Conservation of Priority Birds in Sagebrush Ecosystems[1]

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Abstract

Sagebrush ecosystems occupy over 62,000,000 ha of the western US. However, they have been degraded or completely eliminated by agricultural conversion, overgrazing by domestic livestock, invasion of exotic plants, expansion of pinyon and juniper woodlands, uncharacteristic wildfires, and fragmentation. This habitat loss has led to an increasing number of special status species, including 630 plant and animal species of conservation concern. In this paper, we focus on the 22 taxa of sagebrush associated birds that are priorities in Partners in Flight Bird Conservation Plans. These range from sagebrush obligates–Greater Sage-grouse (*Centrocercus urophasianus*), Gunnison Sage-grouse (*C. minimus*), Sage Thrasher (*Oreoscoptes montanus*), Sage Sparrow (*Amphispiza belli*), Brewer's Sparrow (*Spizella breweri*)–to grassland associates such as Short-eared Owl (*Asio flammeus*) and Vesper Sparrow (*Pooecetes gramineus*). Partners in Flight has identified five of these species for the continental Watch List–Swainson's hawk (*Buteo swainsoni*), both sage-grouse, the Short-eared Owl, and Brewer's Sparrow–which places them among the highest priority species for conservation action in North America. We also examine the extent to which sage grouse may serve as classic umbrella species for shrubsteppe avifauna. These species tended to occur together–83 pairwise correlations of relative abundance were significant (8.55 expected). Factor analysis of these data showed that species formed groups based on habitat associations much as expected, although sage-grouse aligned more closely with the Vesper Sparrow than expected. Population trends for three major physiographic strata that encompass sagebrush ecosystems–the Columbia Plateau, Wyoming Basin, and Basin and Range–showed the Columbia Plateau to have many more declining population trends. Habitat associations for declining species included both sagebrush and grassland types. Historic (1850) and current population sizes were estimated for 12 priority taxa in the Interior Columbia Basin based on predicted areas of historic and current source habitat. Estimated current population sizes are, not surprisingly, drastically reduced from historic numbers. The Western Meadowlark (*Sturnella neglecta*) showed the least percent reduction and Grasshopper Sparrow the most. For six species that had significant or near significant declines in the Columbia Plateau since 1966 and for which we had historic and current habitat estimates, the estimated historical declines were all remarkably similar to recent trends. Trends and management activities on public lands in Idaho, Oregon, and Washington that may be contributing to disproportionate declines in priority birds include an increase in the area burned annually by wildfire, an increase in the biomass of grazing cattle, and continued fencing and water development that spread negative impacts over an ever greater portion of the landscape. We suggest that conservation of sage-grouse populations in reasonable numbers well distributed across their historical ranges also will provide substantial benefits for many, or even most, other bird species that co-occur with these grouse. Given that more than 57 percent of this habitat is in public ownership and that concern for the future of sage-grouse continues to build, we have all the information and opportunity we need to take action. Indeed, if we cannot successfully conserve sage-grouse and the sagebrush ecosystem in the US given our theory, our knowledge, and our large blocks of public land, then one wonders how we can succeed for other species elsewhere.

Key words: Artemisia, Columbia Plateau, conservation plans, Great Basin, Greater Sage-grouse, landbirds, Partners in Flight, population trends, public land, sagebrush.

Introduction

In this paper, we summarize species assessments (Carter et al. 2000) and conservation planning for priority birds of sagebrush ecosystems, particularly from Partners in Flight (Bonny et al. 2000, Rich et al. 2004) and the Interior Columbia Basin Ecosystem Management Project (Wisdom et al. 2000). We also present some new analyses on population trends, habitat trends, and the concept of using Greater Sage-

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grouse (*Centrocercus urophasianus*) and Gunnison Sage-grouse (*C. minimus*) as umbrella species (Caro and O'Doherty 1999) for the sagebrush avifauna. We conclude by suggesting that, because much of the sagebrush ecosystem still exists in very large blocks and is managed by public land agencies, notably the U.S. Bureau of Land Management, and because a substantial amount of planning has already been done using the best available science, we have an excellent opportunity to implement true multi-species, ecosystem management (Odam and Wiens 2002, Groves 2003) to protect and restore portions of this ecosystem and its avifauna.

Sagebrush ecosystems, dominated by various species of woody *Artemisia*, occupy over 62,000,000 ha of the western US (Küchler 1970, West and Young 2000). Losses from the historical extent of these ecosystems have been substantial (Tisdale and Hironaka 1981, Miller and Eddleman 2000, Knick et al. 2003). For example, Hann et al. (1997) estimated that over 30 percent of the sagebrush vegetation in the Interior Columbia Basin has been converted to agriculture, dominated by exotic invasive plants or otherwise lost. West-wide, sagebrush has been degraded or completely eliminated by agricultural conversion (Hann et al. 1997), overgrazing by domestic livestock (Vale 1975, Fleischner 1994, Young 1994, Donahue 1999, West and Young 2000), invasion of exotic plants (Mack 1981, Yensen 1981, Wisdom et al. 2000), expansion of pinyon and juniper woodlands (Miller and Rose 1999), uncharacteristic wild fires (Pellant 1990, Whisenant 1990, Johansen et al. 1993) and fragmentation (Knick and Rotenberry 1995, Hann et al. 1997, Wisdom et al. 2000).

This habitat loss has led to an increasing number of special status species. Rich (unpubl.) compiled a list of 630 plant and animal species of conservation concern that depend on sagebrush ecosystems. These include species identified by the U.S. Bureau of Land Management, Partners in Flight (Paige and Ritter 1999), the Interior Columbia Basin Ecosystem Management Project (Saab and Rich 1997, Wisdom et al. 2000), the Nature Conservancy (Nachlinger et al. 2001) and Defenders of Wildlife (Defenders of Wildlife 1998).

Concern over the status of sagebrush bird communities as the result of multiple impacts was first recognized by Braun et al. (1976). More recently, several species–Greater Sage-grouse, Gunnison Sage-grouse, Columbian Sharp-tailed Grouse (*Tympanuchus phasianellus columbianus*), Mountain Quail (*Oreortyx pictus*) and Loggerhead Shrike (*Lanius ludovicianus*)–have become of great concern to various coalitions of conservation activists. Partners in Flight (PIF) identified five species for the continental Watch List (Rich et al. 2004)–Swainson's Hawk (*Buteo swainsoni*), both sage grouse, the Short-eared Owl (*Asio flammeus*) and Brewer's Sparrow (*Spizella breweri*)–which places them among the highest priority species for conservation action in North America. Rich et al. (2004) also identified six additional Stewardship Species–Gray Flycatcher (*Empidonax wrightii*), Sage Thrasher (*Oreoscoptes montanus*), Green-tailed Towhee (*Pipilo chlorurus*), Black-throated Sparrow (*Amphispiza bilineata*), Sage Sparrow (*A. belli*), and Grasshopper Sparrow (*Ammodramus savannarum*). Stewardship Species have a high percentage of their entire global population within a relatively limited geographic area. Management entities are encouraged to particularly consider needs of these species in land use planning and conservation action.

Management recommendations for birds of sagebrush ecosystems can be found in a variety of recent publications (Dobkin 1995; Paige and Ritter 1998; Bureau of Land Management 2000; Connelly et al. 2000; Wisdom et al. 2002a, 2002b; Knick et al. 2003). Rich et al. (2004) provide continental population estimates and objectives for PIF Watch List and Stewardship Species while PIF Bird Conservation Plans for the western states provide detailed management recommendations at the state level (Neel 1999, Altman and Holmes 2000, Beidleman 2000, Casey 2000, Ritter 2000, Cerovski et al. 2001). Underlying these conservation-oriented accounts is a substantial theoretical base on sagebrush bird populations and ecology (e.g., Rotenberry and Wiens 1980, 1989, 1991; Wiens and Rotenberry 1981, 1985).

