Cassin's Sparrow (*Aimophila cassinii*): A Technical Conservation Assessment

Prepared for the USDA Forest Service, Rocky Mountain Region, Species Conservation Project

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COVER PHOTO CREDIT

Cassin's sparrow (*Aimophila cassinii*). Photograph by Greg Lasley. Used with permission.

Summary of Key Components for Conservation of the Cassin's Sparrow

Due to an overall declining trend in abundance, the Cassin's sparrow (*Aimophila cassinii*) is listed as a species of concern and/or a priority species by several federal and state agencies and organizations for the central shortgrass prairie and semi-desert grasslands of the Great Plains and southwestern United States. This trend is validated by the Breeding Bird Survey trend analysis presented in the Population Trends section of this assessment, which shows significant survey-wide declines in abundance. With approximately 17 percent of the Cassin's sparrow population located within Region 2, conservation of this species should be a high priority throughout the region.

Habitat loss and fragmentation due to the conversion of shrub grasslands to agricultural fields and development of urban areas pose the greatest threats to the conservation of the Cassin's sparrow on its breeding grounds. Management practices, such as intense livestock grazing, shrub removal, and fire, also contribute to the fragmentation and degradation of grassland ecosystems and negatively impact Cassin's sparrow distribution and abundance.

Due to the continued degradation and loss of habitat from these activities, remaining shortgrass and mixed-grass prairies within Region 2 become extremely important to the conservation of this species. Management activities alone or in combination with natural events can have profound effects on habitat suitability and Cassin's sparrow populations. An endemic grassland bird, the Cassin's sparrow requires grassland habitats with scattered shrubs, necessary for perching and skylarking. They avoid overgrazed and recently burned areas. Future management practices and conservation efforts for the Cassin's sparrow should focus on mimicking natural disturbances and habitat distribution by conserving and/or creating a landscape mosaic of grassland parcels of different grass heights and densities throughout this species' breeding range.

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Introduction

This conservation assessment is one of many being produced to support the Species Conservation Project for the USDA Forest Service (USFS) Rocky Mountain Region (Region 2), USDA Forest Service. The Cassin's sparrow is the focus of an assessment because it is listed as a sensitive species in Region 2 and a Management Indicator Species (MIS) on the Comanche National Grassland of the Pike and San Isabel national forests in Region 2 (**Figure 1**). Within the National Forest System, a sensitive species is a plant or animal whose population viability is identified as a concern by a Regional Forester because of significant current or predicted downward trends in abundance or habitat capability that would reduce its distribution [FSM 2670.5 (19)]. A MIS serves as a barometer for species viability at the forest level and can be used to estimate the effects of planning alternatives on fish and wildlife populations [36 CFR 219.19 (a) (1)] and to monitor the effects of management activities on species via changes in population trends [36 CFR 219.19 (a)(6)].

This assessment addresses the biology of the Cassin's sparrow throughout its range in Region 2. The broad nature of the assessment leads to some constraints on the specificity of information for particular locales. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal

Species conservation assessments produced as part of the Species Conservation Project are designed to provide land managers, biologists, other agencies, and the public a thorough discussion of the biology, ecology, conservation, and management of certain species based on available scientific knowledge. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. Although the assessment does not seek to develop prescriptive management recommendations, it does provide the ecological

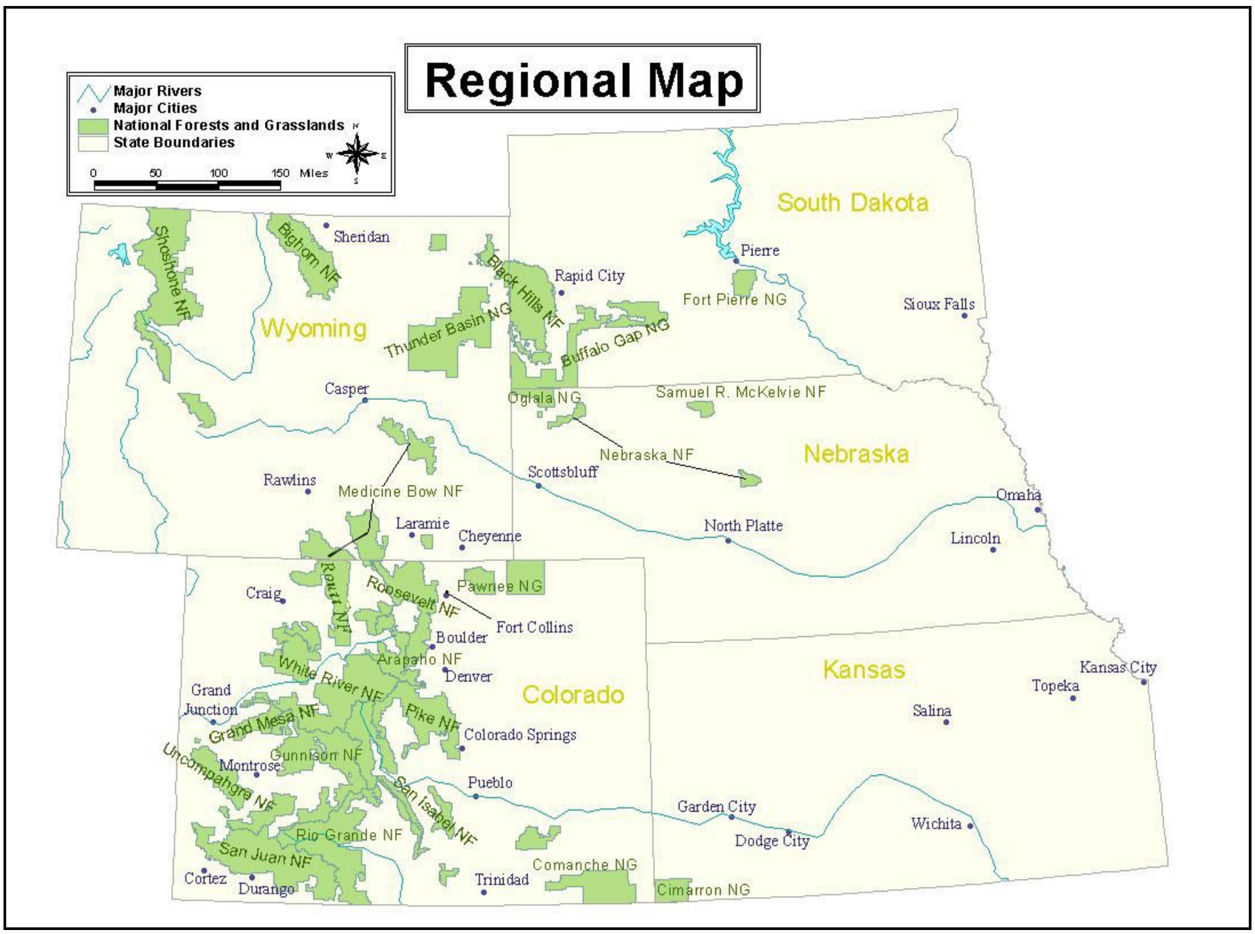

Figure 1. Map of Region 2 USDA Forest Service. National grasslands and forests are shaded in green.

basis upon which management must be based. The assessment also focuses on the consequences of changes in the environment that result from management (i.e., management implications) and examines the available management options and recommendations proposed and implemented elsewhere.

Scope

This conservation assessment examines the biology, ecology, conservation and management of the Cassin's sparrow with specific reference to the geographic and ecological characteristics of the Rocky Mountain Region. Although the majority of the literature on the species originates from field investigations outside the region, this document places that literature in the ecological and social context of the Rocky Mountain Region. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of the Cassin's sparrow in the context of the current environment. The evolutionary environment of the species is considered in conducting the synthesis, but placed in a current context.

In producing the assessment, I reviewed refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies. Not all publications on the Cassin's sparrow are referenced in the assessment, nor were all published materials considered equally reliable. The assessment emphasizes refereed literature because this is the accepted standard in science. Non-refereed publications or reports were regarded with greater skepticism. I chose to use some non-refereed literature in the assessments, however, when refereed information was unavailable elsewhere. Unpublished data (e.g., Natural Heritage Program records) were important in estimating the geographic distribution of the species. These data required special attention because of the diversity of persons and methods used in collection.

Treatment of Uncertainty

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and our observations are limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, strong inference, as described by Platt, suggests that experiments will produce clean results (Hillborn and Mangel 1997). The geologist T.C. Chamberlain (1897) suggested an alternative approach to science where multiple competing hypotheses are confronted with observation and data. Sorting among alternatives may be accomplished using a variety of scientific tools (experiments, modeling, and logical inference). Ecological science is, in some ways, similar to geology because of the difficulty in conducting critical experiments and the reliance on observation, inference, good thinking, and models to guide understanding of the world (Hillborn and Mangel 1997).

Confronting uncertainty, then, is not prescriptive. In this assessment, the strength of evidence for particular ideas is noted, and alternative explanations described when appropriate. While well-executed experiments represent a strong approach to developing knowledge, alternative approaches such as modeling, critical assessment of observations, and inference are accepted as sound approaches to understanding and used in synthesis for this assessment.

Publication of Assessment on the World Wide Web

Species conservation assessments are being published on the Region 2 World Wide Web site. Placing the documents on the Web makes them available to agency biologists and managers and the public more rapidly than publishing them as reports. More important, Web publication facilitates revision of the assessments, which will be accomplished based on guidelines established by Region 2.

Peer Review

Assessments developed for the Species Conservation Project have been peer reviewed prior to their release on the Web. This report was reviewed through a process administered by the Society of Conservation Biology, employing at least two recognized experts on this or related taxa. Peer review was designed to improve the quality of communication and to increase the rigor of the assessment.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

Region 2 of the USFS recently added the Cassin's sparrow to its Regional Forester's Sensitive Species List (USDA Forest Service 2003). It is also listed as a species of concern in "Birds of Conservation Concern 2002", a report issued by the U.S. Fish and Wildlife Service (2002). The report lists the Cassin's sparrow within three distinct geographic scales, from smallest to largest: Bird Conservation Regions (**Figure 2**) 18 (Shortgrass Prairie), 19 (Central Mixed-Grass Prairie), 20 (Edwards Plateau), 35 (Chihuahuan Desert - U.S. portion only), and 36 (Tamaulipan Desert - U.S. portion only), U.S. Fish and Wildlife Service (USFWS) Regions 2 (Southwest Region) and 6 (Mountain-Prairie Region), and the National listing. In addition, several national organizations include the Cassin's sparrow as a species deserving special designation and/or management status. Partners in Flight (PIF) and The National Audubon Society Watchlist mention the Cassin's sparrow as a species of concern (Muehter 1998). The Nature Conservancy gives the Cassin's sparrow a rank of G5, indicating that the species is demonstrably secure globally, but it may be rare in parts of its range, especially at the periphery.

On a state level, the Cassin's sparrow is listed by two Natural Heritage Programs (Wyoming Natural Diversity Database 1997, Colorado Natural Heritage Program 2005). Wyoming gives the Cassin's sparrow a state rank of S1B, indicating that the species is extremely rare in the state; it occurs only in Goshen County. This ranking reflects the fact that Wyoming is at the outermost range of this species. In Colorado, the Cassin's sparrow is listed with a state rank of S4, indicating that it is apparently secure within the state. Furthermore, the Cassin's sparrow is listed as a priority species in the PIF Bird Conservation Plans for the states of Colorado, New Mexico, Arizona, and within specific physiographic areas in Texas and Oklahoma.

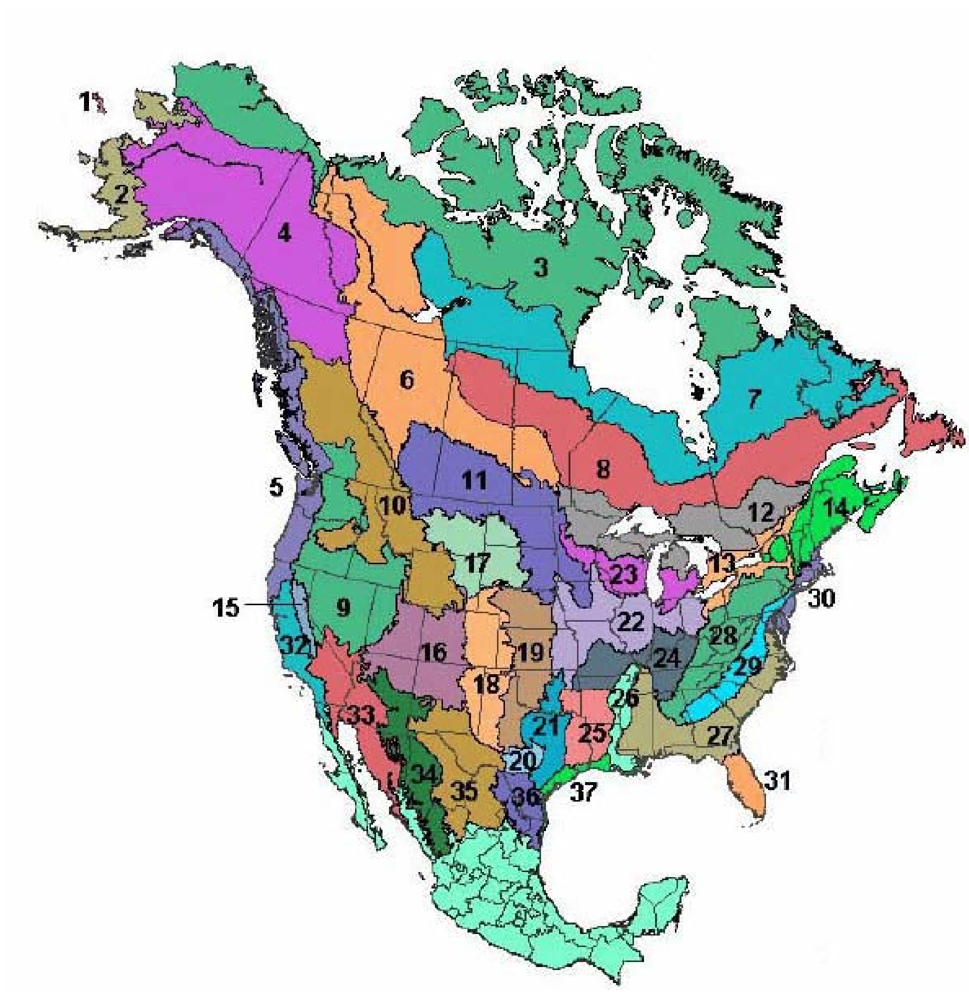

Figure 2. Bird Conservation Regions of the United States.

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

The Cassin's sparrow is protected from "take" in the United States under the Migratory Bird Treaty Act of 1918, and in Mexico under the Convention for the Protection of Migratory Birds and Game Mammals of 1936. The Migratory Bird Treaty Act establishes a federal prohibition, unless otherwise permitted by regulations, to "pursue, hunt, take, capture, kill, attempt to take, possess, offer for sale, sell, offer to purchase, purchase, export, at any time, or in any manner, any migratory bird, including any part, nest, or egg of any such bird" (16 U.S.C. 703). In 1990, PIF was formed through the efforts of the National Fish and Wildlife Foundation, which brought together federal, state, and local government agencies, private foundations, conservation groups, industry, and the academic community, to address issues concerning the status and conservation of migratory and resident birds. PIF has created a national "Flight Plan", that provides guidelines for the development of a Bird Conservation Plan for each state. Conservation plans identify priority species and habitats on local and landscape levels, develop objectives, and provide management recommendations for species in pre-defined physiographic areas.

Outside of Region 2, Arizona has completed a PIF Bird Conservation Plan that includes the Cassin's sparrow as a priority species in the desert grasslands of the Mexican Highlands (Latta et al. 1999). Conservation strategies outlined in the plan include maintaining or improving grassland habitats that are suitable for breeding. The New Mexico PIF Bird Conservation Plan lists the Cassin's sparrow as one of the highest priority species on the Plains-Mesa Sand Shrub, and a high priority on the Chihuahuan Desert Shrub and the Plains and Mesa Grassland areas (New Mexico Partners in Flight 2001). The Plains-Mesa Sand Shrub occurs north of the Chihuahuan Desert in the Rio Grande Valley to Espanola and north of the White Sands Missile Range to areas south of Santa Fe, east to Nara Visa. The Chihuahuan Desert Shrub roughly covers the southern third of the state. The Plains and Mesa Grassland areas extend from the eastern plains from the Texas border, west to the Great Basin grasslands of the northwestern quadrant of the state.

