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# Effects of fire on bird abundance in Okanagan Mountain Provincial Park, British Columbia

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**Abstract:** The Okanagan Mountain Provincial Park bird count is held annually the last weekend of May or the first weekend of June when parties of observers record all birds detected. In 2003 the Okanagan Mountain fire burned 99% of the park at varying intensities, providing a unique opportunity to examine long-term changes in bird species abundance affected by fire. Relative abundance was compared from a period of 11 years before the fire (1993–2003) to a period up to eight years after the fire (five counts from 2006–2011). In total 165 species have been tallied in the 16 counts. The average number of species per count was significantly higher after the burn (104.6) than before (96.3). Of 90 species considered common enough for meaningful statistical analyses, 28 increased in relative abundance after the fire, 11 decreased, and there was no significant difference for 51 species. Increases were particularly noted among: woodpeckers including Hairy, Black-backed, American Three-toed and Northern Flicker; some cavity nesters including House Wren, White-breasted Nuthatch, and Mountain and Western Bluebirds; some insectivores including Olive-sided Flycatcher, Say's Phoebe and Western Wood-Pewee; and shrub-occupying birds including Warbling Vireo, Lazuli Bunting, MacGillivray's Warbler, Song Sparrow and Lincoln's Sparrow. Severe declines were noted for forest inhabiting birds including Red-breasted Nuthatch, Golden-crowned Kinglet and Townsend's Warbler. For most species the response to fire determined by other studies was confirmed.

**Key words:** Okanagan Mountain Provincial Park, bird, bird count, burn, fire

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## Introduction

Single day counts of birds such as the Christmas Bird Count (CBC) are popular as birding events because they are group efforts combining the social and scientific aspects of birding. The strength of the CBC is in its long record (1900 and continuing), and in the large number of counts undertaken each year (>2000 in 2012, National Audubon Society 2012). There are no similar long-running birding events that combine the social aspects of birding with the science of data collection during the breeding season. The summer Breeding Bird Survey requires surveyors to start half-hour before dawn and has a strict protocol to standardize results including only one person doing all the observations during the survey on any given route. Breeding Bird Atlasing in given states or provinces do not allow for regular mass participation because they are only repeated at long intervals and often do not combine social activities with birding. One day breeding bird blitzes of given areas using methods similar to Christmas Bird Counts, *i.e.* count all birds detected in a given area in one day, are therefore popular but have not been organized on anything but a local scale and do not contribute data to any formal single large-scale database.

This report summarizes the results of a long-term annual breeding season bird count in Okanagan Mountain Provincial Park. In 2003 fire burned 99% of the park at varying levels of intensity. Because of this marked change in local habitat, analysis of this count provided insight into bird habitat use that goes beyond the local scale.

Okanagan Mountain Provincial Park (hereafter, "the park") on the east side of Okanagan Lake was gazetted in 1973 after concerted efforts by local natural history societies and environmental groups, particularly the Okanagan-Similkameen Parks Society, with support from the Central Okanagan Naturalist's Club (CONC) of Kelowna, and the South Okanagan Naturalist's Club (SONC) of Penticton. In 1989 at the request of B.C. Parks, CONC started an Annual Pilgrimage hike into the park in mid-summer as an on-going project for the park's support and enhancement (CONC 2001). As many as 45 hikers took part in the hikes from 1989 to 1992. In 1993, these pilgrimages changed to annual bird counts taking place on the last weekend in May or the first weekend in June, and were organized by CONC, SONC, and B.C. Parks (CONC 2001).

Throughout western North America, fire suppression has

become very effective since the 1930's. In southern interior B.C., Blackwell and Gray (2003) defined several historical natural fire regimes. Prior to effective fire suppression, ponderosa pine forests would tend to be affected by frequent (0–35 year cycle) low severity fires that would kill understory trees and burn woody debris on the ground, but leave large moderate to low densities of veteran trees protected by their thick bark from ground fires. Lodgepole pine forests at higher elevations would be renewed on a longer cycle (35–200 years) by higher severity stand-replacement fires. The new generation of lodgepole pines generally regenerate from seed as the serotinous cones are opened by the fire's heat. In low elevation forests where the frequent fires have been suppressed, conifer forests would tend to become older and denser, woody debris will build up on the forest floor, and the potential for large devastating fires will increase. The park master plan of 1990 (B.C. Parks 1990) recognized the build-up of fuels, and the "significant potential for fire to be devastating to the park".

