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The Effects of Human-Induced Environmental Change on Avian Populations

HUMAN-INDUCED CHANGES IN BIRD POPULATIONS IN CONIFEROUS FORESTS IN WESTERN NORTH AMERICA DURING THE PAST 100 YEARS

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Abstract. Data on population trends for bird populations in coniferous forests in western North America over the past 100 years are few and mostly from the United States during the breeding season. The few community and species-specific studies do not indicate similar historic population changes for any one species across habitats. West-wide 24-year trends (Breeding Bird Surveys [BBS]) were noted for 21 species; some of these changes may be caused by fire suppression or logging, the two primary ways humans have affected coniferous forests.

Because most old-growth forests are gone, snag numbers are probably lower than they were historically, and fire patterns have changed, species associated with old-growth forests, snags, and burns are probably less abundant today than they were 100 years ago. Yet, such trends were not substantiated by BBS or other studies. Regional and local changes due to fire suppression and logging have occurred for many species, but many of these changes might be partially compensatory for some species when looked at from a larger scale. Uncommon species, many of which (woodpeckers, nuthatches, creeper) are likely to be those most affected by logging and fire suppression, are not sampled well by BBS. Five of the seven declining species are long- and short-distance migrants. Human-induced changes on wintering grounds may have caused these declines.

If current patterns of forest use continue, species associated with old-growth, snags, burns, and interior forests will continue to decline. Allowing natural disturbance patterns (especially fire) to return to these ecosystems and retaining all ages, components, and landscape patterns of natural forests will help maintain avian populations and diversity.

Key Words: Population change; permanent residents; neotropical migrants.

Humans have changed the coniferous forests of western North America during the past 100 years. Some forests have been converted to fields or housing tracts, but most changes have been more subtle (Norse 1990, Hejl 1992). The age-class distribution of forests, the structure and composition of forest stands, and the pattern of forests across the landscape are a direct result of logging, fire exclusion, and forest restoration. This paper considers how such changes have affected bird populations. I defined Western North America as the region west of and including the Rocky Mountains and Sierra Madre Occidental in Canada, United States, and Mexico. Unfortunately, few studies directly address this subject; most consider only the past few decades and most have been conducted in the United States.

I assessed changes in bird populations by four approaches. First, I searched the general avifaunal literature for community and species-specific studies examining historic changes in bird populations in coniferous forests. Second, I examined U.S. Fish and Wildlife Service's Breeding Bird Survey data (BBS) for the past 24 years (1968–1991). Third, I inferred population trends from our current knowledge of the transformation of western coniferous forests over the past 100 years and our knowledge of bird-habitat relations in natural and treated forests. For these inferences, I assumed that changes in bird populations are a direct result of habitat changes, and that population trends can be estimated based on habitat changes. Fourth, I compared estimates of population change made by researchers in two specific regions of the western United States.

Finally, I discuss limitations of each approach, compare implications for past population trends, predict future trends, and

TABLE 1. CHANGES IN DISTRIBUTION AND ABUNDANCE IN SELECTED BIRD SPECIES BETWEEN HISTORIC AND MORE RECENT TIMES IN "LONG-TERM" COMMUNITY STUDIES IN CONIFEROUS FORESTS IN WESTERN NORTH AMERICA. SPECIES WERE ARBITRARILY SELECTED. SYMBOLS ARE + = INCREASING TREND, − = DECREASING TREND, NT = NO TREND, AND ? = NOT OBVIOUS TREND

Species	Oregon, juniper 1899–1983[1]	Sierra Nevada, burn 1966–1985[2]	Sierra Nevada old growth				Sierra Nevada, logged 1930s–1986[4]	San Benito, CA 1936–1984[5]	Grape-vines, NV 1939–1973[6]	Spring Ranges, NV 1936–1963[7]
			Pon-derosa Pine	Mixed Conifer	Red Fir	Lodge-pole Pine				
Band-tailed Pigeon							NT			+
Hairy Woodpecker		NT	+	NT	NT	+	−	NT		?
Olive-sided Flycatcher		+ burn	+	NT	−	+	−	+		+
Western Wood-Pewee	+	NT	−	NT	−	−	NT	+		+
Dusky Flycatcher		+ burn	NT	−	NT	+		+	+	+
Mountain Chickadee	+	+ burn	NT	NT	NT	−	NT			NT
Red-breasted Nuthatch		+ forest	NT	NT	+	+	+			
Brown Creeper		+ forest	+	NT	+	+	NT			?
Golden-crowned Kinglet		− forest	+	+	+	+	+			
Ruby-crowned Kinglet			−	−	−	NT			+	+
Mountain Bluebird	+	− burn							+	
Swainson's Thrush			−	−			−			
Solitary Vireo		NT	−	NT			NT	NT	+	+
Black-throated Gray Warbler	+		−	−				−		+
Chipping Sparrow	+	− burn	−	NT	−	−				?
Fox Sparrow		+ burn	−	−	−					
Brown-headed Cowbird	+	+ burn				+	+			

[1] Sharp (1985).
[2] Raphael et al. (1987). Trend occurred in the indicated habitat.
[3] Beedy (1982).
[4] Marshall (1988).
[5] Johnson and Cicero (1985).
[6] Johnson (1974).
[7] Johnson (1965).

note management options that will help maintain these species.

HISTORICAL CHANGES IN CONIFER BIRD POPULATIONS

COMMUNITY STUDIES

Researchers in seven community studies in coniferous forests (Johnson 1965, Johnson 1974, Beedy 1982, Johnson and Cicero 1985, Sharp 1985, Raphael et al. 1987, Marshall 1988) compared bird populations in four habitats and three mountain ranges between at least two different points in time. No common trends for individual species were seen across all studies, although some species varied in parallel in a few studies (Table 1; scientific names in Appendix I). The studies differed, however, in methods, habitat, scale, time period, and in the degree to which human-induced and natural changes had occurred. Therefore, it is difficult to compare results or to know if they represented local or regional trends.