Within Region 2, Bird Conservation Plans have been completed for Colorado and Wyoming. Colorado's conservation plan includes the Cassin's sparrow in the Central Shortgrass Prairie Physiographic Area (36), which covers eastern Colorado, some portions of western Kansas, southwestern Nebraska, and southeastern Wyoming (**Figure 3**). Implementation strategies for conserving the Cassin's sparrow and associated habitat are outlined by The PIF Land Bird Conservation Plan for Colorado (Colorado Partners in Flight 2000). Strategies include monitoring efforts already in place by the Breeding Bird Survey (BBS) and will be supplemented by the Rocky Mountain Bird Observatory's Monitoring Colorado's Birds program as data become available within the next five to 12 years. The plan also proposes implementing a list of "Best Management Practices" for bird species of the Central Shortgrass Prairie, to be distributed to public and private land managers. The USFS is currently the only federal or state agency with explicit management guidelines for the Cassin's sparrow, having prepared a manual of "best management practices" for this species on the Comanche National Grasslands in southeastern Colorado (Gillihan 1999).

To address management and conservation issues on the privately owned lands in the Central Shortgrass Prairie region (70 percent of total area), the Land Bird Conservation Plan calls for continued efforts to encourage funding opportunities for landowners through programs such as the Prairie Partners program from Rocky Mountain Bird Observatory. The Prairie Partners program is a cooperative and voluntary program in which with private landowners, leaseholders, and land managers in the United States and Mexico work together to conserve shortgrass prairie and habitat-specific bird species. Strategies outlined to meet this goal include habitat monitoring and Geographic Information System (GIS) mapping through the Prairie Partners program designed to track the quantity and quality of shortgrass prairie on private lands and increasing the number of landowners who participate in the project. The Plan also mentions other conservation opportunities and incentive programs for landowners including the Conservation Reserve Program (CRP), Conservation of Private Grazing Land and Voluntary Debt-for Nature Contract provisions of the 1996 Farm Bill, and U.S. Fish and Wildlife Service's Partners for Wildlife.

The National Forest Management Act requires the USFS to sustain habitats capable of supporting healthy populations of native and desired non-native plant and animal species on the national forests and grasslands. Legally required activities under the 1982 planning regulations include monitoring population trends of management indicator species in relationship to habitat change, determining effects of management practices, monitoring the effects of off-road vehicles, and maintaining biological diversity.

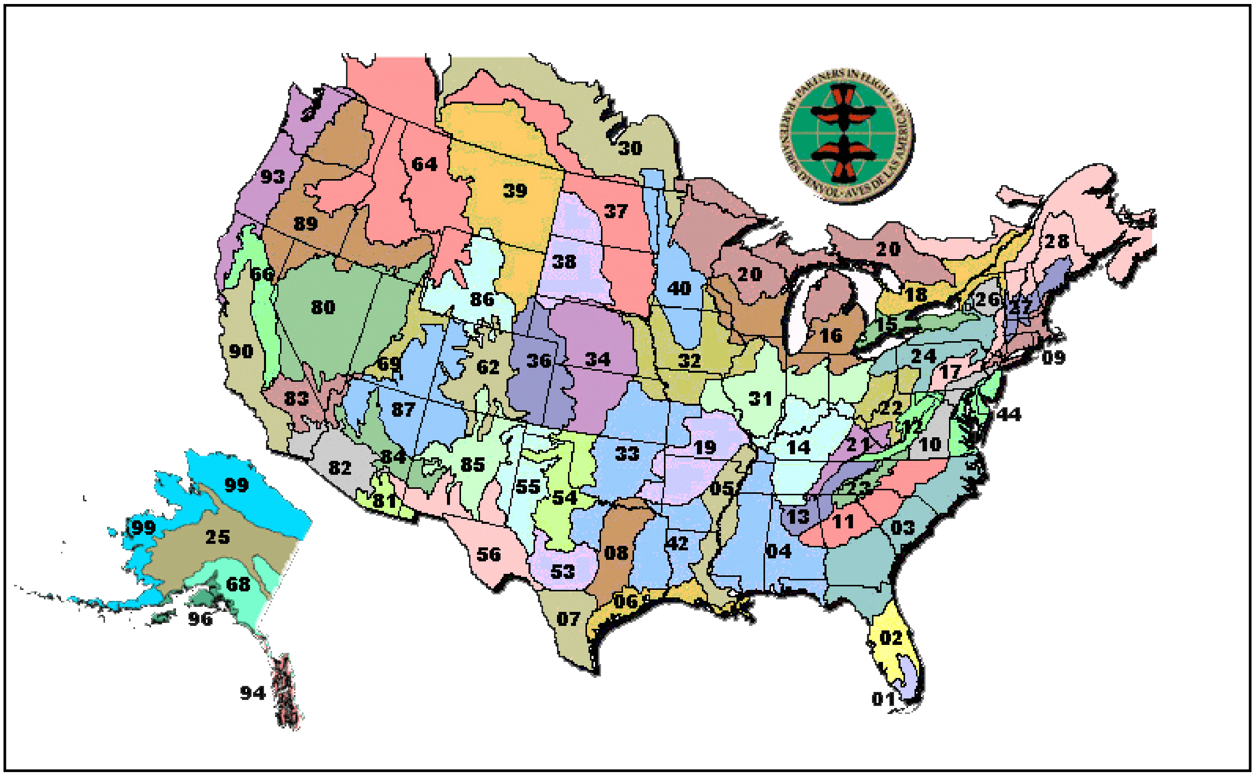

Figure 3. Partners in Flight Physiographic Areas.

The standards and guidelines of the Forest Service Government Performance Results Act ensure that resources are managed in a sustainable manner. The National Environmental Policy Act requires agencies to specify environmentally preferable alternatives in land use management planning. Additional laws with which USFS management plans must comply are the Endangered Species, Clean Water, Clean Air, Mineral Leasing, Federal Onshore Oil and Gas Leasing Reform, and Mining and Minerals Policy acts; all are potentially relevant to Cassin's sparrow conservation.

Most land in the core of the Cassin's sparrow range is privately owned; however, some Cassin's sparrow habitat is protected and managed under federal and state jurisdiction. In Region 2, 71 percent of the Central Shortgrass Prairie Physiographic Area is privately owned while only 7 percent is managed by the USFS as national grasslands and 22 percent is state owned (Colorado Partners in Flight 2000). Of the lands protected within our national grassland system, only three units are located within the distributional range of the Cassin's sparrow: the Pawnee (78,100 ha) and the Comanche (169,570 ha) in Colorado and the Cimarron (43,700 ha) in Kansas. The Comanche National Grassland is the only one possessing a management plan with recommendations specific to the Cassin's sparrow (Gillihan 1999). No information is available on the extent to which the private entities are implementing management practices.

Biology and Ecology

Systematics and general species description

In 1852, Samuel W. Woodhouse first described the Cassin's sparrow, which was named in honor of ornithologist John Cassin (Terres 1980). Although originally placed in the genus *Zonotrichia* (American Ornithologists' Union 1998), it is currently a member of the *Aimophila* genus, and part of the "botterii complex". Members of this complex include Botteri's sparrow (*A. botterii*), Bachman's sparrow (*A. aestivalis*), and Cassin's sparrow, all of which are similar in size and shape. There is no recognized subspecies of the Cassin's sparrow (American Ornithologists' Union 1957, Pyle 1997, Dunning et al. 2000).

The Cassin's sparrow is a grayish, indistinct sparrow with a rounded, whitish-tipped tail, often noticeable in flight in spring and early summer when feathers are fresh. The head is streaked brown and gray, and the breast and throat are dull brownish-gray with fine streaks and spots on the upper chest. The back feathers and uppertail coverts have brown center spots with gray edges, giving it a scaled appearance. Its sides are flanked with faint brown streaks and a whitish belly. The brownish-gray bill is typical of *Aimophila*, large and conical. The legs are pinkish. Similar in appearance to the Botteri's sparrow, the Cassin's sparrow generally appears less darkly streaked with a smaller bill and distinct whitish tips on the two outer tail feathers. The lateral throat stripe is absent in the Botteri's sparrow. The greater coverts are tipped with grayish white to form a conspicuous wing bar not seen as strongly in Botteri's sparrow. Plumage variations include a gray phase and a rufous phase. Coloration on the rufous phase is similar to the more common gray phase described above; however the upper surfaces, hindneck, back, and scapulars have more brown spots, giving a more overall rufescent color. In addition, the belly is more buffed color, and often the flanks are more streaked. In late summer, feathers become worn, and markings are not always discernable, making sparrows of the "botterii complex" more difficult to identify. Juvenile plumage is similar to adults, but it appears duller and buffy with distinctive streaking on the upper breast. Back spots are olive brown or clove brown and tips of tail and covert feathers are tipped buffy. Sexes are alike, with an average length of 15 cm and weight of 17.9 g (Maurer et al. 1989).

Male Cassin's sparrow have a primary song, generally described as a series of six complex notes, beginning with one or two seldom heard introductory notes, followed by a long, high liquid trill, and ending with two lower descending notes (Williams and LeSassier 1968). However, upon further song analysis using a sonogram, Borror (1971) found that the song is even more complex, containing up to five introductory notes, and several high pitched notes following the trill, and sometimes ending with a low whistle after the last two descending notes. The primary song is usually given while defending territories and in courtship, and enough variation in the primary song exists that individual males can often be identified (Schnase and Maxwell 1989).

The secondary song, or "chitter" song, is described as a rapid series of chips, trills, and buzzy notes (Schnase 1984). It is given by mated males, on territory, during courtship and nest initiation, and it may serve as an alarm call (Schnase 1984). Other calls include a "chitter", "tzee tzee tzee", or chip call. Borror (1971) and Schnase (1984) have found some geographic variation in song during studies on population in Texas and southeastern Arizona.

Distribution and abundance

Global current and historical distribution and abundance

Cassin's sparrows are found in the southwestern and western Great Plains of the United States and in central Mexico. The breeding range in the United States extends from southeastern Wyoming and western Nebraska, south through eastern Colorado, western Kansas and Oklahoma, and most of western and central Texas, and west to southeastern Arizona. The core of the range lies in the southeastern plains of Colorado, eastern New Mexico, and western Texas (**Figure 4**). Howell and Webb (1995) report finding breeding Cassin's sparrows in Mexico throughout the northern and the interior south of Sonora, across the Mexican Plateau to Zacatecas, and east to Tamaulipas.

Few historical records exist for breeding Cassin's sparrows, and those available can be confusing, making it difficult to determine occurrences of range expansion or contraction. New breeding records for southeastern Wyoming and southwestern Nebraska may represent a small range expansion in the past 30 years (Ruth 2000). Other records lack confirmed nesting data, with most accounts based on singing males. Phillips (1944) considered the Cassin's sparrow a common non-breeding summer visitor to Arizona, despite evidence of ardent male singing and enlarged testes. Not until 1965, were the first Cassin's sparrow nests recorded (Ohmart 1966) and breeding confirmed for Arizona; however many now believe that breeding populations were present in Arizona at an earlier date. Annual fluctuations in rainfall complicate our understanding of historical distributions of the species as well. In years of abnormal precipitation, changes in plant species composition and/or vegetation densities or heights may create new areas of suitable habitat for small numbers of breeding Cassin's sparrows along the periphery of its range. Thus, in some years it may appear that the Cassin's sparrow is experiencing a range expansion. However, range wide, the conversion of the sandsage and shortgrass prairies to cropland in the last decade has caused some decline in Cassin's sparrow populations throughout the region.

The winter range of the Cassin's sparrow includes the Upper and Lower Sonoran vegetation zones found in the extreme southern tip of its breeding range in southeastern Arizona, southern New Mexico, and Texas

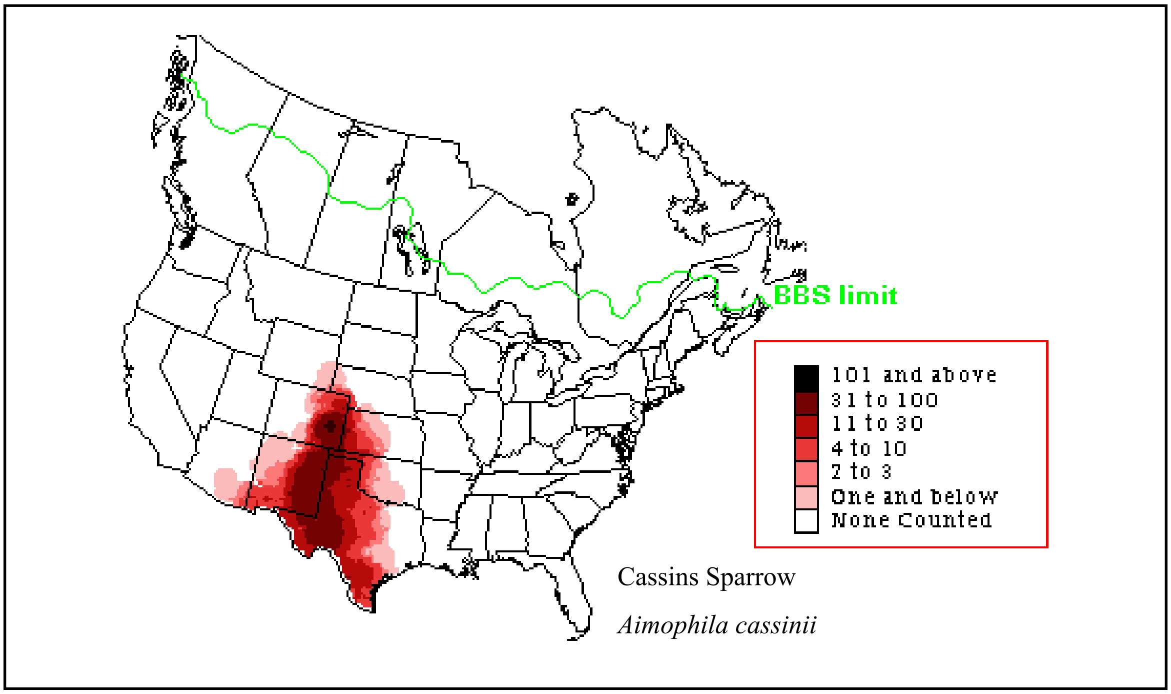

Figure 4. Breeding season distribution and relative abundance (average number of birds per route) of Cassin's sparrows based on Breeding Bird Survey data between 1982 and 1996 (Sauer et al. 2004).

and the northern Mexican states of Sonora, Chihuahua, Coahuila, south to Zacatecas, San Luis Potosi, Nuevo Leon, and Tamaulipas (**Figure 5**; Howell and Webb 1995, Russell and Monson 1998). Local winter abundance, however, depends upon available grasses, seeds, and shrubs influenced by annual rainfall and the intensity of cattle grazing, particularly in southern Arizona (Bock and Bock 1988). For example, studies on wintering populations in the Sonoran Desert found that in years of above average precipitation, Cassin's sparrows became more abundant in ungrazed meadows and appeared in areas not normally recorded (Monson and Phillips 1981, Russell and Monson 1998). Christmas Bird Counts (CBC) of Cassin's sparrows in the United States and Mexico provide the best estimate of winter distribution and abundance (number of birds per 100 party-hours per circle; **Figure 5**). CBC data from 1966 to 1996 show an irregular distribution of Cassin's sparrows; it is reported only 50 percent of the time at only nine sites (Root 1988). Root (1988) reports that the highest abundance of Cassin's sparrows near Big Bend, Texas averages 0.51 individuals per party-hour. In Mexico, CBC data from 1991 and 1994 consistently report low numbers of Cassin's sparrow (10 to 20) in Tamaulipas with a few reports in Sonora (Bavíacora, Yécora, and Alamos), Chihuahua (Rancho el Palomina and Ejido San Pedro), and Guanajuato (San Miguel de Allende). In addition, the BBS conducted three years of surveys in some areas of Mexico from 1993 to 1996, detecting Cassin's sparrows on routes in Tamaulipas near Aldama, with the highest abundance reported in northern Coahuila (65 individuals).