In this paper, we focus on the 22 taxa of sagebrush associated birds (*table 1*) identified by Paige and Ritter (1998). These range from sagebrush obligates–Greater Sage-grouse, Gunnison Sage-grouse, Sage Thrasher, Sage Sparrow, Brewer's Sparrow–whose historical ranges were closely tied to the distribution of woody *Artemisia*, to species more typically associated with grasslands and whose historical ranges are very broad in North America, such as the Short-eared Owl and Vesper Sparrow (*Pooecetes gramineus*). Grassland species are of interest because they are widespread in sagebrush vegetation and they help us understand the status of the important grass component of those ecosystems.

Table 1— *Priority bird species of sagebrush habitats and geographic areas where they are a priority.*

Species[a,b]	Scientific name	Birds of North America reference	Sagebrush ecosystems (Paige and Ritter 1998)	Interior Columbia Basin[c] (Wisdom et al. 2000)	Idaho[c] (Ritter 2000)	Montana[c] (Casey 2000)	Nevada[c] (Neel 1999)	Columbia Plateau[c] (Altman and Holmes 2000)	Colorado[c] (Beidleman 2000)	Wyoming[c] (Cerovski 2001)
Swainson's Hawk	*Buteo swainsoni*	England et al. 1997	x		x	x	x		x	
Ferruginous Hawk	*Buteo regalis*	Bechard and Schmutz 1995	x		x	x	x	x	x	x
Prairie Falcon	*Falco mexicanus*	Steenhof 1998	x		x		x		x	
Greater Sage-grouse	*Centrocercus urophasianus*	Schroeder and Braun 1999	x	x	x	x	x	x	x	
Gunnison Sage-grouse	*Centrocercus minimus*	Schroeder and Braun 1999	x	[d]	[d]	[d]	[d]	[d]	x	[d]
Columbian Sharp-tailed Grouse	*Tympanuchus phasianellus columbianus*	Connelly et al. 1998	x	x	x	x	[e]	x		
Long-billed Curlew	*Numenius americanus*	Dugger and Dugger 2002	x		x	x	x		x	x
Burrowing Owl	*Athene cunicularia*	Haug et al. 1993	x	x		x	x	x	x	x
Short-eared Owl	*Asio flammeus*	Holt and Leasure 1993	x	x	x	x	x		x	x
Gray Flycatcher	*Empidonax wrightii*	Sterling 1999	x		x		x		x	
Loggerhead Shrike	*Lanius ludovicianus*	Yosef 1996	x	x	x	x	x	x	x	x
Horned Lark	*Eremophila alpestris*	Beason 1995	x						x	
Rock Wren	*Salpinctes obsoletus*	Lowther et al. 486	x		x					
Sage Thrasher	*Oreoscoptes montanus*	Reynolds et al. 1999	x	x	x	x	x	x		x
Green-tailed Towhee	*Pipilo chlorurus*	Dobbs et al. 1998	x			x			x	
Brewer's Sparrow	*Spizella breweri*	Rotenberry et al. 1999	x	x	x	x		x	x	x

Table 1— *(contd.)*

Species[a,b]	Scientific name	Birds of North America reference	Sagebrush ecosystems (Paige and Ritter 1998)	Interior Columbia Basin[c] (Wisdom et al. 2000)	Idaho[c] (Ritter 2000)	Montana[c] (Casey 2000)	Nevada[c] (Neel 1999)	Columbia Plateau[c] (Altman and Holmes 2000)	Colorado[c] (Beidleman 2000)	Wyoming[c] (Cerovski 2001)
Vesper Sparrow	*Pooecetes gramineus*	Jones and Cornely 2002	x	x			x			x
Lark Sparrow	*Chondestes grammacus*	Martin and Parrish 2000	x	x	x	x		x		x
Black-throated Sparrow	*Amphispiza bilineata*	Johnson et al. 2002	x	x		d		x		
Sage Sparrow	*Amphispiza belli*	Martin and Carlson 1998	x	x	x		x	x	x	x
Grasshopper Sparrow	*Ammodramus savannarum*	Vickery 1996	x	x	x	x		x	x	x
Western Meadowlark	*Sturnella neglecta*	Lanyon 1994	x	x						

[a]Species in bold are on the Partners in Flight continental Watch List (Rich et al. 2004).
[b]Species in italics are on the Partners in Flight Stewardship Species list (Rich et al. 2004).
[c]Blanks indicate that species was not listed as a priority in subject reference.
[d]Species or subspecies does not occur in area covered by reference.
[e]Historical occurrence uncertain.

We also examine the extent to which sage grouse may serve as classic umbrella species (Caro and O'Doherty 1999) for shrubsteppe avifauna. Because of long-term population declines and habitat loss, it is likely that significant conservation actions will be taken to conserve the two species of sage-grouse. We believe it is important to understand how many other species of concern might benefit from such actions, and to what degree. Then, actions can be designed to be effective for substantial components of the ecosystem rather than just for single species. Although our interest here is in other bird species, we encourage exploration of multi-species approaches that also benefit other animal and plant taxa.

Finally, opportunities to conserve these birds and their habitats are particularly good because much of the sagebrush ecosystem is public land–land belonging to all American citizens–and is managed by the U.S. Bureau of Land Management (BLM). In fact, BLM manages 22,389,000 ha of sagebrush, which includes 57 percent of the entire ecosystem (Schueck, pers. comm.). We further suggest that the broad scale land management actions of BLM may provide information useful in examining the current condition of sagebrush habitats, particularly in regard to grazing of domestic livestock. The construction of fences and the provision of water through pipelines, for example, reveal the degree to which public land is managed to accommodate livestock in landscapes and habitats where livestock grazing could not otherwise occur. We suggest that the continual expansion of livestock grazing across the public lands of western landscapes has impacted and will continue to impact the quality of those habitats and their ability to support source populations of sagebrush bird species.

Methods

Data used in the analysis of species co-occurrence come from the "State-Province Abundance Checklists" of the Breeding Bird Survey (BBS; Sauer et al. 2001). Data consist of the mean relative abundances of sagebrush-associated bird species over the period 1966-1996 in each state-physiographic unit defined by the BBS. These units consist of that portion of a BBS

physiographic strata, (e.g., Columbia Plateau), that occurred within a given state. There were 52 such units.

Statistical analyses were conducted on the relative abundances of only those species that had sufficient sample sizes. A sample size was considered sufficient if there were non-zero relative abundances in at least 27 of the units. While the non-occurrence of a species in this context does constitute useful information, we wanted to avoid inflating the correlations with large counts of zero relative abundance. This screen excluded the Grasshopper Sparrow and Columbian Sharp-tailed Grouse from this analysis. Data for the newly-described Gunnison Sage-grouse are combined with those for Greater Sage-grouse so no analysis for this species was possible. Nineteen species remained for further analysis.

Inspection of these relative abundance data revealed that the square-root transformation (Zar 1996) was appropriate to produce normal distributions. Variances were approximately homogeneous. A correlation matrix was produced among species with sufficient sample sizes and an exploratory factor analysis with varimax rotation was run in which the factors were defined by the loadings of particular species. Analyses were conducted in which the number of factors was set to 14, 12, 10, 8, 6, and 4, respectively. This approach created progressively fewer groupings of species and allowed the examination of how robust the species associations were as the number of factors was reduced (Rich 2002). Statistical analyses were conducted with Statgraphics® Plus software (Manugistics 1992).