The greatest strength of these studies might be in allowing us to better understand natural and human-induced changes in bird populations. In studies from several mountain ranges in the southwestern United States, Johnson (1974) suggested that a natural factor, short-term global cooling, was contributing to increases of boreal species. Johnson and Cicero (1985) similarly proposed that changes in bird populations at San Benito, California were caused by the recent shift toward cooler, moist summer climates. Sharp (1985) and Raphael et al. (1987) linked changes in bird populations to changes in vegetation. Sharp (1985) attributed increases in Chipping Sparrows to the increase of juniper in an Oregon grassland. Raphael et al. (1987) concluded that the changes in abundance on burned and unburned plots were due to changing vegetation structure, not variations in weather. Shrub cover and the density of overstory trees increased on the burned plot, as did the numbers of birds that foraged on the

ground or searched for food in the brush or in foliage. When the density of snags left after the fire decreased so did the numbers of bark-gleaning birds.

Beedy (1982) and Marshall (1988) attributed bird population changes to human-induced factors. In four old-growth habitats in Yosemite National Park, Beedy (1982) concluded that many changes were likely caused by the effects of fire exclusion on forest structure and composition. For example, Golden-crowned Kinglets, which prefer dense, shaded forests, probably increased due to the encroachment of fir saplings. Numbers of Fox Sparrows and Green-tailed Towhees decreased, possibly because shading reduced shrub habitat. In a virgin and a second-growth forest in the Sierra Nevada, Marshall (1988) ascribed declines in six species (e.g., Flammulated Owl and Hairy Woodpecker) and increases of two species to logging and declines of Olive-sided Flycatcher and Swainson's Thrush to the loss of winter habitat.

Burns and fire exclusion appear to have the opposite effect on some forest birds. Seventy percent of the species common in burned habitat in the eastern Sierra Nevada (Raphael et al. 1987) have become less abundant in at least one old-growth habitat in the western Sierra Nevada, where fire had been excluded (Beedy 1982). Calliope Hummingbird, Green-tailed Towhee, and Fox Sparrow were less abundant in all old-growth habitats in which they were found. On the other hand, 66% of the species common in unburned, forested habitat in the eastern Sierra Nevada (e.g., Red-breasted Nuthatch, Brown Creeper, Golden-crowned Kinglet) (Raphael et al. 1987) have increased in at least one old-growth habitat in the western Sierra Nevada (Beedy 1982).

Individual Species Trends

I searched the literature for population trends for individual species, excluding the most well-documented—Marbled Murrelet, Spotted Owl, and Brown-headed Cowbird, which are covered by Ralph (1994), Gutiérrez (1994), and Rothstein (1994), respectively.

Regional or local changes are indicated for some species during the last half of this century. Northern Goshawk may have declined on the North Kaibab in northern Arizona, especially between 1972 and 1988 (Crocker-Bedford 1990, but see Reynolds et al. 1992) and Hairy Woodpecker in Washington and Oregon between 1953 and 1982 (Morrison and Morrison 1983). The Barred Owl has recently expanded its range southwestward into the Northern Rockies and Pacific Northwest (Taylor and Forsman 1976). Chestnut-backed Chickadee expanded southward in the Sierra Nevada over 40 years ago, and populations have seemed stable since (Brennan and Morrison 1991). Since 1960, Hermit Warblers may have declined in the Puget Sound region and expanded in the northern Cascades (Chappell and Ringer 1983). Red-breasted Sapsuckers may have extended their range in the last 50 years in coastal California (Shuford 1986). No population changes were recorded for woodpeckers between 1953 and 1982 along the entire Pacific Coast (Morrison and Morrison 1983) or for Black-capped and Mountain chickadees in the Pacific Northwest from 1944 to 1985 (Brennan and Morrison 1991).

American Birds uses information from active birders to create "Blue Lists" of species that show local or widespread population declines or range contractions. The most recent (Tate 1986) indicates decline in only three coniferous forest birds (Cooper's Hawk, Hairy Woodpecker, and Purple Martin) in one or two subregions of the West.

The causes of any of these apparent changes are unknown. Moreover, the status of some species may have since changed, and most have not been intensively studied over large geographic areas. Woodpecker (Morrison and Morrison 1983) and chickadee (Brennan and Morrison 1991) trends, however, were based on the Christmas Bird Count (CBC) data, which are widespread and relatively long-term (>30–40 yr).

TABLE 2. SIGNIFICANT BREEDING BIRD SURVEY TRENDS FOR THE WESTERN UNITED STATES AND CANADA FOR CONIFEROUS FOREST BIRD SPECIES WITH AVERAGE ABUNDANCE GREATER THAN 1.00 PER ROUTE WHEN MORE THAN 50 ROUTES WERE IN THE SAMPLE. SPECIES ARE LISTED IN ASCENDING ORDER FROM MOST NEGATIVE 24-YR TREND