Regional current and historical distribution and abundance

Within Region 2, breeding Cassin's sparrows are reported as common to abundant in the southeastern plains of Colorado, especially in Otero, central Las Animas, Baca, and Prowers counties, with the highest count of 300 on 27 May 1988 in the Cimarron River area of Baca County (Andrews and Righter 1992). From 1988 to 1997, the Cassin's sparrow was present on 72.36 percent (SE = 3.07) of all BBS routes on the Central Shortgrass Prairie Region in Colorado, with an average abundance of 33.54 (SE = 3.18) individuals per route (Colorado Partners in Flight 2000). Colorado Breeding Bird Atlas data (Kingery 1998) show a concentration of birds in the southeastern region of the state. Additional nesting areas located in the northeastern plains contain approximately 20 percent of the United States breeding population. Cassin's sparrow distribution in this region of Colorado is irregular and depends on rainfall; however they are found most notably along the South Platte River from Weld to Sedgewick counties, with the highest count of 50 occurring in the Pawnee National Grassland in 1977 (Andrews and Righter 1992). In Kansas, Breeding Bird Atlas data show

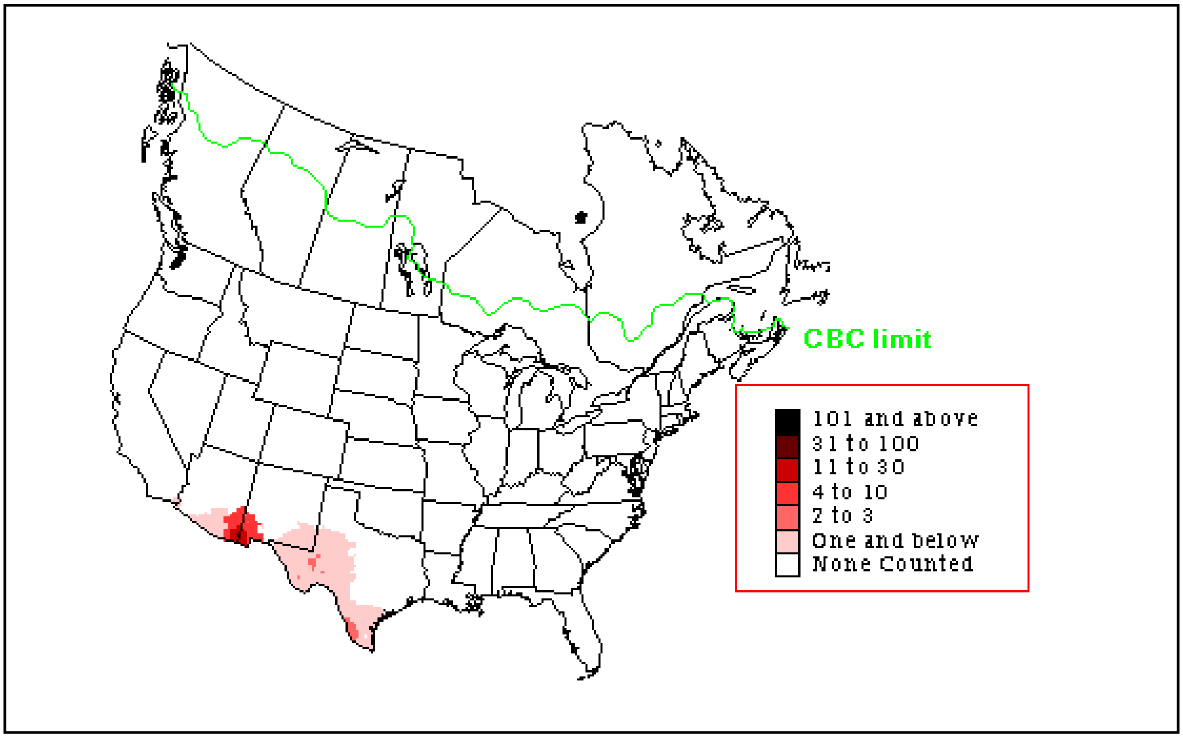

Figure 5. Winter season distribution and relative abundance of Cassin's sparrow based on Christmas Bird Count data between 1966 and 1996 (Sauer et. al 1996).

Cassin's sparrows in the southwestern corner of the state encompassing Hamilton, Finney, and Comanche counties (High Plains) in all seven years of study (Busby and Zimmerman 2001). They also are frequent in the western portion of the Red Hills, but they are very irregular and absent during some years to the north and east of these areas, such as the Smokey Hills, with most observations occurring in 1994 and 1996 (Busby and Zimmerman 2001). Atlas data do not reveal abundance in Kansas. The BBS consistently detected Cassin's sparrows on routes in Kearney, Wallace, and Sherman counties (Sauer et al. 2004). In southwestern Nebraska, along the northern edge of the range, the BBS detected only a few Cassin's sparrows on routes located in Hitchcock, Cheyenne, Morrill, Sioux, and Scotts Bluff counties. Breeding records are also reported in Deuel, Garden, Perkins, and Dundy counties (Hubbard 1977, Faanes et al.1979, Johnsgard 1979). In Wyoming, the Cassin's sparrow is considered an accidental breeder, with only two reported nests, in Natrona and Goshen counties (Faanes et al.1979, Dorn and Dorn 1995).

There are very few reports of estimated densities for the Cassin's sparrow. Most data come from one or two years of collection and should be reviewed with caution due to large annual fluctuations in local populations often tied to precipitation levels. For example, in 1982 densities of singing males on Santa Rita Experimental Range in Arizona mesquite savannah and grassland habitats were 4.9 per km² and 43.2 per km² respectively, jumping to 34.5 per km² and 71.2 per km² in 1983 (Maurer 1985). Rocky Mountain Bird Observatory's National Grassland Inventory Project estimated densities of Cassin's sparrows on the Kiowa National Grassland of 14.5 per km² and on the Rita Blanca National Grassland of 12.09 per km² (Hanni 2003). Maxwell (1979) reports that breeding densities in Arizona ranged from 33 per 40.4 ha in scrubby mesquite grassland, 11 to 7 per 40.4 ha in grassland with defoliated mesquite and upland mesquite woodland, and as low as 1 per 40.4 ha in bottomland mesquite woodlands. Luerkering et al. (2001) report densities of Cassin's sparrows to be highest in grassland (181 individuals on 12 transects) and sage shrubland (30 individuals on 2 transects), followed by semi-desert shrubland (110 individuals on 8 transects).

Population trends

Breeding Bird Survey data and analysis provide the best population trend information for the Cassin's sparrow (**Table 1**; Sauer et al. 2004). However, trend analysis is not straightforward and should be viewed with care since large annual fluctuations in local and regional abundance are common for this somewhat nomadic species. For example, annual fluctuations

Table 1. Breeding Bird Survey population trends (average percent change per year) for Cassin's sparrows (From Sauer et al. 2004).

	1966-2003			1966-1979			1980-2003		
	Trend	**P value**	**N**	**Trend**	**P value**	**N**	**Trend**	**P value**	**N**
Survey-wide	-2.2	0.00*	240	0.5	0.80	92	-1.7	0.00*	227
REGIONS									
Central Region	-2.1	0.00*	180	0.4	0.86	73	-1.4	0.00*	169
Western Region	-2.7	0.01*	60	1.1	0.79	19	-2.7	0.02*	58
USFWS									
Region 2**	-2.0	0.00*	184	1.9	0.34	77	-1.5	0.00*	175
Region 6	-4.1	0.00*	56	-8.7	0.05*	15	-2.7	0.00*	52
STATES									
Arizona***	-5.9	0.52	4	—	—	—	-24.3	0.45	4
Colorado	-4.2	0.00*	39	-9.4	0.08	8	-2.8	0.01*	39
Kansas***	-3.5	0.32	14	-3.2	0.64	6	-1.5	0.80	11
Nebraska***	-0.6	0.96	3	—	—	—	21.6	0.35	2
New Mexico	-0.9	0.32	41	1.6	0.89	9	-1.6	0.06	40
Oklahoma***	-2.6	0.41	23	5.2	0.43	8	-4.1	0.04*	21
Texas**	-2.4	0.00*	116	2.05	0.33	59	-1.4	0.03	110
PHYSIOGRAPHIC STRATA									
Intermountain Grasslands	1.0	0.62	22	0.7	0.75	3	0.5	0.83	21
High Plains	-4.3	0.00*	43	-9.2	0.05*	10	-2.7	0.01	42
High Plains Borders	-3.6	0.12	16	5.9	0.37	9	-4.2	0.01*	12
Rolling Red Plains**	-0.6	0.72	24	-0.9	0.79	9	-0.3	0.79	23
South Texas Brushlands**	-2.9	0.05*	27	5.8	0.07	16	-4.6	0.00*	26
Edwards Plateau	-6.1	0.00*	20	-6.4	0.04	13	-4.0	0.01*	20
Staked Plains	-0.6	0.48	30	-1.4	0.78	11	-0.1	0.64	28
Chihuahuan Desert	-4.0	0.00*	31	1.0	0.82	14	-4.3	0.00	30
Mexican Highlands***	-9.3	0.33	6	—	—	—	-20.2	0.25	6

* Denotes significant change.

** Denotes BBS regional credibility measure of data with important deficiency such as low regional abundance, sample size, or imprecision.

***Denotes BBS regional credibility measure of data with deficiency.

have occurred on BBS routes in Colorado with numbers jumping from 20 to 60 birds one year to a maximum of 359 birds the following year. Small sample size poses an additional problem, and several states do not have sufficient data to make inferences or to detect population trends for this species. The BBS considers a sample size over 14 to be fairly reliable; however between 1966 and 1979 small sample sizes were a problem for all states with the exception of Texas (n = 59). Furthermore, in 1974, data show a definite peak in the population, and this may also skew results. Thus, there is need for caution in interpreting the following population trend data.

Survey-wide population trend estimates from BBS data indicate a significant decline ($P \leq 0.00$) in Cassin's sparrow populations between 1966 and 2003 (**Table 1**, **Figure 6**). On a regional level, overall declines are reported for USFWS Regions 2 and 6 and the Central BBS Region. Since USFWS Region 6 encompasses all of the USFS Region 2 breeding range for Cassin's sparrows, this consistent decrease in trend is especially important. Examination of trends for physiographic areas or strata indicate significant declines on the High Plains and just slightly less significant declines in the High Plains Borders, with the greatest decline for this area seen from 1980 to 2003. When the data are broken

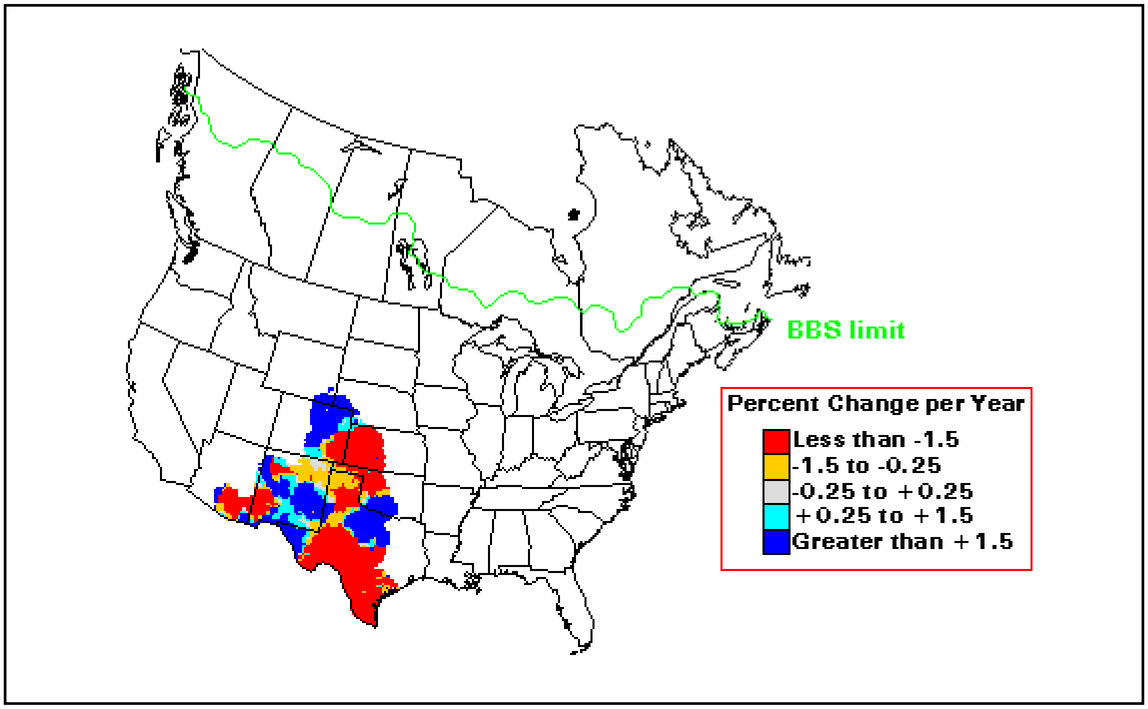

Figure 6. Cassin's sparrow population trend (average percent population change per year) based on Breeding Bird Survey data between1966 and 1996 (Sauer et al. 2004).

down into smaller time intervals, several states and regions show significant population declines in more recent years (1980-2003). In states and regions on the periphery of the species' range, for most of which sample sizes are small, population declines are not surprising. However, even for areas with sufficient sample size, most of which are outside Region 2, this species has shown an overall declining trend.

Activity pattern and movements

Circadian, seasonal, circannual

Schnase et al. (1991) studied the daily time budgets for Cassin's sparrow and found that they exhibit diurnal and interphasic variations in activity patterns. Over a two-year study during the breeding season, the percentage of daily activities for males and females was divided into five phases: unmated, pre-incubation, incubation, nestling care, and fledgling care (**Table 2**). For mated birds, they found that except during the pre-incubation phase males spent the majority of the day perched (73%), whereas females spent this time on ground activity (95%) during all phases. Daily activity patterns have not been studied for Cassin's sparrow on the wintering grounds.

Spring migrants leave their wintering grounds in Mexico from late February to late March and even early April (Hubbard 1977). Cassin's sparrows are reported migrating through southeastern Arizona during March and April (Phillips et al. 1964) while winter residents depart between late April and mid-May (Phillips 1944). Singing males become conspicuous in March and early April in much of the southern portions of the breeding range such as Texas, New Mexico, and Oklahoma (Sutton 1967, Williams and LeSassier 1968, Hubbard 1977, Schnase et al. 1991) with the earliest accounts (first few weeks in March) occurring in Texas (Hubbard 1977). Later arrival dates (April to May) are recorded for Colorado, Kansas, and Nebraska. In Colorado, Cassin's sparrows arrive mid-April (Andrews and Righter 1992); however Breeding Bird Atlas surveys did not detect singing male Cassin's sparrows until mid-May, possibly due to delayed courtship behavior (Kingery 1998). In Arizona, males can be heard from July to August, coinciding with monsoon rains (Phillips et al. 1964, Ohmart 1966, Maurer et al.1989). Across the specie's breeding range, females arrive two weeks later than males (Schnase 1984, Schnase et al. 1991).

Departure from the breeding range begins as early as July and August in the northern portion of their range. In more southern states, such as New Mexico and Texas, departure continues as late as November. Extreme dates include Oklahoma records that report departure as late as 21 November (Sutton 1967).

Table 2. Mean percentage of the active day (0600-2200) that adult male and female Cassin's sparrows spent in five activities during all phases of the breeding season (From Schnase et al. 1991).

Phase	Number of birds	Ground activity	Skylarking	Perching	Flying	Perched singing
Unmated	4 (M)	64.3	1.0	27.0	0.0	7.7
Pre-incubation	4 (M)	58.5	12.0	24.7	1.3	3.2
	2 (F)	93.5	—	3.5	3.0	—
Incubation	3 (M)	19.3	1.0	77.3	1.3	1.1
	2 (F)	97.0	—	2.0	1.0	—
Nestling care	3 (M)	20.7	1.0	77.0	0.3	1.0
	2 (F)	98.2	—	1.0	0.8	—
Fledgling care	1 (M)	19.0	4.0	65.0	5.0	7.0
	1 (F)	90.0	—	5.0	5.0	—

Dorn and Dorn (1995) report seeing interspecies flocks of juvenile Cassin's sparrows with lark buntings and Brewer's, chipping, clay-colored, and vesper sparrows in late August, just before fall departure. Wolf (1977) and Johnsgard (1979) report that Cassin's sparrows form flocks during the winter.

Broad scale movement patterns

The Cassin's sparrow is a short-distance, partial migrant. In general, birds breeding in the northern part of their range migrate south into the southern-most parts; while birds breeding in the southern portions may make only short southern retreats. In general, concrete information about the migratory movement patterns of Cassin's sparrows is from outside of Region 2 and observations have been inconclusive. Several hypotheses about the migratory nature of the species during the breeding season, as well as its residency and winter status, have been made outside of Region 2 in the southern portion of its range. Phillips (1944) proposed lateral east to west migrations that follow spring and summer precipitation patterns while Ohmart (1969) suggested dual breeding behavior of a single population making a longitudinal migration from north to south, fueled by the availability of food supplies for nestlings. Others have theorized that singing birds found in Arizona in late summer are early migrants from the Great Plains and comprised of non-breeding males (Hubbard 1977, Wolf 1977). Furthermore, movement patterns and residence status in Texas are also not fully understood. Although most records of Cassin's sparrows trail off in November and begin again in March, it is unclear whether the species migrates or whether the lack of records is due to the species' elusive and quiet nature during non-breeding months. Other reports of seasonal movements include a banding study near Tucson, Arizona, which reports that individual wintering Cassin's sparrows did not return to breed during July and August (Dunning et al. 2000). Furthermore, no color-banded birds were recaptured in the area the following winter, suggesting weak local philopatry or possibly seasonal, nomadic movements. Sex and age differences in dispersal capabilities and patterns are unknown.

Potential links to, or isolation from, other segments of the population; connectivity

Annual fluctuation and changes in abundance indicate that Cassin's sparrows are capable of dispersing into other areas. In years of abnormal precipitation, breeding populations of this species have been reported along the periphery of the range in Nebraska and Kansas, in areas where the species was not normally found in prior years. Thus, it is unlikely that populations of Cassin's sparrows are in danger of isolation. See Effects of climatic variability on habitat in the next section for further clarification of the effects of precipitation on bird distributions.