Historic and current population sizes for selected sagebrush steppe bird species in the Columbia Plateau were calculated using historical and current habitat areas from Wisdom et al. (2000). Historical bird population sizes were estimated by multiplying the historical habitat area by the maximum density for the species reported in the Birds of North America series (references in *table 1*) and/or reported by Wiens and Rotenberry (1981). We assumed that during the historic period, population densities for all species were at least as high as the highest densities known from recent studies. Because all habitats are degraded from historic conditions (Wisdom et al. 2000), we reasoned that this was actually a conservative estimate.

Current bird population sizes were estimated by multiplying the current habitat area (Wisdom et al. 2000) by an estimate of current bird density based on BBS data (Sauer et al. 2001) and a method by which BBS data can be converted to densities (Rosenberg and Blancher this volume). Historic population trends (r) were then calculated for those species for which historical and current population estimates could be made for the Columbia Plateau. Trends were calculated using the equation $N_t = N_0 * e^{rt}$ where N_t is the estimated current population size, N_0 was the estimated population size in 1850, e is the base of natural logarithms, r was the annual rate of change, and t was 151 years. Rates also were calculated for changes in the population size both 10 times and one-tenth that estimated to provide perspective on how sensitive r was to the population estimates.

Results

Sagebrush Steppe Species of Concern

Twenty-one species and one subspecies in the western US are priorities in Partners in Flight Bird Conservation Plans (Paige and Ritter 1998) or in regional assessments (see Carter et al. 2000, Panjabi et al. 2001 for assessment methodology) for some part of the sagebrush ecosystem (*table 1*). Although most of these species appear on most state and regional priority lists, only the relatively widespread Loggerhead Shrike was of concern in all eight of the analyses listed. All of the widespread sagebrush obligates–Greater Sage-grouse, Sage Thrasher, Brewer's Sparrow, and Sage Sparrow–were of concern in seven of eight analyses, but there also were four species of grassland birds of concern in seven of eight analyses–Ferruginous Hawk (*Buteo regalis*), Burrowing Owl (*Athene cunicularia*), Short-eared Owl, and Grasshopper Sparrow.

In addition to assessment at the state level, PIF has species assessment scores for the breeding season for each of the relevant Bird Conservation Regions (North American Bird Conservation Initiative (2000). Among the 22 taxa of interest here, none differed by more than 3 points among the three Bird Conservation Regions (BCRs) in question (*table 2*). These scores show the two species of sage-grouse to be of highest concern. Only the widespread grassland species–Vesper Sparrow, Western Meadowlark (*Sturnella neglecta*) and Horned Lark (*Eremophila alpestris*)–scored uniformly lower across the three BCRs.

Co-occurrence of Sagebrush Species

The degree to which species co-occur at spatial scales from the territory to the continent help us determine how to design, or even if we can design, management strategies for multiple species at those different scales. We chose to examine co-occurrence from the perspective of sage-grouse because significant comprehensive conservation actions are likely to be taken for these species. Thus, we need some understanding of how other species co-occur with grouse.

Table 2— *Bird Conservation Region Scores for priority bird species of sagebrush habitats. Maximum possible score is 35; minimum is 7.*

	Bird Conservation Region		
Species	**Northern Rockies**	**Great Basin**	**Southern Rockies/ Colorado Plateau**
Swainson's Hawk	22	21	22
Ferruginous Hawk	23	23	20
Prairie Falcon	22	25	23
Greater Sage-grouse	25	24	22
Gunnison Sage-grouse	[a]	[a]	35
Columbian Sharp-tailed Grouse	[b]	[b]	[b]
Long-billed Curlew	21	21	20
Burrowing Owl	18	17	19
Short-eared Owl	19	21	19
Gray Flycatcher	21	21	22
Loggerhead Shrike	19	19	18
Horned Lark	12	14	13
Rock Wren	18	17	19
Sage Thrasher	19	19	18
Green-tailed Towhee	21	19	21
Brewer's Sparrow	22	24	21
Vesper Sparrow	16	16	16
Lark Sparrow	17	19	18
Black-throated Sparrow	18	20	20
Sage Sparrow	21	22	23
Grasshopper Sparrow	19	19	16
Western Meadowlark	15	16	14

[a]Species does not occur in BCR.
[b]Scoring for subspecies not complete.

At the largest spatial scale, the overlap of the breeding ranges of other priority species with Greater Sage-grouse varied from a maximum of 68 percent for Sage Sparrow and Sage Thrasher to a minimum of 0 percent for Gunnison Sage-grouse (*table 3*). Note that no measurement was available for the Columbian Sharp-tailed Grouse subspecies. Birds with an affinity for sagebrush or other western shrubs had the highest overlaps, but both the Long-billed Curlew (*Numenius americanus*) and Ferruginous Hawk had a greater overlap than Brewer's Sparrow. In the Interior Columbia Basin (Wisdom et al. 2000) overlap of historical source habitats between the Greater Sage-grouse and three other species of sagebrush obligate birds was estimated to be: Sage Sparrow (99 percent), Sage Thrasher (94 percent), and Brewer's Sparrow (94 percent).

At a finer spatial scale, we can examine the co-occurrence of these species in the 52 state/physiographic units defined by the BBS (see Methods). Note that correlations among relative abundances measure overlap of both spatial distribution and frequency of occurrence. Among the 19 species with sufficient sample sizes from the BBS, there was a high level of species co-occurrence over the period 1966-1996. The total number of correlations among species pairs was 171 (19x18/2) and we would expect 8.55 of these to be significant at P = 0.05 by chance alone. The actual number of significant correlations was 83, thereby quantifying the simple fact that these species tend to occur together at a high level.

Of particular interest were the significant correlations between the relative abundances of ten species (with sufficient sample sizes) with the relative abundance of sage-grouse (*table 4*). Grouse often are not considered to be well monitored by the BBS, yet these correlations are all ecologically reasonable. Sage Thrasher and Brewer's Sparrow showed the highest correlations but three species with grassland affinities–Short-eared Owl, Vesper Sparrow, and Western Meadowlark–also co-occurred at a significant level. The significant association with the Green-tailed Towhee also is instructive as that species typically uses mixed shrub habitats with species such as *Artemisia tridentata vaseyena*, *Purshia tridentata*, and *Ceonothus* spp., which are typically found at higher elevations. Notably, Vesper Sparrow–a grassland bird also found at higher elevations–had a higher correlation (r = 0.50) than Sage Sparrow (r = 0.47).

Table 3— *Area of overlap between the breeding range of Greater Sage-grouse and that of other priority sagebrush bird species.*

Species	North American breeding range (km^2)	Area of overlap with Greater Sage-grouse (km^2)	Percent of range overlapped (%)
Greater Sage-grouse	1,407,570	1,407,570	100
Sage Sparrow	1,087,917	738,387	68
Sage Thrasher	1,752,253	1,188,765	68
Gray Flycatcher	1,143,281	701,065	61
Green-tailed Towhee	1,735,138	1,006,463	58
Long-billed Curlew	2,069,362	1,070,270	52
Ferruginous Hawk	2,435,562	1,153,358	47
Brewer's Sparrow	3,221,685	1,392,172	43
Prairie Falcon	3,793,501	1,400,717	37
Rock Wren	5,419,745	1,403,572	26
Lark Sparrow	5,600,839	1,345,393	24
Black-throated Sparrow	2,834,537	679,578	24
Burrowing Owl	5,613,560	1,334,432	24
Western Meadowlark	6,708,163	1,407,570	21
Swainson's Hawk	7,465,918	1,407,570	19
Vesper Sparrow	7,375,124	1,375,608	19
Loggerhead Shrike	8,850,519	1,372,587	16
Grasshopper Sparrow	5,207,266	558,885	11
Sharp-tailed Grouse[a]	6,044,256	574,991	10
Horned Lark	15,593,137	1,405,630	9
Short-eared Owl	12,417,599	964,000	8
Gunnison Sage-grouse		0	0

[a]Measurements are for the full species.