Species	24-yr trend[1] (1968–1991)		10-yr trend (1982–1991)		Migratory status[2]
	%	N	%	N	
Olive-sided Flycatcher	−3.5*	343	−2.7*	281	long
Band-tailed Pigeon	−3.2*	186	−9.0*	138	long
Rufous Hummingbird	−3.1*	182	−3.9*	136	long
Golden-crowned Kinglet	−2.8*	229	−1.5	192	permanent
Chipping Sparrow	−2.7*	527	−0.5	407	long
Plain Titmouse	−2.5*	174	−2.6*	131	permanent
Western Bluebird	−2.2*	229	−2.0	161	short
Lark Sparrow	−1.2	395	−2.6*	283	long
Orange-crowned Warbler	−0.6	325	+2.7*	265	long
Black-capped Chickadee	−0.1	293	+2.4*	247	permanent
Wilson's Warbler	+0.4	332	−3.5*	246	long
Acorn Woodpecker	+0.9	137	+3.1*	96	permanent
Scrub Jay	+1.2*	244	+0.5	198	permanent
Winter Wren	+1.2*	157	−2.6*	129	permanent
Hermit Thrush	+1.9*	301	+1.7	238	short
Nashville Warbler	+2.0*	156	−2.0	134	long
Varied Thrush	+2.2*	140	−1.8	109	permanent
Black-throated Gray Warbler	+2.2*	188	−1.2	150	long
Red-breasted Nuthatch	+2.2*	341	+6.2*	290	permanent
Cedar Waxwing	+2.3*	274	+5.5*	224	short
Warbling Vireo	+2.3*	469	+2.8*	377	long
House Wren	+2.3*	475	+3.6*	380	long
Tree Swallow	+2.4*	493	+1.2	393	short
Solitary Vireo	+2.5*	351	+5.2*	276	long
Red-tailed Hawk	+2.6*	676	+1.1	563	short
Common Raven	+3.2*	623	+1.5	524	permanent

[1] Trend = the rate of change in the population, expressed as percent annual change; * denotes a significant trend ($P < 0.10$).
[2] Migratory status: long = long-distance migrant species that breed in North America and spend their nonbreeding period primarily south of the United States, short = short-distance migrants that breed and winter extensively in North America, permanent = permanent resident species that primarily have overlapping breeding and nonbreeding areas.

BREEDING BIRD SURVEYS FROM 1968 TO 1991

I examined U.S. Fish and Wildlife Service Breeding Bird Surveys (BBS) for Western Northern America, using their weightings and statistical tests. John Sauer performed the analyses using the methods described by Geissler and Sauer (1990) and Sauer and Geissler (1990). I listed the "coniferous forest" species (broadly defined) with average abundance greater than 1.0/route, when more than 50 routes were included in a sample that had statistically significant ($P < 0.10$) 24- or 10-year trends (Table 2).

Of 113 western coniferous forest species detected, only 57 (50%) met the abundance and number of routes criteria (Appendix I). Seven had significant declining trends over the past 24 years, seven had significant declining trends over the past 10 years, and four species declined significantly over both periods (Table 2). Fourteen species had significant increasing trends in the past 24 years, and eight had significant increasing trends in the past 10 years. Three species with nonsignificant or increasing trends over 24 years had significant declining 10-year trends.

Many coniferous forest species are not sampled well enough by the BBS routes in the West to discern trends. In general, these were raptors (especially owls), grouse, woodpeckers, "eastern" warblers, and birds peculiar to the southwestern and northern

United States and Canada, but also included a few widespread birds of coniferous forests (e.g., White-breasted Nuthatch, Pygmy Nuthatch, and Brown Creeper).

Extrapolating from 24-year BBS trends to 100-year trends presents problems, even for the best-sampled species. The number of survey routes changes each year, continues to increase, and emphasizes roadside birds, whose trends do not necessarily apply to forest birds, especially "interior" forest species (but see Hutto et al. in press). Coverage is spotty, especially in Alaska, Canada, and Mexico. Roadsides, and thus species composition, are also likely to change due to local plant succession and fragmentation of the surrounding area. Since BBS routes do not just cover conifer habitats and since some "conifer" species breed in other habitats as well, changes in BBS data may not be caused by changes in coniferous forest habitats.

INFERENCES ABOUT HISTORICAL CHANGES IN BIRD POPULATIONS IN CONIFEROUS FORESTS

Transformation of Western Coniferous Forests

The six major ways in which humans have changed forest composition and structure in the past 100 years are: fire exclusion, logging, grazing, introduction of foreign organisms (diseases, insects, and plants), residential development, and chemical applications. Fire exclusion and logging have had the greatest effects, and are the best studied.

The exclusion of fire for the past 50 or more years has been the most significant factor affecting today's western forests. Almost all wildfires have been fought, even in wilderness areas. Only since the 1960s have federal agencies allowed some fires to burn (Taylor and Barmore 1980). The result of past fire control is usually a decrease in frequency and increase in intensity of fires (see Weatherspoon et al. 1992).

Logging practices and silvicultural recommendations have changed frequently for specific forest types and geographic areas. In general, the most accessible forests (i.e., near railroad construction camps, mining camps, or cities) and commercially valuable tree species were logged first. Early on, land was often stripped either of all trees or of the favored species and size classes ("high-grading"). Small trees and defective trees were often not harvested.

In the late 1800s and early 1900s, both clearcutting and selective logging were used in many forest types throughout the west. Sanitation logging (the removal of dead, damaged, or susceptible trees to prevent the spread of insects and diseases) and salvage logging (the removal of dead, dying, or deteriorating trees before the timber becomes "worthless") occurred in many areas after World War I and have continued as important practices to the present (Wellner 1984, McKelvey and Johnston 1992).

Timber harvest increased as technologies improved, especially after World War II (McKelvey and Johnston 1992). Large clearcuts separated by small strips of standing trees were the norm in some areas on public land [e.g., Douglas-fir in Rocky Mountains (Wellner 1984) and Pacific Northwest (Norse 1990)], whereas in other areas, clearcutting was infrequent (e.g., mixed-conifer forests in Sierra Nevada, McKelvey and Johnston 1992). Higher elevation forests, such as spruce-fir, were rarely logged before 1950 (Alexander 1986; but see Losensky 1990). Pinyon-juniper has been chained for the past 40 years to convert areas either to grassland for livestock or to shrubland for game management (Evans 1988). In the 1970s and 1980s, logging treatments became more varied as federal agencies and the public attained a broader knowledge of the multiple uses of forests.

Fire exclusion across the west has allowed many forests to change from open to closed stands and has altered fire regimes which naturally differed among forest types (Weatherspoon et al. 1992). The effects of logging varied. High-grading took the healthiest, largest, usually shade-intolerant,

trees, leaving stands of inferior, usually shade-tolerant, trees. After fires, windstorms, or insect or disease damage, snags and dying trees were salvaged for lumber or firewood. If artificial regeneration were used, planting usually involved one or a few economically valuable species rather than the natural diversity of the prelogging forest.

