Studies in Avian Biology No. 15:173–190, 1994.

POPULATION TRENDS IN THE LANDBIRDS OF WESTERN NORTH AMERICA

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Abstract. We examined avifaunal literature of the states and provinces of western North America to gather evidence of population changes in landbirds over the past 100 years, and we analyzed population trend ranks (PTRs) developed by Carter and Barker for migratory landbirds from 26 years of North American Breeding Bird Survey (BBS) data for western states. We identified 75 native landbird species whose breeding populations decreased substantially in at least one state or province in the past 100 years and 65 species that increased. Destruction of riparian habitat, destruction of grasslands, shooting, overgrazing, logging and clearing of forests, and cowbird parasitism were the major factors responsible for the decreases, while increased agricultural, suburban, and urban development and irrigation were the major factors responsible for the increases. We identified 58 species of migratory landbirds that showed decreasing population trends in either the past 26 or past 13 years, 44 species that showed increasing trends, and 35 species that showed no trends. Significantly more short-distance migrants decreased during the past 26 years than increased ($P < 0.001$) but no such relationship existed for long-distance migrants, which generally showed fewer and smaller decreasing trends and more increasing trends than short-distance migrants. Populations of most short- and long-distance migrants generally fared better during the past 13 years than during the past 26 years. Our results qualitatively agree with other analyses of BBS data that do not include information on the magnitude or uncertainty of the population trends, but quantitatively tend to show more and stronger negative trends. Finally, we discuss limitations of BBS data and suggest key elements for an integrated population monitoring system for western landbirds.

Key Words: Population trends; landbirds; western North America; BBS.

The Centennial Year of the Cooper Ornithological Society, 1993, marks the milestone of 100 years of organized study of birds in western North America. As such, it is a fitting time to review what is known of the population changes in the landbirds of western North America, particularly in light of the extensive human-caused environmental changes that have occurred over the past century. Moreover, attention has been focused recently on populations of Neotropical migratory landbirds that appear to be declining, at least in eastern North America (Robbins et al. 1989, Terborgh 1989, Askins et al. 1990). The Neotropical Migratory Bird Conservation Program, "Partners in Flight," was established in 1991 to reverse these apparent population declines. Many federal and state agencies and private organizations have become involved with this program and are committed to its goal.

In this paper, western North America is defined as all states west of Montana, Wyoming, Colorado, and New Mexico inclusive, along with Alberta, British Columbia, Yukon Territory, and Alaska. This area thus includes all of continental North America west of and including the Rocky Mountains (except for the mountains of western Texas and a portion of the Black Hills of South Dakota and Nebraska), along with the western edge of the Great Plains.

Despite the fact that this huge area includes much of the least populated portions of North America, the human-caused environmental changes wrought on this region have been enormous. Most of the watersheds have been dammed, diverted, or otherwise managed; most of the grasslands and even much of the forests, scrublands, and deserts have been grazed (or overgrazed) by cattle, sheep, and horses, and a great proportion of the native perennial grasses has been replaced by introduced annuals; virtually all of the forests have been harvested at least once and most have undergone many years of attempted fire suppression; and the

natural habitats of the valleys and surrounding hills of many areas have been converted to agriculture, industry, and housing.

Two basic types of avifaunal changes could accompany these human-induced environmental changes. First are population changes in which the numbers of birds of any given species increase or decrease during the breeding season, nonbreeding season, or migration periods; second are distribution (range or habitat) changes in which species appear or disappear from certain areas or habitats. Both types are intimately related: when population size for a given species in a given area decreases to (or increases from) zero, a distributional change has taken place. Despite this inter-relatedness, the two types of changes do not always occur in parallel. It is possible, for example, for a species to be undergoing major population declines over much of its range and still be expanding its range elsewhere.

Here we concentrate on population changes in western landbirds, especially those changes that may be anthropogenically caused. Distributional changes in western landbirds, particularly those caused by "natural" climatic changes, are the focus of a paper by Johnson (1994). Population changes were assessed by two methods. First, we perused the avifaunal literature for general evidence of population changes over the past 100 years. Second, for quantitative evidence, we analyzed population trend ranks developed by Carter and Barker (1993) from 26 years of data from the North American Breeding Bird Survey (BBS) (Robbins et al. 1986) and compared our results to those obtained recently by Sauer and Droege (1992) and Peterjohn and Sauer (1993). We discuss these population changes in terms of their possible causes, general population dynamic considerations, and the adequacy of the data. Finally, we suggest key elements for an integrated population monitoring scheme for western landbirds.

METHODS

We reviewed major state-level literature on the distribution and abundance of birds in western North America for evidence of population changes in landbirds (Gabrielson and Jewett 1940, Grinnell and Miller 1944, Munro and McTaggert-Cowan 1947, Jewett et al. 1953, Gabrielson and Lincoln 1959, Ligon 1961, Phillips et al. 1964, Bailey and Niedrach 1967, Burleigh 1971, Behle and Perry 1975, Salt and Salt 1976, Alcorn 1988, Campbell et al. 1990). In general, these sources provided information on landbird population changes only when the distribution of a given species expanded or contracted over a substantial portion of the state or when population changes were so pronounced as to command attention. Very little mention was made of more subtle population trends, simply because no quantitative data existed from which such trends could be extrapolated. We also compared abundance designations provided by these sources with those compiled by DeSante and Pyle (1986) for each state and province for additional evidence of population changes, as well as the USFWS list of species of management concern (Office of Migratory Bird Management 1987).

The BBS, begun in 1965 (1968 in western North America), is the only quantitative source of information regarding regional changes in the breeding populations of western landbirds. The BBS consists of more than 2000 randomly located permanent survey routes established along secondary roads throughout the continental United States and southern Canada that are surveyed annually during the height of the breeding season, usually in June (Robbins et al. 1986). Each route is 39.4 km long and consists of 50 stops spaced at 0.8-km intervals. Observers start 0.5 hr before local sunrise and at each stop count all birds detected within a 0.4-km radius circle during a 3-min period. For each species, the total number of individuals recorded at all stops along the route is used as an index of relative abundance. Long-term population trends for each of about 370 species are provided by the BBS for every state and province in North America by a route-regression method. Route trends are estimated using a linear

regression of the log-transformed counts on year, with observer data included as covariables. The slope of the year variable, when back-transformed, provides the estimate of route trend for a species. Regional trends are estimated from weighted averages of the route trends (Sauer and Droege 1992, Peterjohn and Sauer 1993).

Using these population trend data, Carter and Barker (1993) derived a population trend rank (PTR) and population trend uncertainty rank (PTUR) for each migratory landbird species in each of the 11 western states. The PTUR was based on the number of routes in a state on which a species was recorded, the number of routes with a statistically significant trend for the species, and the proportion of routes with trends that agreed with the overall state trend for the species. The PTR was based upon the magnitude and direction of the trend and the associated PTUR. Carter and Barker's PTR indices are as follows: 1 = definite increase—moderate increase (>1% but <5% annually) with very low uncertainty, or large increase (>5% annually) with low or very low uncertainty; 2 = increasing trend—small increase (<1% annually) with low or very low uncertainty, moderate increase with moderate or low uncertainty, or large increase with moderate uncertainty; 3 = trend unknown—small increase or decrease (<1% annually) with moderate uncertainty or any increase or decrease with high uncertainty; 4 = decreasing trend—small decrease with low or very low uncertainty, moderate decrease (>1% but <5% annually) with moderate or low uncertainty, or large decrease (>5% annually) with moderate uncertainty; and 5 = definite decrease—moderate decrease with very low uncertainty or large decrease with low or very low uncertainty. Carter and Barker calculated these PTRs separately for the entire 26-year period that the BBS has been in operation (1966–1991; actually only 1968–1991 in western North America) and for the most recent 13 years (1979–1991).

