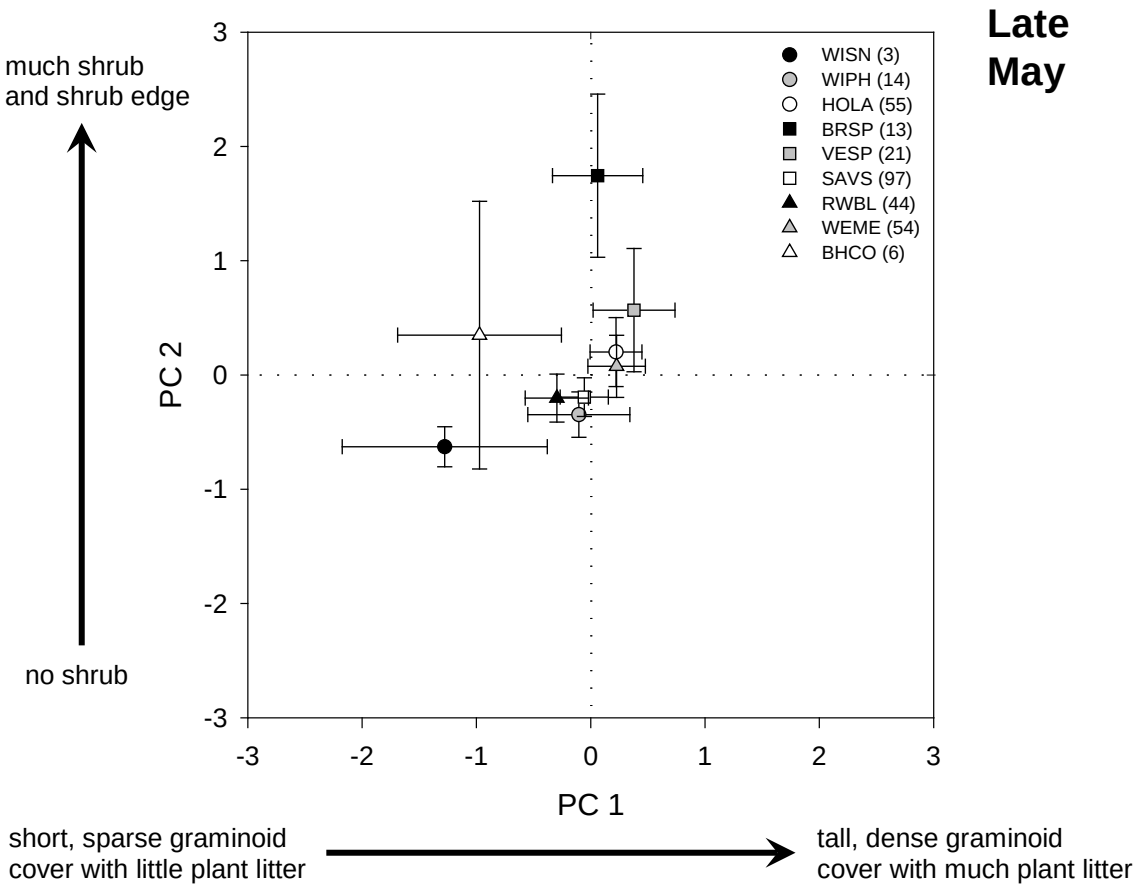

Figure 10. Gradients of the two major habitat factors that explain nearly 50% of the variation in distribution of nine common species of breeding birds in meadows at Baca National Wildlife Refuge, south central Colorado, during late May, 2008. The figure is derived from a Principal Components (PC) Analysis. Birds were surveyed on a random sample of 140 3.1-ha (7.8-ac) circular plots. Species include Wilson's snipe (WISN), Wilson's phalarope (WIPH), horned lark (HOLA), Brewer's sparrow (BRSP), vesper sparrow (VESP), Savannah sparrow (SAVS), red-winged blackbird (RWBL), western meadowlark (WEME), and brown-headed cowbird (females; BHCO). For each species, the number of plots on which at least one indicated breeding pair was detected is in parentheses. Horizontal and vertical error bars around each species are 95% confidence intervals for each of PC 1 and PC 2, respectively. The origin of the plot (0, 0) represents average habitat conditions for PC 1 and PC 2.