Various short-term aspects of fire effects on bird abundance have been studied. Relative abundance in a variety of recent burns 1–4 years old were examined by Hutto (1995). Hutto (1995) noted that some studies of birds in burns found few species changes, but also noted that sample size and fire intensity were often low in these comparisons. Saab and Powell (2005) edited a compendium of 10 papers that each summarized fire effects on avian ecology in different biomes of North America including Saab *et al.* (2005) for the Rocky Mountains, Hannan and Drapeau (2005) for the boreal forest, Huff *et al.* (2005) for the maritime Pacific Northwest. Each of these biomes shared many bird species with the park. None of the studies cited in those review papers compared sites before and after wildfire. Studies were limited to comparing current occupancy of different habitats in post-hoc evaluations. The only large or comprehensive study to compare bird relative abundance before a wildfire to the same place afterwards was Smucker *et al.* (2005) in northwest Montana. They compared relative abundance on point counts surveyed for five years before a mixed-severity fire to the relative abundance 1–3 years after. No burned sites seem to have been studied long-term by any study.

The 256 km<sup>2</sup> Okanagan Mountain fire of 2003 affected 99% of the park area, burning well beyond the park boundaries and into the City of Kelowna. The fire dramatically altered most of the vegetated habitats in the park, which provided an unrivalled opportunity to compare the bird population of the dense conifer-dominated fire-suppressed habitat before the fire to the burned forests after the fire. The Okanagan Mountain Bird Count differed from all other studies in that there was a long-standing record (11 years) of bird occurrence and relative abundance prior to the massive and intense fire of 2003. In this study comparisons were not affected by possible differences in physical setting; the only difference before and after the fire were the habitat changes caused by the fire.

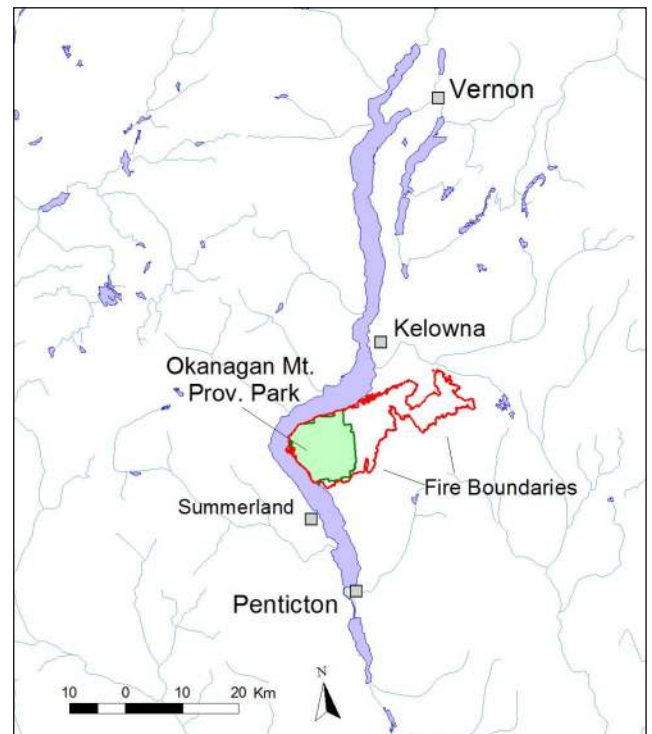


Figure 1. Location of Okanagan Mountain Provincial Park, B.C., and 2003 Okanagan Mountain fire boundaries.

## Study Area

Okanagan Mountain Provincial Park is a Class A provincial park of 105.8 km<sup>2</sup> on the east side of Okanagan Lake with 32 km of lakeshore (Figure 1) (B.C. Parks 1990). It extends from the lakeshore (342 m elevation) to the top of Okanagan Mountain (1579 m). The park is dominated by Okanagan Mountain, with its striking canyons and rugged rock outcrops at lower elevations. Okanagan Mountain is treed to the top as it is not high enough to be in the alpine or subalpine zone. The southern boundary of the park is 20 km north of downtown Penticton, and the northern boundary of the park is 13 km south of downtown Kelowna.