We examined Carter and Barker's PTRs and identified those species that exhibited consistently decreasing (more than 50% of the states for which data were sufficient to calculate trends showed decreasing trends or definite decreases, and no more than 25% of the states showed increasing trends or definite increases) or increasing (vice versa) trends in either time period. We then examined these lists for overall patterns with regard to the migratory status of the species. Because the data from the 13-year period are included within the 26-year data set, the two data sets are not independent. Thus, it is invalid to use inferential statistics to analyze differences in trends between these periods (Sauer and Droege 1992). Therefore, we compared the trends between the 26-year and 13-year periods in a qualitative manner to determine whether or not there were consistent changes between the two periods. Finally, we compared these results to other analyses of BBS data and to other data sets and to the general historical information that we assembled.

RESULTS

A review of the major state-level avifaunal literature produced a list of 75 native landbird species whose breeding populations were known to have decreased substantially in at least one state or province in western North America in the past 100 years (Table 1; see Appendix for scientific names). Although these species were nearly equally divided between passerines (41, 55%) and non-passerines (34, 45%), the most severe and widespread declines were generally among the larger non-passerine species, particularly various grouse (especially grassland species), Yellow-billed Cuckoo, and Burrowing Owl. Except for (Masked) Northern Bobwhite in Arizona, these were the only landbird species to have been extirpated from any of the western states or provinces. Shooting was a major contributor to the decline of some of these larger non-passerines, although habitat loss and overgrazing were probably more important and pervasive factors. Some of these species have mostly recovered or at least stabilized since shooting was regulated earlier in this

TABLE 1. NATIVE SPECIES OF LANDBIRDS KNOWN TO HAVE DECREASED IN WESTERN NORTH AMERICA OVER THE PAST 100 YEARS, STATES (OR PROVINCES) WHERE THEY HAVE DECREASED, AND PROBABLE CAUSES FOR THEIR DECREASES. UNDERLINED STATES (OR PROVINCES) ARE AREAS WHERE MAJOR DECREASES (>50% POPULATION DECLINES) HAVE OCCURRED; * = EXTIRPATED

Species	Where decreased	Probable causes
Spruce Grouse	AK AB WA	Shooting, clearing of forests
Blue Grouse	BC WA OR CA NV ID CO AZ NM	Shooting, clearing of forests
White-tailed Ptarmigan	WY NM	Unknown
Ruffed Grouse	WA OR CA	Shooting
Sage Grouse	BC* AB WA OR CA NV ID MT UT NM*	Shooting, overgrazing, destruction of grasslands
Greater Prairie-Chicken	AB* MT* CO	Shooting, destruction of grasslands
Lesser Prairie-Chicken	CO NM	Shooting, destruction of grasslands
Sharp-tailed Grouse	AK BC AB WA OR* CA* NV* ID MT WY UT CO NM*	Shooting, overgrazing, destruction of grasslands
Wild Turkey	CO AZ NM	Shooting
Montezuma Quail	AZ NM	Overgrazing
Northern Bobwhite	WY AZ* NM	Overgrazing, hunting
Scaled Quail	AZ NM	Overgrazing, destruction of grassland
California Quail	CA	Shooting (essentially recovered at present)
Mountain Quail	CA	Shooting (mostly recovered at present)
Band-tailed Pigeon	WA OR CA	Shooting (mostly recovered at present)
Yellow-billed Cuckoo	BC* WA* OR* CA NV ID UT AZ	Destruction of riparian habitat
Greater Roadrunner	CA	Agricultural development, urbanization
Northern Hawk-Owl	AB	Clearing of forests
Ferruginous Pygmy-Owl	AZ	Destruction of riparian habitat
Elf Owl	CA	Destruction of riparian habitat
Burrowing Owl	BC AB* CA NV ID MT CO AZ NM	Destruction of grasslands, elimination of fossorial mammals, agricultural development, urbanization
Spotted Owl	BC CA AZ	Logging, particularly of old-growth forests
Long-eared Owl	CA NV	Destruction of riparian habitat
Short-eared Owl	CA NM	Destruction of grasslands
Lesser Nighthawk	NM	Pesticide use?
Common Nighthawk	AB	Pesticide use?
White-throated Swift	CA AZ	Unknown
White-eared Hummingbird	AZ	Unknown
Belted Kingfisher	OR CA AZ	Shooting by fisherman (entirely recovered at present)
Lewis' Woodpecker	BC OR CA UT	Cutting of old oak woodlands and snags, competition with starlings
Gila Woodpecker	CA	Destruction of riparian habitat
Ladder-backed Woodpecker	AZ	Unknown (destruction of mesquite woodlands?)
Northern (Gilded) Flicker	CA AZ	Destruction of riparian habitat
Pileated Woodpecker	CA	Logging (partially recovered because of increasing adaptation to second-growth forests)
Olive-sided Flycatcher	CA	Destruction of wintering habitat?
Willow Flycatcher	CA AZ	Destruction of riparian habitat, cowbird parasitism
Buff-breasted Flycatcher	AZ	Overgrazing of woodland habitat
Vermillion Flycatcher	CA NV	Destruction of riparian habitat
Cassin's Kingbird	CA	Unknown
Horned Lark	AZ	Destruction of grasslands
Purple Martin	WA OR CA AZ	Competition with starlings, snag removal (some increases recorded early in the century)

TABLE 1. CONTINUED

Species	Where decreased	Probable causes
Bank Swallow	CA	Channelization and bank stabilization of rivers
Chihuahuan Raven	CO	Unknown
Common Raven	OR CA	Unknown (local reductions, now increasing?)
Cactus Wren	CA	Urbanization
California Gnatcatcher	CA	Urbanization
Western Bluebird	NV AZ	Competition with starlings, overgrazing of woodland habitat
Mountain Bluebird	AB NV	Competition with starlings
Crissal Thrasher	CA	Destruction of riparian mesquite habitat
LeConte's Thrasher	CA AZ	Loss of habitat to agriculture?
Sprague's Pipit	AB	Destruction of grasslands
Loggerhead Shrike	CA	Pesticides?
Bell's Vireo	CA AZ	Cowbird parasitism, destruction of riparian habitat
Gray Vireo	CA AZ	Cowbird parasitism?
Lucy's Warbler	CA AZ	Destruction of riparian mesquite habitat
Yellow Warbler	OR CA AZ	Cowbird parasitism, destruction of riparian habitat
Common Yellowthroat	CA AZ	Drainage of marshes and loss of riparian habitat, cowbird parasitism?
Yellow-breasted Chat	CA NV	Destruction of riparian habitat, cowbird parasitism?
Summer Tanager	CA AZ	Destruction of riparian habitat
Lazuli Bunting	UT	Unknown
Painted Bunting	AZ	Unknown
Dickcissel	AZ	Degradation of wintering habitat?
Botteri's Sparrow	AZ	Overgrazing, destruction of grasslands
Rufous-winged Sparrow	AZ	Overgrazing
Chipping Sparrow	BC WA OR	Unknown (cowbird parasitism?)
Vesper Sparrow	WA OR	Destruction of grasslands?
Black-throated Sparrow	NV	Unknown
Lark Bunting	CA NV	Destruction of grasslands
Baird's Sparrow	AB AZ	Destruction of grasslands
Grasshopper Sparrow	BC WA NV UT CO	Unknown
Song Sparrow	AZ	Destruction of marshes and riparian habitat
McCown's Longspur	AB AZ NM	Destruction of grasslands
Chestnut-collared Longspur	AB AZ NM	Destruction of grasslands
Tricolored Blackbird	CA	Drainage of marshes, pesticides?
Yellow-headed Blackbird	CA	Drainage of marshes

century, although Burrowing Owls and grassland grouse continue to decline and Yellow-billed Cuckoos only persist in very small numbers.

Destruction of riparian habitat was implicated as a cause of decline for the largest number of species (16); destruction of grassland habitat was a close second (15 species), followed by shooting (13), overgrazing (9), logging and clearing of forests (7), cowbird parasitism (7), destruction of marshes (4), urbanization (4), competition with starlings for nest holes (4), possible pesticide use (4), possible degradation of tropical wintering habitat (2), agricultural development of desert habitat (2), streambank channelization and stabilization (1), and elimination of fossorial mammals (1). Permanent resident species comprised the largest proportion (38.7%) of the 75 decreasing species, followed by short-distance (32.0%) and long-distance (29.3%) migrants.