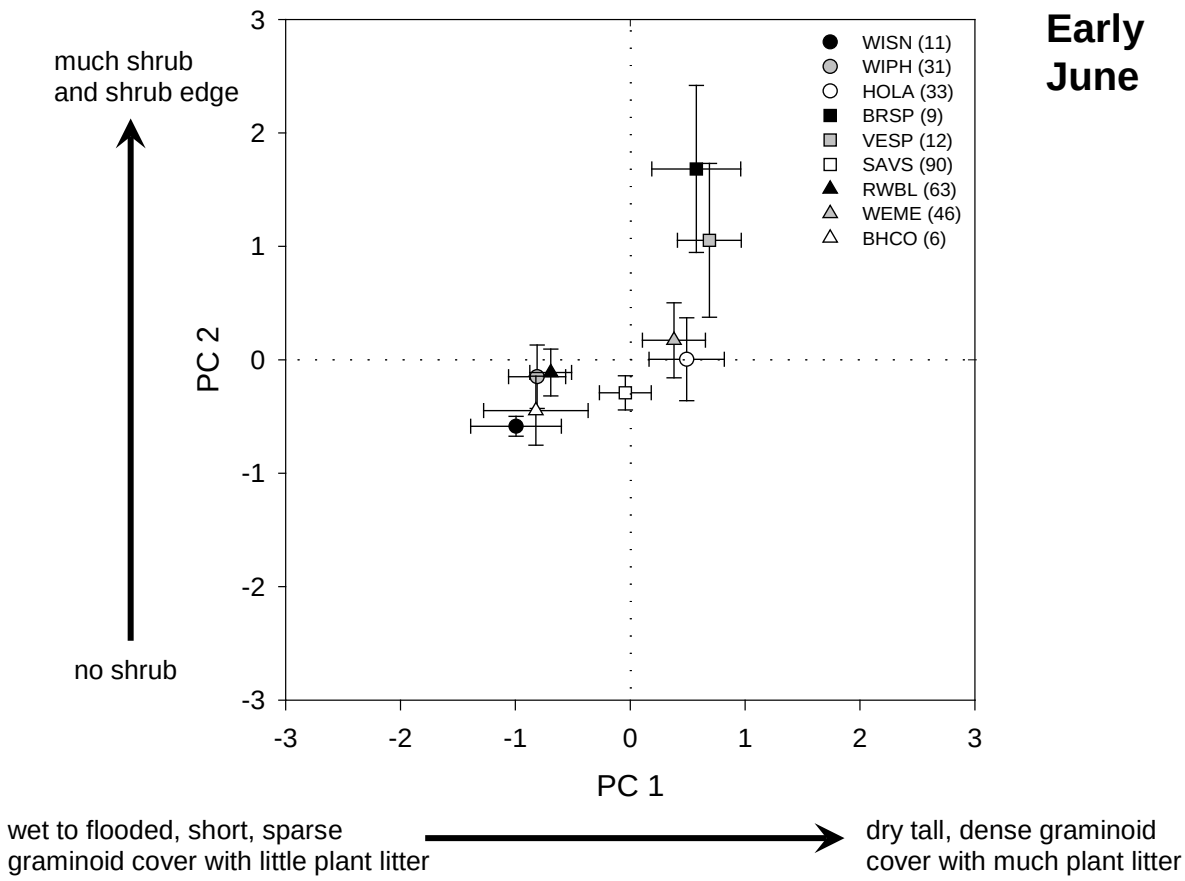

Figure 11. Gradients of the two major habitat factors that explain nearly 50% of the variation in distribution of nine common species of breeding birds in meadows at Baca National Wildlife Refuge, south central Colorado, during early June, 2008. The figure is derived from a Principal Components (PC) Analysis. Birds were surveyed on a random sample of 140 3.1-ha (7.8-ac) circular plots. Species include Wilson's snipe (WISN), Wilson's phalarope (WIPH), horned lark (HOLA), Brewer's sparrow (BRSP), vesper sparrow (VESP), Savannah sparrow (SAVS), red-winged blackbird (RWBL), western meadowlark (WEME), and brown-headed cowbird (females; BHCO). For each species, the number of plots on which at least one indicated breeding pair was detected is in parentheses. Horizontal and vertical error bars around each species are 95% confidence intervals for each of PC 1 and PC 2, respectively. The origin of the plot (0, 0) represents average habitat conditions for PC 1 and PC 2.