The park is almost entirely natural with its wilderness character persisting (B.C. Parks 1990). There are no developments in the park except for communications towers at the top of Okanagan Mountain and a guide-outfitters cabin. The only public road into the park is Lakeshore Drive extending 4 km into the park along the lakeshore at the north end. There are three separate blocks of private land holdings along Okanagan Lake that are not part of the park: the most northerly (1.17 km<sup>2</sup>) is accessible from Lakeshore Road, the others (0.72 km<sup>2</sup>, and 0.39 km<sup>2</sup>) accessible only by boat.

Biogeoclimatic Ecosystem Classification (BEC) zones in the park (Figure 2) include Ponderosa Pine (PP) at the lowest elevations, up to 800 m on south slopes, and about 600 m on north slopes; Interior Douglas-fir xeric (IDFx) at mid elevations from 800–1150 m on south slopes, and 600–800 m north

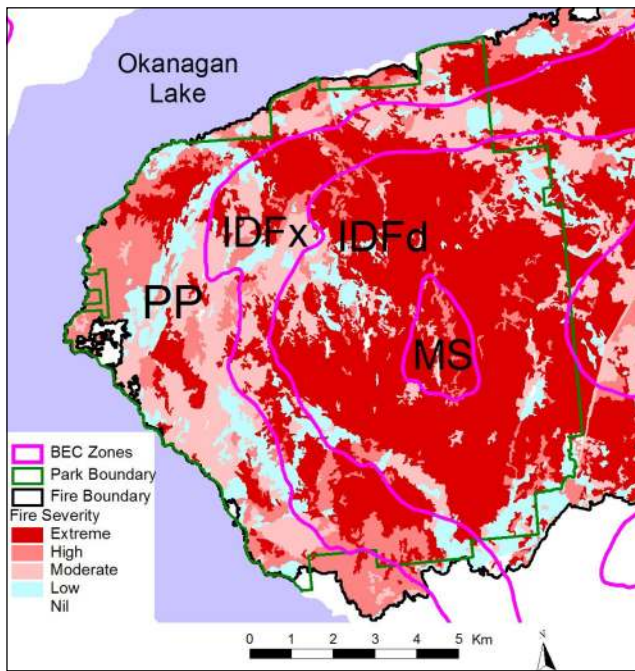


Figure 2. 2003 fire severity and Biogeoclimatic Ecosystem Classification (BEC) zones in Okanagan Mountain Provincial Park, B.C. PP = Ponderosa Pine zone, IDFx = Interior Douglas-fir xeric subzone, IDFd = Interior Douglas-fir dry subzone, MS = Montane Spruce.

slopes; Interior Douglas-fir dry (IDFd) subzone at mid elevations from 1150–1500 m on south slopes, and 800–1350 m on north slopes; and Montane Spruce (MS) zone from 1500 m on south slopes and 1350 m on north slopes to the top of Okanagan Mountain at 1579 m. Forests in the PP are dominated by ponderosa pine (*Pinus ponderosae*), in the IDFx by a mix of ponderosa pine and Douglas-fir (*Pseudotsuga menziesii*), in the IDFd by a mix of Douglas-fir and lodgepole pine (*Pinus contorta*), and in the MS by lodgepole pine.

Prior to the Okanagan Mountain fire of 2003, the upper elevation forests were mostly closed canopy (>40% crown closure) while lower elevation forests were mostly of moderate canopy closure (26–40% crown closure) (Figure 3). These estimates were based on forest cover mapping produced by the B.C. Forest Service. As the park had very few timber values and was mostly mapped as Non-Productive Forest, the polygons tended to be large and hid a lot of variability from rock outcrop openings within that range of crown closure. After the 2003 fire, the B.C. Forest Service produced a highly detailed digital map layer of the fire intensity and remaining live crown. Less than 1% of the park’s area remained untouched by the fire. High or extreme fire activity, where almost all mature trees were killed, covered 66% of the park area and moderate or low fire activity covered 33% (Figure 2). Extreme and high fire intensities covered 81% of the upper elevations (MS and IDFd), but only 50% of the lower elevations (PP and IDFx). After the fire, the majority of stands at higher elevations had very low crown closure, *i.e.* all standing trees had been killed in most stands, and there were only small remnant live tree patches (Figure 3). The post-fire forests at lower elevations were a mosaic of completely burned and partially burned patches with many remnant live trees with a wider spread of crown closures.