A list of 65 landbird species whose breeding populations were known to have in-

TABLE 2. SPECIES OF LANDBIRDS KNOWN TO HAVE INCREASED IN WESTERN NORTH AMERICA OVER THE PAST 100 YEARS, STATES (OR PROVINCES) WHERE THEY HAVE INCREASED, AND PROBABLE CAUSES FOR THEIR INCREASES. UNDERLINED STATES (OR PROVINCES) ARE AREAS WHERE MAJOR INCREASES (>50% POPULATION INCREASES) HAVE OCCURRED

Species	Where increased	Probable causes
Rock Dove	BC AB WA OR CA NV ID MT WY UT CO AZ NM	Range expansion, urbanization, agricultural practices, development
Band-tailed Pigeon	BC	Northward range expansion
Mourning Dove	BC WA OR	Clearing of forests, agricultural practices, urbanization
Inca Dove	NV AZ NM	Urbanization, range expansion
Common Ground-Dove	CA AZ	Agricultural practices, irrigation
Barn Owl	BC CA	Agriculture, increased nesting sites, range expansion
Western Screech-Owl	CA	Logging, settlement of grassland (recent decreases have occurred)
Barred Owl	BC WA OR CA ID	Westward and southward range expansion
Whip-poor-will	CA NV UT	Northward range expansion
White-throated Swift	BC OR	Range expansion
Berylline Hummingbird	AZ	Northward range expansion
Violet-crowned Hummingbird	AZ	Northward range expansion
Magnificent Hummingbird	CO	Northward range expansion
Black-chinned Hummingbird	BC	Flower gardens and feeders
Anna's Hummingbird	BC WA OR CA	Flower gardens and feeders
Allen's Hummingbird	CA	Flower gardens and feeders
Red-headed Woodpecker	NM	Westward range expansion (following telephone poles?)
Williamson's Sapsucker	BC	Westward range expansion
Hammond's Flycatcher	AK	Northward range expansion
Black Phoebe	NM	Agricultural practices, irrigation
Brown-crested Flycatcher	NV UT	Northward range expansion
Tropical Kingbird	AZ	Northward range expansion
Thick-billed Kingbird	AZ	Northward range expansion
Western Kingbird	WA	Settlement of grasslands
Scissor-tailed Flycatcher	NM	Settlement of grasslands
Rose-throated Becard	AZ	Northward range expansion
Cliff Swallow	AK AB WA OR CA	Increased nesting sites
Cave Swallow	AZ NM	Northward range expansion, increased nesting sites
Barn Swallow	AK AB WA OR CA	Increased nesting sites
Blue Jay	MT WY CO	Westward range expansion
Black-billed Magpie	AK AB	Range expansion following development
American Crow	AB WA OR CA NV NM	Increased agriculture and urbanization
Common Raven	AK AB	Range expansion following development
Verdin	AZ	Increase in brushlands
Bushtit	BC CA	Increased development and urbanization
White-breasted Nuthatch	AB	Northward range expansion
American Robin	CA	Increased development and urbanization
Northern Mockingbird	AB OR CA NV	Increased development and urbanization, northward range expansion
Brown Thrasher	AB	Northward range expansion
Bendire's Thrasher	AZ	Agricultural practices and development
Curve-billed Thrasher	AZ	Development and urbanization
White Wagtail	AK	Range expansion
American Pipit	CA NV	Westward range expansion
European Starling	AK BC AB WA OR CA NV ID MT WY UT CO AZ NM	Range expansion, agricultural practices, development, urbanization
Warbling Vireo	BC AB WA OR	Increased adaptation to towns
Townsend's Warbler	OR	Unknown
Grace's Warbler	NV CO	Northward range expansion
Red-faced Warbler	AZ	Northward range expansion

TABLE 2. CONTINUED

Species	Where increased	Probable causes
Painted Redstart	NV	Northward range expansion
Hepatic Tanager	CA NV	Northward range expansion
Northern Cardinal	AZ	Range expansion
Indigo Bunting	AZ	Range expansion
California Towhee	CA	Development and urbanization
Song Sparrow	CA	Agricultural practices (irrigation)
Bobolink	AB WA OR CA	Westward range expansion, agricultural practices, irrigation (more recently, numbers have decreased)
Red-winged Blackbird	CA	Agricultural practices, irrigation
Western Meadowlark	AB WA OR CA	Agricultural practices, irrigation
Brewer's Blackbird	CA	Development, urbanization
Great-tailed Grackle	CA NV UT CO AZ NM	Range expansion, agricultural practices, development
Bronzed Cowbird	AZ	Range expansion, livestock, agricultural practices
Brown-headed Cowbird	BC WA OR CA NV AZ	Livestock, agricultural practices, range expansion
Hooded Oriole	CA AZ	Planting of palm trees, urbanization, range expansion
House Finch	BC AB WA OR CA	Development, urbanization, agricultural practices
American Goldfinch	WA	Development, spread of agriculture
House Sparrow	BC AB WA OR CA NV ID MT WY UT CO AZ NM	Range expansion, urbanization, agricultural practices, development

creased substantially in at least one state or province in western North America in the past 100 years is presented in Table 2. In contrast to the decreasing species, the majority (47, 72%) were passerines; moreover, six of the 18 increasing non-passerine species were hummingbirds. The most frequent cause for population increase was range expansion (38 species), particularly northward range expansion (18 species; see also Johnson 1994).

Increased agriculture was implicated as a cause for the next largest number of increasing species (17), followed by increased development (14), urbanization (14), irrigation (5), increases in nesting sites (4), settlement of grassland (3), flower gardens and hummingbird feeders (3), clearing of trees (2), livestock practices (2), increases in brushland (1), planting of palm trees (1), and adaptation to towns (1). Three introduced species that arrived by range expansion from the east, Rock Dove, European Starling, and House Sparrow, showed the largest and most widespread increases. The next largest and most widespread increases were shown by American Crow, Great-tailed Grackle, Brown-headed Cowbird, House Finch, Barn and Cliff swallows, and the rapidly expanding Barred Owl. All but the owl are closely tied to agricultural practices and urban development and adapt well to human modification of the environment. In contrast to decreasing species, long-distance migrants comprised the largest proportion (40.0%) of increasing species, followed by permanent residents (32.3%) and short-distance migrants (27.7%).

We used data on population trends for 130 migratory landbird species in western United States, as compiled by Carter and Barker (1993), to investigate recent population changes. An additional 56 migratory landbird species that have bred in the western states but are too local or rare to be sampled effectively by the BBS and another 91 primarily resident species were not included in this analysis. We identified 58 migratory species that decreased in either the past 26 or 13 years (Table 3), 44 that in-

TABLE 3. SPECIES OF MIGRATORY LANDBIRDS FOR WHICH OUR ANALYSIS OF BBS DATA INDICATES A DECREASING POPULATION TREND IN THE WESTERN UNITED STATES DURING EITHER THE PAST 26 OR PAST 13 YEARS (SEE TEXT)