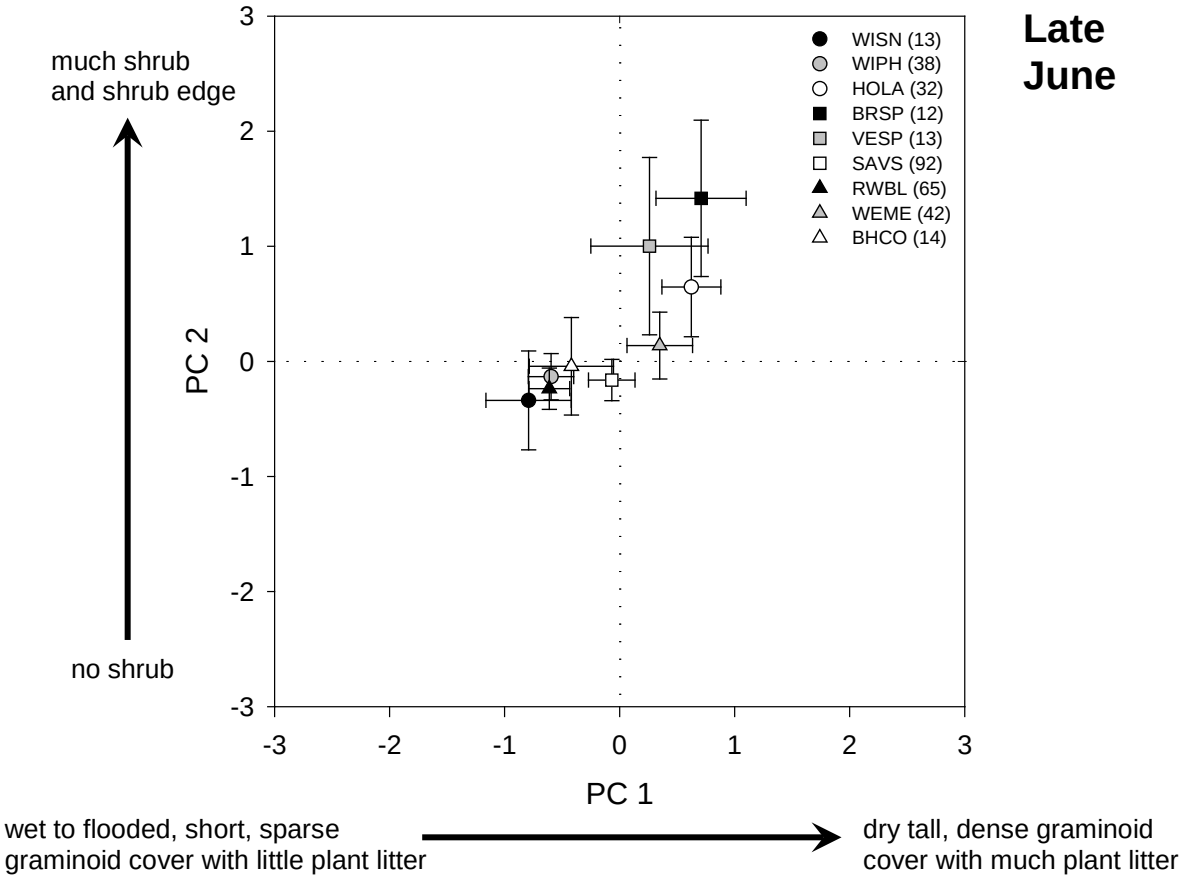

Figure 12. Gradients of the two major habitat factors that explain nearly 50% of the variation in distribution of nine common species of breeding birds in meadows at Baca National Wildlife Refuge, south central Colorado, during late June, 2008. The figure is derived from a Principal Components (PC) Analysis. Birds were surveyed on a random sample of 140 3.1-ha (7.8-ac) circular plots. Species include Wilson's snipe (WISN), Wilson's phalarope (WIPH), horned lark (HOLA), Brewer's sparrow (BRSP), vesper sparrow (VESP), Savannah sparrow (SAVS), red-winged blackbird (RWBL), western meadowlark (WEME), and brown-headed cowbird (females; BHCO). For each species, the number of plots on which at least one indicated breeding pair was detected is in parentheses. Horizontal and vertical error bars around each species are 95% confidence intervals for each of PC 1 and PC 2, respectively. The origin of the plot (0, 0) represents average habitat conditions for PC 1 and PC 2.

short, sparse, meadow vegetation, and not with shrub shrub and shrub edge. Wilson's snipe was detected almost exclusively at plots in the hay-graze category of management in all survey periods (Fig. 13).

Savannah sparrow. – In all survey periods, Savannah sparrow exhibited a distinct and consistent location in PC space just below the plot origin (0, 0). Thus, it associated closely with the average conditions of meadow vegetation during late May through late June and generally was not associated with shrub. Across the survey periods, the sparrow occurred 25-50% more frequently in plots with a hay-graze management history than in plots categorized as idle (Fig. 13).