Habitat

The Cassin's sparrow is an endemic prairie species that breeds in grassland habitats interspersed with shrubs, avoiding pure stands of either (Hubbard 1977, Faanes et al. 1979). On the High Plains of Colorado and Kansas, this bird prefers shortgrass prairie, dominated by buffalo grass (*Buchloe dactyloides*) and blue grama (*Bouteloua gracilis*), and mixed-grass prairie, dominated by little bluestem (*Schizachyrium scoparium*) and side oats grama (*B. curtipendula*) interspersed with sagebrush (*Artemisia* spp.) and rabbitbrush (*Chrysothamnus* spp.; Andrew and Righter 1992, Busby and Zimmerman 2001, Mollhoff 2001). It will also use shrubland and sandsage prairies of northeastern Colorado, particularly along the south side of the South Platte River in Yuma County (Andrew and

Righter 1992) and in western Kansas (Rising 1996). Sandsage prairie is found in sandy soils dominated by sand bluestem (*Andropogon hallii*), prairie sand-reed (*Calamovilfa longifolia*), and sagebrush (*Artemisia filifolia*). The Colorado Breeding Bird Atlas reports finding 50 percent of all Cassin's sparrows in shortgrass prairie and 25 percent in sandsage shrublands (Kingery 1998). In Wyoming, Dorn and Dorn (1995) describe similar habitat of rolling sandhills dominated by sand sagebrush while Faanes et al. (1979) report Cassin's sparrows using south-facing, grassy slopes with sagebrush, greasewood (*Sarcobatus vermiculatus*), and prickly pear (*Opuntia* spp.). Nebraska birds were also reported using sandhills of the north-central region, where extensive sand dunes are covered with mixed-grass prairie (Sharpe 2001). Outside of Region 2, in southern parts of the breeding range in Arizona, New Mexico, and Texas, Cassin's sparrows are also found in open grasslands with scattered shrubs. There, species composition transitions from rabbitbrush and sagebrush to mesquite (*Prosopis* spp.), juniper (*Juniperus* spp.), hackberry (*Celtis reticulata*, *C. pallida*), shinnery oak (*Quercus harvardii*), yucca (*Yucca* spp.), and ocotillo (*Fouquieria splendens*; Williams and LeSassier 1968, Oberholser 1974, Wolf 1977, Maurer et al. 1989).

At a finer scale, habitat selection appears to involve the balance of two main vegetative components, grasses and shrubs (or shrub-like species). Cassin's sparrows prefer landscapes that are dominated by grasses with some percentage of shrub cover, which is required for perching and skylarking (Bock and Webb 1984, Bock and Bock 1988). However, these percentages will vary due to changes in species composition and habitat availability across the varying grassland ecosystems across its range. Thus, habitat measurements and density estimates may at first glance appear contradictory. For example, in occupied regions with low shrub densities, such as those found within Region 2 and parts of Arizona, Cassin's sparrows appear to select habitat patches dominated by greater shrub cover than adjacent patches. However, when compared to regions with higher overall shrub densities, these same patches have a much lower shrub cover. Therefore, specific cover percentages and descriptions of habitat requirements, as well as density estimates, must be considered within the context of its geographic location and their associated grassland ecosystems.

Within Region 2, only two studies have investigated habitat relationships for the Cassin's sparrow, both in Colorado. On the Comanche National Grassland, Cassin's sparrows were detected in habitats dominated by grasslands with low overall shrub cover (0.9 percent low shrub [<1 m], and 4.1 percent tall shrub [>1 m], 27 percent bare ground, 14.8 percent shortgrass, 37.8 percent midgrass, 8.5 percent forbs, 2.4 percent cholla, 4.6 percent yucca; Leukering 1999). In addition, Leukering et al. (2001) report that the highest breeding densities were found in grassland (181 individuals on 12 transects) and sage shrubland (30 individuals on 2 transects), followed by semi-desert shrubland (110 individuals on 8 transects).

Similar shrub and bird densities were reported in parts of Arizona, where open grasslands have not yet given way to more mesquite-dominated landscapes. On the Appleton-Whittell Research Ranch, Cassin's sparrows were found to avoid areas with less than 6 percent shrub cover and greater than 35 percent bare ground (Bock and Webb 1984, Bock and Bock 1988), and to prefer plots dominated by grasses (80 percent; Bock et al. 1984). Density estimations conducted in mesquite grasslands in southeastern Arizona (Maurer 1986) found a negative association with habitats containing high densities of mesquite trees and low grass cover. Study plots in mesquite-savannah habitat with mesquite densities ranging from 104 to 162 trees per ha had much lower densities of singing males (1982, 4.9 per km²; 1983, 34.5 per km²) than did grassland habitat with mesquite densities ranging from 33 to 79 trees per ha (1982, 43.2 per km²; 1983, 71.2 per km²; Maurer 1985).

For regions containing overall higher densities of shrubs, Cassin's sparrows often used mesquite-dominated shrublands, such as those found in parts of Arizona and throughout Texas. In Texas, Schnase (1984) found that breeding territories contained an averaged of 28.4 percent mesquite thickets, whereas those found in semi-desert mesquite savannah on the Buenos Aires National Wildlife Refuge in Arizona occupied areas that were dominated by up to 60 percent mesquite (Gordon and Leitner 1996). At these latter sites, mesquite trees were located in patches concentrated in small arroyos and drainages, with a mean canopy height of 8 m, and with ground cover dominated by Lehmann's lovegrass (*Eragrostis lehmanniana*; 90 percent). Maxwell (1979) reported densities during 1976 and 1977 were highest in scrubby mesquite grassland (33 and 20/40.4 ha), with lower densities occurring in grassland with defoliated mesquite (7 and 11/40.4 ha), upland mesquite woodlands (7 and 8/40.4 ha), and in bottomland mesquite woodlands (6 and 140.4 ha).

Nests are placed on the ground or just off the ground in a low shrub, with approximately equal reports of each (Williams and LeSassier 1968). Ground nests are often well concealed in tall grass, or near the base of shrubs and are not placed flush with the ground. Those found in low shrubs or shrub-like structures are generally located 4 to 20 cm off the ground (Schnase 1984, Maurer et al. 1989, Dunning et al. 2000). Aboveground nest substrates include sandsage, prickly pear cactus, yucca, rabbitbrush, desert broom (*Baccharis pteranioides*), and bunchgrasses (Ohmart 1966, Williams and LeSassier 1968, Kingery and Julian 1971, Dorn and Dorn 1995, Kingery 1998). Data collected from 10 nests in Texas reveal that nests open to the north to northwest (Schnase 1984). Average nest plant heights range from 0.4 to 0.74 m (Schnase 1984, Maurer et al. 1989, Dunning et al. 2000).

Cassin's sparrows winter outside of Region 2 in the southern portion of their breeding grounds and in Mexico. There, they use habitat similar to that found on the breeding ground, arid and semi-arid grasslands scattered with shrubs. Oberholser (1974) described migrating and wintering Cassin's sparrows in Texas using brushy draws and canyons in desert areas and areas scattered with patches of thick brush and cactus in savannah grasslands. Winter surveys found few Cassin's sparrows using upland mesquite (2 per 40.4 ha) and juniper-live oak savannah (1 per 40.4 ha) habitats.

Effects of climatic variability on habitat

The shrub grassland habitat preferred by Cassin's sparrows is found in patches and fragments throughout the western Great Plains and southwestern United States. However, changes in habitat characteristics brought on by annual rainfall patterns may provide a reason for the large annual fluctuations in the distribution exhibited by this species, particularly along the periphery of the breeding range. Cable (1975) links grassland productivity with summer rainfall. Thus, in regions where vegetation is normally unsuitable due to changes in species composition and/or high vegetation densities or heights, population increases would occur during periods of drought, when vegetation is stunted. Similarly, areas that once contained suitable habitat may experience decreases in abundance with increases in precipitation. In southeastern Arizona, increased rainfall led to higher densities of Cassin's sparrows (Maurer 1985) and increases in reproductive success (Dunning et al. 2000). However, Baumgartner and Baumgartner (1992) report that in Oklahoma the abundance of Cassin's sparrows increased in the eastern portion of their range during years of drought, when grass and vegetation heights were lower than normal. There have also been reports of similar responses in Texas. Thus, a landscape mosaic of diverse grassland patches is important in providing Cassin's sparrow populations with suitable breeding habitat during years of drought or exceptionally heavy rains. Unfortunately, causal factors for this response to changes in annual precipitation are poorly understood, and no clear evidence has been presented.

Geographic distribution and changes over time in habitat

The shortgrass, mixed-grass, and sandsage prairies of the western Great Plains and the semi-desert grasslands of the Southwest have suffered losses, fragmentation, and degradation from intense grazing, agriculture, urban development, oil and gas development, and increases in exotic grasses. Nearly 32 percent of the shortgrass prairie region in the southwestern Great Plains (including 30.7 percent in Colorado, 78 percent in Kansas, 65.4 percent in Nebraska, and 12.1 percent in Wyoming) has been converted to cropland (Knopf and Rupert 1999), resulting in a loss of habitat for the Cassin's sparrow. The Edwards Plateau and South Texas Brushlands, two regions that have shown significant declines in Cassin's sparrow abundance (**Table 1**), have faced major changes at a landscape-level. Grasslands and oak savannahs are now dominated by juniper, oak, and mesquite woodlands due to intense grazing and a decrease in fire frequency, both of which promote the expansion of woody plants (Fowler and Dunlap 1986, Rappole et al. 1986, Taylor and Smeins 1994).

Food habits

During the breeding season, the diet of the Cassin's sparrow consists mainly of insects, including grasshoppers, caterpillars, moths, beetles, true bugs, ants, bees, wasps, weevils, as well as spiders and snails (Williams and LeSassier 1968, Oberholser 1974, Bock et al. 1992, Kaufman 1996). However, on breeding grounds in June and July, Wolf (1977) reports that the stomach contents of 10 individuals contained animal and vegetable material in equal proportions (52 to 48 percent), whereas stomach content from five migrants contained anywhere from 90 to 100 percent animal material. Their winter diet consists of seed from grasses and weeds including chickweed (*Alsinaceae* spp.), panicum (*Panicum* spp.), plantain (*Plantago* spp.), woodsorrel (*Xanthoxalis* spp.), sedge (*Carex* spp), and sorghum (Sorghum spp.; Williams and LeSassier 1968, Oberholser 1974, Schnase 1984). Flower buds of the blackthorn bush (*Condalia spathulata*) are also eaten when in season (Williams and LeSassier 1968). Young are fed almost entirely insects (Kaufman 1996). During 18 hours of observation at one nest, Bock et al. (1992)

reports that 95 percent of the insects fed to the nestlings were grasshoppers. Dunning et al. (2000) reference a study in southeastern Arizona that found that parents at two nests delivered an average of 1.9 grasshoppers per 10 min ± 0.59 SD during 988 minutes of observation.

Using energy parameters and models developed for the savannah sparrow and other species, Schnase et al. (1991) determined rates of energy expenditure and estimates of food requirements for the Cassin's sparrow. Models predicted that during the breeding season, territorial male Cassin's sparrows expend 59.0 to 63.4 kJ per day during phases of lowered activity (incubation, nestling, fledgling) and require between 13 and 15 g per day of fresh arthropods. When activity levels are at their greatest during the pre-incubation phase, males spend up to 36 percent of the day singing and skylarking, expending up to 118 kJ per day. This requires an estimated daily intake of 26 g of fresh arthropods. Males during the incubation phase spent approximately 3 hr each day foraging at a rate of 4 g of arthropods per hour.

During this same study (Schnase et al. 1991), determined nestling food requirements. On day 9 a female and two nestlings require 38 g per day of fresh arthropods while a female and three nestlings require 50 g per day. Assuming that 75 percent of the female's time on the ground is spent gathering arthropods at a rate of 4 g per hr, she is able to acquire a total of 34 g daily for nestlings. Thus, it would likely be necessary for the male to assist in feeding nestlings in clutches larger than two.

Cassin's sparrows forage almost entirely on the ground in bare areas, but at times they will take insect larvae from shrubs or mesquite (Wolf 1977). During the nesting phase, Schnase (1984) observed some foliage gleaning from plant stems and low shrubs. Fledglings foraged independently on the ground and in vegetation.

The need for water in Cassin's sparrows is not clearly understood, and observations have been very minimal. Williams and LeSassier (1968) suggested that drinking water is not needed since territories did not include a water source and birds were not often seen leaving the territory. However, Schnase (1984) reports observing Cassin's sparrows drinking water from a small pool after a rain.

Grasshopper abundance and factors affecting their populations are important to Cassin's sparrow since grasshoppers are a main food item and generally one of the most available in grassland habitats. Grasshopper populations are affected by a variety of environmental factors including rainfall, grazing, and competition. Studies on the effects of weather indicate that precipitation levels are a main factor in stimulating increases in grasshopper populations and infestations in grassland ecosystems (Nerney 1961, Capinera and Horton 1989). Additionally, during a short-term study in Arizona, Bock et al. (1992) found that grassland birds limit grasshopper populations, and in the absence of avian predators increases in grasshopper densities resulted in higher levels of herbivory. Bock et al. (1986) found that grasshopper numbers were less abundant on plots dominated by exotic grasses. Capinera and Thompson (1987) found that densities and assemblage of grasshopper populations were not affected by applications of nitrogen fertilizers and the herbicide atrazine.

Breeding biology

Phenology and behavior of courtship and breeding

The amount of time between arrival onto the breeding grounds and territory establishment is unclear (Rising 1996, Dunning et al. 2000). Singing males become conspicuous in late March and early April in the southern portions of their range (Sutton 1967, Williams and LeSassier 1968, Hubbard 1977, Schnase et al. 1991), with later dates (mid-April and early May) reported for more northern regions such as Colorado, Kansas, and Nebraska. Territorial boundaries are established through song, and Schnase et al. (1991) found no evidence of physical contact or visual displays. During this time most of the male's energy is spent singing and engaging in song duals from favored perches used throughout the breeding season (Williams and LeSassier 1968, Wolf 1977, Schnase et al. 1991, Earsom personal communication 2003). Once other males arrive to the area, singing males can be seen performing highly established song flights, or skylarks. Activity levels and song frequency are highest during the morning hours and resume briefly before sunset (Schnase et al. 1991). Although skylarking has been observed during territorial establishment, this behavior is relatively infrequent, until the arrival of the females several weeks later (Schnase 1984, Schnase et al. 1991).

Upon arrival of the females, pre-incubation activities begin; these last anywhere from 10 to 19 days, at which time Cassin's sparrows presumably form monogamous pair bonds (Schnase 1984). During this time, Schnase et al. (1991) reports that males begin singing and skylarking up to one hour prior to sunset, expending 35 percent of their daily energy. Timing and increase in frequency of the flight song indicate that skylarking is an important part of pair formation. Males perform song flights from an exposed perch within their territory, flying up anywhere from 2 to 15 m, then slowly fluttering or gliding flat-winged down with the tail often elevated. The beginning notes of the primary song are given as the bird climbs, and the song usually ends as the bird lands on a nearby shrub several meters away (Williams and LeSassier 1968, Wolf 1977). Song is a chief means of identification (Oberholser 1974), and of six species of sparrows, including Bachman's and Botteri's sparrows, the Cassin's sparrow appears to be the only one that frequently sings in flight (Borror 1971). Thus, surveys are best done when singing and skylarking are most fervent between 0600-1000 hours during the unmated and pre-incubation stages (Schnase et al. 1991). In Colorado, Breeding Bird Atlas data indicate that Cassin's sparrows begin to sing shortly after they arrive in late-April, with reports of courtship behavior continuing to mid-July (Kingery 1998). Although the effects of wind and temperature have not been directly studied, it appears that skylarking activities cease when wind velocities exceed above 30 km per hour (Schnase et al. 1991).

During courtship, the male and female engage in short chases around the territory while giving a rapid "tzee-tzee-tzee" call (Williams and LeSassier 1968) or "chitter" call (Schnase 1984). Males perform courtship displays by elevating, fanning, and fluttering the tail, and fluttering the wings outward with the head down. Displays and copulation most often occur on the ground in dense grasses or from low perches in mesquite trees or shrubs. Thus, there are only a few records of copulation events, each of which were preceded by a courtship display (Williams and LeSassier 1968, Schnase 1984).

The female Cassin's sparrow most likely selects the nest site and constructs the nest, but there are few records documenting this. Schnase et al. (1991) report that only females were seen carrying nest material. The nest is a deep, open cup constructed of grasses, weed stems, shreds of bark and other vegetable fibers, lined with finer grasses, rootlets, and hair, and placed on the ground or just off the ground in a low shrub (Williams and LeSassier 1968, Oberholser 1974). Maurer et al. (1989) and Schnase (1984) report averages for cup diameter of 6.5 (± 0.4) and 5.9 (± 0.6) cm and cup depth of 5.4 (± 0.4) and 6.4 (± 1.0) cm respectively.