Natural regeneration of lodgepole pine at higher elevations occurred within 2–4 years in most places with many seedlings 1 m tall by 2011. Regeneration of conifers at lower elevations appeared to have been much slower. Post-fire shrub growth of red-stem ceanothus at low and mid elevations from seed stock dormant in the soil resulted in many thickets up to 2 m tall by 2011. Burned-over aspen groves had suckered into dense 2–3 m tall aspen stands by 2011.

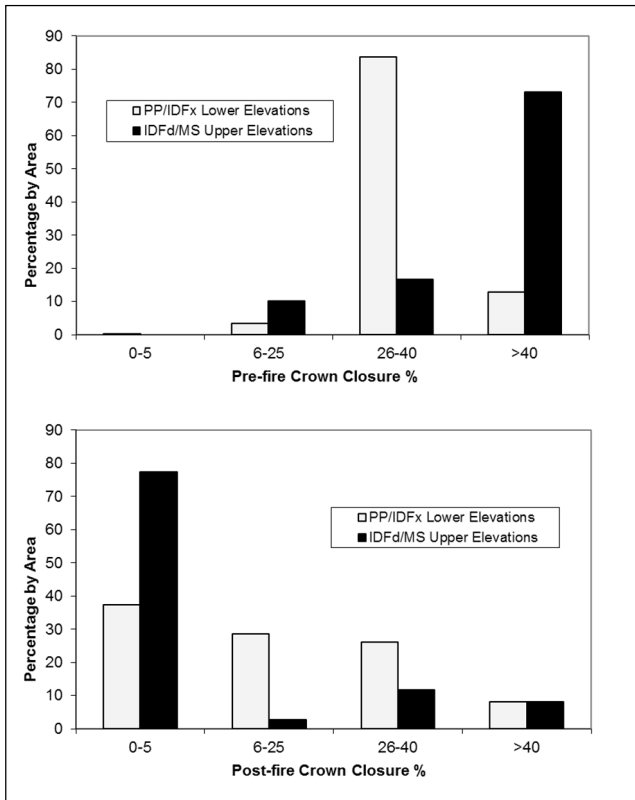


Figure 3. Summary of crown closure by area of Okanagan Mountain Park prior to the 2003 fire and in the fall of 2003 after the fire from BC Forest Service Forest Cover mapping.

## Methods

The Okanagan Mountain Park Bird and Critter Count consisted of a single annual count similar in methods to a Christmas Bird Count. Parties of observers were assigned routes to cover in the park and tallied all birds detected by species. Notes were taken on occurrence of all other animals as well but that information was not summarized here. For the first 11 years the count was a single Saturday on the last weekend in May. After the fire the count became a two-day

Table 1. Okanagan Mountain Provincial Park bird count summary statistics, 1993-2011, before and after the 2003 fire. SD = Standard Deviation.

Parameter	Before fire (1993-2003)		After fire (2006-2011)		Statistics <sup>1</sup>		
	Mean	SD	Mean	SD	U <sub>1</sub>	U <sub>2</sub>	Result
Counts ( <i>n</i> )	11		5				
Observers	41.6	9.5	31.8	7.4	10.5	44.5	0
Effort (party-hours)	54.6	11.9	50.8	11.0	21	34	0
Total Birds Counted	1938	510	1865	357	23	32	0
No. of Species	96.3	8.9	104.6	2.9	49	6	+

<sup>1</sup> Mann-Whitney U critical level given samples sizes of 11 and 5 for alpha = 0.05 is 9.

0 = no significant difference; + = significantly higher post fire; - = significantly lower post fire.

event either on the last weekend in May or the first weekend in June. No route was covered more than once in any given year and the coverage was similar whether the event was held on one day or over more days. Occasionally a route could not be covered on count day or count weekend so it would be covered within 3 days of the count day or weekend. Only one route is accessible for its entire length by car on Lakeshore Road at the north end of the park. One route is along the lakeshore by boat. The remainder of the routes are hiking or walking trails.