Wilson's phalarope, red-winged blackbird, brown-headed cowbird. – Wilson's phalarope and red-winged blackbird closely overlapped in use of meadow vegetation of average structure in late May and shifted distinctly to flooded, short-sparse meadow vegetation in early and late June. Habitat of the cowbird was poorly defined in late May, perhaps due to infrequent detection, but distinctly overlapped that of Wilson's phalarope and red-winged blackbird in early and late June. None of the species appeared to be associated with shrub, based on PC 2. All three species occurred far more frequently in hay-graze plots than in idle plots (Fig. 13).

Horned lark and western meadowlark. – The lark and meadowlark occupied close to average structural conditions of meadow vegetation and little shrub in late May but shifted to dry, denser, taller meadow vegetation and more shrub in early and late June, overlapping somewhat with Brewer's sparrow and vesper sparrow. Both species were more frequently detected in idle plots than in hay-graze plots (Fig. 13).

Brewer's sparrow and vesper sparrow. – In late May, both sparrow species were associated with meadow vegetation of average structure and both overlapped much in their broad affinities for shrub. In early and late June, however, both shifted towards dry, dense, tall meadow vegetation while remaining distinctly shrub-associated. Brewer's sparrow and vesper sparrow were most likely found on idle plots (Fig. 13).

Area of meadow in landscape versus species richness and occurrence of individual species. – The mean number of species detected per plot was 4.1 ± 0.2. Richness appeared to be less on idle plots than on plots in other management categories (Fig. 14). On hay-graze plots, there was evidence of a positive relationship between species richness and area of wet meadow within 500 m of plot centers ($R^2 = 0.27$, $P = 0.002$; Fig. 15), but no relationships between richness and meadow area in the landscape were noted for idle or graze-only categories of management ($P < 0.05$). On a species level, Brewer's sparrow and vesper sparrow occurred on plots where the area of meadow in the