Table 4— *Correlations between the relative abundance of sage grouse and that of other co-occurring sagebrush species in the western US. (N = 52).*

Species	R	P
Sage Thrasher	0.71	< 0.001
Brewer's Sparrow	0.63	< 0.001
Vesper Sparrow	0.50	< 0.001
Sage Sparrow	0.47	< 0.001
Gray Flycatcher	0.38	< 0.01
Green-tailed Towhee	0.37	< 0.01
Rock Wren	0.36	< 0.01
Western Meadowlark	0.31	< 0.05
Prairie Falcon	0.29	< 0.05
Short-eared Owl	0.29	< 0.05

A comparison of the proportion of range overlap (*table 3*) with the correlations of relative abundance (*table 4*) suggests that those correlations are not simply a direct function of area overlap. Proportion of range overlap does not explain a significant amount of the variation in relative abundance correlation ($R^2 = 0.24$, $F = 2.51$, $P = 0.15$).

In the exploratory factor analysis of the relative abundance correlation matrix, species groups were defined by those species that had high loadings (>0.70) on a particular factor. For example, for the analysis with 14 factors, 11 different groups were defined (*fig. 1*). As the number of factors in the analysis was reduced, species were consolidated into progressively fewer groups.

The Burrowing Owl, Short-eared Owl, Prairie Falcon, and Green-tailed Towhee tended to maintain their individual axes. That is, their patterns each maintained a large degree of independence from the other groups. Although three of the sagebrush obligates–Sage Thrasher, Brewer's Sparrow, Sage Sparrow–formed a coherent group from the beginning with Gray Flycatcher and Rock Wren, sage-grouse were not part of that group. Rather, sage-grouse relative abundance aligned more closely with the Vesper Sparrow, repeating an association revealed in previous analyses of these data. The Black-throated Sparrow and Loggerhead Shrike also showed a consistent association, independent of the other groups.

Recent Population Trends

Population trends were available for three major physiographic strata defined by the BBS that encompass sagebrush ecosystems–the Columbia Plateau, Wyoming Basin and Basin and Range (*fig. 2*). None of the species in this analysis showed significant trends in

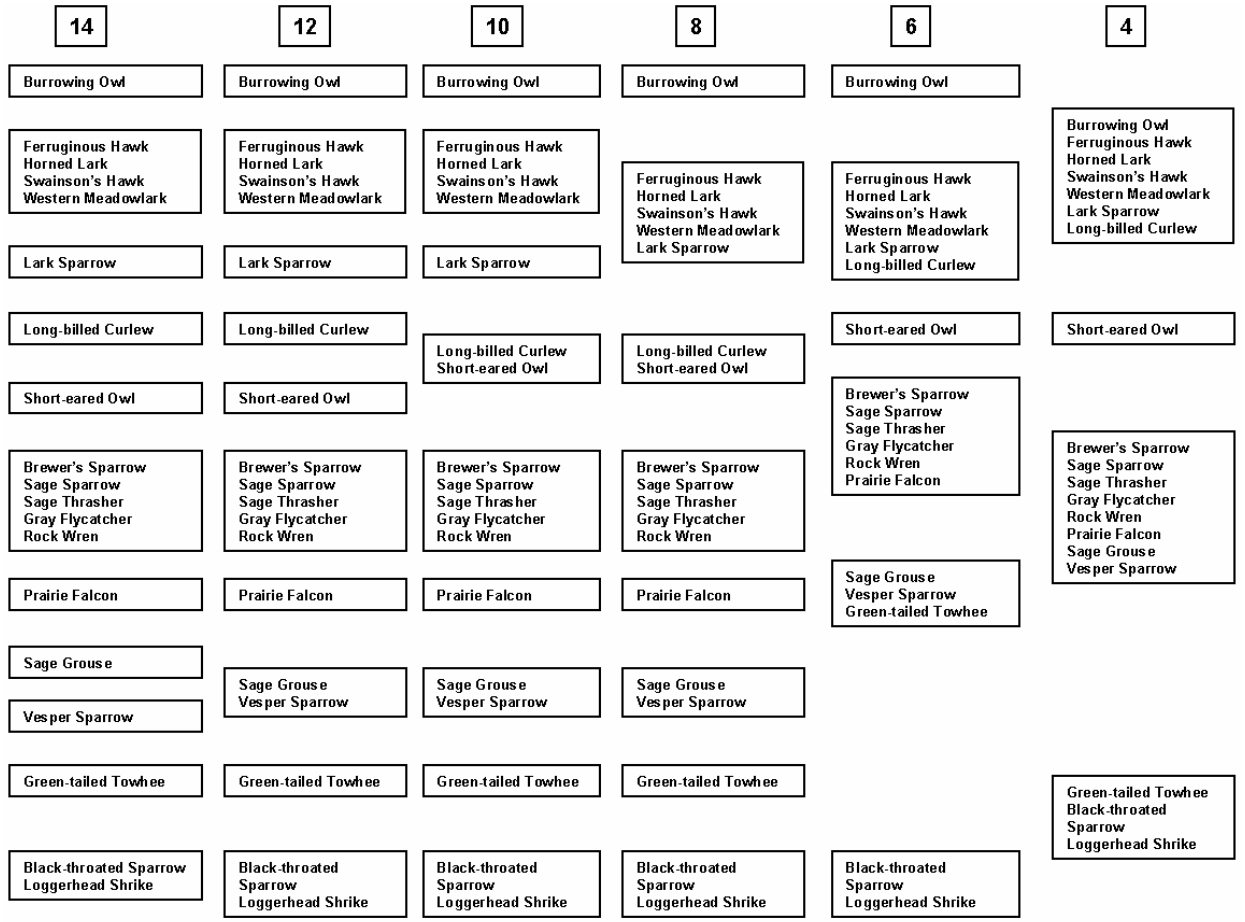

Figure 1— Groups defined by a factor analysis, from 16 to 4 factors, of the relative abundance data from the Breeding Bird Survey for 19 species of sagebrush bird species during the breeding season in the western United States.

all three strata (*table 5*). The Loggerhead Shrike and Grasshopper Sparrow both showed significant or nearly significant declines in two of the strata, although the combination of marginal P values and only fair or poor coverage made those trends weak. The BBS is conventionally not considered to be an effective tool for long-term trend monitoring of grouse, particularly at the finer scales of the physiographic strata, and other sources of data must be used. According to Braun (1998), Schoeder et al. (1999) and Connelly et al. (2000), both species of sage-grouse have declined steadily and have certainly shown significant declines range-wide since 1966.

In the Wyoming Basin, only the Grasshopper Sparrow showed a significant trend. And although that species apparently has had a precipitous decrease, the BBS coverage is rated as poor. In the Basin and Range physiographic strata, both the Short-eared Owl and Sage Sparrow had significant increases while the Loggerhead Shrike showed the only significant decline.

All the other clear trends were in the Columbia Plateau, with 10 of the 21 taxa occurring there–in addition to Greater Sage-grouse–having significant, or nearly significant, population trends. BBS coverage was good for seven species. Eight of the ten showed declining trends and two, increasing. Habitat associations for declining species include both sagebrush and grassland types. Habitat associations for the two increasing species, the Long-billed Curlew and Burrowing Owl, were similar–grassland types with low-stature vegetation and few shrubs.