Egg laying can begin as early as March (Wolf 1977) and may extend as late as August in some areas, with the majority of activity in the High Plains of Colorado and Kansas recorded between mid-May and mid-July (Wolf 1977, Johnsgard 1979, Kingery 1998). In Arizona, nest records are reported from late June extending to early September (Ohmart 1966, Maurer et al. 1989). Females lay three to five white, unmarked eggs successively each morning. Incubation begins with the penultimate egg and is reported to last between 9 and 11 days (Schnase et al. 1991, Dunning et al. 2000). Studies by Schnase et al. (1991) in Texas found that females brood for the first 2 to 3 hours after sunrise and then leave the nest unattended for long periods of time during the day. They estimated that ambient temperatures in mid-June were enough to keep the eggs warm. Dunning et al. (2000) report that females brood during the night, through fledging. In Arizona, a female, when flushed, flew only 4 to 5 m, beating her wings noisily, and then hopped on the ground for several minutes (Dunning et al. 2000).

No information is available on hatching events, and little is known of hatching success. From studies done by Schnase (1984), altricial young are almost completely naked, with a few light gray down feathers on the head and back, red gape and yellow rectal flanges. By day two, nestlings are able to hold their head upright. Their eyes are closed until day three, when they begin to make high-pitched peeps. By day 6 or 7 most feathers have broken from their sheaths. Parents remove fecal sacs from the nest by either eating them or carrying them off (Dunning et al. 2000). Both parents feed nestlings (Johnsgard 1979, Dunning et al. 2000), with the majority of feeding done by the female (Williams and LeSassier 1968). Although, Schnase et al. (1991) did not observe males feeding nestlings with nests containing 3 nestlings, energetic analysis indicate that feeding of nestlings by the male may become necessary with clutch sizes larger than 2. During this stage the male spends most of his time perched on alert and foraging on the ground with the female (Schnase et al. 1991).

Fledge dates range from late May to early August with the majority of fledglings seen in June and July (Ohmart 1966, Sutton 1967, Wolf 1977, Johnsgard 1979, Dorn and Dorn 1995, Rising 1996, Kingery 1998). Due to the length of the breeding season, with fledglings found as early as 21 May in Colorado (Kingery 1998), and as late as 15 August in Wyoming (Dorn and Dorn 1995), it has long been believed that Cassin's sparrows will double-brood. However, until recently no studies have provided clear evidence of this hypothesis. In 1996, Earsom (personal communication 2003) recorded a single instance of double brooding on the Comanche National Grassland in Colorado. On 27 June, a pair of adults was observed simultaneously feeding a fledgling, still unable to fly, while the female constructed a new nest. By 3 July, the new nest contained four eggs and was active until 13 July, when the nest was found depredated.

Nests monitored by Schnase et al. (n = 1; 1991) and Earsom (n = 3; personal communication 2003) fledged young at 9 days. However, Dunning et al. (2000) report that four nests in Arizona fledged between 7 and 9 days, but they also note notes that some may have fledged early due to observer presence. Schnase et al. (1991) found that fledglings are able to fly 10 to 15 m by day two and stay within dense thickets, beginning to forage independently at 8 days. Although both adults have been observed feeding fledglings, the female is primarily responsible for care. At this time the male resumes singing and skylarking within the territory, responding to alarm calls from the female. The female may begin constructing a second nest immediately upon fledging the first clutch.

Fledglings form flocks of 10 to 20 individuals from adjacent territories (Schnase 1984) and move through territories without disturbing other pairs. By late August in Wyoming, Dorn and Dorn (1995) reported seeing interspecies flocks of juvenile Cassin's sparrows with lark buntings, Brewer's sparrows, chipping sparrows, clay-colored sparrows, and vesper sparrows.

Demography

Genetic issues

There have been no reports providing genetic information for the Cassin's sparrow since very few studies have monitored or collected blood samples from banded individuals. However, due to the nomadic nature of this species and its apparently low site fidelity, genetic issues do not appear to pose any problems in its conservation. There have also been no reports of hybridization or geographic variation. In addition, due to the paucity of copulation events (3) reported in the literature, it is unknown if extra-pair copulation occurs in this species.

Recruitment, survival, immigration, age at reproduction

Although few studies on reproduction of the Cassin's sparrow exist, most first-year male and female passerines are able to reproduce, and pairs often re-nest throughout the breeding season if the first attempt fails. Second broods of Cassin's sparrows have been documented in Colorado (Earsom personal communication 2003) and are assumed to occur throughout their breeding range. One exception is Arizona, where a short breeding season of only two to three months (Williams and LeSassier 1968, Schnase 1984) makes second broods unlikely. Clutch size ranges from three to five eggs. Mean clutch sizes in Oklahoma and the High Plains of Texas were 4.2 (n = 6; Sutton 1967) and 4.4 ± 0.61 (n = 34; Berthelsen and Smith 1995), respectively, while in Arizona Maurer et al. (1989) and Dunning et al. (2000) reported mean clutch sizes of 3.0 ± 0.9 (n = 10) and 3.3 ± 0.48 (n = 22), respectively. In Nebraska, Bock and Scharf (1994) found three nests each containing five eggs.

Small sample sizes and dissimilar methods of analysis make it difficult to compare the few reports on nesting success (i.e., portion of nests that fledge at least one fledgling). In Texas, Schnase et al. (1991) report 54 percent success, with six nests producing 13 fledglings over a two-year period. Berthelsen and Smith (1995) found similar results (46 percent success) for 30 nests found in blue grama/sideoats grama fields on CRP lands. Dunning et al. (2000) report that 10 of 19 nests were successful in producing at least one fledgling, with six failures and three unknowns in a study near Tucson, Arizona. In Region 2, Earsom (personal communication 2003) calculated a daily survival rate of 0.913 (n = 23) using the Mayfield method; an average of only 14.8 percent of nests that reached the incubation stage survived to produce at least one fledgling.

Lifecycle graph and model development (prepared by David B. McDonald)

The studies of Schnase (1984), Schnase et al. (1991), Berthelsen and Smith (1995), and Dunning et al. (2000) provided the basis for formulating a lifecycle graph for the Cassin's sparrow that comprised two stages (censused at the fledgling stage and "adults"). We used a mean fledging rate of 0.977 female fledglings per year as the basis for calculating fertilities. This measure was based on averaging two independent estimates of fledgling number: 1) an estimated clutch size of 2.3 female eggs (based on latitudinal trends in clutch size described in the section on Demography, and assuming a 1:1 sex ratio) and a fledging success of 0.46 from Berthelsen and Smith (1995); and 2) production of 20 female fledglings (assuming a 1:1 sex ratio) in 23 nests documented by Schnase (1984). Because of a lack of data, we did not assume a change in fertility with age, an assumption that is often justified in avian demography (Ricklefs 1973, McDonald and Caswell 1993). No estimates of survival were available for this species, so we used a bracketed system of large and small difference between first-year and "adult" survival as the basis for estimated survival rates. Our initial variant (Variant 1 – which we will refer to as the "differential survival" variant) assumed that first-year and "adult" survival were quite different (P_{21} = 0.25, P_a = 0.76), with the values adjusted until the population growth rate (λ) = 1.002. This "missing element" method (McDonald and Caswell 1993) is justified by the fact that, over the long term, λ must be near 1.0, or the species will go extinct or grow unreasonably large. The alternative model (Variant 2 – "balanced survival") assumed that first-year survival (P_{21} = 0.35) was more similar to "adult" survival (P_a = 0.66). From the resulting lifecycle graphs (**Figure 7**), we produced a matrix population analysis with a post-breeding census for a birth-pulse population with a one-year census interval (McDonald and Caswell 1993, Caswell 2001). The models had two kinds of input terms: P_i describing survival rates, and *m* describing the number of female fledglings per female (**Table 3**). **Figure 8a** shows the symbolic terms in the projection matrices corresponding to the lifecycle graphs for both variants. **Figure 8b** and **Figure 8c** give the corresponding numeric values for the two variants. The model assumes female demographic dominance so that, for example, fertilities are given as female offspring per female; thus, the fledgling number used was half the total annual production of fledglings, assuming a 1:1 sex ratio. Note also that the fertility terms (F_i) in the top row of the matrix include both a term for fledgling production (m_i) and a term for the survival of the mother (P_i) from the census (just after the breeding season) to the next birth pulse almost a year later. Based on the estimated vital rates used for the matrix, λ equaled 1.002 for both variants. Although this suggests a stationary population, the value was used as an assumption for deriving a vital rate, and it should not be interpreted as an indication of the general well being of the population. Other parts of the analysis provide a better guide for assessment.

Sensitivity analysis: A useful indication of the state of the population comes from the sensitivity and elasticity analyses. Sensitivity is the effect on population growth rate (λ) of an absolute change in the vital rates (a_{ij}, the arcs in the lifecycle graph [**Figure 7**] and the cells in the matrix, A [**Figure 9**]). Sensitivity analysis provides several kinds of useful information (see Caswell 2001, pp. 206-225). First, sensitivities show how important a given vital rate is to λ, which Caswell (2001, pp. 280-298) has shown to be a useful integrative measure of overall fitness. One can use sensitivities to assess the relative importance of survival (P_i) and fertility (F_i) transitions. Second, sensitivities can be used to evaluate the effects of inaccurate estimation of vital rates from field studies. Inaccuracy will usually be due to a paucity of data, but it could also result from the use of inappropriate estimation techniques or other errors of analysis. In order to improve the accuracy of the models, researchers should concentrate additional effort on transitions with large sensitivities. Third, sensitivities can quantify the effects of environmental perturbations, wherever those

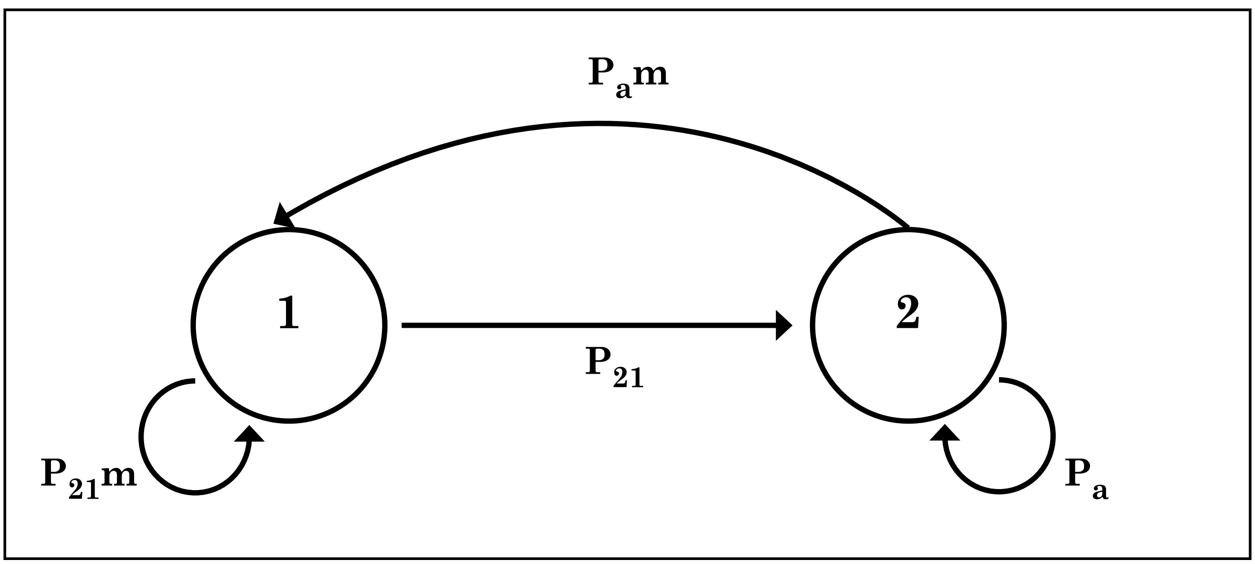

Figure 7. Lifecycle diagram for the Cassin's sparrow. The numbered circles ("nodes") represent the two stages (first-year birds and "adults"). The arrows ("arcs") connecting the nodes represent the vital rates – transitions between age-classes such as survival (P_{ii}) or fertility (the arcs pointing back toward the first node).

Table 3. Parameter values for the component terms that make up the vital rates in the projection matrix for the Cassin's sparrow.

Parameter	Numeric value	Interpretation
m	0.977	Number of female fledglings produced by a female
P_{21}	0.25 or 0.35	First-year survival under the "differential" and "balanced" variants
P_a	0.76 or 0.66	Survival rate of "adults" under the "differential" and "balanced" variants

	1	2
1	$P_{21}m$	$P_a m$
2	P_{21}	P_a

Figure 8a. Symbolic values for the projection matrix of vital rates, **A** (with cells a_{ij}) corresponding to Cassin's sparrow lifecycle diagram of **Figure 7**. Meanings of the component terms and their numeric values are given in **Table 3**.

	1	2
1	0.244	0.741
2	0.25	0.758

Figure 8b. Numeric values for matrix Variant 1, assuming a high "differential" between first-year and "adult" survival rates.

	1	2
1	0.342	0.645
2	0.35	0.66

Figure 8c. Numeric values for matrix Variant 2, assuming more "balanced" first-year and "adult" survival rates.

can be linked to effects on stage-specific survival or fertility rates. Fourth, managers can concentrate on the most important transitions. For example, they can assess which stages or vital rates are most critical to increasing the population growth of endangered species or the "weak links" in the life cycle of a pest. **Figure 9** shows the "possible sensitivities only" matrices for this analysis (one can calculate sensitivities for non-existent transitions, but these are usually either meaningless or biologically impossible – for example, the biologically impossible sensitivity of λ to the transition from Stage 2 "adult" back to being a Stage 1 first-year bird).

The summed sensitivity of λ to changes in survival was lower under the balanced survival Variant 2 model (65.4 percent of total sensitivity accounted for by survival transitions) than in the differential survival Variant 1 model (75.2 percent of total). Under either variant, first-year and "adult" survival were almost equally important (**Figure 9a** and **Figure 9b**). The major conclusion from the sensitivity analysis is that survival rates are most important to population viability when changes in the vital rates are absolute (as opposed to proportional, as discussed below in the section on elasticity analysis).

Elasticity analysis: Elasticities are useful in resolving a problem of scale that can affect conclusions drawn from the sensitivities. Interpreting sensitivities can be somewhat misleading because survival rates and reproductive rates are measured on different scales. For instance, an absolute change of 0.5 in survival may be a large alteration (e.g., a change from a survival rate of 90 to 40 percent). On the other hand, an absolute change of 0.5 in fertility may be a very small proportional alteration (e.g., a change from a clutch of 3,000 eggs to 2,999.5 eggs). Elasticities are the sensitivities of λ to proportional changes in the vital rates (a_{ij}) and thus partly avoid the problem of differences in units of measurement (e.g., we might reasonably equate changes in survival rates or fertilities of 1 percent). The elasticities have the useful property of summing to 1.0. The difference between sensitivity and elasticity conclusions results from the weighting of the elasticities by the value of the original arc coefficients (the a_{ij} cells of the projection matrix). Management conclusions will depend on whether changes in vital rates are likely to be absolute (guided by sensitivities) or proportional (guided by elasticities). By using elasticities, one can further assess key life history transitions and stages as well as the relative importance of reproduction (F_i) and

	1	2
1	0.244	0.249
2	0.739	0.756

Figure 9a. Possible sensitivities only matrix, S_p for the "differential" survival Variant 1 matrix (blank cells correspond to zeros in the original matrix, A). The population growth rate (λ) of the Cassin's sparrow is most sensitive to changes in "adult" survival (Cell s_{22} = 0.756).

	1	2
1	0.341	0.341
2	0.644	0.659

Figure 9b. Possible sensitivities only matrix, S_p for the "balanced" survival Variant 2 matrix (blank cells correspond to zeros in the original matrix, A). Under this variant, the λ of the Cassin's sparrow is most sensitive to changes in "adult" survival (Cell s_{22} = 0.659) closely followed by changes in first-year survival (Cell s_{22} = 0.644).

survival (P_1) for a given species. It is important to note that elasticity as well as sensitivity analysis assumes that the magnitude of changes (perturbations) to the vital rates is small. Large changes require a reformulated matrix and reanalysis.