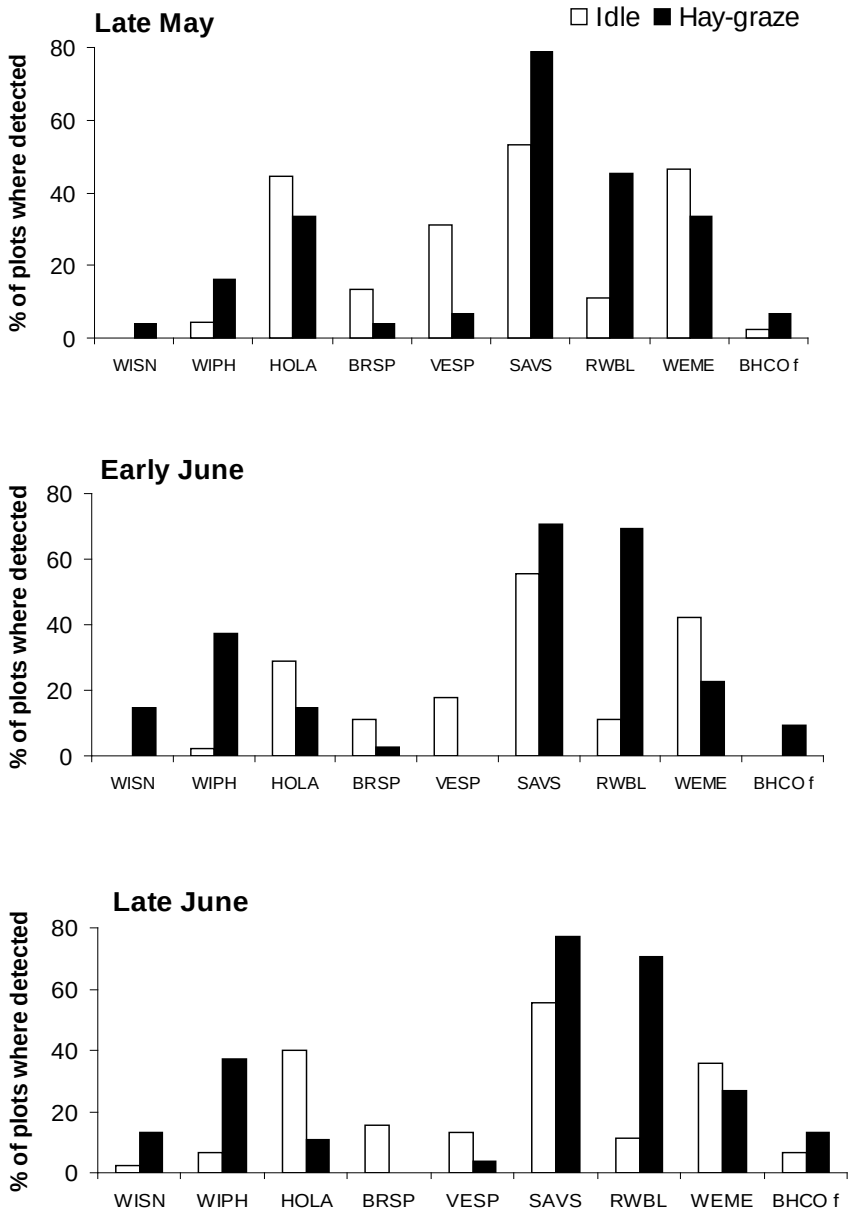

Figure 13. Frequency of occurrence of common species of breeding birds in relation to management history in meadows at Baca National Wildlife Refuge, Colorado, 2008. Data were collected by using 8-minute, fixed-radius point counts on randomly selected, 3.1-ha (7-8 ac) circular plots during three survey periods. In plots categorized as idle (n = 45), no harvesting of hay or grazing by cattle occurred the previous year. Hay-graze plots (n = 75) were hay-harvested then grazed by cattle in the previous late summer and fall. Species include Wilson's snipe (WISN), Wilson's phalarope (WIPH), horned lark (HOLA), Brewer's sparrow (BRSP), vesper sparrow (VESP), Savannah sparrow (SAVS), red-winged blackbird (RWBL), western meadowlark (WEME), and brown-headed cowbird (females; BHCO).