Statistical comparisons based on single day counts of areas (e.g. Christmas Bird Count) or routes (e.g. Breeding Bird Survey) are generally only made for many areas or routes grouped together because of high variance among counts or routes and high annual variance on any given count or route. Only with the rather dramatic change in habitat that occurred in Okanagan Mountain Park was there likely to be a large enough change in bird abundance by species to be detectable when comparing a single annual count over time.

Relative abundance for each species was the number counted divided by the search effort in party-hours. Data was available from 11 years prior to the 2003 fire (1993–2003), and for 5 years after the fire (2006–2007, 2009–2011). After the 2003 fire, the park was closed to the public in 2004 and 2005 so the count did not begin again until 2006. Relative abundance after the fire in the period from 2006–2011 included any post-fire successional vegetation changes such as herb, shrub and tree seedling/sapling growth but did not include the two immediate post-fire years when there may have been little shrub or tree seedling/sapling regrowth. No salvage logging of any burned or live timber took place within the park.

Species considered sufficiently common for meaningful statistical analyses were those tallied on >60% of the counts either before or after the fire, and with mean annual count >3 either before or after the fire. Total effort, number of species counted, number of birds counted, and relative abundance of each common species was contrasted before and after the fire using non-parametric Mann-Whitney *U* tests at the alpha = 0.05 level to test for significance.

Changes in the breeding bird populations after the fire were assumed to be for the most part a result of responses to habitat change, and not direct mortality to the birds themselves from the fire. The fire occurred in late August when breeding for almost all species would have been finished, young would have been already fledged, and many would have already departed on migration. For any birds that remained, we assume that most of them would simply have flown away from the advancing fire front.

Scientific names of birds mentioned are presented in Appendix 2.

## Results

The number of species counted per year on the Okanagan Mountain Provincial Park count was significantly higher after the fire with, on average, 8.3 more species counted per year (Table 1). Average number of observers decreased by 10 per year after the fire but number of party-hours did not change significantly. After the fire, available observers were spread more thinly to continue to attempt consistent coverage with an average 4.2 people per party before the fire compared to 2.9 after the fire.

In total, 165 species have been counted in the 16 years of the count. Ninety of these were common species (Table 2), and 75 not common enough to compare statistically (Appendix 1). Twenty-eight of these common species (31%) increased significantly in relative abundance after the fire. Eleven common species (12%) decreased significantly in relative abundance after the fire. Fifty-one common species (57%) did not change significantly in relative abundance.

Only two species (Black-backed Woodpecker and Mountain Bluebird) were never counted prior to the fire but were relatively common after the fire. Four other species (Western Bluebird, Gray Catbird, Lincoln's Sparrow and Lazuli Bunting) were counted three times or fewer in total on all the pre-fire counts but were relatively common after the fire.

The biggest increases were for birds that breed success-

Table 2. Relative abundance (number counted per party-hour) and response to fire-caused changes in habitat of 90 common bird species in Okanagan Mountain Provincial Park before and after the 2003 fire. Species sorted by taxonomic order. SD = Standard Deviation.