Fire exclusion and logging have opposite effects on the age-class distribution of forests. Little is left of the original old-growth forests in the West (e.g., less than 13–37% in Pacific Northwest Douglas-fir forests, Hejl 1992). Because of logging, the proportion of young forests is greater today than 100 years ago in some of the Pacific Northwest (Raphael et al. 1988). In contrast, because of fire exclusion and in spite of logging, the proportion of early successional forests is often similar or smaller today in the Northern Rocky Mountains (Gruell 1983). The age-class distribution in specific forest types in the Northern Rockies may have changed more than the proportion of forests considered young or old growth (Hejl 1992). For example, in one area on the Bitterroot National Forest, the amount of mature and older ponderosa pine stands had decreased due to logging, but older Douglas-fir stands had increased because of fire exclusion, with the result that the total amount of older forests is the same today as in 1900.

Current landscape patterns are different from those of 100 years ago and reflect the combined effects of logging, fire, and other factors. Large expanses of continuous forest with relatively little diversity once covered the moist areas of Pacific Northwest and the Sierra Nevada (Rosenberg and Raphael 1986, Norse 1990, Laudenslayer and Darr 1990). Further inland, as in the drier Rocky Mountains, forests were more heterogeneous due to topographic, climatic, and fire effects (Gruell 1983, Hejl 1992). Grasslands, shrubsteppes, and deserts create forest islands in the Great Basin and southeast Arizona; yet, northern Arizona has the largest continuous stand of ponderosa pine (Brawn and Balda 1988).

Patterns of habitat fragmentation have varied among forest types. For example, cutting regimes in the Rocky Mountains have tended to vary from large clearcuts that are often densely spaced in moist forests (e.g., spruce-fir and cedar-hemlock forests) to repeated entries of selective cutting in drier forests (e.g., ponderosa pine, western larch, or Douglas-fir forests; S. Arno, pers. comm.). Staggered clearcuts result in a patchwork of uncut "old growth" and new plantations or young forests, increasing landscape heterogeneity (Franklin and Forman 1987). Selectively logged forests can result in even-aged stands and decreased landscape heterogeneity (McKelvey and Johnston 1992).

Differences in Birds Among Natural Young, Mature, and Old-growth Stands

Douglas-fir forest birds were studied extensively and intensively in the Pacific Northwest from 1984 to 1986 (Ruggiero et al. 1991). Bird populations were compared in three age-classes of natural forests: young (42–75 years), mature (105–165), and old-growth (250–500). Eight breeding species were clearly associated with old-growth forests: Allen's Hummingbird (California only), Vaux's Swift (Oregon and Washington only), Hairy Woodpecker, Pileated Woodpecker, Red-breasted Sapsucker (Oregon and Washington only), Western (Pacific-slope) Flycatcher, Chestnut-backed Chickadee, and Brown Creeper. Brown Creeper was the only species often associated with mature forests and Black-throated Gray Warbler was the only species often associated with young forests. All ages of natural stands may also be important winter habitat for resident species (Raphael 1984, Manuwal and Huff 1987, Ruggiero et al. 1991).

Other comparisons of bird species in different age-classes of natural forests include three studies in the Rocky Mountains (Catt 1991, Hallock 1989–1990, Moore 1992) and one in the Pacific Northwest (Kessler and Kogut 1985). Whereas several species were

associated with particular age classes, none was associated with a particular forest age class in all studies.

The reasons for the differences among studies are unknown. Indeed, one might not expect many differences within any one study, since natural young and mature forests often contain a number of structural characteristics typical of old-growth forests, such as snags and logs.

Logging Effects on Birds

Most studies of the effects of logging have compared clearcuts to control forests (presumably uncut or lightly cut), or various partially logged areas to control forests. Hejl et al. (in press) made both comparisons across conifer forests in the Rocky Mountains. Thirteen species (Three-toed Woodpecker, Black-capped Chickadee, Mountain Chickadee, Red-breasted Nuthatch, Brown Creeper, Winter Wren, Golden-crowned Kinglet, Ruby-crowned Kinglet, Swainson's Thrush, Varied Thrush, Solitary Vireo, Townsend's Warbler, Evening Grosbeak) were always less abundant in recent clearcuts than in uncut forest. In contrast, the Mountain Bluebird was always more abundant in recent clearcuts. Differences were less dramatic between partially logged forests and unlogged forests. Brown Creeper, Pygmy Nuthatch, and Pine Grosbeak were always less abundant in partially logged forests than in unlogged forests. Calliope Hummingbird was always more abundant in partially logged forests. In general, forest species were found less often in clearcuts, and species that frequent open forests or open habitats were found more often in clearcuts. Resident species tended to decrease after any kind of harvesting, while only about half of the migrants decreased. In contrast, almost all the species that increased after partial cutting or soon after clearcutting were migrants, and most on the recent clearcuts were short-distance migrants. Similar patterns have been documented in chained pinyon-juniper areas (O'Meara et al. 1981, Sedgwick and Ryder 1987) as in clearcuts from other forest types.

Hejl et al. (in press) also compared differences in bird populations between old-growth and mature second-growth forests (intensively logged 60–120 years ago) in the Rocky Mountains. No species was consistently more abundant in either situation. When there were differences, woodpeckers and nuthatches, in general, were more abundant in old-growth than in mature second-growth. At least three owl species (Flammulated Owl, Spotted Owl, and Boreal Owl) also seemed to be associated with old-growth habitats.