Species	Mig. status[1]	Past 26 yrs (1966–1991)			Past 13 yrs (1979–1991)		
		Trend[2]	Number states	Mean PTR[3]	Trend[2]	Number states	Mean PTR[3]
Band-tailed Pigeon	S	D	3	4.00	D	3	4.00
Mourning Dove	S	d	11	3.27	D	11	3.73
Black-billed Cuckoo	L	D	1	4.00	D	1	4.00
Burrowing Owl	S	d	5	3.40	d	5	3.20
Short-eared Owl	S	D	1	4.00	d	4	3.25
Common Poorwill	S	D	1	4.00	–	3	3.00
Vaux' Swift	L	D	3	4.33	–	3	3.33
White-throated Swift	S	–	3	3.67	D	4	3.75
Black-chinned Hummingbird	L	D	1	5.00	–	4	3.75
Anna's Hummingbird	S	D	1	4.00	–	1	3.00
Rufous Hummingbird	L	D	2	5.00	D	2	4.50
Allen's Hummingbird	L	D	1	5.00	–	1	3.00
Belted Kingfisher	S	D	6	3.67	–	7	3.43
Lewis' Woodpecker	S	D	1	4.00	–	2	3.50
Williamson's Sapsucker	S	D	1	5.00	D	1	5.00
Northern Flicker	S	–	10	3.70	d	11	3.36
Olive-sided Flycatcher	L	D	4	4.25	D	6	4.00
Say's Phoebe	S	D	10	3.70	–	10	3.10
Eastern Kingbird	L	–	5	2.80	D	6	3.67
Horned Lark	S	D	11	3.73	D	11	3.91
North. Rough-winged Swallow	L	–	9	2.78	d	11	3.36
Bank Swallow	L	d	4	3.25	–	6	3.00
Rock Wren	S	D	11	4.18	D	11	3.55
Golden-crowned Kinglet	S	(D)	4	4.00	–	4	3.50
Veery*	L	I	3	2.00	D	4	3.75
Swainson's Thrush	L	D	5	3.80	–	6	2.83
Sprague's Pipit	S	D	1	4.00	D	1	4.00
Loggerhead Shrike	S	–	9	3.11	D	9	4.00
Bell's Vireo	L	–	1	3.00	D	2	4.00
Red-eyed Vireo*	L	I	2	1.50	D	2	4.00
Nashville Warbler*	L	d	4	3.25	I	4	2.00
Lucy's Warbler	L	D	1	4.00	–	1	3.00
Yellow-rumped Warbler	S	d	7	3.43	–	8	2.88
Black-throated Gray Warbler*	L	D	3	3.67	I	3	1.67
American Redstart*	L	I	1	2.00	D	1	4.00
MacGillivray's Warbler	L	D	5	3.60	–	7	3.14
Wilson's Warbler	L	D	5	4.40	–	6	2.83
Lazuli Bunting	L	–	7	2.86	d	8	3.50
Chipping Sparrow	S	D	10	4.30	D	11	4.36
Brewer's Sparrow	S	D	7	4.57	D	7	4.00
Black-chinned Sparrow	L	D	1	5.00	D	1	5.00
Black-throated Sparrow	S	D	5	4.60	–	5	3.40
Baird's Sparrow*	S	I	1	2.00	D	1	5.00
Grasshopper Sparrow	L	(D)	6	3.67	–	6	3.17
Fox Sparrow	S	D	1	4.00	–	2	2.50
Song Sparrow	S	D	8	3.88	–	8	3.50
White-crowned Sparrow	S	d	5	3.40	d	7	3.43
Dark-eyed Junco	S	D	5	3.80	D	7	4.00
Bobolink	L	D	1	4.00	D	1	5.00
Eastern Meadowlark	S	D	1	4.00	D	1	4.00
Western Meadowlark	S	D	10	3.90	–	11	3.27
Brewer's Blackbird	S	D	8	4.12	–	9	3.56
Bronzed Cowbird	S	–	–	–	D	1	4.00
Hooded Oriole	L	D	1	4.00	–	2	2.50
Scott's Oriole*	L	D	4	4.25	I	4	2.25
Pine Siskin	S	–	7	3.71	D	8	4.00
Lesser Goldfinch	S	D	4	4.00	–	6	3.17
Lawrence's Goldfinch	S	D	1	5.00	D	1	4.00

creased in either of the two time periods (Table 4), and 35 for which trends could be identified in neither of the two time periods (Table 5).

The mean (±SD) PTR of all 125 species under consideration during the 26-year period (1966–1991) was 3.20 ± 0.85, suggesting a small decreasing trend. Sixty-eight of these 125 species (54.4%) showed evidence of decreasing or increasing population trends over the 26 years. Of these 68 species, the proportion of decreasing species (66%) was significantly greater than the proportion of increasing species (34%, P = 0.01, binomial test). When we examined the 130 species under consideration during the 13-year period (1979–1991), we found that the mean PTR (3.01 ± 0.81) indicated virtually no trend whatsoever. Of the 64 species that showed evidence of population trends over these 13 years, the proportion of decreasing species (50%) was the same as the proportion of increasing species (50%, P ≫ 0.95). Thus, when all species are considered, there was a declining trend in the abundance of migratory birds in the western United States over the past 26 years, but no trend over the past 13 years.

We next divided the species into two groups based on the location of their major wintering grounds: short-distance migrants that winter extensively in the temperate areas of North America and long-distance migrants that winter primarily in the tropics (Tables 3, 4, and 5). Of the 34 short-distance migrants that showed evidence of population trends over the past 26 years, 27 (79%) declined while only seven (21%) showed increasing trends (P = 0.0008); their mean PTR over this period was 3.31 ± 0.78. This pattern was still evident, but was not statistically significant, for short-distance migrants during the the past 13 years, when 20 (59%) of 34 declined and 14 (41%) increased (P = 0.39); their mean PTR for this period was 3.09 ± 0.77. The proportion of decreasing and increasing species did not differ among the long-distance migrants for either time period (proportion of declining species = 53% for last 26 years [P = 0.86] and 40% for last 13 years [P = 0.36]), suggesting that these species as a group did not undergo any significant population trends in the western United States in the past 26 or 13 years. Their mean PTRs over these two periods were 3.07 ± 0.92 and 2.93 ± 0.77.

The mean PTRs for most species groups generally decreased somewhat between the past 26 years and the past 13 years (Table 6). For decreasing species, there was a consistent tendency for the rate of decline to be lower over the past 13 years than over the entire 26 years. For increasing species, there was a tendency for the rate of increase to be higher over the past 13 years than over the past 26 years, at least for short-distance migrants. For species that showed no trends in the past 26 or 13 years, there was also a tendency for the mean PTRs to be more positive. Thus, there is no evidence for an increasing rate of decline in western migratory landbirds as has been observed in many species of Neotropical migrants in the eastern United States (Robbins et al. 1989, Sauer and Droege 1992).

←

[1] Migration status: S = short-distance migrant; substantial numbers winter in temperate North America. L = long-distance migrant; virtually all individuals winter in the tropics.

[2] D = strong decreasing trend; more than 50% of the states showed decreasing trends (PTR = 4) or definite decreases (PTR = 5), not more than 25% of the states showed increasing trends (PTR = 2) or definite increases (PTR = 1), and the mean PTR was greater than 3.50. d = weak decreasing trend; same as D except mean PTR not greater than 3.50. (D) = local decreasing trend; less than 50% of the states showed decreasing trends or definite decreases, or more than 25% of the states showed increasing trends or definite increases, but the mean PTR was greater than 3.50. I = strong increasing trend; more than 50% of the states showed increasing trends or definite increases, not more than 25% of the states showed decreasing trends or definite decreases, and the mean PTR was less than 2.50. i = weak increasing trend; same as I except mean PTR not less than 2.50. (I) = local increasing trend; less than 50% of the states showed increasing trends or definite increases, or more than 25% of the states showed decreasing trends or definite decreases, but the mean PTR was less than 2.50.

[3] Mean PTR = mean population trend ranking (see text).

* Included on both the decreasing and increasing lists.