Species	Before Fire (1993–2003)		After Fire (2006–2011)		Statistics <sup>1</sup>			Other Studies <sup>2</sup>	
	Mean	SD	Mean	SD	U <sub>1</sub>	U <sub>2</sub>	Response <sup>3</sup>	Response <sup>3</sup>	n
Canada Goose	1.92	1.56	0.45	0.56	47	8	-		
Mallard	0.57	0.31	0.21	0.13	49	6	-		
Ring-necked Duck	0.10	0.17	0.04	0.07	35.5	19.5	0		
Common Merganser	0.18	0.11	0.06	0.12	46	9	-		
Ruffed Grouse	0.24	0.20	0.08	0.06	49	6	-	-	3
California Quail	0.18	0.22	0.47	0.32	12	43	0		
Turkey Vulture	0.13	0.09	0.56	0.28	0	55	+		
Osprey	0.09	0.05	0.13	0.10	19	36	0		
Red-tailed Hawk	0.07	0.06	0.20	0.13	7	48	+		
American Kestrel	0.02	0.03	0.16	0.15	2	53	+	+	4
American Coot	0.05	0.04	0.19	0.19	21	34	0		
Spotted Sandpiper	0.49	0.37	0.18	0.15	45	10	0		
Ring-billed Gull	0.07	0.09	0.04	0.04	31	24	0		
Mourning Dove	0.47	0.30	0.42	0.11	25	30	0	+	3
Vaux's Swift	0.11	0.08	0.03	0.03	45	10	0		
White-throated Swift	0.28	0.34	0.47	0.27	11	44	0		
Calliope Hummingbird	1.02	0.34	0.56	0.21	48	7	-		
Rufous Hummingbird	0.15	0.07	0.09	0.07	39	16	0	0	2
Red-naped Sapsucker	0.32	0.19	0.15	0.09	48	7	-	0-	4
Downy Woodpecker	0.03	0.02	0.08	0.07	14	41	0	0+	4
Hairy Woodpecker	0.10	0.08	0.58	0.18	0	55	+	+	10
Black-backed Woodpecker	0.00	0.00	0.08	0.06	0	55	+	+	12
Northern Flicker	0.51	0.18	0.91	0.34	8	47	+	+	8
Pileated Woodpecker	0.12	0.08	0.11	0.07	28	27	0	0-	4
Am. Three-toed Woodpecker	0.02	0.03	0.08	0.06	6	49	+	+	10
Olive-sided Flycatcher	0.02	0.02	0.26	0.13	0	55	+	+	6
Western Wood-Pewee	0.20	0.17	0.63	0.39	6	49	+	+	6
Hammond's Flycatcher	0.56	0.31	0.72	0.23	17	38	0	m	3
Dusky Flycatcher	1.00	0.36	1.93	0.85	8	47	+		
Pacific-slope Flycatcher	0.11	0.10	0.06	0.06	33	22	0		
Say's Phoebe	0.01	0.02	0.09	0.06	3	52	+		
Cassin's Vireo	0.66	0.30	0.48	0.21	38	17	0	0-	3
Warbling Vireo	0.51	0.30	1.13	0.45	5	50	+	0-	4
Gray Jay	0.09	0.09	0.02	0.04	41	14	0	m	6
Steller's Jay	0.06	0.05	0.07	0.04	20	35	0	-	2
Clark's Nutcracker	0.30	0.32	0.20	0.07	27	28	0	m	6
Black-billed Magpie	0.06	0.04	0.01	0.01	51	4	-		
American Crow	0.13	0.11	0.11	0.05	28	27	0		
Common Raven	0.49	0.18	0.41	0.18	33	22	0	0	3
Tree Swallow	0.34	0.23	0.39	0.18	24	31	0	+	8
Violet-green Swallow	3.38	2.20	1.47	0.51	45	10	0		
Nor. rough-winged Swallow	0.26	0.13	0.09	0.05	50	5	-		
Barn Swallow	0.09	0.08	0.13	0.13	21	34	0		
Black-capped Chickadee	0.31	0.22	0.15	0.08	40	15	0	0	4
Mountain Chickadee	0.53	0.22	0.34	0.17	42	13	0	-	4
Red-breasted Nuthatch	1.60	0.70	0.72	0.15	55	0	-	-	6
White-breasted Nuthatch	0.04	0.05	0.17	0.12	6	49	+		
Pygmy Nuthatch	0.32	0.18	0.30	0.15	30	25	0		
Rock Wren	0.06	0.05	0.06	0.06	28.5	26.5	0		
Canyon Wren	0.04	0.04	0.07	0.05	17	38	0		
House Wren	0.05	0.05	2.15	1.49	0	55	+	+	5
Pacific Wren	0.25	0.27	0.14	0.07	32	23	0	m+	6
Golden-crowned Kinglet	0.55	0.58	0.02	0.02	55	0	-	-	3
Ruby-crowned Kinglet	0.33	0.26	0.31	0.15	26	29	0	m-	8
Western Bluebird	0.00	0.01	0.21	0.15	0	55	+		
Mountain Bluebird	0.00	0.00	0.32	0.14	0	55	+	+	7
Townsend's Solitaire	0.54	0.27	0.40	0.08	32	23	0	m	5
Veery	0.09	0.09	0.22	0.11	7	48	+		
Swainson's Thrush	0.20	0.17	0.37	0.22	13	42	0	0	5
Hermit Thrush	0.09	0.08	0.08	0.04	25	30	0	m	8