Studies elsewhere have produced similar results. Raphael et al. (1988) compared birds in three stages of forest development following logging, fire, windthrow, or landslide in northwestern California: brush/sapling, pole/sawtimber, and mature Douglas-fir forests. Eleven species found in forests greater than 100 years of age were never found in shrub/sapling stands which are primarily less than 20 years old. Seventeen species were either much more abundant or found only in shrub/sapling stands. Migrants predominated in the shrub/sapling stages; most species were ground or brush foragers. Most species associated with forests were permanent residents. All but one of the bole-foraging species were forest obligates. A majority of forest species were canopy or air foragers.

For many species, snags are important for nesting, foraging, perching, and roosting. Cavity-nesting bird density varied in proportion to snag density in logged, burned, and natural forests (Cunningham et al. 1980, Raphael and White 1984, Zarnowitz and Manuwal 1985). In two studies, cavity-nesting bird density declined 53–77% after snags were removed (Scott and Oldemeyer 1983, Raphael and White 1984). Cavity-nesting birds are more likely to nest in large snags or trees and thus are common in old growth (Mannan et al. 1980). In some areas, certain tree species (e.g., western larch) are preferred (McClelland et al. 1979).

Fire and Fire Suppression Effects on Birds

Fire affects bird communities differently depending on its intensity. High intensity fires often create habitat for primary cavity nesters, secondary cavity nesters, and shrub users (Taylor and Barmore 1980, Raphael et al. 1987), whereas low intensity fires create habitats for birds that prefer open forests. Some species (Black-backed Woodpecker, Olive-sided Flycatcher, and Mountain Bluebird) even seem relatively restricted to conditions after fires (R. L. Hutto, pers. comm.). The benefits of fires are sometimes short-term.

Six species were more abundant in high intensity burns than in unburned forests in the Sierra Nevada (Raphael et al. 1987) and Rockies (Taylor and Barmore 1980): Hairy Woodpecker, Black-backed Woodpecker, Northern Flicker, Western Wood-Pewee, House Wren, and Mountain Bluebird. Three species were more abundant in unburned forests in both areas: Red-breasted Nuthatch, Golden-crowned Kinglet, and Western Tanager. The shrub-nesting species present after the Sierra Nevada burn (e.g., Green-tailed Towhee and Fox Sparrow) were notably absent from severely burned areas in the Rockies.

Moderate and low intensity burns show less dramatic immediate effects than high intensity burns. For the first few years after a moderate burn in the Rockies, birds characteristic of severely burned forests as well as unburned forests were present (Taylor and Barmore 1980). In the Sierra Nevada, Granholm (1982) found that Hairy Woodpecker, Black-backed Woodpecker, Steller's Jay, and Cassin's Finch responded positively to surface burns. Northern Flicker, typically associated with high intensity burns, was as abundant in unburned forests as in surface burns. Hammond's Flycatcher, Mountain Chickadee, Hermit Thrush, and Golden-crowned Kinglet consistently responded negatively to surface burns.

Open forest species may be lost with fire suppression. In pine-oak forests of southern Arizona and northern Mexico (Sonora and Chihuahua), Marshall (1963) found marked differences in bird populations due to different fire regimes (suppressed in Arizona, unchecked fires in Mexico). Many open forest species (e.g., Purple Martin and Western Bluebird) were more abundant in Mexico or often found only in lowlands in Arizona. Several brush or dense forest species were more abundant in Arizona (e.g., Black-throated Gray Warbler).

Logged burns probably benefit fewer burn-associated species than unlogged burns. Overturf (1979) described bird communities on three severely burned ponderosa pine forests that were later logged in Arizona. Nine species that had been abundant in at least one of the unlogged high intensity burns (Taylor and Barmore 1980, Raphael et al. 1987) were also present in the logged burns. However, three of these species were equally abundant in an "unlogged," unburned area and the other six species were only present in one of the three burns.

Importance of Landscape Patterns to Birds

The greatest effects of logging and fire exclusion on bird populations may be through changes in landscape patterns, but this is difficult to isolate (Dobkin 1992). Concerns about human-induced changes in western landscapes include forest fragmentation, juxtaposition of various habitats, and loss of landscape elements. Forest fragmentation is difficult to quantify since most western forests are not isolated patches surrounded by nonforested habitats but are interconnected with other forests of different ages and species composition.

Several studies (Rosenberg and Raphael 1986, Lehmkuhl et al. 1991, Hejl 1992, Keller and Anderson 1992, Hejl and Paige in press) have addressed relationships between birds and various landscape patterns. Our knowledge on these issues is rudimentary. Some species are associated with continuous forest (Winter Wren). Others seem to

avoid edges (Band-tailed Pigeon). Some species may be less abundant in insular forests (Golden-crowned Kinglet) and in more fragmented landscapes (Brown Creeper). Certain species (Acorn Woodpecker) may be more abundant in conifer stands with adjacent hardwoods. As in the east (Askins et al. 1990), changes in western forest landscapes may negatively affect nest productivity for these species and others through an increase in nest predation or nest parasitism (Verner and Ritter 1983, Hejl and Paige in press).

Because we have little knowledge, no experimental studies, and the effects of changing landscapes are likely cumulative and may have a time-lag associated with them, we cannot estimate how much current bird populations are different from historical populations due to landscape changes.

Estimated Historical Trends Based on Forest Changes and Bird-habitat Relations

Because we do not know the current or historical acreages of natural and logged forests of different ages, and thus cannot ascertain changes in total acres of forest today from the past, we can only guess how bird numbers might have changed in the past 100 years. We do know, however, that most old-growth habitats are gone, that snag numbers are probably much lower, and that the intensity (usually higher) and frequency (usually lower) of fires have changed. Because our understanding of the effects of forestry practices on birds is based mostly on recent, short-term studies, any generalizations must be tentative. However, strong evidence suggests that: 1) some species clearly associate with old-growth forests, even when those forests are compared to natural younger forests that contain a legacy of "old-growth" characteristics; 2) logging treatments generally decrease the abundance of almost all permanent residents and half the migrants; 3) density of cavity-nesters is directly related to snag density, with cavity-nesters selecting large snags of certain preferred species; 4) fire suppression causes changes in populations in old-growth and other forests, especially among species that forage in shrubs or on the ground; and 5) fire creates habitat for Three-toed Woodpeckers, Black-backed Woodpeckers, other primary and secondary cavity nesters, and shrub-nesters. Therefore, I hypothesize that those species associated with burns, old-growth forests, or snags are less abundant today than they were 100 years ago. The greatest declines have probably occurred for snag-users that preferentially live in burned areas or old-growth forests. Other scientists (Brawn and Balda 1988, Raphael et al. 1988) made similar suggestions.