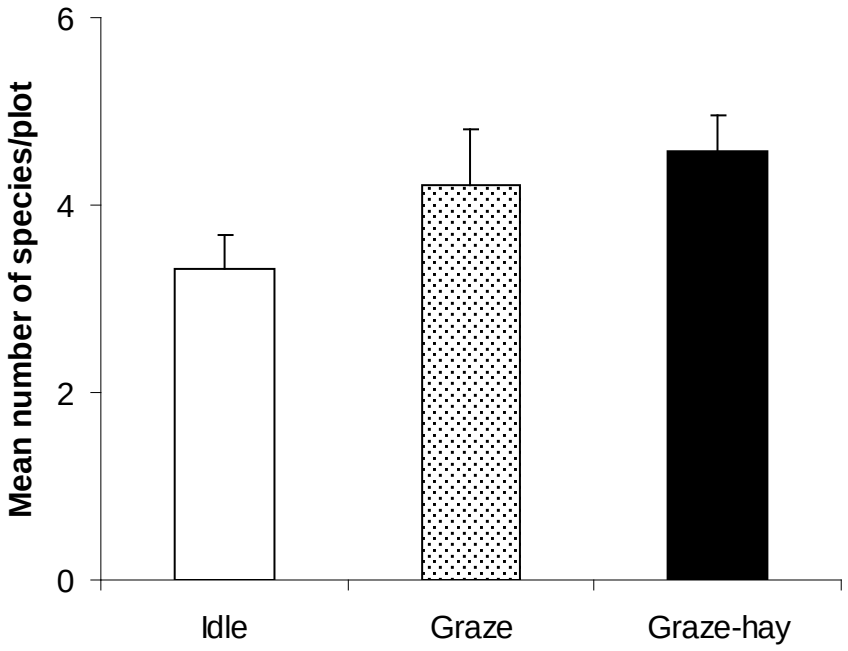

Figure 14. Species richness of breeding birds by management category in meadows at Baca National Wildlife Refuge, south central Colorado, spring 2008. For each category, the total number of species detected on each plot across three surveys (late May, early June, late June) was averaged. Birds were surveyed on randomly selected, 3.1-ha (7.8-ac) circular plots. In plots categorized as idle (n = 45), no harvesting of hay or grazing by cattle occurred the previous year. Hay-graze plots (n = 75) were hay-harvested then grazed by cattle in the previous late summer and fall. Graze plots (n = 14) were grazed by cattle in the previous fall but were not hay-harvested in at least the previous year. Error bars are 95% confidence intervals.

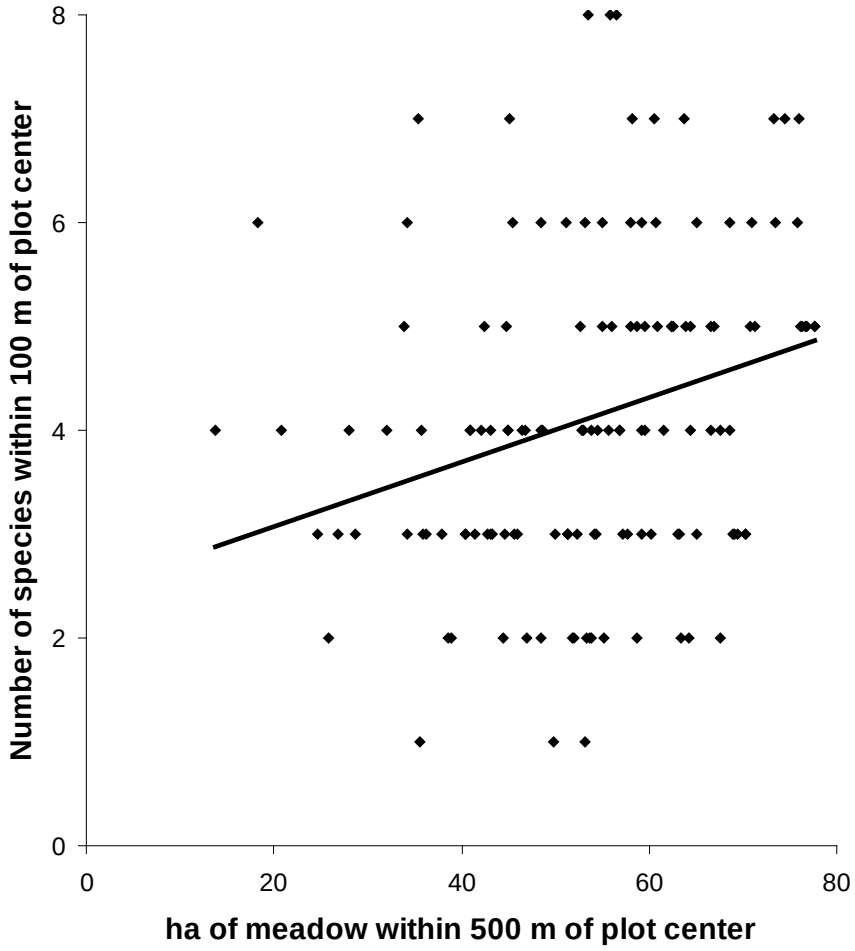

Figure 15. Relationship between bird species richness (number of species) and area (ha) of meadow within 500 m of centers of 3.1-ha (7.8-ac) circular plots (n = 140) at which breeding species of birds were surveyed at Baca National Wildlife Refuge, Colorado, late May through late June, 2008.