Elasticities for the Cassin's sparrow are shown in **Figure 10a** and **Figure 10b**. In **Figure 10a** the λ of the Cassin's sparrow is most elastic to changes in "adult" survival (e_{22} = 0.572), followed by "adult" fertility and first-year survival (e_{12} = e_{21} = 0.184). In **Figure 10b** the λ of the Cassin's sparrow is most elastic to changes in "adult" survival (e_{22} = 0.434), followed by second-year fertility and first-year survival (e_{12} = e_{21} = 0.225). Under this variant, the relative importance of each of the four kinds of transitions (vital rates) is more even than under the "differential" model (e.g., "adult" survival is only 3.7 times as great compared to a 9.7 fold difference under the "differential" variant). λ was most elastic to changes in "adult" survival for both variants (e_{22} = 57.2 percent ["differential" Variant 1] or 43.4 percent ["balanced" Variant 2], where the e_{22} is the percentage of total elasticity on arc P_{22}, the self-loop from the second node back to the second node in **Figure 8**). Next most elastic were first-year survival and "adult" reproduction (e_{12} = e_{21} = 18.4 percent [Variant 1] or 22.5 percent [Variant 2] of total elasticity). Least important was reproduction by first-year birds (5.9 percent or 11.7 percent respectively of total elasticity). The sensitivities and elasticities for Cassin's sparrows were generally consistent in emphasizing survival transitions with the elasticities strongly emphasizing adult survival, whereas the sensitivity analysis gave almost equal weight to first-year survival. Thus, survival rates, particularly "adult" survival rates, are the data elements that warrant careful monitoring in order to refine the matrix demographic analysis.

Other demographic parameters: The stable stage distribution (SSD; **Table 4**) describes the proportion of each age-class or stage in a population at demographic equilibrium. Under a deterministic model, any unchanging matrix will converge on a population structure that follows the stable stage distribution, regardless of whether the population is declining, stationary, or increasing. Under most conditions, populations not at equilibrium will converge to the SSD within 20 to 100 census intervals. For Cassin's sparrows at the time of the post-breeding annual census (i.e., just after the end of the breeding season), fledglings represent 49.4 percent of the population, regardless of the model variant used. Reproductive values (**Table 5**) can be thought of as describing the value of a stage as a seed for population growth relative to that of the

	1	2
1	0.059	0.184
2	0.184	0.572

Figure 10a. Elasticity matrix, E (remainder of matrix consists of zeros) for the "differential" survival Variant 1 matrix.

	1	2
1	0.117	0.225
2	0.225	0.434

Figure 10b. Elasticity matrix, E (remainder of matrix consists of zeros) for the "balanced" survival Variant 2 matrix.

Table 4. Stable age distribution (right eigenvector). At the census, 57 percent of the individuals in the population should be fledglings. The rest will be older "adult" females (yearlings or older).

Stage	Description	Proportion	Mean age (± SD) Variant 1	Mean age (± SD) Variant 2
1	Fledglings (to yearling)	0.494	0 ± 0	0 ± 0
2	"Adult" females	0.506	4.1 ± 3.6	2.9 ± 2.4

Table 5. Reproductive values (left eigenvector). Reproductive values can be thought of as describing the "value" of an age class as a seed for population growth relative to that of the first (newborn or, in this case, egg) age class. The reproductive value of the first age class is always 1.0. The peak reproductive value (second-year females) is highlighted.

Age Class	Description	Variant 1 ("differential")	Variant 2 ("balanced")
1	Fledglings/first-year females	1.0	1.0
2	"Adult" females	3.0	1.9

first stage, in this case, fledgling (Caswell 2001). The reproductive value is calculated as a weighted sum of the present and future reproductive output of a stage discounted by the probability of surviving (Williams 1966). The reproductive value of the first stage is, by definition, 1.0. An "adult" female individual in Stage 2 is "worth" 3.0 fledglings under the "differential" survival model of Variant 1, but worth only 1.9 fledglings under the "balanced" survival Variant 2. The "adult" females are therefore important stages in the life cycle, particularly if the "differential" Variant 1 more closely depicts the actual demographic condition of Cassin's sparrows. The cohort generation time for this species was 4.1 years (SD = 3.6 years) under the "differential survival" Variant 1 and 2.9 years (SD = 2.4 years) under the "balanced survival" Variant 2.

Stochastic model: We conducted a stochastic matrix analysis for the Cassin's sparrow. We incorporated stochasticity in several ways (**Table 6**), by varying different combinations of vital rates, by varying the amount of stochastic fluctuation and by varying the "base matrix" (the "differential" or "balanced" survival variants of **Figure 10a** and **Figure 10b**). We varied the amount of fluctuation by changing the standard deviation of the truncated random normal distribution from which the stochastic vital rates were selected. To model high levels of stochastic fluctuation we used a standard deviation of one quarter of the "mean" (with this "mean" set at the value of the original matrix entry [vital rate], a_{ij} under the deterministic analysis). Under Case 1 we subjected both fertility arcs (F_{11} and F_{12}) to high levels of stochastic fluctuations (SD one quarter of mean) using the "differential" survival Variant 1 matrix. Under Case 2 we varied both survival arcs (P_{21} and P_{22}) with high levels of stochasticity (SD one quarter of mean), again with the "differential" Variant 1 matrix. Under Case 3 we again varied survival with high levels of stochastic fluctuation, but using the "balanced" survival Variant 2 matrix. Case 4 varied survival with "differential" survival Variant 2 matrix, but with only half the stochastic fluctuations (SD one eighth of mean). Each run consisted of 2,000 census intervals (years) beginning with a population size of 10,000 distributed according to the Stable Stage Distribution (SSD) under the deterministic model. Beginning at the SSD helps avoid the effects of transient, non-equilibrium dynamics. The overall simulation consisted of 100 runs (each with 2,000 cycles). We calculated the stochastic growth rate, log λ, according to Eqn. 14.61 of Caswell (2001), after discarding the first 1,000 cycles in order to further avoid transient dynamics.

The stochastic model (**Table 6**) produced two major results. First, high variability on survival rates using the "differential" survival Variant 1 matrix had the strongest detrimental effects. For example, 98 of 100 runs led to extinctions with stochasticity affecting both survival rates and acting on the low first-year survival matrix (Case 2). The next greatest effect came from stochastic survival for the "balanced" survival Variant 2 matrix (Case 3), which had 74 extinctions. The difference in the effects of which arc was most important is predictable largely from the elasticities. λ was most elastic to changes in survival, especially under the "differential" survival variant. This detrimental effect of stochasticity occurs despite the fact that the average vital rates remain the same as under the deterministic model – the random selections are from a symmetrical distribution. This apparent paradox is due to the lognormal distribution of stochastic ending population sizes (Caswell 2001). The lognormal distribution has the property that the mean exceeds the median, which exceeds the mode. Any particular realization population dynamics (compare Variants 2 and 4 in **Table 6**). With low level of stochastic variation directed at the "differential" survival variant, only one population went extinct, although 67 of 100 underwent

Table 6. Results of four cases of different stochastic projections for the Cassin's sparrow. Stochastic fluctuations have the greatest effect when acting on survival rates for the "differential" survival variant (Case 2).

	Case 1 (Variant 1)	Case 2 (Variant 2)	Case 3 (Variant 2)	Case 4 (Variant 1)
Input factors:				
Affected cells	F_{11} and F_{12}	P_{21} and P_a	P_{21} and P_a	P_{21} and P_a
S.D. of random normal distribution	1/4	1/4	1/4	1/8
Output values:				
Deterministic λ	1.002	1.002	1.002	1.002
# Extinctions / 100 trials	0	98	74	1
Mean extinction time	N.a.	814	1,126	1,959
# Declines / # surviving populations	17/100	2/2	23/26	66/99
Mean ending population size	554,126	1,420	6,151	428,880
S.D.	1.1×10^6	674	18,468	2.4×10^6
Median ending size	98,806	1,420	256	3,001
Log λ_s	0.0013	-0.0125	-0.0072	-0.0005
λ_s	1.0013	0.988	0.993	0.9995
% reduction in λ	0.1	1.5	0.9	0.3

declines (vs. 98 extinctions and all 100 populations declining under the high stochasticity case). These results indicate that populations of Cassin's sparrows are somewhat vulnerable to high levels of stochastic fluctuations in survival (due, for example, to annual climatic change or to human disturbance). This effect will be especially pronounced if the difference between first-year and "adult" survival is fairly large, as in our "differential" Variant 1 model. Pfister (1998) showed that for a wide range of empirical life histories, high sensitivity or elasticity was negatively correlated with high rates of temporal variation. That is, most species appear to have responded to strong selection by having low variability for sensitive transitions in their life cycles. The Cassin's sparrow, however, may have little flexibility in reducing variability in first-year survival. Variable early survival is likely to be the rule rather than the exception.

Potential refinements of the models: Clearly, data on survival rates are needed in order to increase confidence in any demographic analysis. The most important "missing data elements" in the life history for the Cassin's sparrow are for survival rates, which emerge as vital rates to which λ is sensitive as well as most elastic. Data from natural populations on the range of variability in the vital rates would allow more realistic functions to model stochastic fluctuations. For example, time series based on actual temporal or spatial variability, would allow construction of a series of "stochastic" matrices that mirrored actual variation. One advantage of such a series would be the incorporation of observed correlations between variations in vital rates. Using observed correlations would improve on our "uncorrelated" assumption, by incorporating forces that we did not consider. Those forces may drive greater positive or negative correlation among life history traits. Other potential refinements include incorporating density-dependent effects. At present, the data appear insufficient to assess reasonable functions governing density dependence.

Summary of major conclusions from matrix projection models:

- ❖ Survival accounts for 75 percent of the total "possible" sensitivity under the "differential" survival Variant 1 matrix, and 65 percent of the total under the "balanced" survival Variant 2 matrix. Any absolute changes in survival rates will have major impacts on population dynamics.

- ❖ Survival (P_{21} and P_{22}) accounts for 76 percent ("differential" variant) or 66 percent ("balanced" variant) respectively of the total elasticity. Proportional changes in first-year and especially in "adult" survival will have a major impact on population dynamics.

- ❖ The reproductive value of "adult" females is higher under the "differential" variant (3.0) than under the "balanced" variant (1.9). With the former variant, the higher reproductive value of "adults" makes them possible buffers against the detrimental effects of variable conditions.

- ❖ Stochastic simulations echoed the elasticity analyses in emphasizing the importance of variation in survival to population dynamics. In comparison to life histories of other vertebrates, especially those with long lifespan, the Cassin's sparrow appears slightly less vulnerable to environmental stochasticity because of the buffering effect of a reservoir of "adult" females and because of the relatively even importance of different vital rates, as assessed by the sensitivities and elasticities.

Spacing, defense, and size of area

Cassin's sparrows defend their territories by song duels (Schnase et al. 1991), and nesting and foraging activities take place within mutually exclusive territories. Territory size may vary, and available information is difficult to compare due to differences in data collection and analysis. Most density data are reported as the number of singing males per area or the number detected along a line transect.

Cassin's sparrow densities on CRP land on the southern High Plains of Texas averaged 1.7 pairs per ha (± 1.78; n = 32) in grassland habitat dominated by blue grama (Berthelsen and Smith 1995). Gordon and Leitner (1996), however, report 15 territories per 61 ha on Buenos Aires Wildlife Refuge in Arizona. In south-central Texas, Schnase (1984) found territory size averaging 2.6 (± 0.5) ha, spaced 15 to 75 m apart, while Johnsgard (1979) found territories spaced up to 100 m apart.

During winter in Arizona, Dunning et al. (2000) report that Cassin's sparrows are highly territorial, defending territories less than 0.25 ha in size, with only one of 32 color-banded birds relocating during the season. Although sex was unknown, they assumed that both males and females defend winter territories. No published data are available on whether the Cassin's sparrow demonstrates site fidelity on the wintering grounds.

Some researchers describe the Cassin's sparrow as a semi-colonial nester (Williams and LeSassier 1968, Johnsgard 1979). However, locally high breeding densities may be due to the patchiness of quality habitat.

Dispersal

Little is known about patterns of dispersal of juvenile and adult Cassin's sparrows. However, Schnase (1984) found that upon fledging, juveniles form fledgling flocks of 10 to 20 individuals from adjacent territories, moving through territories without disturbing other pairs.

Factors limiting population growth

As a migrant, more than half of the Cassin's sparrow's life cycle is spent on the wintering grounds to the south of Region 2. Thus, understanding the limiting factors that affect population growth becomes more difficult. As with many other migrant passerines, factors such as post-fledging and adult mortality that regulate breeding populations of Cassin's sparrows may be occurring during migration or on wintering grounds. These are beyond the scope of most demographic studies.

There are few reports of nest parasitism for Cassin's sparrow and no information on the impact of parasitism on host productivity at the population level. However, since female cowbirds will often remove one or more host eggs before laying their own, cowbird parasitism will limit reproductive success. In Texas, Friedmann (1963) lists a total of 10 records of brown-headed cowbird (*Molothrus ater ater* and *M. a. obscurus*) parasitism while Schnase (1984) found 25 percent (n = 12) of nests parasitized. There have been only two additional reports of cowbird parasitism, both within Region 2 on the Comanche National Grassland in Colorado. Kingery and Julian (1971) reported the first case of parasitism in which one nest contained two Cassin's sparrow eggs and one cowbird egg. The second found two of 23 nests parasitized by brown-headed cowbirds during the 1996 breeding season (Earsom personal communication 2003). There are no known records of brood parasitism by bronzed cowbirds (*M. aeneus*).

Community ecology

Predators and relationship to habitat use

There are few studies or records concerning predators of Cassin's sparrows. Williams and LeSassier (1968) found an adult Cassin's sparrow impaled on a yucca spine by a loggerhead shrike (*Lanius ludovicianus*). A study of the diet of Aplomado falcons (*Falco femoralis*) in Mexico found that although the Cassin's sparrow was one of the most common birds during surveys, it was not a prey item, possibly due to its small size (Montoya et al.1997). They found that birds of similar size were also absent from the falcon's diet, but larger birds such as meadowlarks (*Sturnella* spp.), mourning doves (*Zenaida macroura*), and northern mockingbirds (*Mimus polyglottos*) were common prey items. Reports of nest predators of Cassin's sparrows are also sparse. Dunning et al. (2000) report that snakes were presumably responsible for the failure of four nests during a 1983 study in Arizona. Williams and LeSassier (1968) report finding a nestling almost completely consumed by red ants, but it was unclear if this was the primary cause of death. Changes in habitat use by Cassin's sparrows in relation to specific predators have not been reported. Likewise, there are no reports of the effects of fragmentation and habitat patch characteristics on changes in predation rates and/or nesting success.

Competitors

The grasshopper sparrow (*Ammodramus savannarum*) and the Botteri's sparrow occur in similar habitat as Cassin's sparrow and thus may compete for similar resources. However, few studies have documented the effect that these potential competitors have on Cassin's sparrow populations. Maurer's (1986) model for predicting habitat quality for grassland birds suggests that lower than predicted numbers of Cassin's sparrows may be due to competition with grasshopper sparrows, but it presents no evidence to support this hypothesis. In arid grasslands in Arizona, the territories of Botteri's sparrows and Cassin's sparrows overlap (Dunning et al. 2000). Although male Cassin's sparrows were observed chasing Botteri's sparrows, both species shared the same perch after extensive singing with no interactions. They also report grasshopper sparrows chasing Cassin's sparrows. Austin and Russell (1972) observed several attacks of ash-throated flycatchers (*Myiarchus cinerascens*) on Cassin's sparrows, knocking them to the ground. They suggest that this behavior was mistaken aggression towards a possible competitor since skylarking may appear similar to aerial hawking maneuvers.

Parasites or disease

There is no literature on parasites or diseases in the Cassin's sparrow.

Envirogram

An envirogram is a tool to depict the proximal and distal causes/components that affect a species' chance to survive and reproduce. Within the envirogram model (**Figure 11**), the environment consisting of the "centrum" and the "web" comprises everything that might influence a Cassin's sparrow chance to survive and reproduce. The "centrum" includes proximate causes of change in the physiology and behavior of the species. These are recognized as directly acting components of the environment. Everything else acts indirectly, through an intermediary or a chain of intermediaries that ultimately influences the activity of one or other of the components in the "centrum". All of these indirectly acting components are placed in the "web" (Andrewartha and Birch 1984).

Within the "centrum", the directly acting components are classified into four subdivisions according to the response of the animal to the component and the consequent reaction of the component to the animal. The four subdivisions are "mates", "resources", "predators", and "malenities". The names "resources" and "mates" refer to well-understood colloquial meanings. "Malentities" differ from "predators" in that they are components that directly affect the animal, causing a decrease in life expectancy or fecundity, but the consequent component activity decreases or do not change. "Predators" also cause a decrease in life expectancy or fecundity in the animal, but, unlike "malentities", the consequent component activity increases.

An envirogram depicts the relationships described above. In the case of the Cassin's sparrow, some pathways serve as hypotheses and are not necessarily substantiated relationships, but an ecological summary.