BIRD TRENDS IN THE PACIFIC NORTHWEST AND THE SOUTHWEST

Raphael et al. (1988) used current bird populations of three seral stages, and estimates of past and current forest area in each seral stage, to hypothesize historic trends in bird populations in Douglas-fir forests in northwest California (Table 3). With a change of 20% considered significant, twenty-two species have probably declined and 18 species have probably increased. Historic populations were likely dominated by migrants that foraged in the forest canopy and air. Current populations have increased and are also dominated by this group, although some individual species (e.g., Hammond's Flycatcher) have declined. Ground and brush foragers are found more abundantly in the current avifauna. Resident species that forage in canopy and air have declined. Seven bole-foraging species likely have decreased. This group of birds apparently has been most adversely affected by shifts from forested to nonforested land.

Brawn and Balda (1988) speculated on the reasons for long-term changes in the ponderosa pine avifauna in the southwestern United States. Purple Martin and Lark Sparrow may have been nearly extirpated because of snag removal and fire exclusion. Declines in 13 other species may be due to

TABLE 3. HYPOTHESIZED POPULATION CHANGES FOR CONIFEROUS FOREST BIRDS FROM PRESETTLEMENT TIMES IN SOUTHWESTERN PONDEROSA PINE (MODIFIED FROM BRAWN AND BALDA 1988) AND IN NORTHWESTERN DOUGLAS-FIR (MODIFIED FROM RAPHAEL ET AL. 1988). PERCENTAGE CHANGE ARE ONLY INDICATED FOR DOUGLAS-FIR FORESTS

Species	Ponderosa pine[1]	Douglas-fir
Sharp-shinned Hawk		+19
Cooper's Hawk		−19
Blue Grouse		−34
Mountain Quail		+84
Band-tailed Pigeon		−25
Calliope Hummingbird		+243
Broad-tailed Hummingbird	−	
Acorn Woodpecker	−	−42
Red-breasted Sapsucker		−15
Hairy Woodpecker	NT	−36
Three-toed Woodpecker	−	
Northern Flicker	NT	−4
Pileated Woodpecker		−38
Olive-sided Flycatcher		+2
Western Wood-Pewee	NT	+78
Hammond's Flycatcher		−43
Dusky Flycatcher		+216
Western (Pacific-slope) Flycatcher		−39
Western (Cordilleran) Flycatcher	+	
Purple Martin	−	
Violet-green Swallow	−	
Steller's Jay	NT	−5
Scrub Jay		+243
Common Raven		−42
Mountain Chickadee	−	
Chestnut-backed Chickadee		−36
Red-breasted Nuthatch		−37
White-breasted Nuthatch	−	−42
Pygmy Nuthatch	−	
Brown Creeper	−	−35
House Wren	+	+228
Winter Wren		−47
Golden-crowned Kinglet		−45
Western Bluebird	−	+236
Mountain Bluebird	−	
Townsend's Solitaire	+	−36
Hermit Thrush	+	−32
American Robin	−	−22
Solitary Vireo	+	−26
Hutton's Vireo		−39
Warbling Vireo		−19
Orange-crowned Warbler		+190
Nashville Warbler		+129
Virginia's Warbler	+	
Yellow-rumped Warbler	+	+41
Black-throated Gray Warbler		+87
Hermit Warbler		−40
Grace's Warbler	+	
MacGillivray's Warbler		+162
Wilson's Warbler		+67
Red-faced Warbler	−	
Olive Warbler	?	
Western Tanager	+	−28
Green-tailed Towhee		+200
Chipping Sparrow	−	+241
Lark Sparrow	−	
Fox Sparrow		+243
Dark-eyed Junco	NT	+18
Brown-headed Cowbird		+5
Purple Finch		+76
Red Crossbill		−37
Pine Siskin	?	+2
Lesser Goldfinch		+84
Evening Grosbeak		−17

[1] "+" = increased population, "−" = decreased population, "NT" = no trend, and "?" = no data.

loss of the herbaceous layer, reduction in old trees and snags, and decline in Gambel's oaks. Increases in nine species may be due to more dense thickets, more productive foliage, more shrubby understory and the presence of downed slash, changes resulting from logging and fire exclusion.

Comparing estimates of trends from the Northwest and Southwest, only 18 of 64 bird species that were speculated to have increased or decreased were present in both ponderosa pine and Douglas-fir (Brawn and Balda 1988, Raphael et al. 1988; Table 3). Nine had similar trends (using the 20% criterion). Acorn Woodpecker, White-breasted Nuthatch, Brown Creeper, and American Robin had declined; Northern Flicker, Steller's Jay, and Dark-eyed Junco were unchanged; and House Wren and Yellow-rumped Warbler had increased. Six species had opposite trends in the two areas.

SYNTHESIS

No data substantiate human-induced, 100-yr, west-wide trends for any species of bird in western coniferous forests. Regional and local changes, however, were seen for many species (e.g., range contraction of Swainson's Thrush and extension of Chestnut-backed Chickadee), and short-term, west-wide trends were shown by BBS. I suggest that birds associated with burns, old-growth forests, and snags have probably declined (see also Brawn and Balda 1988,

Raphael et al. 1988), although this has not been confirmed by BBS, individual or community studies.