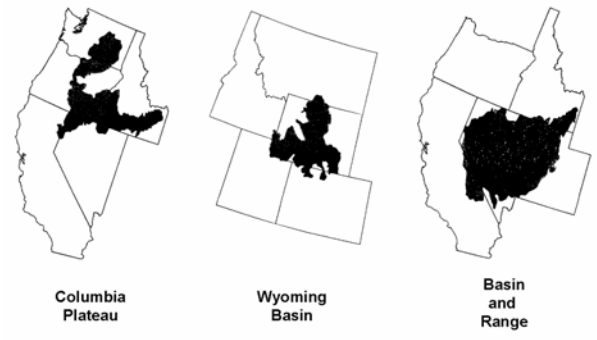

Figure 2— The Columbia Plateau, Wyoming Basin, and Basin and Range physiographic strata from the Breeding Bird Survey.

Table 5— *Population trends (1966-2001), significance and data quality from the Breeding Bird Survey for three physiographic areas.*

	Columbia Plateau			Basin and Range			Wyoming Basin		
Common Name	**Trend (%/yr)**	**P**	**Quality**	**Trend (%/yr)**	**P**	**Quality**	**Trend (%/yr)**	**P**	**Quality**
Swainson's hawk	4.20	0.35	fair	3.80	0.19	fair	-4.60	0.42	poor
Ferruginous hawk	1.80	0.27	poor	5.50	0.28	poor	5.50	0.28	poor
Prairie falcon	-4.10	0.25	poor	-1.30	0.90	poor	19.10	0.20	poor
Greater Sage-grouse	-13.8	0.12	poor	3.50	0.87	poor	2.00	0.62	fair
Gunnison Sage-grouse	[a]			[a]			[a]		
Columbian Sharp-tailed Grouse	[b]			[b]			[a]		
Long-billed curlew	**4.00**[c]	**0.01**	**good**	[a]			26.00	0.50	poor
Burrowing owl	**13.10**	**0.07**	**poor**	11.90	0.17	poor	-24.80	0.56	poor
Short-eared owl	-0.6	0.72	fair	**14.80**	**0.00**	**poor**	[a]		
Gray flycatcher	4.60	0.25	poor	1.00	0.87	poor	[a]		
Loggerhead shrike	**-2.7**	**0.00**	**good**	**-3.00**	**0.09**	**fair**	-7.20	0.14	fair
Horned Lark	**-3.3**	**0.00**	**good**	1.10	0.28	good	-0.90	0.48	good
Rock Wren	**-1.6**	**0.08**	**good**	-0.80	0.78	fair	1.10	0.65	good
Sage thrasher	0.20	0.81	fair	-0.70	0.39	good	0.90	0.62	good
Green-tailed towhee	1.50	0.68	poor	-0.10	0.97	good	-3.20	0.35	fair
Brewer's sparrow	**-3.8**	**0.01**	**good**	-0.50	0.78	good	-0.30	0.78	good
Vesper sparrow	-0.2	0.77	good	-0.50	0.59	good	0.30	0.88	fair
Lark sparrow	**-2.2**	**0.05**	**good**	0.80	0.59	good	-0.60	0.86	fair
Black-throated sparrow	**-10.60**	**0.05**	**poor**	0.50	0.75	good	a		
Sage sparrow	1.90	0.65	fair	**4.10**	**0.10**	**fair**	0.90	0.72	good
Grasshopper Sparrow	**-4.80**	**0.01**	**good**	15.60	0.18	poor	**-41.40**	**0.02**	**poor**
Western Meadowlark	**-0.80**	**0.08**	**fair**	1.90	0.14	good	-0.30	0.87	fair

[a]Taxon does not occur in physiographic strata.
[b]Taxon not sampled by BBS.
[c]Trends at P <= 0.10 are in bold.

Table 6— *Estimated historic and current population sizes and estimated historic population trends (1850-2001) for selected species in the Columbia Plateau physiographic area.*

Species	Maximum historic population size estimate		Current population size estimate	Rate of change (r) based on BNA	For change 10x greater	For change 10x less	Rate of change (r) based on W&R 1981	For change 10x greater	For change 10x less
	Densities from BNA accounts	Densities from W&R 1981[a]							
Greater Sage-grouse	5,183,460		14,533	-0.0389	-0.0542	-0.0237			
Columbian Sharp-tailed Grouse	341,040		5,396	-0.0275	-0.0427	-0.0122			
Short-eared Owl	4,047,936		11,953	-0.0386	-0.0538	-0.0233			
Loggerhead Shrike		1,386,780	39,772				-0.0235	-0.0388	-0.0083
Sage Thrasher	31,083,360	10,949,820	939,786	-0.0232	-0.0384	-0.0079	-0.0163	-0.0315	-0.0010
Brewer's Sparrow		175,282,380	1,077,626				-0.0337	-0.0490	-0.0185
Vesper Sparrow		7,378,644	397,836				-0.0193	-0.0346	-0.0041
Lark Sparrow	61,677,200	10,176,738	100,713	-0.0425	-0.0578	-0.0273	-0.0306	-0.0458	-0.0153
Black-throated Sparrow		31,361,644	69,769				-0.0405	-0.0557	-0.0252
Sage Sparrow		77,423,736	346,940				-0.0358	-0.0511	-0.0206
Grasshopper Sparrow	98,692,800		9,703	-0.0611	-0.0764	-0.0459			
Western Meadowlark		27,969,920	2,584,435				-0.0158	-0.0310	-0.0005

[a] Wiens and Rotenberry 1981.

Historic and Current Population Sizes for the Columbia Plateau

Population size estimation involves many assumptions and we propose the following historic and current estimates only as a starting point for further dialogues. Historic (1850) and current population sizes (*table 6*) were estimated for 12 priority taxa in the Interior Columbia Basin based on predicted areas of historic and current source habitat (Wisdom et al. 2000). The habitat and population estimates should be viewed with caution because an accuracy assessment of the vegetation classification was not conducted. According to these estimates, the largest historic population was for Brewer's Sparrow with an estimated size of 175,282,380 birds (*table 6*). The Columbian Sharp-tailed Grouse had the smallest estimated population–341,040.

Estimated current population sizes (*table 6*) are, not surprisingly, drastically reduced from historic numbers. The Western Meadowlark showed the least reduction with a current population estimate of 2,584,435 birds, about 9 percent of its historic size. It has apparently replaced the Brewer's Sparrow as the most abundant bird in the Interior Columbia Basin, among those species considered here. At the other extreme, the Grasshopper Sparrow was estimated to have been reduced to only 0.000098 of its historic population size. Only the Columbian Sharp-tailed Grouse is estimated to have a lower total population size.

Historic Population Trends for the Columbia Plateau

Historic population declines necessary to produce the changes from estimated historic to estimated current numbers were highest for the Grasshopper Sparrow at -6.1 percent/yr (*table 6*). For a change an order of magnitude less, the rate would have been -4.6 percent/yr, and for an order of magnitude more, -7.6 percent/yr. Declines were estimated to have been least for the Western Meadowlark at -1.6 percent/yr (*table 6*).

For six of the species that had significant or near significant declines in the Columbia Plateau physiographic strata since 1966, and for which we have historic and current habitat estimates–Loggerhead Shrike, Brewer's Sparrow, Lark Sparrow, Black-throated Sparrow, Grasshopper Sparrow and Western Meadowlark – the estimated historical declines were all remarkably similar to recent trends from the BBS (*table 5*). In fact, rates for the Loggerhead Shrike and Brewer's Sparrow were nearly identical. We emphasize that the estimates of current and historical declines were independent.