TABLE 4. SPECIES OF MIGRATORY LANDBIRDS FOR WHICH OUR ANALYSIS OF BBS DATA INDICATES AN INCREASING POPULATION TREND IN THE WESTERN UNITED STATES DURING EITHER THE PAST 26 OR PAST 13 YEARS (SEE TEXT)

Species	Mig. status[1]	Past 26 yrs (1966–1991)			Past 13 yrs (1979–1991)		
		Trend[2]	Number states	Mean PTR[3]	Trend[2]	Number states	Mean PTR[3]
Lesser Nighthawk	L	I	2	1.50	I	2	2.00
Costa's Hummingbird	S	—	1	3.00	I	1	2.00
Red-naped Sapsucker	S	I	3	1.33	—	5	2.40
Red-breasted Sapsucker	S	I	3	2.00	I	3	1.00
Western Wood-Pewee	L	I	9	2.44	—	10	3.20
Willow Flycatcher	L	—	6	3.17	I	7	2.14
Least Flycatcher	L	—	1	3.00	I	1	2.00
Hammond's Flycatcher	L	—	4	3.00	I	4	2.25
Dusky Flycatcher	L	—	6	2.50	I	7	2.00
Gray Flycatcher	L	—	2	3.00	I	2	2.00
Ash-throated Flycatcher	L	I	6	2.17	I	6	2.17
Brown-crested Flycatcher	L	I	1	1.00	I	1	1.00
Western Kingbird	L	—	11	2.91	I	11	2.36
Violet-green Swallow	L	(I)	11	2.36	—	11	3.00
Cliff Swallow	L	I	11	2.45	I	11	2.45
House Wren	S	—	7	2.86	I	8	2.12
Blue-gray Gnatcatcher	L	—	2	3.00	I	4	2.00
Townsend's Solitaire	S	—	4	2.75	I	5	2.00
Veery*	L	I	3	2.00	D	4	3.75
Hermit Thrush	S	—	5	2.60	(I)	6	2.33
Cedar Waxwing	S	—	5	3.40	I	5	2.40
Phainopepla	S	—	2	2.50	I	2	1.50
Solitary Vireo	L	I	6	2.33	—	9	3.00
Warbling Vireo	L	I	7	2.29	I	7	2.29
Red-eyed Vireo*	L	I	2	1.50	D	2	4.00
Orange-crowned Warbler	S	i	4	2.75	—	4	3.25
Nashville Warbler*	L	d	4	3.25	I	4	2.00
Black-throated Gray Warbler*	L	D	3	3.67	I	3	1.67
American Redstart*	L	I	1	2.00	D	1	4.00
Northern Waterthrush	L	—	—	—	I	1	2.00
Common Yellowthroat	S	—	7	2.86	(I)	7	2.43
Yellow-breasted Chat	L	I	6	2.33	—	6	3.17
Black-headed Grosbeak	L	I	9	1.78	I	10	2.40
Blue Grosbeak	L	I	4	2.25	I	5	2.20
Rufous-sided Towhee	S	—	10	3.30	i	11	2.64
Cassin's Sparrow	L	I	2	2.00	—	2	3.00
Clay-colored Sparrow	L	I	2	1.50	—	2	2.50
Savannah Sparrow	S	—	6	3.00	i	7	2.50
Baird's Sparrow*	S	I	1	2.00	D	1	5.00
Lincoln's Sparrow	S	I	1	2.00	I	3	2.33
McCown's Longspur	S	I	1	1.00	I	2	1.50
Chestnut-collared Longspur	S	I	1	2.00	I	1	2.00
Scott's Oriole*	L	D	4	4.25	I	4	2.25
Purple Finch	S	—	3	3.00	I	3	2.33

[1] See Table 3 for definitions.
[2] See Table 3 for definitions.
[3] See Table 3 for definitions.
* Included on both the decreasing and increasing lists.

Table 6 also indicates that the mean PTRs of short-distance and long-distance migrants did not differ much or were lower for short-distance migrants for increasing species and for species with no trends. Mean PTRs for short-distance migrants, however, tended to be higher than those for long-distance migrants for decreasing species and for total species, again confirming the tendency for greater decreases among short-

TABLE 5. SPECIES OF MIGRATORY LANDBIRDS FOR WHICH OUR ANALYSIS OF BBS DATA INDICATES A DECREASING OR INCREASING POPULATION TREND IN THE WESTERN UNITED STATES DURING NEITHER THE PAST 26 OR PAST 13 YEARS (SEE TEXT)

Species	Mig. status[1]	Past 26 yrs (1966–1991)			Past 13 yrs (1979–1991)		
		Trend[2]	Number states	Mean PTR[3]	Trend[2]	Number states	Mean PTR[3]
White-winged Dove	L	—	2	2.50	—	1	3.00
Common Nighthawk	L	—	10	3.10	—	11	2.91
Black Swift	L	—	—	—	—	2	3.50
Calliope Hummingbird	L	—	3	3.33	—	4	2.75
Broad-tailed Hummingbird	L	—	2	3.50	—	4	3.00
Cassin's Kingbird	L	—	4	3.50	—	4	3.00
Purple Martin	L	—	1	3.00	—	2	3.50
Tree Swallow	L	—	8	2.75	—	8	2.75
Barn Swallow	L	—	10	3.30	—	11	3.00
Brown Creeper	S	—	3	3.33	—	3	3.00
Marsh Wren	S	—	2	3.00	—	2	3.00
Ruby-crowned Kinglet	S	—	7	2.71	—	7	2.71
Western Bluebird	S	—	5	3.20	—	6	2.83
Mountain Bluebird	S	—	10	2.70	—	10	2.60
American Robin	S	—	11	3.00	—	11	2.91
Gray Catbird	L	—	3	2.67	—	4	3.50
Northern Mockingbird	S	—	6	2.67	—	6	2.67
Sage Thrasher	S	—	6	2.83	—	6	2.83
Bendire's Thrasher	L	—	—	—	—	3	3.33
Virginia's Warbler	L	—	—	—	—	1	3.00
Yellow Warbler	L	—	8	3.00	—	8	3.12
Townsend's Warbler	S	—	2	3.00	—	2	2.50
Hermit Warbler	L	—	2	3.00	—	2	2.50
Western Tanager	L	—	7	3.00	—	11	2.64
Green-tailed Towhee	L	—	5	2.80	—	8	2.50
Vesper Sparrow	S	—	10	3.00	—	10	3.00
Lark Sparrow	S	—	9	3.22	—	11	3.18
Sage Sparrow	S	—	4	2.75	—	4	2.50
Lark Bunting	S	—	3	3.00	—	4	3.25
Red-winged Blackbird	S	—	11	3.18	—	11	3.09
Yellow-headed Blackbird	S	—	8	3.00	—	8	3.12
Brown-headed Cowbird	S	—	11	3.00	—	11	2.64
Northern Oriole	L	—	10	3.00	—	11	3.18
Cassin's Finch	S	—	7	3.43	—	8	2.88
American Goldfinch	S	—	7	3.14	—	7	3.00

[1] See Table 3 for definitions.
[2] See Table 3 for definitions.
[3] See Table 3 for definitions.

distance than among long-distance migrants. None of the differences, however, were significant.

There was relatively little comparability between the decreasing species found on lists generated from BBS data versus those generated from long-term avifaunal information on population changes in the various states. Of 58 migratory landbird species identified as decreasing from relatively recent BBS data, 20 also occurred on the long-term decreasing list while 13 occurred on the long-term increasing list. The situation was even more disparate for the 44 migratory species identified as increasing from BBS data, as only five were on the long-term increasing list while seven were on the long-term decreasing list. This suggests that the major factors affecting populations of migratory landbirds are different today than they were more than half a century ago.

DISCUSSION

Our indices of population trends from BBS data involve three factors: the magnitude of the trend over the census period in a par-

TABLE 6. MEAN PTR[1] VALUES FOR WESTERN MIGRATORY SPECIES IN THE WESTERN UNITED STATES FOR THE PAST 26 YEARS (1966–1991) AND THE PAST 13 YEARS (1979–1991)

	Past 26 years		Past 13 years	
	Number species	PTR[1] (mean ± SD)	Number species	PTR[1] (mean ± SD)
Decreasing species[2]				
Short-distance migrants	32	3.88 ± 0.55	33	3.65 ± 0.54
Long-distance migrants	25	3.66 ± 0.97	25	3.38 ± 0.84
Total	57	3.78 ± 0.76	58	3.53 ± 0.69
Increasing species[3]				
Short-distance migrants	17	2.49 ± 0.67	17	2.34 ± 0.85
Long-distance migrants	26	2.45 ± 0.73	27	2.47 ± 0.71
Total	43	2.47 ± 0.70	44	2.44 ± 0.76
Species with no trends[4]				
Short-distance migrants	18	3.01 ± 0.22	18	2.87 ± 0.23
Long-distance migrants	14	3.03 ± 0.30	17	3.01 ± 0.32
Total	32	3.02 ± 0.25	35	3.94 ± 0.28
Total species[5]				
Short-distance migrants	66	3.31 ± 0.78	67	3.09 ± 0.77
Long-distance migrants	59	3.07 ± 0.92	63	2.93 ± 0.77
Total	125	3.20 ± 0.85	130	3.01 ± 0.77

[1] PTR = population trend ranking: 5.00 = definite decrease, 4.00 = decreasing trend, 3.00 = no trend or trend unknown, 2.00 = increasing trend, 1.00 = definite increase (see text).
[2] Species identified as decreasing in either the past 26-year or 13-year period.
[3] Species identified as increasing in either the past 26-year or 13-year period.
[4] Species showing a decreasing or increasing trend in neither the past 26-year or 13-year period.
[5] Total species does not equal the sum of the decreasing, increasing, and no trend species because seven species (identified by * in Tables 3 and 4) decreased in one period and increased in the other and, consequently, were placed on both the decreasing and increasing species lists.

ticular state, the uncertainty of the trend within the state, and the consistency of the trend across all western states (see Carter and Barker [in press] for a discussion of the first two factors). Thus, our index only allows us to detect changes that are more or less consistent in most of the western states.