Perhaps no trends exist. It is possible, for example, that logging and burning create similar habitat for many birds, that a similar number of acres have been logged as would have burned under "natural" fire regimes, and that fire exclusion compensates for any differences between logged habitats and unburned habitats. Or, because many species are found in many different coniferous forests, regional changes may counter one another at the large, half-a-continent scale. For example, the Western Bluebird and Chipping Sparrow were speculated to have increased in Douglas-fir in the Northwest (Raphael et al. 1988) and to have decreased in ponderosa pine in the Southwest (Brawn and Balda 1988). These seemingly contradictory trends may have been due to the increase of early successional habitats created by logging in the Northwest and the closing in of habitats due to fire exclusion in the Southwest.

Sources of information on population trends of coniferous forest birds are poor. BBS currently is our best source of quantitative data on large-scale trends in breeding birds. Unfortunately, many coniferous forest habitats and species have not been sampled adequately, especially those (woodpeckers, nuthatches, Brown Creeper) that are negatively affected by logging and fire suppression. While greater coverage would be beneficial, adding routes will not improve the sampling for all 51 species that had low abundances (the "poorer" and "poorest" classifications in Appendix I) and probably only help us examine trends for species whose optimum habitat has been missed. It will not improve sampling for those species that are sampled poorly due to low density, time-of-year, or time-of-day problems. If "interior" forest species exist or if species are more or less successful in forests than they are along roadsides, it would be useful to supplement BBS with a systematic program of habitat-based, off-road surveys (DeSante and George 1994). Special surveys are needed for rare and nocturnal species.

Sources of information on the effects of human activities on western forest birds are limited; there are few studies on the effects of silviculture, fire, fire suppression, or of changing landscape patterns, and even fewer on the effects of other human-induced changes. Most studies are based on a few study sites, are short-term, are based on secondary population parameters, and in most cases the data are not adequate for statistical tests. In three studies in which sample sizes were sufficient, researchers only analyzed the most common species individually (from 28% [Hejl et al. 1988] to 38% [Hejl and Woods 1991] to 63% [Tobalske et al. 1991]), making inferences tentative for the other species.

Many of the species with recent and significant declines according to BBS are long- and short-distance migrants. Pyle et al. (1994) identify three additional species that breed in coniferous forests. Human-induced changes on wintering grounds should be considered as a possible cause of these declines.

Predicting the future is even more difficult than understanding the past. Raphael et al. (1988) expect bird species associated with young timber in Douglas-fir in California to increase most in the future and those associated with mature forest or the brush/sapling stage to decrease. Species that prefer old-growth forests will remain in reduced numbers and may decline even further. Resident birds that forage in the forest canopy or in the air will continue to decline as a whole. Raphael et al. (1988) concluded that future avian communities in Californian Douglas-fir will become more similar to the original communities than to those of the present. Brawn and Balda (1988) predicted that secondary cavity nesters in Southwest ponderosa pine forests will decline as snags and other trees are removed, especially for fuelwood. Birds in general, however, may increase due to improved for-

est vigor resulting from more frequent natural and managed fires. If current patterns of forest use across the west continue, I predict species associated with old-growth forests, snags, burns, and interior forests will continue to decline.

Allowing natural disturbance patterns (especially fire) to return to these ecosystems and retaining all ages, components, and landscape patterns of natural forests (especially old-growth, snags, and all tree species) will help maintain avian populations and diversity in western landscapes. While we do not know all of the specifics of bird-habitat relations, we understand many principles that would help maintain healthy forests for most bird species: retain old growth, encourage old-growth characteristics in logged forests, leave snags and replacement trees to become snags, leave or plant the natural diversity of trees (including hardwoods) found in an area, burn and allow fires to happen in a manner similar to natural fire regimes, and mimic natural landscape patterns and patch dynamics. Many wildlife managers are currently adhering to these principles.

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APPENDIX I. Ability of current Breeding Bird Survey routes to sample individual coniferous forest bird species in western United States and Canada. Four categories are listed: 1) good: average abundance ≥1.0/route and ≥50 routes, 2) poor: average abundance ≥1.0/route but <50 routes, 3) poorer: <1.0/route but ≥50 routes, and 4) poorest: <1.0/route and <50 routes.

GOOD: AVERAGE ABUNDANCE ≥1.0/route and ≥50 routes:

Red-tailed Hawk (*Buteo jamaicensis*), American Kestrel (*Falco sparverius*), Mountain Quail (*Oreortyx pictus*), Band-tailed Pigeon (*Columba fasciata*), Broad-tailed Hummingbird (*Selasphorus platycercus*), Rufous Hummingbird (*Selasphorus rufus*), Acorn Woodpecker (*Melanerpes formicivorus*), Olive-sided Flycatcher (*Contopus borealis*), Western Wood-Pewee (*Contopus sordidulus*), Hammond's Flycatcher (*Empidonax hammondii*), Dusky Flycatcher (*Empidonax oberholseri*), Tree Swallow (*Tachycineta bicolor*), Violet-green Swallow (*Tachycineta thalassina*), Steller's Jay (*Cyanocitta stelleri*), Scrub Jay (*Aphelocoma coerulescens*), Pinyon Jay (*Gymnorhinus cyanocephalus*), Common Raven (*Corvus corax*), Black-capped Chickadee (*Parus atricapillus*), Mountain Chickadee (*Parus gambeli*), Chestnut-backed Chickadee (*Parus rufescens*), Plain Titmouse (*Parus inornatus*), Red-breasted Nuthatch (*Sitta canadensis*), House Wren (*Troglodytes aedon*), Winter Wren (*Troglodytes troglodytes*), Golden-crowned Kinglet (*Regulus satrapa*), Ruby-crowned Kinglet (*Regulus calendula*), Western Bluebird (*Sialia mexi-*