Habitat Trends for the Columbia Plateau

Public Land Statistics (PLS; e.g., Bureau of Land Management 2001) report several statistics annually that provide some insight into habitat trends on public land in the West and, for this paper, the Columbia Plateau. To our knowledge, the long-term patterns in these statistics have never been examined. Although these statistics are reported by state, rather than by ecoregion, they were nonetheless easily correlated with various physiographic areas for broad-scale considerations. PLS data for "non-forest" BLM lands in the states of Idaho, Oregon, and Washington align well with the Columbia Plateau (*fig. 2*).

Trends in the Area Burned by Fire

The area of non-forest BLM land burned annually provides a strong indication, not only of the loss of sagebrush, but also the spread of exotic cheatgrass (*Bromus tectorum*) and other invasive plants in the region. The area burned has varied greatly from 1946 to 2000 (*fig. 3*), including a minimum of 3,255 ha in 1956 and a maximum of 322,974 ha in 1996. Most importantly, the area burned annually has increased significantly over time ($Y = -2.1*10^6 + 1100X$, $P = 0.02$).

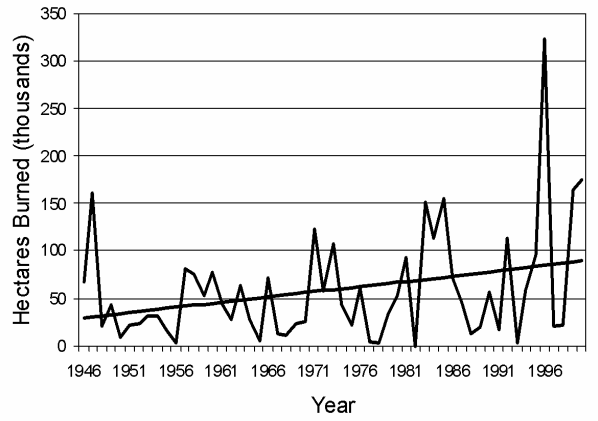

Figure 3— Number of hectares of non-forest land managed by the U.S. Bureau of Land Management that was burned in each year in Idaho, Oregon, and Washington. The linear regression is significant ($Y = -2.1*10^6 + 1100X$, $P = 0.02$).

Trends in Livestock Grazing

The number of livestock on BLM lands is reported in Animal Unit Months (AUMs), which is one cow and one calf for one month. Cattle AUMs in Idaho, Oregon, and Washington on BLM lands have varied little over the period from 1949 to 2000 (*fig. 4*). A low of 1,554,081 AUMs was reported in 1993 while the peak was 2,056,629 in 1985. There were actually more AUMs on the public lands in these states in 2000 than in 1949, when records were begun. The noteworthy point is that AUMs have remained roughly the same for the past half-century, contrary to the conventional wisdom that cattle numbers on public land have steadily decreased. Further, livestock have been selected so that the mean mass of individuals has increased over time (*fig. 5*). Thus, the total grazing impact on the vegetation and other resources is substantially greater than it was historically.

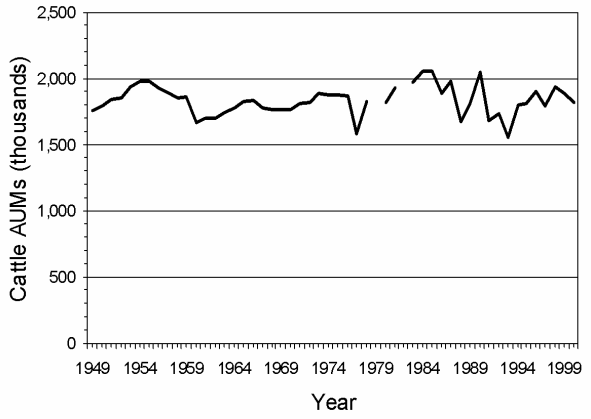

Figure 4— Number of cattle Animal Unit Months (AUMs) permitted each year on land managed by the U.S. Bureau of Land Management in Idaho, Oregon, and Washington.

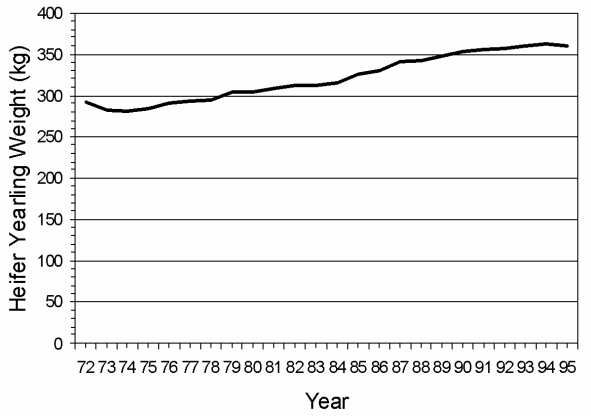

Figure 5— Mean weight of yearling hereford heifers in the Rocky Mountain region from 1972 to 1995. The sample size averages 6250 individuals per year.

Trends in the Supply of Water to Livestock in the Uplands

To maintain the numbers of cattle grazing on public lands at essentially constant levels (*fig. 4*) while implementing a policy to greatly improve the condition of riparian areas (Bureau of Land Management 1993), BLM has spread that grazing more broadly across the landscape. This has been accomplished by two practices–by providing water to upland areas that do not have natural water supplies and by building fences to prevent cattle from leaving those upland areas. The

kilometers of water pipeline built in the three-state area on BLM lands was highest in the 1960s and 1970s (*fig. 6*). However, pipelines continue to be constructed on public lands to date, with over 740 km built over the last decade in Idaho, Oregon and Washington.

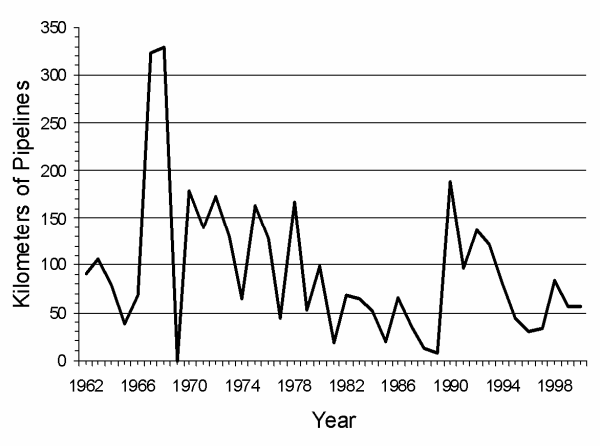

Figure 6— Kilometers of pipeline built each year on land managed by the U.S. Bureau of Land Management in Idaho, Oregon, and Washington.

In a related activity, natural springs have been "developed" to provide water for livestock. This process typically involves installing a structure to capture the natural flow of water to put it into a pipeline or off-site trough for cattle. As with the construction of pipelines, spring development was highest in the 1960s and 1970s but the process continues (*fig. 7*). In the past decade, 1991-2000, 218 springs were developed in the region.

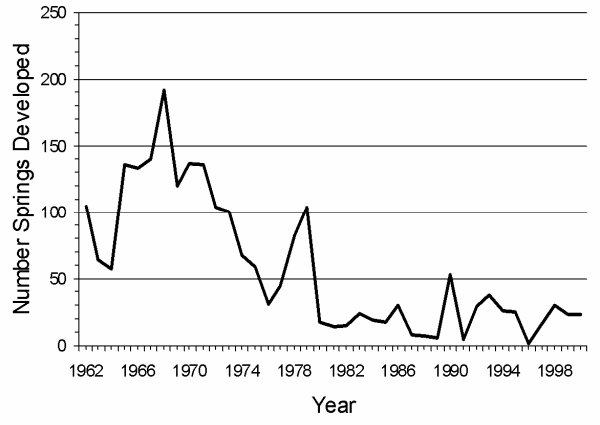

Figure 7— Number of springs developed each year on land managed by the U.S. Bureau of Land Management in Idaho, Oregon, and Washington.