Conservation

Threats

Historically grasslands were one of the most "disturbed" North American ecosystems, and currently they are one of our most threatened (Knopf and Samson 1994). Natural disturbances including grazing by native herbivores, fire, and climate are the driving forces that have influenced the evolution of our native grasslands and endemic grassland birds, including the Cassin's sparrow. However, current land-use activities have thwarted or modified these natural disturbance processes, triggering changes in vegetation at a landscape scale. Activities such as agricultural and human development, intensive livestock grazing, and fire suppression lead to the loss, fragmentation, and degradation of our native grasslands and threaten the conservation of the Cassin's sparrow. All of these threats have complex interactions,

Web 4	Web 3	Web 2	Web 1	CENTRUM
				RESOURCES
		water/weather	vegetation	food: insects — Cassin's sparrow
		water/weather	vegetation	food: seeds — Cassin's sparrow
		precipitation	vegetation	food — Cassin's sparrow
soil type	water/weather	fire	vegetation	food: cover — Cassin's sparrow
topography	water/weather	vegetation	microhabitat	cover — Cassin's sparrow
humans	grazing	water/weather	vegetation	food: cover — Cassin's sparrow
	human	habitat	vegetation	food: cover — Cassin's sparrow
				MALENTITIES
humans	grazing	water/weather	vegetation	fecundity, densities — Cassin's sparrow
humans	grazing	soil; vegetation	disturbance	fecundity, densities — Cassin's sparrow
humans	brush removal	fragmentation	vegetation	fecundity, densities — Cassin's sparrow
humans	agriculture	exotic annual grasses	fragmentation/ habit loss	population decline — Cassin's sparrow
	water/vegetation	vegetation	microclimate	nest phenology — Cassin's sparrow
	water/weather	vegetation	habitat selection	distribution — Cassin's sparrow
	human	agriculture	fragmentation/ habit loss	population decline — Cassin's sparrow
	human	prescribed fire	vegetation	fecundity, densities — Cassin's sparrow
		humans	grazing	nest mortality — Cassin's sparrow

PREDATORS/ COMPETITORS

topography	water/weather	vegetation	microhabitat	loggerheaded shrikes	predation — Cassin's sparrow
	water/weather	vegetation	insects/seeds	Grasshopper sparrow Brewer's sparrow	abundance — Cassin's sparrow
			humans	grazing	brown-headed cowbird abundance — Cassin's sparrow

Figure 11. Envirogram outlining resources, malentities, and predators/competitors centrum of Cassin's sparrow.

making it difficult to understand how each influences population viability. Thus, inferences about these influences should be viewed with caution.

Agriculture

In Region 2, direct habitat loss from the conversion of grassland to cropland poses the most immediate threat to Cassin's sparrow populations. In southeastern Colorado, at the core of the specie's breeding range, at least 22 percent of the total landscape has been converted to cropland (USDA National Agricultural Statistics Service 2005). Since Cassin's sparrows avoid these areas altogether, additional conversion of suitable habitat to cropland would be detrimental to this species (Sutton 1967). Unlike urban development, this type of land conversion may not be permanent; fields are often rotated and placed in the CRP. Although CRP lands may provide some habitat for Cassin's sparrows in Region 2, these sites are seeded with exotic grasses 2.5 times more often than with native seed, posing an additional problem for the Cassin's sparrow (Bock and Bock 1995). In 1992, Bock and Bock found that compared to native grasslands, Cassin's sparrow and grasshopper abundances were significantly lower on non-native plots. If planted with native grasses, CRP lands could provide suitable breeding habitat for this species (Berthelsen and Smith 1995). In addition to the direct planting of non-native species within CRP lands, cropland development increases soil compaction and disturbance, encouraging further introduction and spread of non-native plants into adjacent natural habitats. Furthermore, agricultural areas often introduce tree species into grassland ecosystems, thereby increasing populations of brown-headed cowbirds and corvids, such as common ravens (*Corvus corax*), American crows (*C. brachyrhynchos*), and black-billed magpies (*Pica hudsonia*), which can be major nest predators (Marzluff et al. 1994).

Besides the direct loss of habitat, agricultural activities contribute to the fragmentation and degradation of grassland ecosystems. The long-term effects of agricultural changes on grassland systems, though not entirely understood, are likely detrimental to Cassin's sparrow populations (Knopf 1996).

Although the nomadic nature of this species allows it to move annually between suitable habitat patches, fragmentation may decrease the probability of colonization/re-colonization of a patch as the distance between remaining patches increases. This is especially important during years of abnormal precipitation when Cassin's sparrows may be required to occupy areas not normally used during years of average rainfall.

Pesticide and herbicide use

Because pesticide and herbicide application often coincides with both peak insect production and the breeding period, the threat to grassland bird species associated with the use of chemicals is two-fold. Several studies on the effects of pesticides and herbicides on similar grassland species, such as longspurs, have shown significant declines in abundance due to direct mortality of adults and nestlings, and decreases in food (McEwen et al. 1972). On the Pawnee National Grassland in Colorado, application of the insecticide toxaphene caused direct mortality of McCown's longspur nestlings (McEwen and Ells 1975). Similar results were found for chestnut-collared longspurs with the applications of Baygon (o-isopropoxphenyl methylcarbamate), diazinon (O, O-diethyl O-[2-isopropyl-4-methyl-6-pyrimidinyl] phosphorothionate), fenithrothion (O, O-dimethyl O-[4-nitro-m-tolyl] phosphorothionate), and BAY 77488 (phenylglyoxylonitrile oxime O, O-diethyl phosphorothioate) in Wyoming and Montana (McEwen et al. 1972). Herbicide application poses similar threats. In Kansas, 3.323 million lbs. are applied two to three times annually to 35 percent of all pasturelands for weed and shrub control (USDA National Agricultural Statistics Service 2005). Although Capinera and Thompson (1987) did not detect changes in grasshopper populations after the herbicide atrazine was applied on pasturelands, herbicides often target the shrubs and shrub-like weed species that Cassin's sparrows prefer and require for perching and skylarking.

Grazing

Historically (pre-European American settlers) the shortgrass prairie was grazed by native ungulate species that produced a diversity of grazing regimes on the landscape, with some areas heavily grazed while others were barely touched. This created a natural mosaic on the landscape with patches of different successional stages and quality. Cassin's sparrows were most likely not associated with the intensely grazed habitats that the large herds of bison once created on the Great Plains grasslands (Knopf 1996). With the introduction of domestic cattle, and the subsequent reduction in native ungulate herds, this mosaic of structural diversity has been greatly reduced. Ideally, grazing management would replicate the natural grazing patterns, yet more often, livestock grazing practices favor homogenous patches of intensely grazed pasture. Direct effects of livestock grazing include changes in vegetation species composition and structure, vegetation height, density and percent cover, all main factors affecting habitat quality and ultimately the distribution and abundance of Cassin's sparrows. However, these effects can be complex, depending on grazing intensity, season, duration, and extent of the alteration to native vegetation. Therefore, livestock management, particularly grazing intensity, is an important factor affecting the distribution and abundance of Cassin's sparrows (Knopf 1996).

Although the effects of grazing intensity on Cassin's sparrows in Region 2 have not been studied directly, several studies in similar grassland habitats in Arizona have found that livestock grazing negatively influences habitat quality and Cassin's sparrow abundance. During a two-year study, Bock et al. (1984) found significant differences ($P < 0.001$) in vegetation and Cassin's sparrow habitat use between ungrazed and grazed plots. Ungrazed plots had higher percentages of grass cover (80.4 vs. 55.6 percent) and herbs (12.0 vs. 5.6 percent), lower percentages of bare ground (17.6 vs. 34.6 percent), and significantly higher total number of woody plants (37.6 vs. 9.5 plants per plot; $P < 0.001$). In addition, several woody plant species (*Baccharis pteronioides*, *Haplopappus tenuisectus*, and *Senecia douglasii*) were significantly taller and of a greater crown diameter than those found on grazed plots. Due to this species' preference for habitats dominated by grass interspersed with shrubs, Cassin's sparrows were completely absent from grazed plots during both summer and winter months. Bock and Bock (1988) extended the above study for another year to include additional plots, confirming that Cassin's sparrows avoided grazed sites with greater than 35 percent bare ground and less than a 6 percent shrub cover required for perching and skylarking. On the San Pedro Riparian National Conservation Area in Arizona, Cassin's sparrow densities increased at an annual rate of 2.42 birds per km between 1986 and 1990 after the removal of cattle in 1987 (Krueper et al. 2003). Although shrub densities within the riparian corridor and surrounding mesquite uplands did not show significant changes, herbaceous vegetation densities and heights increased dramatically. On semi-desert grasslands unique to Arizona and New Mexico, the habitat needs for Cassin's sparrow indicate that intense grazing would most likely have negative effects on the central shortgrass prairie as well.

Intense grazing pressure not only reduces habitat quality by causing changes in cover types and percentages, it often selects for annual grasses and leads to an increase in soil disturbance and an introduction of exotic plants, causing a complete shift in species composition over time. In addition, intense grazing practices encourage the eventual encroachment of shrubs, increasing densities beyond levels tolerated by Cassin's sparrow. Shifts in species composition and increases in shrub density often prompt the removal of all woody vegetation in order to increase forge and cattle production. Currently, there are no data on the amount of grassland and shrubland habitats that have undergone intense shrub removal efforts. However, continued clearing may contribute to a decrease in available habitat and abundance of Cassin's sparrows. In cases when growth of native grasses and sprouting of young mesquite and low bushes followed clearing, Oberholser (1974) reported that Cassin's sparrows had benefited. Unfortunately, current mechanical and chemical means of removal have become more efficient, resulting in the extirpation of all woody vegetation from the area and rendering it unsuitable to Cassin's sparrows. Thus, unlike some grassland sparrows and longspurs, Cassin's sparrows react negatively to heavy grazing practices, preferring lightly grazed or ungrazed grasslands (Sutton 1967, Bock and Webb 1984, Bock and Bock 1988).

Fire

Little is known about the historic role of fire on the shortgrass prairie and semi-arid grasslands. However, due to the slow recovery (two to four years) of native plant species on the western Great Plains during years of even normal precipitation (Wright and Bailey 1980, Bock and Bock 1992), fire was most likely a less frequent disturbance event than on the mixed-grass and tall-grass prairies of the eastern Great Plains (Weaver et al. 1996). Furthermore, the fact that Cassin's sparrows prefer areas with scattered shrubs implies that fire did not play a major role in maintaining grass vigor as it did in other regions of the Great Plains where shrubs are often absent from the landscape (Knopf. 1996). Today, human encroachment and development throughout grassland ecosystems have shifted the role of fire on these landscapes, and in some cases fire suppression in the West has lead to the conversion of grassland to shrubland (Wright and Bailey 1982, McPherson 1995).

Although the long-term influences of fire on Cassin's sparrows have not been studied, short-term data have found that post-fire habitats are generally unsuitable for Cassin's sparrows during the breeding season due to the immediate reduction or complete removal of grass and shrub cover. In 1987 and 1988, Bock and Bock (1992) studied the response of several species of birds to a prescribed fire in native and non-native grasslands in southeastern Arizona. Fire reduced grass and shrub cover on all sites and increased herbaceous growth. They found that during the breeding season Cassin's sparrows avoided burned sites with low grass cover for the first 2 years and unburned exotic grasslands during all years. Cassin's sparrow abundance was highest on unburned native grasslands sites and on burned sites in years with intermediate grass cover. Data collected by Aid (1990) from another post-fire study done in southeastern Arizona support these findings. He found that of a variety of species, the Cassin's sparrow exhibited the greatest prolonged aversion to burned sites, and fire had a significantly negative impact on Cassin's numbers.

However, infrequent fires often create a mosaic of habitat in a variety of successional stages. Although Cassin's sparrows may avoid the burned areas for several years post-fire, a mosaic would maintain the availability of suitable habitat at both a local and landscape level. Unfortunately, the long-term effects of prescribed burns on Cassin's sparrows are unknown; nonetheless, complete fire suppression or frequent wildfire may be detrimental to the conservation of this species.

Climatic conditions

Climatic changes, particularly changes in annual rainfall patterns, are an important factor attributing to fluctuations in the distribution of the Cassin's sparrow, yet causal factors are poorly understood. Due to the positive relationship between grassland productivity and summer rainfall (Cable 1975), changes in habitat characteristics may provide one reason for these fluctuations. Baumgartner and Baumgartner (1992) report that in Oklahoma, Cassin's sparrows increase in the eastern portion of their range during years of drought, when grass and vegetation heights are lower than normal, resulting in more suitable habitat. There have been reports of similar responses in Texas. Equally, areas that once contained suitable habitat may experience decreases in abundance of Cassin's sparrows with increases in precipitation. Changes in food availability may also be a factor in population fluctuations. Studies of the effects of weather indicate that precipitation levels are a main factor in stimulating increases in populations and infestations of grasshoppers and other insects, main prey items for Cassin's sparrows (Nernery 1961, Maurer 1985, Capinera and Horton 1989). Therefore, if a mosaic of habitat types is not available to buffer annual fluctuations in abundance, changes in climatic conditions may result in population declines in the Cassin's sparrow at local and regional scales.

Conservation Status of the Cassin's Sparrow in Region 2

Due to an overall declining trend in abundance in Region 2, the Cassin's sparrow is listed as a species of concern and/or priority species by several federal and state agencies. With 17 percent of the Cassin's sparrow population located within Region 2, there should be a high priority to conserve this species throughout the region. This need is validated by the BBS trend analysis presented in the Population trend section, which shows significant survey-wide declines in abundance. BBS data also indicate that Colorado as a whole and USFWS Region 6, which encompasses all of the USFS Region 2, have shown consistently large and significant declines over the past 35 years.

Life history traits for the Cassin's sparrow indicate that the species may be vulnerable to changes in vegetation cover type and shrub density caused by overgrazing and fire. The nomadic nature of this species suggests that it has evolved within a landscape mosaic of varying habitat types created by an irregular pattern of natural disturbance. Population declines for this species coincide with a departure from this necessary landscape matrix and the decline of available habitat (patches of open grasslands interspersed with shrubs). Causes of these declines, however, can be difficult to pinpoint.

Loss of suitable breeding habitat (shrub grasslands) to cropland, human development, and changes in species composition and habitat cover due to livestock grazing practices are all likely factors in Cassin's sparrow declines. Annual fluctuations in Cassin's sparrow populations may also result from local and region changes in precipitation levels, making it difficult to determine the response to different management regimes (e.g., grazing, restoration, prescribed fire). With approximately 70 percent of the land at the core of Cassin's sparrow range in private ownership and threatened by crop production and livestock activities, efforts to conserve viable populations on federal and state lands become even more crucial to the persistence of this species. Currently, only one of the three national grasslands within Cassin's sparrow breeding range in Region 2 has taken specific steps to ensure the conservation of this species. The Comanche National Grassland has selected the Cassin's sparrow to serve as a barometer for species viability as a

Management Indicator Species (MIS) and has developed guidelines that outline management needs and practices (Gillihan 1999). However, data on how management activities within Region 2 directly effect populations of Cassin's sparrow at multiple spatial and temporal scales are lacking. In addition, patterns of habitat use and subsequent inferences to habitat quality have been based on abundance indices and not on reproductive success, which may be misleading (Van Horne 1983). Without additional demographic information, linking cause and effect relationships between management, habitat quality, and species viability will be difficult. These answers are necessary for the development of sound management strategies that will reverse downward trends and stabilize existing populations.

Potential Management of the Cassin's Sparrow in Region 2

Implications and potential conservation elements

Difficulties in conserving Great Plains species stem from their irregular use of disjunct patches of changing habitat (Skagen and Knopf 1994). Due to continued loss and degradation of habitat from activities discussed above, management of remaining short and mixed-grass prairie habitat within Region 2 becomes increasingly important to Cassin's sparrows. Management activities alone or in combination with natural events can profoundly affect habitat suitability and Cassin's sparrow populations. Thus, future management practices and conservation efforts for Cassin's sparrows should focus on mimicking natural disturbance processes, and habitat distribution conserving and/or creating a landscape mosaic of grassland parcels ranging in different heights and densities throughout the breeding range. This would accommodate annual variability in precipitation and habitat quality caused by natural processes and human activities, and thus provide Cassin's sparrow populations with options for establishing breeding sites in any given year (Colorado Partners in Flight 2000). It would also ensure the availability of suitable breeding habitat to offset the negative effects of inevitable losses in habitat due to the continued increase in a variety of land development. However, proper management of these remaining, undeveloped tracks and multi-use areas is not always straightforward.

The Comanche and Cimarron national grasslands lie within the core of the Cassin's sparrow's range. Management activities that can greatly influence this species on these grasslands include grazing and fire prescription. Planning for these activities that consider habitat requirements and breeding biology of Cassin's sparrows can help to reverse downward population trends. For example, grazing systems and stocking rates on shortgrass and sandsage ecotypes can alter vegetation structure and species composition in ways that maintain and create suitable habitat for Cassin's sparrows. This can be achieved at both regional and local levels by implementing grazing regimes that consider the seral stages and range conditions, patch size, and current use of surrounding lands in order to replicate a natural landscape mosaic. Since both the Comanche and Cimarron national grasslands represent a fragmented ownership pattern, cooperation with adjacent land owners is crucial to the success of a management plan focused on the conservation of grassland birds. Since the majority of core breeding habitat is privately owned, cooperative partnerships between federal, state, and private land owners may prove to be one of the most important factors for the long-term population viability of this species in Region 2. The Comanche and Cimarron national grasslands are in a position to provide guidance and serve as a role model for surrounding landowners by maintaining ecological integrity and biodiversity while providing for multiple use activities.