cana), Mountain Bluebird (*Sialia currucoides*), Swainson's Thrush (*Catharus ustulatus*), Hermit Thrush (*Catharus guttatus*), American Robin (*Turdus migratorius*), Varied Thrush (*Ixoreus naevius*), Cedar Waxwing (*Bombycilla cedrorum*), Solitary Vireo (*Vireo solitarius*), Warbling Vireo (*Vireo gilvus*), Orange-crowned Warbler (*Vermivora celata*), Nashville Warbler (*Vermivora ruficapilla*), Black-throated Gray Warbler (*Dendroica nigrescens*), Townsend's Warbler (*Dendroica townsendi*), Hermit Warbler (*Dendroica occidentalis*), American Redstart (*Setophaga ruticulla*), MacGillivray's Warbler (*Oporornis tolmiei*), Wilson's Warbler (*Wilsonia pusilla*), Western Tanager (*Piranga ludoviciana*), Green-tailed Towhee (*Pipilo chlorurus*), Chipping Sparrow (*Spizella passerina*), Lark Sparrow (*Chondestes grammacus*), Fox Sparrow (*Passerella iliaca*), White-throated Sparrow (*Zonotrichia albicollis*), White-crowned Sparrow (*Zonotrichia leucophrys*), Brown-headed Cowbird (*Molothrus ater*), Purple Finch (*Carpodacus purpureus*), Cassin's Finch (*Carpodacus cassinii*), Red Crossbill (*Loxia curvirostra*), Pine Siskin (*Carduelis pinus*), Lesser Goldfinch (*Carduelis psaltria*), Evening Grosbeak (*Coccothraustes vespertinus*).

POOR: AVERAGE ABUNDANCE ≥ 1.0/route but <50 routes:

Marbled Murrelet (*Brachyamphus marmoratus*), Virginia's Warbler (*Vermivora virginiae*), Grace's Warbler (*Dendroica graciae*), Red-faced Warbler (*Cardellina rubrifrons*), Yellow-eyed Junco (*Junco phaeonotus*).

POORER: <1.0/route but ≥ 50 routes:

Sharp-shinned Hawk (*Accipiter striatus*), Cooper's Hawk (*Accipiter cooperii*), Northern Goshawk (*Accipiter gentilis*), Blue Grouse (*Dendragapus obscurus*), Ruffed Grouse (*Bonasa umbellus*), Great Horned Owl (*Bubo virginianus*), Northern Pygmy-Owl (*Glaucidium gnoma*), Vaux's Swift (*Chaetura vauxi*), Calliope Hummingbird (*Stellula calliope*), Lewis' Woodpecker (*Melanerpes lewis*), Williamson's Sapsucker (*Sphyrapicus thyroideus*), Hairy Woodpecker (*Picoides villosus*), White-headed Woodpecker (*Picoides albolarvatus*), Pileated Woodpecker (*Dryocopus pileatus*), Gray Flycatcher (*Empidonax wrightii*), Purple Martin (*Progne subis*), Gray Jay (*Perisoreus canadensis*), Clark's Nutcracker (*Nucifraga columbiana*), White-breasted Nuthatch (*Sitta carolinensis*), Pygmy Nuthatch (*Sitta pygmaea*), Brown Creeper (*Certhia americana*), Townsend's Solitaire (*Myadestes townsendi*), Hutton's Vireo (*Vireo huttoni*), Tennessee Warbler (*Vermivora peregrina*), Magnolia Warbler (*Dendroica magnolia*), Pine Grosbeak (*Pinicola enucleator*).

POOREST: <1.0/route and <50 routes:

Harlequin Duck (*Histrionicus histrionicus*), Spruce Grouse (*Dendragapus canadensis*), Wild Turkey (*Meleagris gallopavo*), Flammulated Owl (*Otus flammeolus*), Northern Hawk-owl (*Surnia ulula*), Spotted Owl (*Strix occidentalis*), Barred Owl (*Strix varia*), Great Gray Owl (*Strix nebulosa*), Long-eared Owl (*Asio otus*), Northern Saw-whet Owl (*Aegolius acadicus*), Magnificent Hummingbird (*Eugenes fulgens*), Allen's Hummingbird (*Selasphorus sasin*), Three-toed Woodpecker (*Picoides tridactylus*), Black-backed Woodpecker (*Picoides arcticus*), Greater Pewee (*Contopus pertinax*), Yellow-bellied Flycatcher (*Empidonax flaviventris*), Boreal Chickadee (*Parus hudsonicus*), Bohemian Waxwing (*Bombycilla garrulus*), Gray Vireo (*Vireo vicinior*), Blackpoll Warbler (*Dendroica striata*), Painted Redstart (*Myioborus pictus*), Olive Warbler (*Peucedramus taeniatus*), Hepatic Tanager (*Piranga flava*), Golden-crowned Sparrow (*Zonotrichia atricapilla*), White-winged Crossbill (*Loxia leucoptera*).

SPECIES NOT LISTED IN THE BREEDING BIRD SURVEY DATABASE. Most were not listed because of recent taxonomic changes; data on some of the earlier species' names were listed.

Thick-billed Parrot (*Rhynchopsitta pachyrhyncha*), Boreal Owl (*Aegolius funereus*), Whip-poor-will (*Caprimulgus vociferus*), Yellow-bellied Sapsucker (*Sphyrapicus varius*), Red-naped Sapsucker (*Sphyrapicus nuchalis*), Red-breasted Sapsucker (*Sphyrapicus ruber*), Northern Flicker (*Colaptes auratus*), Pacific-slope Flycatcher (*Empidonax difficilis*), Cordilleran Flycatcher (*Empidonax occidentalis*), Mexican Chickadee (*Parus sclateri*), Siberian Tit (*Parus cinctus*), Gray-cheeked Thrush (*Catharus minimus*), Yellow-rumped Warbler (*Dendroica coronata*), Dark-eyed Junco (*Junco hyemalis*).