Trends in Fencing

Because cattle are notorious both for staying in the bottoms of valleys and returning to those bottoms once herded higher on slopes, it is necessary to construct fences to keep cattle away from bottoms, streams, and riparian vegetation. As with both the building of pipelines and the development of springs, fence building on BLM lands in Idaho, Oregon, and Washington peaked in the 1960s (*fig. 8*). However, fence building has again increased noticeably over the last decade. The 434 km built in 1998 was the most in a single year since 1973.

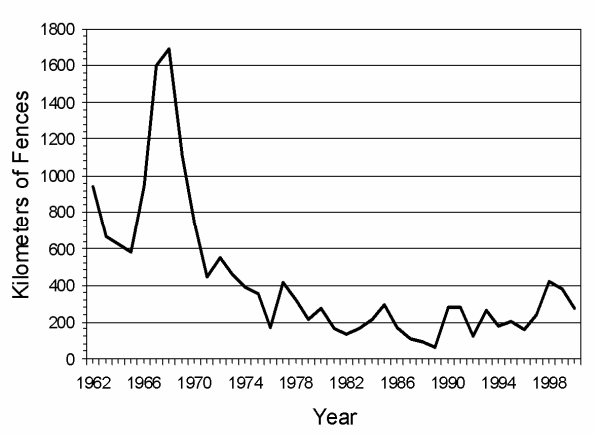

Figure 8— Kilometers of fence built each year on land managed by the U.S. Bureau of Land Management in Idaho, Oregon, and Washington.

Palatability and Conservation Status of Forbs

In sagebrush ecosystems, 431 species of forbs were of management concern to various agencies and non-governmental organizations in 2000 (Rich, unpubl. data). These forbs can be ranked by their palatability to wildlife as good, fair, or poor (Rosentreter, pers. comm.). The null hypothesis was that equal numbers (143.67) of forb species of conservation concern would occur in each of the three palatability categories. However, the distribution of species (*fig. 9*) was significantly different from expected (X^2 = 67.1, P < 0.001). Far more species of conservation concern were of good palatability, and the number of fair palatability exceeded the number of poor.

Discussion

Habitat loss and other adverse impacts to sagebrush avifauna were first recognized as a widespread problem by Braun et al (1976). Although Greater and Gunnison sage-grouse have received the most attention recently (Dobkin 1995; Connelly et al. 2000; Wisdom et al. 2000, 2002a, 2002b; Knick et al. 2003), several other bird species dependent on sagebrush also are of conservation concern more or less across their ranges (Paige and Ritter 1998, Neel 1999, Altman and Holmes 2000, Beidleman 2000, Casey 2000, Ritter 2000, Cerovski et al. 2001, Rich et al. 2004).

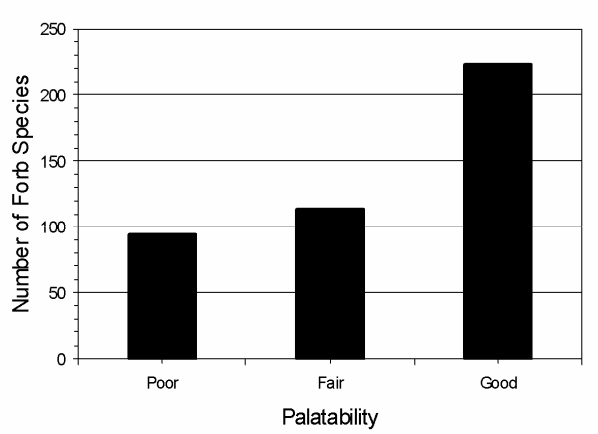

Figure 9—The number of forb species of conservation concern in sagebrush ecosystems with poor, fair, and good palatability to wildlife. The distribution of species is significantly different from the expected even distribution (X^2 = 67.1, P < 0.001).

Sagebrush itself typically provides critical nest sites, perch sites, cover, and even food for these bird species, and thus has been the habitat component most studied over the years. However, it is noteworthy that bird species that depend largely on the grass component of sagebrush systems–Columbian Sharp-tailed Grouse, Long-billed Curlew, Burrowing Owl, Short-eared Owl, Vesper Sparrow, Lark Sparrow, Grasshopper Sparrow, and Western Meadowlark–also are of conservation concern and show clear associations with sage-grouse across the West. Perennial native bunchgrasses such as those in the genera *Agropyron*, *Poa*, *Stipa*, *Festuca*, and *Elymus*, *Pseudoroegneria* and *Oryzopsis* are integral components of sagebrush ecosystems (Vavra et al. 1994, West and Young 2000) that have not always been well examined in bird-habitat relations research. Grasses are important in providing food and cover for birds directly, and in providing a substrate for a volume and diversity of insects which serve as additional food items. The value of grasses in providing cover for successfully nesting sage-grouse has been documented by Connelly et al. (1991).

Data and analysis presented here reveal widespread co-occurrence of sagebrush bird species. Not only do their ranges overlap broadly in western North America, but the relative abundance of various species show high correlations on BBS routes independent of degree of range overlap. This includes the sagebrush obligate and other shrub species as well as those using the grass component of the ecosystem. Even sage-grouse, which are thought to be poorly monitored by the BBS for trend purposes, showed significant correlations with 10 other species, including the grassland species Vesper Sparrow, Western Meadowlark and Short-eared Owl. Perhaps surprisingly, sage-grouse actually aligned most closely with Vesper Sparrow in the factor analysis presented here. Again, this strongly hints at the association of grouse with the grass component of this ecosystem (e.g., Connelly et al. 1991).

Population trend is only one of the seven factors used by PIF to assess the biological status of species in a given geographic area (Carter et al. 2000, Panjabi et al. 2001). Thus, a number of the species of conservation concern (*table 1*) have not necessarily had significantly declining population trends (*table 4*). The Greater Sage-grouse and Loggerhead Shrike are of most concern across the three sagebrush ecoregions (*fig. 2*). But among the other species, there is a clear problem in the Columbia Plateau where eight additional species have declining trends. We believe the reason for this is directly related to the reason that two other species–the Long-billed Curlew and Burrowing Owl–are increasing in the ecoregion. That is the conversion of shrubsteppe habitat to cheatgrass (Wisdom et al. 2000, 2002a, 2002b; Knick et al. 2003). Most native shrubsteppe birds either do not use cheatgrass or occur in much lower densities there (Shaw et al. 1999). Cheatgrass domination produces an open landscape with low-stature vegetation used by the Long-billed Curlew and Burrowing Owl.

The estimates of historical population sizes for selected species presented here for the Columbia Plateau are valuable in helping to establish baseline populations against which to compare current population sizes and future objectives. Not surprisingly, all species' populations are vastly reduced from historic numbers, with the Western Meadowlark declining the least and Grasshopper Sparrows declining the most.

These population estimates also give us an unusual opportunity to estimate historic population trends for these species, trends going back far beyond the 1966-present period of the BBS. These trend estimates depend on the methodology developed to convert BBS data into density estimates (Rosenberg and Blancher this volume) and many assumptions are involved (Rich et al. 2004). Nonetheless, historical trend estimates are perhaps even more valuable than absolute numbers because they provide another baseline with which to compare more recent trends and future trend objectives.