Peterjohn and Sauer (in press) provide a summary of 26 years (1966–1991) of BBS data for North America as a whole, for three major geographical regions (Eastern, Central, Western), and for various species guilds based on migratory status, breeding habitat, and nest location. They found that the proportion of increasing species among all species with sufficient sample size was higher in the Western Region (56.5%; differs from the expected value of 50.0% at $P < 0.10$) than in either the Eastern (52.7%; $P > 0.10$) or Central (36.8%; $P < 0.01$) regions. They also found that the proportion of increasing species in the Western Region was exactly 50.0% for both permanent resident and short-distance migrant species, but was 62.1% (differs from the expected value of 50.0% at $P < 0.10$) for long-distance migrants. Their results echo those of Sauer and Droege (1992) who found that 65% ($P < 0.05$) of 48 long-distance migrant species had increasing trends in the Western Region over the long-term (1966–1988), whereas 68% ($P < 0.05$) of 47 species had increasing trends in a more recent time period (1978–1988). Moreover, they also found differences in the proportion of increasing species among the Eastern, Central, and Western regions in the latter time period ($P < 0.06$), primarily because of a higher proportion of increasing species in the West.

Our analyses of BBS data from the western states, based upon Carter and Barker's (1993) population trend ranks (PTRs), provide qualitatively similar but quantitatively different results. Like Peterjohn and Sauer (1993), we suggest that long-distance migrant species fared better in the West during the last quarter-century than did short-distance migrants. But, in contrast to their re-

sults, we suggest that long-distance migrants as a whole showed no trend while short-distance migrants showed a decreasing trend. Peterjohn and Sauer suggest that long-distance migrants showed an increasing trend (as did Sauer and Droege [1992]), while short-distance migrants (and permanent residents) showed no trend. Like Sauer and Droege (1992), however, our results suggest that population trends for long-distance migrants (and short-distance migrants) improved somewhat during the more recent 13 years compared to the entire 26-year period.

We explain differences between our results and those of Peterjohn and Sauer (1993) and Sauer and Droege (1992) by our use of data (PTRs generated by Carter and Barker [1993]), which included measures of both the magnitude and the uncertainty of the trends, rather than data limited only to the number of species undergoing decreasing or increasing trends. The results of analyses that include information on the magnitude and uncertainty of the trends appear to be less optimistic than the results of analyses that do not include this information.

Our results also agree well with data on passage migrants from Southeast Farallon Island (SEFI) over the past 25 years (Pyle et al. 1994). They showed that nocturnal migrant arrivals to SEFI decreased overall between 1968 and 1992, and that this decrease was significant in spring but not in fall. They also showed that species and groups of species showing declines outnumbered those showing increases 28 to 16, and that significant decelerating declines during the 25-year period were detected in 21 species and 5 groups, whereas accelerating declines were detected in only one species and no group. Virtually all analyses of BBS data, including ours, also show smaller decreases (or larger increases) over the last 12–13 years than over the entire 25–26 year period in western North America.

Some major points emerge from these results. First, the most important cause of the decline of landbird species in western North America has been the destruction of riparian habitat. Because the key to human activity in arid lands is water, the most important management strategy that should be implemented immediately in western North America is the complete protection and, as possible, the restoration of riparian habitats. Such areas provide critical breeding habitat for a number of declining species, important habitat for wintering populations of many species, and stop-over locations for most long- and short-distance migrants.

A second point is that short-distance migrants, particularly species associated with grasslands and shrublands, appear to be declining in western North America. The historical record implicates the destruction of grasslands and overgrazing as the second and fourth most important causes of population declines of western landbirds during the past century, and BBS data suggest that the declines are continuing. Arguments to stop the extensive grazing of public lands in western United States deserve a fair hearing. The possibility that the declines in a number of western sparrows (Table 3) may be linked to habitat degradation on their wintering grounds in southwestern United States and northwestern Mexico also deserves study. Moreover, a probable connection between grazing on public lands and increased cowbird parasitism is obvious.

A third point is that accelerating declines in forest-inhabiting, long-distance migrant species, recently documented from eastern and central North America (Robbins et al. 1989, Terborgh 1989, Askins et al. 1990, Sauer and Droege 1992), do not seem to be occurring in western North America. This is *not* to say that western populations of such species are not being affected by deforestation and forest fragmentation on both their temperate breeding grounds and tropical wintering grounds; rather, the effects are not yet as acute as in eastern North America.

Forest-inhabiting long-distance migrants from eastern North America winter primarily in the Caribbean Basin (eastern Mex-

ico, Central America, extreme northern South America, and the West Indies), a very small land area compared to the area of their breeding grounds. In contrast, forest-inhabiting long-distance migrants from western North America winter primarily in western and southern Mexico, an area that equates to a relatively larger proportion of their breeding grounds. As a result, eastern species may winter in higher densities so that degradation of winter habitat may have a relatively greater effect on eastern than on western species. Moreover, the wintering habitat for forest-inhabiting Neotropical migrants is likely more intact overall for western species than for eastern ones (Hutto 1988). Still, it should be noted that significant declines were found on SEFI, at least in spring, for species wintering in western Mexico (Pyle et al. 1994). A similar situation may also exist on the breeding grounds. Despite massive deforestation, forest fragmentation, and destruction of old-growth forests in the past quarter-century, the forests of western North America are still more intact than those over much of eastern North America, where both old growth and large tracts of forested land are becoming vanishingly small.

Another change is the increased occurrence rates of vagrant, out-of-range species in western North America. From 10 years of unbiased data from SEFI (1968–1978), DeSante (1983) suggested that the increase in vagrants was a real phenomenon and not an artifact of increased observation. This was confirmed by Pyle et al. (1994) who showed that eastern forest-inhabiting species had increasing trends on SEFI over the past 25 years in both spring and fall. This is especially noteworthy because 1) most other landbird species showed decreasing trends on SEFI and 2) overall populations of eastern forest-inhabiting species appear to be decreasing, particularly in the past 10–12 years. These results suggest that the proportion of vagrant individuals is increasing in populations of these eastern forest-inhabiting species. DeSante (1983) hypothesized that this increase could be caused by a selective increase in both the proportion of dispersing individuals and the dispersal distances of those individuals (vagrants being merely the extremes of dispersal) in response to increased rates of habitat change and disturbance.

Inferences about population trends in western landbirds are constrained by the limited and anecdotal nature of historical data and by deficiencies of BBS data (Hagan et al. 1992). First, the quarter-century from which BBS data are now available is very short. It is possible that patterns in landbird populations are much more cyclic than we believe and reflect weather phenomena (and associated changes in food supply, breeding success, and survivorship) that are not well understood and that may be changing because of natural or human-caused changes in global climate. It may not be a coincidence that the proportion of increasing species among all long-distance migrants decreased significantly in eastern North America from the decade of the seventies to the eighties, when it tended to increase in western North America (Sauer and Droege 1992; see also DeSante 1992, 1993 for further discussion).