One example of this type of cooperative effort is the Land Bird Conservation Plan produced by PIF. The plan calls for continued efforts to encourage funding opportunities for landowners through programs such as the Prairie Partners program created by the Rocky Mountain Bird Observatory. The Prairie Partners program is a cooperative and voluntary program working with private landowners, leaseholders, and land managers in the United States and Mexico to conserve shortgrass prairie and habitat-specific bird species. Strategies outlined to meet this goal include habitat monitoring and GIS mapping designed to track the quantity and quality of shortgrass prairie on private lands and to increase the number of landowners participating in the project. The Plan also mentions others conservation opportunities and incentive programs for landowners including the CRP, Conservation of Private Grazing Land and Voluntary Debt-for Nature Contract provisions of the 1996 Farm Bill, and U.S. Fish and Wildlife Service's Partners for Wildlife.

Tools and practices

Species inventory/population monitoring

Federal land managers are faced with the task of balancing multiple use activities while maintaining biological integrity. To help accomplish this task, agencies can monitor population trends of species and their response to management activities and then make the necessary adjustments to management plans. Since it is not often feasible to monitor all species, managers often select a suite of species to serve as indicators of responses to changed habitat conditions.

Birds are excellent indicators of ecosystem health and have been used to gain insight into the effects of influences on the physical and biological factors in many habitats, including grasslands. Since many species of birds are easily detected, are sensitive to changes in habitat, and have their population trends nationally monitored through the BBS, monitoring bird populations can also be cost-effective. By using standardized songbird inventory and monitoring protocols and analyses, researchers and managers can benefit from the existence of nationally standardized programs and protocols that provide repeatability and aide in interpretation of results (e.g., Ralph et al. 1995, Martin et al. 1997). Monitoring results can then be related to habitat characteristics and changes in those characteristics, and evaluated at multiple spatial and temporal scales. This provides a better understanding of the causes for population changes and helps in identifying and testing management actions.

Forest and regional level population monitoring programs should apply an integrated approach, including both simple count-based inventory, as well as a more in-depth demographic study (Marzluff et al. 1994). This will ensure that management decisions are based upon a solid foundation, enabling managers to identify and prioritize potential management strategies necessary to conserve Cassin's sparrow populations in Region 2.

Species inventory methods are most often used to spatially and temporally monitor population trends, based on the relative abundance and distribution of a species. Two main methods are used: 1) index counts, which use bird detection data as an index of relative abundance, and 2) model based techniques, which use the probability of detection for each species to estimate density (Rosenstock et al. 2002). Index counts include variations of point count methods, which have been extensively used in bird studies in multiple habitats and geographic regions (Martin and Geupel 1993, Ralph et al. 1995, Hutto and Young 1999). However, the biases and limitations of index-counting procedures have undergone extensive debate, and overwhelming criticism of this method has increased the use and acceptance of model-based distance sampling techniques. The main criticism of index counts centers on the fact that they rely on assumptions concerning detectability that may be difficult or impossible to meet in most field studies (Rosenstock et al. 2002). The primary assumption is that each detection represents a constant proportion of actual numbers present across space in time. However, detectability of each bird may vary depending upon observer ability, training, and experience, weather conditions, and bird behavior and physical appearance. All of these factors will introduce bias and reduce the validity of the data. Further discussion on the pros and cons of each method can be found in Rosenstock et al. (2002) and Hutto and Young (2002).

The most well known inventory and monitoring database, North American Breeding Bird Surveys (Robbins et al. 1986, Peterjohn and Sauer 1999) and the Christmas Bird Counts (Root 1988), can provide information on the distribution and population trends of birds across a large geographic area, but they may not be adequate for determining population changes at subregional and local scales. For example, in Colorado, BBS data are only able to adequately monitor 23 percent of the state's bird species (Colorado Partners in Flight 2000). The BBS monitoring program uses index-count methods as described above. Surveys are based on road networks that may limit the ability to sample population distributions and to estimate abundance over the matrix of available landscapes (Anderson et al. 2000), even though the internal bias due to presence of dirt-tracked or little used roads on bird counts in grassland habitats may not be significant. As mentioned above, the BBS and other large-scale surveys have come under increasing criticism because of their inability to estimate biases in the detectability of birds and the subsequent failure to incorporate differential detectability into trend analyses. Thus, in order to provide reliable information, it is recommended that some form of detectability sampling methods be employed at a forest and regional level specific to Region 2.

Some avian ecologists propose that detectability-based techniques deserve wider application (e.g., Fancy and Sauer 2000, Rosenstock et al. 2002), and many monitoring programs, including those on some National Forest System lands, have recently adopted distance sampling for long-term monitoring of songbirds (e.g., the National Park Service, Utah Division of Wildlife, Monitoring Colorado's Birds). Distance sampling can be easily incorporated into current index count-based programs and provides a more robust sampling method. Methods are similar to point or line-transect surveys commonly used with index counts, but perpendicular distances for each detection are recorded. Distances are then analyzed using the program DISTANCE (Buckland et al. 1993), and density estimates as a function of detectability are calculated.

The Monitoring Colorado's Birds project provides a comprehensive protocol for inventorying Cassin's sparrows using line-transect and distance-sampling methods (Leukering et al. 2001). This method is currently used to monitor grassland songbirds in Colorado, and Cassin's sparrows are likely to be detected in the early spring when singing and skylarking is most fervent. In addition, these methods are also used in statewide bird monitoring programs in Wyoming, Montana, and New Mexico, and on several national forests (San Juan National Forest – year 3, Black Hills National Forest – year 4, Bighorn National Forest – year 2, and Shoshone National Forest – year 2). By using a widely accepted and standardized monitoring protocol, results will be comparable to these statewide and national forest surveys, while providing additional credibility to future forest activities.

Other methods that consider detectability include the double-observer method and double sampling. Double-observer methods use two observers simultaneously detecting birds at each survey point and then calculate a detection rate, assuming independence among observers (Nichols et al. 2000). The double-sampling method is similar to index-count methodology but includes a second more intense count. This second count, which is a random sub-sample of the first, is used as a correction factor of the first (Bart and Earnst 2000). This method of inventory and monitoring, however, is not as robust as distance sampling, since it assumes that all birds are counted within the sub-sample of units.

Few studies present demographic data for the Cassin's sparrow. Demographic monitoring provides insight into the reason for changes in abundance and may help to explain population trends. Ralph et al. (1993) and Martin et al. (1997) have outlined standardized protocol for nest-searching and monitoring, and mist-netting and color-banding breeding birds to collect demographic data. Additional productivity and survivorship data can then be used to develop a more comprehensive model for the Cassin's sparrow and assist in the identification and evaluation of current management and the long-term viability of the species.

Habitat inventory and monitoring

Integrating population trend and demographic monitoring, and relating them to habitat characteristics across the landscape, is critical for determining the causes of population changes of Cassin's sparrows. Therefore, these activities should be conducted concurrently with habitat inventory and monitoring. Vegetation and habitat should be characterized at multiple spatial scales and measurements of both horizontal and vertical structure should be taken in areas where sparrows are detected and where they are not. Emphasis should be placed on monitoring variables that are of potential biological importance (i.e., grass cover and height, shrub density, prevalence of exotic grasses) for Cassin's sparrows. Habitat measurements can be coupled with bird inventories to establish species habitat selection within the area of concern. This information can be used as baseline information in subsequent monitoring of long-term avian population trends and the effects of land use and management actions. Additional details for vegetation sampling and analysis can be found in Young and Hutto (2002) and BBIRD protocols (Martin et al. 1997).

Habitat management

Management of a particular site for Cassin's sparrows will depend on site potential. Nonetheless, the following are suggested goals for achieving the desired conditions for this species; these suggestions are taken in part from Best Management Practices for Comanche National Grassland and PIF Bird Conservation Plans for Colorado, Arizona, and New Mexico.

Overall, Cassin's sparrows are associated with grassland habitats that provide a mixture of shortgrass and midgrass (40 to 80 percent total cover), bare ground (20 to 30 percent), and scattered shrubs (6 to 60 percent). Negative associations have been found with habitats containing high densities of mesquite trees or other shrubs and low grass cover (Maurer 1986). Therefore, management and natural events that encourage the encroachment of dense shrubs (>60 percent cover) (e.g., livestock grazing, fire suppression) or produces pure grassland habitats (e.g., shrub removal, high intensity fire) would be detrimental to Cassin's sparrow populations. Although minimal patch size requirements and density estimates for Cassin's sparrow are unclear, it has been suggested that managers maintain numerous parcels consisting of 30 to 100 ha tracts of suitable shrub grassland habitat to sustain viable populations. More specifically, PIF Bird Conservation Plans for each state recommend maintaining 250 blocks (16 ha each) of high to moderate quality mixed grass and shrubs distributed throughout 4045 ha blocks of contiguous grassland to provide suitable breeding habitat. Within each 16 ha block, they suggest a minimum of 2 ha blocks of dense *Grama* spp. and bunchgrasses. With the exception of the Best Management Practices developed for Cassin's sparrows on the Comanche National Grassland, current management in Region 2 of activities such as grazing or prescribed fire does not specifically address the habitat requirements necessary for the conservation of the Cassin's sparrow.

At a landscape level, long-term conservation of the Cassin's sparrow depends on the conservation of our remaining grasslands and the proper management of those currently under federal and state ownership. Management recommendations for mixed-grass and shortgrass prairies focus on maintaining species diversity and providing a mosaic of grassland habitats. Land managers may wish to incorporate the following suggestions/approaches when developing a management plan that includes conservation measures for Cassin's sparrow and its associated habitats:

1. Create a heterogeneous landscape mosaic of habitat using livestock, prescribed burns, and other tools so that breeding birds are always offered a patchwork of grassland parcels 50 ha (125 acres) each, in a variety of structural stages and with varying amounts of forbs and shrubs.

2. Reduce habitat fragmentation by managing parcels with a minimum patch size of 50 ha, shaped to maximize the core interior and to minimize the edge.

3. Provide a diversity of grazing regimes on a rotational schedule to create a mosaic of vegetation structure. This will depend on the characteristics of the region. For example, areas that receive more precipitation and consist of larger proportions of tall grass can most likely handle, and may indeed need, more moderate to heavy grazing intensities; on the other hand, arid grasslands consisting of short, sparse grasses may require alternate grazing regimes or very light use.

4. Limit agriculture activities such as plowing, haying, or burning to early spring or fall to avoid disturbances during the nesting season.

5. Apply integrated pest management practices, including alternatives to chemical control of grasshoppers and other insects since chemical control could reduce the food base for insectivorous birds. If pesticide use is necessary, postpone applications until after the young have fledged.

6. If prescribed burns are used, rotate burned plots, leaving numerous unburned plots available for breeding Cassin's sparrows.

7. Encourage private landowners to seed CRP lands in native grasses.

8. Implement monitoring programs in order to track the distribution, population trends, and abundance of Cassin's sparrows and their habitat at a regional and local level, using techniques described in the Tools and practices section.

9. Most importantly, develop partnerships with adjoining public and private land managers, encouraging them to create, maintain, or restore shortgrass prairie habitats on their properties and to work jointly in the conservation of grassland bird species.

Finally, defining additional management strategies is difficult without continued research focused on a full understanding of the biology and ecology of the species and how management activities affect populations. There still are considerable gaps in our knowledge of the long-term effects of grazing strategies, prescription burns, and encroachment of exotic vegetation on Cassin's sparrow populations in Region 2.

Information Needs

The Cassin's sparrow, an endemic grassland species, has shown consistent declines in population trends throughout Region 2. However, there are large gaps that hinder our understanding of the species. Thus, furthering our knowledge of the biology and ecology of the species and its relationship to habitat characteristics is critical in determining the causes in population changes and in identifying, as well as testing, management actions and conservation strategies to reverse population declines.

Basic life history and ecology information is lacking for the Cassin's sparrow. Few studies present demographic data such as adult and juvenile dispersal and survivorship and nesting and hatching success. Even fewer address the limiting factors that may affect these parameters (e.g., food availability, climate, predator/ prey relationships). Furthermore, habitat relationships have been poorly studied in Region 2. Unfortunately the data appear insufficient to determine the minimum patch size needed for breeding and to assess reasonable functions governing density dependence. These are necessary to develop effective management plans designed to protect and restore suitable Cassin's sparrow habitat. There is also a paucity of studies and records concerning predators for Cassin's sparrows. Changes in habitat use in relation to specific predators are unknown as are the effects of fragmentation and habitat patch characteristics on changes in predation rates and/or nesting success.

As mentioned in the previous section, monitoring efforts in conjunction with assessments of the habitats associated with Cassin's sparrows are needed to provide insights into the ecological correlates of declining or increasing populations. Although the BBS provide large-scale trend data, they may not be adequate for land managers who are developing management plans for smaller areas that will influence local populations of breeding Cassin's sparrows. Therefore, site-specific inventory and monitoring programs such as those mentioned in the Tools and practices section may be necessary.

Many have observed that the distribution and abundance of Cassin's sparrows are closely related to annual fluctuations in precipitation levels, but causal factors are unclear. Long-term studies relating the changes in precipitation levels, vegetation, and food availability with local and regional Cassin's sparrow population fluctuations would provide valuable information.

There also is a need for information on the response to different management activities and techniques specific to Region 2. We do not have a full understanding of how habitat suitability, and ultimately distribution and abundance of Cassin's sparrows, is affected by grazing pressure, fire frequency, and human disturbances. These activities may lead to habitat fragmentation and degradation. Thus, studies on the effects of fragmentation, edge effect, and distance between patches would benefit managers in understanding the implications of such activities and land-use practices.

Studies on livestock grazing have mostly taken place on semi-desert grasslands in southeastern Arizona; these grasslands may be more susceptible to grazing impacts than areas in Region 2, where the climate is less arid. Thus, comparative studies are required to determine if Cassin's sparrows respond differently to grazing pressure. Intensities of grazing that may create or maintain suitable habitat for Cassin's sparrows in Arizona may destroy similar habitat in Colorado. Furthermore, research on habitat relationships is generally limited to two or three years, often due to funding constraints. However, since Cassin's sparrow populations may show large fluctuations in abundance from year to year, especially along the periphery of the breeding range, data from these studies may be misleading. Long-term studies on the effects of grazing and other management activities increase our chances of finding patterns in population changes associated with these changes in habitat and are vital to the future conservation of the species.

Although the Cassin's sparrow spends most of its life cycle in migration and on wintering grounds in the southern portion of its breeding range, south of Region 2, we know very little about its winter ecology and the limiting factors that effect population changes during that time. Like many other migrant passerines, factors such as post-fledging and adult mortality that regulate breeding populations of Cassin's sparrow may be occurring during migration or on wintering grounds. In addition, information gaps exist concerning the winter breeding ecology and habitat use of Cassin's sparrow, as well as the distribution and abundance of the species in Mexico.

Research priorities in Region 2

The Colorado PIF Bird Conservation Plan (2000) outlines six research priorities for the central shortgrass prairie: (1) the interplay of precipitation, habitat condition, and population distributions at the landscape level; (2) the effects of prescribed burning on bird populations; (3) the effects of different grazing regimes; (4) identification of key migratory stopover and wintering areas; (5) effects of prairie dog hunting and sport hunting on bird populations, and; (6) patch-size effects and area sensitivity of shortgrass prairie birds. Additionally, the impacts of new construction for gas and oil exploration, wind-power development, and water well drilling should be investigated. Best Management Practices for the Comanche National Grasslands provides the following research priorities for Cassin's sparrow: (1) quantify nesting habitat conditions at different spatial scales: nest site (10 m radius; 33 ft), within-territory (250 m radius; 275 yd), and landscape (1 km radius; 1.6 mi). Features measured should include amount and type of grass, forb, shrub, and bare ground covers, and average size of contiguous patches. This could be accomplished with intensive nest searches followed by on-site habitat measurements for the smallest scale, and GIS analysis for the larger scales; (2) map nest sites annually, and compare nest densities and habitat measurements (vegetation and prey, especially grasshoppers) among all occupied and unoccupied breeding sites to clarify the reasons for this species' shifting breeding grounds; and (3) monitor nest success in response to different management regimes (grazing, prescribed fire) in order to arrive at the practices most acceptable to this species.

DEFINITIONS

Bird Conservation Regions – ecologically distinct regions in North America with similar bird communities, habitats, and resource management issues within which bird conservation efforts are planned and evaluated, as endorsed by the North American Bird Conservation Initiative (2000).

Physiographic Area – Partners in Flight planning units defined on the basis of biotic communities and bird distribution; used in bird conservation planning.

Physiographic Strata – Breeding Bird Survey regional areas defined on the basis of similar vegetation, soil, and physiographic features and used in the analysis of bird species' population trends and relative abundance.

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