◀ Table 2

Species	Before Fire (1993–2003)		After Fire (2006–2011)		Statistics <sup>1</sup>			Other Studies <sup>2</sup>	
	Mean	SD	Mean	SD	U <sub>1</sub>	U <sub>2</sub>	Response <sup>3</sup>	Response <sup>3</sup>	n
European Starling	0.25	0.16	0.41	0.13	12	43	0		
Orange-crowned Warbler	0.21	0.14	0.41	0.37	24	31	0	0	2
Nashville Warbler	0.89	0.42	0.55	0.30	41	14	0		
Yellow Warbler	0.13	0.08	0.12	0.10	30	25	0		
Yellow-rumped Warbler	1.58	0.70	1.95	0.87	17	38	0	m	8
Townsend's Warbler	1.03	0.56	0.22	0.07	55	0	-	0	4
Northern Waterthrush	0.03	0.03	0.08	0.05	11	44	0		
MacGillivray's Warbler	0.30	0.18	0.87	0.36	2	53	+	m	2
Wilson's Warbler	0.24	0.19	0.21	0.10	27	28	0		
Western Tanager	0.75	0.40	0.71	0.19	24	31	0	m	8
Spotted Towhee	0.58	0.25	1.30	0.86	9	46	+		
Chipping Sparrow	1.61	0.80	1.82	0.69	22	33	0	m	8
Vesper Sparrow	0.05	0.04	0.07	0.10	29.5	25.5	0		
Song Sparrow	0.09	0.08	0.72	0.54	0	55	+	-	2
Lincoln's Sparrow	0.00	0.01	0.15	0.11	0	55	+	m	3
White-crowned Sparrow	0.04	0.11	0.26	0.17	5	50	+	+	3
Dark-eyed Junco	1.75	1.03	1.65	0.62	26	29	0	m+	8
Lazuli Bunting	0.00	0.00	0.14	0.10	0	55	+	0+	2
Red-winged Blackbird	0.11	0.09	0.40	0.30	5	50	+		
Brewer's Blackbird	0.03	0.04	0.23	0.05	0	55	+		
Brown-headed Cowbird	0.88	0.31	0.90	0.15	20	35	0	0	2
Bullock's Oriole	0.09	0.11	0.16	0.10	9	46	+		
Cassin's Finch	0.24	0.18	0.12	0.06	40	15	0	+	4
House Finch	0.39	0.31	0.31	0.15	29	26	0		
Red Crossbill	0.75	0.93	0.05	0.04	42	13	0	0-	5
Pine Siskin	1.13	0.80	0.56	0.37	40.5	14.5	0	m	7
American Goldfinch	0.07	0.09	0.16	0.09	15.5	39.5	0		
Evening Grosbeak	0.93	1.17	0.33	0.28	35	20	0	m-	2

<sup>1</sup> Mann-Whitney *U* critical level given samples sizes of 11 and 5 for alpha = 0.05 is ≤9.

<sup>2</sup> Responses from 16 other studies as summarized in Saab *et al.* (2005), Hannon and Drapeau (2005), Huff *et al.* (2005) and Smucker *et al.* (2005). Only species with more than one study cited. The number of studies (n) that gave a result for each species if given.

<sup>3</sup> Responses to fire: 0 = no significant difference; + = significantly higher post fire; - = significantly lower post fire, m = mixed results. Where there were several results from previous studies, the dominant response was given first, followed by subdominant trend.

fully in post-fire habitats, either associated with standing dead trees, semi-open country, or with dense and abundant shrubs.

Woodpeckers that feed on wood-boring insects increased significantly in numbers after the fire. Black-backed Woodpeckers had never been encountered in the park prior to the fire but were present after the fire. Relative abundance of Hairy Woodpeckers and American Three-toed Woodpeckers were four to six times higher after the fire.