Remarkably, most of the estimated historical population trends are similar to recent trends from the BBS. Because these estimates are independent, they suggest that the trends are real. They also suggest that significant, and relatively steep, declines have been underway for at least 151 years for some species. Doubtless, population trends vary over given periods of time and different factors affecting birds and their habitats come into play. But on the whole, this is not encouraging evidence for these species in this region.

Declines for the Greater Sage-grouse are particularly alarming due to their small current population size (total sage-grouse estimated at 142,000 in 1998 [Braun 1998]) and poor recruitment in recent years. We estimated declines to be 3.89 percent/yr since 1850. This compares to an estimated 1.3 percent/yr for all sage-grouse rangewide over the period 1850-1998 (Braun 1998).

Losses in the historical extent of sagebrush have been estimated for various regions and in various ways (Tisdale and Hironaka 1981, Hann et al. 1997, Miller and Eddleman 2000, Knick et al. 2003). Not only sagebrush itself, but also native grasses have been greatly diminished over the last century by livestock grazing (Mack and Thompson 1982, Fleischner 1994). Negative effects of livestock grazing on birds (Saab et al. 1995) may be substantially due to this impact, although research on the cause-effect relationships is still lacking. Similarly, the fact that at least 431 species of forbs are currently of conservation concern (Rich, unpubl. data, Nachlinger et al. 2001), and that these species tend to be palatable (this paper), suggests that many of these species are far below their historical densities and, possibly, geographic extent. This group of plants has been almost completely ignored by ornithologists in habitat research. The exception is for sage-grouse researchers who have long appreciated the critical role of herbaceous vegetation for food, cover, health of prelaying hens, and juvenile survival (Saab and Marks 1992, Schroeder et al. 1999, Connelly et al. 2000). It seems likely that these forbs also historically provided food and cover directly, and, just as with the perennial bunch grasses, served as substrate for yet another large variety of insects which provide food for adult and young birds of all species.

Data presented here for BLM lands in the Columbia Plateau complement those in Wisdom et al. (2000) which account for the habitat loss and habitat degradation that doubtless continue to contribute to bird population declines. The area of rangeland burned every year is increasing significantly, with a concomitant increase in the area degraded, or completely dominated, by cheatgrass (Hann et al. 1997). The number of cattle AUMs was actually higher in 2000 than in 1949 and the mean weight of these animals has increased by over 20 percent. The evidence suggests that this continuance of livestock grazing is being accommodated by moving cattle out of riparian habitat and into the uplands where impacts on sagebrush birds actually are increasing. BLM has had a policy of improving riparian habitats for many years (Bureau of Land Management 1993). While this goal is critically important and effective for riparian birds (Krueper et al. 2003), we suggest that the steady construction of fences and provision of water through spring development and pipeline construction, is shifting the impacts to the upland habitats where sagebrush species occur. The fact that more palatable species of forbs are more apt to be of conservation concern is consistent with this purported ecological impact.

Many recommendations already have been provided for the conservation of sagebrush landscapes (Mack 1981, Mack and Thompson 1982, Fleischner 1994, Hann et al. 1997, Wisdom et al. 2000, Knick et al. 2003) and birds (Neel 1999, Altman and Holmes 2000, Beidleman 2000, Casey 2000, Ritter 2000, Cerovski et al. 2001). It is not our intent to repeat those here. But of particular interest are recent guidelines for conservation of sage-grouse (Dobkin 1995; Braun 1998; Schroeder et al. 1999; Connelly et al. 2000; Wisdom et al. 2000, 2002a, 2002b). Sage-grouse may serve as classic umbrella species (Caro and O'Doherty 1999) for sagebrush birds and other ecological components of sagebrush ecosystems. According to Caro and O'Doherty (1999), "an umbrella species may be employed as a surrogate to delineate the size of area or type of habitat over which protection should occur." Further, "effective protection of a viable population in this area is assumed to protect populations of other sympatric members of the same guild .... or appreciable parts of the ecosystem..." We suggest that conservation of Greater and Gunnison Sage-grouse populations in reasonable numbers well distributed across their historical ranges also will provide for the conservation of many, or even most, other bird species that co-occur with these grouse.

Sage-grouse populations require expanses of sagebrush habitat with a diverse and substantial understory of native grasses and forbs. Their requirements for lek sites, nesting, brood-rearing and wintering habitat are reasonably well understood (Schroeder et al. 1999, Connelly et al. 2000) and these requirements broadly overlap the requirements for other sagebrush birds (references in *table 1*). Further, sage-grouse need large blocks of these types of habitat in appropriate spatial mixes across the landscape. In one example from Idaho, that area requirement is roughly 2500 km^2 (Connelly, pers. comm.). These spatial requirements are vastly greater than those of any other sagebrush bird population.

Although Caro and O'Doherty (1999) pointed out the umbrella concept remains largely untested, Suter et al. (2002) found some support for the value of Capercaillie (*Tetrao urogallus*) as an umbrella for other forest bird species. We do not suggest that the umbrella effect of sage-grouse conservation will protect all components of all sagebrush ecosystems everywhere. The factor analysis, based on relative abundance correlations, showed a particularly close association between sage-grouse and Vesper Sparrows which suggests that the umbrella effect may be more pronounced in mesic

habitats. Further, Sage Thrashers, Loggerhead Shrikes, and Gray Flycatchers require relatively tall sagebrush plants for nest sites. We can readily imagine a landscape that provides plants tall enough for sage-grouse but that does not provide enough tall sage for these three species. There also could be habitats that supply grouse with sagebrush food during winter but which have an understory of pure cheatgrass. In this case, the value of the site to almost all other species during the breeding season would be very low. Much simpler to envision is how a local, endemic plant population might be left completely outside the umbrella.

Because of the sage-grouse's extensive distribution, large home ranges, and divergent areas of seasonal use (Schroeder et al. 1999, Connelly et al. 2000), conditions necessary to support viable populations of sage-grouse must be assessed at landscape scales that encompass millions of hectares. Wisdom et al. (2002a) evaluated performance of two complementary models designed to assess landscape conditions for sage-grouse across 13.6 million ha of sagebrush steppe in the interior Columbia Basin. *A priori* expectations were that models should predict substantially worse environmental conditions and a substantially higher probability of extirpation in areas where sage-grouse occurred historically but no longer do. Results for both models met these expectations. These results suggest that the models provided reliable landscape predictions for the conditions tested. This finding is important for conservation planning in the Interior Columbia Basin and perhaps in the other sage-dominated ecoregions discussed here–the Great Basin and Wyoming Basin.

In summary, it seems prudent to suggest that use of sage-grouse as an umbrella species for any given geographic area requires that: 1) the species assumed to be protected under the sage-grouse "umbrella" be listed; 2) the specific reasons for sage-grouse functioning as an umbrella be listed for each of those species; and 3) that additional species of concern associated with sagebrush that are not assumed to be protected under the umbrella also be listed.

Knick et al. (2003) provide an excellent assessment of the additional information needed to take the most effective action for the conservation of sagebrush birds and the sagebrush ecosystem. Yet much is already known and detailed recommendations are already available that certainly have not been widely implemented (Dobkin 1995; Paige and Ritter 1998; Neel 1999; Altman and Holmes 2000; Beidleman 2000; Casey 2000; Connelly et al. 2000; Ritter 2000; Wisdom et al. 2000, 2002a, 2002b; Cerovski et al. 2001). Given that more than 57 percent of this habitat is in public ownership under the management of a single agency, and that concern for the future of sage-grouse continues to build, we have all the information and opportunity we need to take action now. Indeed, if we cannot successfully conserve sage-grouse and the sagebrush ecosystem in the US given our theory, our knowledge, and our large blocks of public land, then one wonders how we can succeed for other species, for other land ownerships, and for other regions of the world.

Acknowledgments

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