Second, the BBS can provide reliable information only for relatively common species. Of the 75 species that we identified from historical accounts as decreasing in the past century and the 65 species we identified as increasing, 23 (31%) and 20 (31%), respectively, were too rare or local in the west to be sampled effectively by the BBS. Indeed, the Monitoring Working Group (1992) suggested that the BBS was unable to monitor effectively 31% (79 of 256 species) of Neotropical migratory species.

Third, BBS data are limited to roadsides, which often include a large proportion of fragmented and edge habitats. This may cause biases both in the kinds of species that are detected on BBS routes and in the counts of these species (O'Connor 1992). Furthermore, roadside biases could be positive for some species and negative for others. A re-

lated problem with BBS data is that they are not habitat specific, thereby making it difficult to relate population trends to specific habitat changes in any particular habitat type or to large-scale habitat changes in general.

A final shortcoming of BBS data, and of all census or survey data, is that they only provide information on secondary population parameters (e.g., population size, density, age structure) and not on primary parameters (e.g., productivity, fecundity, survivorship, dispersal). Primary parameters may be more useful than secondary parameters in determining the causes of population change because environmental variation affects primary parameters directly and can be observed over a short time period (Hutto 1988, Temple and Wiens 1989). Because of buffering effects of floater individuals and density-dependent responses of populations, there may be substantial time lags between changes in primary parameters and resulting changes in population size or density as measured by census or survey methods (Temple and Wiens 1989). Thus, a population could be in trouble long before it becomes evident from survey data. Finally, because of the vagility of most bird species, local variations in secondary population parameters may often be masked by recruitment from a wider region (George et al. 1992) or accentuated by lack of recruitment from a wider area (DeSante 1990).

Substantially greater monitoring and research efforts than are currently underway will be required to obtain the data necessary to manage western landbird populations effectively in the face of the challenges that will be presented by human population growth and development in the twenty-first century. We recommend the establishment of a continent-wide "integrated avian population monitoring system," patterned after the scheme pioneered in Great Britain (Baillie 1990), that should include the following elements:

1. Increased coverage of existing and proposed BBS routes, especially in the West where coverage in many areas is inconsistent and incomplete.
2. Implementation of a systematic program of habitat-specific, off-road surveys, perhaps concentrating on public lands.
3. Implementation of a program of intensive surveys of rare species that cannot be surveyed adequately by large-scale, broad-based programs.
4. Increased and improved analyses of existing population trend data. Few analyses of BBS data at a local or regional scale exist for western North America, and only cursory analyses of trends within habitat types have been attempted (Carter and Barker 1993, Peterjohn and Sauer 1993). Moreover, most analyses of BBS data, including ours, have used relatively long time periods. James et al. (1990, 1992) showed that exploratory analyses of short-term trends using nonparametric, nonlinear route regression may provide insights that are not evident from linear route regression that is used in most BBS analyses.
5. Increased efforts to monitor primary demographic parameters through programs such as the Monitoring Avian Productivity and Survivorship (MAPS) program, coordinated by The Institute for Bird Populations, and the Breeding Biology Research Database (BBIRD) program, coordinated by T. E. Martin.
6. A concerted effort, using DNA fingerprinting and increased analysis of banding recoveries, to determine, on as fine a scale as possible, the wintering localities for local populations of breeding migratory landbirds. Marshall (1988) suggested that the disappearance of certain populations of long-distance migratory birds in California may have been caused by the destruction of their wintering grounds in a relatively limited area of Central America.

We further recommend that the operation of an effective integrated avian population monitoring system should: (1) allow the standardized collection of data on both primary and secondary population param-

eters; (2) allow the interpretation of these data using population-modelling techniques capable of describing interrelationships between population variables and readily-measured environmental covariables; (3) assist in establishing action thresholds for management and/or further research; (4) facilitate identification of changes caused by anthropogenic factors by comparing observed population trends with those predicted from environmental data and from preceding population levels; and (5) lead to the testing and refining of current models for population processes and the development of new ones.

In summary, the past 100 years have witnessed pronounced changes in the characteristics of avian habitats in western North America, substantial changes in the populations of landbirds associated with those habitats, the beginning of effective efforts to monitor and understand the causes of those changes, and the first coordinated resolve to prevent further decreases in landbird populations. Today, western landbird populations are facing a growing number of environmental problems of ever increasing severity, including accelerating habitat loss, global climate change, and widespread toxic pollution. It is generally agreed that these threats could bring about rates of avian extinction and avian range change that could exceed the highest rates ever recorded in the fossil record. Indeed, the next 100 years (or considerably less) will provide a real test of the resolve to prevent further decreases in landbird populations.

ACKNOWLEDGMENTS

We thank the hundreds of able volunteers who collected BBS data for western North America during the past quarter-century, M. Carter and K. Barker for the use of their population trend ranking system, and the editors of this volume for their helpful comments. This is Contribution No. 13 of The Institute for Bird Populations.

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APPENDIX. Scientific names of species mentioned in the text or tables.

Spruce Grouse (*Dendragapus canadensis*), Blue Grouse (*Dendragapus obscurus*), White-tailed Ptarmigan (*Lagopus leucurus*), Ruffed Grouse (*Bonasa umbellus*), Sage Grouse (*Centrocercus urophasianus*), Greater Prairie-Chicken (*Tympanuchus cupido*), Lesser Prairie-Chicken (*Tympanuchus pallidicinctus*), Sharp-tailed Grouse (*Tympanuchus phasianellus*), Wild Turkey (*Meleagris gallopavo*), Montezuma Quail (*Cyrtonyx montezumae*), Northern Bobwhite (*Colinus virginianus*), Scaled Quail (*Callipepla squamata*), California Quail (*Callipepla californica*), Mountain Quail (*Oreortyx pictus*), Rock Dove (*Columba livia*), Band-tailed Pigeon (*Columba fasciata*), White-winged Dove (*Zenaida asiatica*), Mourning Dove (*Zenaida macroura*), Inca Dove (*Columbina inca*), Common Ground-Dove (*Columbina passerina*), Black-billed Cuckoo (*Coccyzus erythropthalmus*), Yellow-billed Cuckoo (*Coccyzus americanus*), Greater Roadrunner (*Geococcyx californianus*), Barn Owl (*Tyto alba*), Western Screech-Owl (*Otus kennicottii*), Northern Hawk-Owl (*Surnia ulula*), Ferruginous Pygmy-Owl (*Glaucidium brasilianum*), Elf Owl (*Micrathene whitneyi*), Burrowing Owl (*Athene cunicularia*), Spotted Owl (*Strix occidentalis*), Barred Owl (*Strix varia*), Long-eared Owl (*Asio otus*), Short-eared Owl (*Asio flammeus*), Lesser Nighthawk (*Chordeiles acutipennis*), Common Nighthawk (*Chordeiles minor*), Common Poorwill (*Phalaenoptilus nuttallii*), Whip-poor-will (*Caprimulgus vociferus*), Black Swift (*Cypseloides niger*), Vaux's Swift (*Chaetura vauxi*), White-throated Swift (*Aeronautes saxatalis*), White-eared Hummingbird (*Hylocharis leucotis*), Berylline Hummingbird (*Amazilia beryllina*), Violet-crowned Hummingbird (*Amazilia violiceps*), Magnificent Hummingbird (*Eugenes fulgens*), Black-chinned Hummingbird (*Archilochus alexandri*), Anna's Hummingbird (*Calypte anna*), Costa's Hummingbird (*Calypte costae*), Calliope Hummingbird (*Stellula calliope*), Broad-tailed Hummingbird (*Selasphorus platycercus*), Rufous Hummingbird (*Selasphorus rufus*), Allen's Humming-