landscape was less than that on plots where they were not detected (Table 2). Conversely, plots on which Wilson's snipe, Savannah sparrow, red-winged blackbird, or brown-headed cowbird occurred had more area of meadow in the landscape than did plots where they did not occur. Area of meadow in landscapes did not appear to differ between plots where Wilson's phalarope, horned lark, or western meadowlark were and were not detected.

TENTATIVE CONCLUSIONS

Data from this general, preliminary assessment suggest that traditional management of meadows tends to favor short-sparse, intermittently to seasonally flooded, herbaceous vegetation with little upland shrub in the largest areas. Conversely, relatively small or narrow meadows tend to have tall-dense, less frequently flooded vegetation interspersed with upland edges of upland shrub and grass. A pattern of frequent flooding, haying, and grazing in large meadows may favor Wilson's snipe, Wilson's phalarope, Savannah sparrow, red-winged blackbird, brown-headed cowbird, and overall species richness. Increased area of relatively dry, idle meadow may favor Brewer's sparrow and vesper sparrow. However, relatively few wetland-dependent species were detected frequently during this assessment, perhaps because the peak in runoff from snowmelt in nearby mountains was later than usual in 2008. More species, such as rails and ducks, probably would be common on meadows in years when at least an average amount of runoff occurs and reaches a peak in mid-May. Conversely, in such years, some species considered common in meadows in this inventory may be uncommon, particularly those that prefer relatively dry conditions.

A critical gap in knowledge at Baca NWR is the value of large areas of flooded meadow that either were idle the previous year, or were fall-grazed but not hayed. Few such areas were available for this assessment and could pose opportunities for enhancing bird diversity. A more finely scaled assessment that includes these and the other management approaches across representative years of spring runoff seems warranted. Regardless, approaches considered should account for control of introduced plant species and direct and indirect influences of historic ecosystem processes on native plant diversity.

Table 2. Comparison of mean area (ha; ± 95% confidence interval) of meadow within 500 m of centers of 3.1-ha (7.8-ac) circular plots (n = 140) at which common breeding species of birds were detected and not detected during three surveys at Baca National Wildlife Refuge, Colorado, late May through late June, 2008. The number of plots a which a given species was detected or not detected is in parentheses.

Species	Detected	Not detected
Wilson's snipe	67.6 + 3.2 (21)	50.9 + 2.4 (119)
Wilson's phalarope	59.3 + 6.4 (58)	49.2 + 6.0 (82)
Horned lark	50.7 + 3.4 (74)	56.4 + 3.0 (66)
Brewer's sparrow	44.5 + 4.8 (26)	55.0 + 2.5 (114)
Vesper sparrow	43.5 + 5.2 (32)	56.3 + 2.3 (108)
Savannah sparrow	55.9 + 3.0 (117)	40.6 + 2.8 (23)
Red-winged blackbird	58.5 + 3.0 (77)	47.1 + 3.1 (63)
Western meadowlark	52.3 + 2.8 (87)	55.2 + 4.0 (53)
Brown-headed cowbird	61.3 + 2.4 (21)	52.0 + 2.6 (119)

ACKNOWLEDGMENTS

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Working list of draft appendices to complete (20 March 2009):

- List of common and scientific names of biota
- Species of birds likely to nest . . .
- Nests of birds found incidental to field activities
- Protocol for bird surveys
- Fine-scale classification of habitat of birds in meadows
- Histograms of detection distances of common bird species
- Draft classification of vegetation in meadows for monitoring purposes
- Main Database