bird (*Selasphorus sasin*), Belted Kingfisher (*Ceryle alcyon*), Lewis' Woodpecker (*Melanerpes lewis*), Red-headed Woodpecker (*Melanerpes erythrocephalus*), Gila Woodpecker (*Melanerpes uropygialis*), Red-naped Sapsucker (*Sphyrapicus nuchalis*), Red-breasted Sapsucker (*Sphyrapicus ruber*), Williamson's Sapsucker (*Sphyrapicus thyroideus*), Ladder-backed Woodpecker (*Picoides scalaris*), Northern (Gilded) Flicker (*Colaptes auratus*), Pileated Woodpecker (*Dryocopus pileatus*), Olive-sided Flycatcher (*Contopus borealis*), Western Wood-Pewee (*Contopus sordidulus*), Willow Flycatcher (*Empidonax traillii*), Least Flycatcher (*Empidonax minimus*), Hammond's Flycatcher (*Empidonax hammondii*), Dusky Flycatcher (*Empidonax oberholseri*), Gray Flycatcher (*Empidonax wrightii*), Buff-breasted Flycatcher (*Empidonax fulvifrons*), Black Phoebe (*Sayornis nigricans*), Say's Phoebe (*Sayornis saya*), Vermilion Flycatcher (*Pyrocephalus rubinus*), Ash-throated Flycatcher (*Myiarchus cinerascens*), Brown-crested Flycatcher (*Myiarchus tyrannulus*), Tropical Kingbird (*Tyrannus melancholicus*), Cassin's Kingbird (*Tyrannus vociferans*), Thick-billed Kingbird (*Tyrannus crassirostris*), Western Kingbird (*Tyrannus verticalis*), Eastern Kingbird (*Tyrannus tyrannus*), Scissor-tailed Flycatcher (*Tyrannus forficatus*), Rose-throated Becard (*Pachyramphus aglaiae*), Horned Lark (*Eremophila alpestris*), Purple Martin (*Progne subis*), Tree Swallow (*Tachycineta bicolor*), Violet-green Swallow (*Tachycineta thalassina*), Northern Rough-winged Swallow (*Stelgidopteryx serripennis*), Bank Swallow (*Riparia riparia*), Cliff Swallow (*Hirundo pyrrhonota*), Cave Swallow (*Hirundo fulva*), Barn Swallow (*Hirundo rustica*), Blue Jay (*Cyanocitta cristata*), Black-billed Magpie (*Pica pica*), American Crow (*Corvus brachyrhynchos*), Chihuahuan Raven (*Corvus cryptoleucus*), Common Raven (*Corvus corax*), Verdin (*Auriparus flaviceps*), Bushtit (*Psaltriparus minimus*), White-breasted Nuthatch (*Sitta carolinensis*), Brown Creeper (*Certhia americana*), Cactus Wren (*Campylorhynchus brunneicapillus*), Rock Wren (*Salpinctes obsoletus*), House Wren (*Troglodytes aedon*), Marsh Wren (*Cistothorus palustris*), Golden-crowned Kinglet (*Regulus satrapa*), Ruby-crowned Kinglet (*Regulus calendula*), Blue-gray Gnatcatcher (*Polioptila caerulea*), California Gnatcatcher (*Polioptila californica*), Western Bluebird (*Sialia mexicana*), Mountain Bluebird (*Sialia currucoides*), Townsend's Solitaire (*Myadestes townsendi*), Veery (*Catharus fuscescens*), Swainson's Thrush (*Catharus ustulatus*), Hermit Thrush (*Catharus guttatus*), American Robin (*Turdus migratorius*), Gray Catbird (*Dumetella carolinensis*), Northern Mockingbird (*Mimus polyglottos*), Sage Thrasher (*Oreoscoptes montanus*), Brown Thrasher (*Toxostoma rufum*), Bendire's Thrasher (*Toxostoma bendirei*), Curve-billed Thrasher (*Toxostoma curvirostre*), Crissal Thrasher (*Toxostoma crissale*), LeConte's Thrasher (*Toxostoma lecontei*), White Wagtail (*Motacilla alba*), American Pipit (*Anthus rubescens*), Sprague's Pipit (*Anthus spragueii*), Cedar Waxwing (*Bombycilla cedrorum*), Phainopepla (*Phainopepla nitens*), Loggerhead Shrike (*Lanius ludovicianus*), European Starling (*Sturnus vulgaris*), Bell's Vireo (*Vireo belli*), Gray Vireo (*Vireo vicinior*), Solitary Vireo (*Vireo solitarius*), Warbling Vireo (*Vireo gilvus*), Red-eyed Vireo (*Vireo olivaceus*), Orange-crowned Warbler (*Vermivora celata*), Nashville Warbler (*Vermivora ruficapilla*), Virginia's Warbler (*Vermivora virginiae*), Lucy's Warbler (*Vermivora luciae*), Yellow Warbler (*Dendroica petechia*), Yellow-rumped Warbler (*Dendroica coronata*), Black-throated Gray Warbler (*Dendroica nigrescens*), Townsend's Warbler (*Dendroica townsendi*), Hermit Warbler (*Dendroica occidentalis*), Grace's Warbler (*Dendroica graciae*), American Redstart (*Setophaga ruticilla*), Northern Waterthrush (*Seiurus noveboracensis*), MacGillivray's Warbler (*Oporornis tolmiei*), Common Yellowthroat (*Geothylpis trichas*), Wilson's Warbler (*Wilsonia pusilla*), Red-faced Warbler (*Cardellina rubrifrons*), Painted Redstart (*Myioborus pictus*), Yellow-breasted Chat (*Icteria virens*), Hepatic Tanager (*Piranga flava*), Summer Tanager (*Piranga rubra*), Western Tanager (*Piranga ludoviciana*), Northern Cardinal (*Cardinalis cardinalis*), Black-headed Grosbeak (*Pheucticus melanocephalus*), Blue Grosbeak (*Guiraca caerulea*), Lazuli Bunting (*Passerina amoena*), Indigo Bunting (*Passerina cyanea*), Painted Bunting (*Passerina ciris*), Dickcissel (*Spiza americana*), Green-tailed Towhee (*Pipilo chlorurus*), Rufous-sided Towhee (*Pipilo erythrophthalmus*), California Towhee (*Pipilo crissalis*), Botteri's Sparrow (*Aimophila botterii*), Cassin's Sparrow (*Aimophila cassinii*), Rufous-winged Sparrow (*Aimophila carpalis*), Chipping Sparrow (*Spizella passerina*), Clay-colored Sparrow (*Spizella pallida*), Brewer's Sparrow (*Spizella breweri*), Black-chinned Sparrow (*Spizella atrogularis*), Vesper Sparrow (*Pooecetes gramineus*), Lark Sparrow (*Chondestes grammacus*), Black-throated Sparrow (*Amphispiza bilineata*), Sage Sparrow (*Amphispiza belli*), Lark Bunting (*Calamospiza melanocorys*), Savannah Sparrow (*Passerculus sandwichensis*), Baird's Sparrow (*Ammodramus bairdii*), Grasshopper Sparrow (*Ammodramus savannarum*), Fox Sparrow (*Passerella iliaca*), Song Sparrow (*Melospiza melodia*), Lincoln's Sparrow (*Melospiza lincolnii*), White-crowned Sparrow (*Zonotrichia leucophrys*), Dark-eyed Junco (*Junco hyemalis*), McCown's Longspur (*Calcarius mccownii*), Chestnut-collared Longspur (*Calcarius ornatus*), Bobolink (*Dolichonyx oryzivorus*), Red-winged Blackbird (*Agelaius phoeniceus*), Tricolored Blackbird (*Agelaius tricolor*), Eastern Meadowlark (*Sturnella magna*), Western Meadowlark (*Sturnella neglecta*), Yellow-headed Blackbird (*Xanthocephalus xanthocephalus*), Brewer's Blackbird (*Euphagus cyanocephalus*), Great-tailed Grackle (*Quiscalus mexicanus*), Bronzed Cowbird (*Molothrus aeneus*), Brown-headed Cowbird (*Molothrus ater*), Hooded Oriole (*Icterus cucullatus*), Northern Oriole (*Icterus galbula*), Scott's Oriole (*Icterus parisorum*), Purple Finch (*Carpodacus purpureus*), Cassin's Finch (*Carpodacus cassinii*), House Finch (*Carpodacus mexicanus*), Pine Siskin (*Carduelis pinus*), Lesser Goldfinch (*Carduelis psaltria*), Lawrence's Goldfinch (*Carduelis lawrencei*), American Goldfinch (*Carduelis tristis*), House Sparrow (*Passer domesticus*).