Birds found in semi-forested or open habitats were well up. Both Mountain Bluebirds and Western Bluebirds were either not observed or rare in the park prior to the fire, but both were common afterwards. Olive-sided Flycatchers, a species considered Threatened in Canada because of 40% declines in numbers in the past 50 years (COSEWIC 2007), increased ten-fold in abundance. Turkey Vultures, Brewer's Blackbirds, American Kestrels and Say's Phoebe also increased. Red-winged Blackbirds appeared to increase because they were observed using upland burned-over shrub areas as part of their habitat where they would not have used the forests prior to the fire. The cat-tail marshes they breed in appeared to remain relatively unchanged before and after the fire, but the increase in use of upland habitat may have allowed higher densities overall in the same habitats. White-breasted Nuthatch increased, even though they

are a species normally inhabiting live ponderosa pine forests as well. The open ponderosa pine forests created by the fire may be more similar to the more natural open forests in which they likely evolved, rather than the very closed and dense ponderosa pine forests prior to the fire that may not be ideal habitat.

Some bird species associated with shrubs increased greatly in abundance. The most significant increase was in House Wren numbers, with an average of 2.6 counted per year before the fire to an average of 101.2 per year after the fire. Only one Lazuli Bunting had ever been counted in the entire 11 years of the count prior to the fire, but it was a regular after the fire with an average of seven counted per year. Warbling Vireos were particularly abundant in the suckering aspen groves, doubling in abundance. Other shrub-associate species that increased were Veery, MacGillivray's Warbler, Song Sparrow, and Lincoln's Sparrow.

Within the 2006–2011 post-fire period, there were obvious increases for only three species. House Wren relative abundance increased from 0.92 per party hour in 2006 to 2.92 in 2011; MacGillivray's Warbler increased from 0.51 to 1.26; and Spotted Towhee increased from 0.47 to 1.49. The relative abundance of Spotted Towhee was higher in

2009-2011 than in 2006-2007 and higher than in any year prior to the fire. The response of Spotted Towhee to post-fire shrub succession may have been slightly slower than other species, and was only beginning to be shown six years post-fire.

Declines were significant for 11 species after the fire. The largest declines were for those species that inhabit mature closed forests. Abundance of Ruffed Grouse, Red-breasted Nuthatch, and Townsend's Warbler were down to 25–67% of pre-fire levels. Golden-crowned Kinglets declined to 3% of their pre-fire level. Red-naped Sapsuckers also declined by 45% as most of the aspen groves they tended to inhabit were burned severely. Several other uncommon forest species including Boreal Chickadee, Brown Creeper and Varied Thrush appeared to decline as well (see Appendix 1). Summing up the totals for all counts, only one Boreal Chickadee was counted after the fire in five years compared to 17 before in 11 years. No Brown Creepers or Varied Thrushes were counted after the fire compared to 18 and 24 before the fire. Brown Creepers have been observed occasionally in the park after the fire (Pers. comm., Deirdre and Jim Turnbull, Naramata), so it would appear that Brown Creepers 3–8 years after the fire were still so uncommon that they had yet to be detected on count days.

Significant declines were noted for some water birds including Canada Goose, Mallard and Common Merganser. Most of the Canada Geese counted were flying overhead, rather than in breeding, foraging or resting habitat, as there is almost no Canada Goose breeding or foraging habitat within the park. The decline in Canada Goose relative abundance may represent the results of an egg-adding program to reduce numbers in the Okanagan Valley which would result in fewer geese commuting to and from foraging habitat in Penticton and Kelowna. The shoreline in general is too rocky and plunges directly to depth with virtually no shoreline marshes suitable for waterfowl. Reasons why Mallard or Common Merganser numbers may have declined are unknown.

No significant changes were noted in some of the signature birds of the park such as Canyon Wren and White-throated Swift that are associated with cliff and talus rather than with conifer forests. Yellow-rumped Warbler, which one might ordinarily associate with conifer forests, showed no decline at all and appeared just as abundant in forests of standing dead trees as in the dense pre-fire conifers. Similarly, many other common species that we might ordinarily associate with forests such as Western Tanager, Mountain Chickadee, Nashville Warbler, Pacific Wren, Hermit Thrush and Swainson's Thrush showed no significant changes in relative abundance. None of the common finches including Cassin's Finch, House Finch, Red Crossbill, Pine Siskin, American Goldfinch and Evening Grosbeak showed any significant change in relative abundance before and after the fire.

## Discussion

Within the period from 3–8 years after the Okanagan Mountain fire, no common bird species were eliminated from Okanagan Mountain Park because of the habitat changes caused by the 2003 fire even with what would appear to any observer to be major habitat changes. The majority of bird species showed no great changes in numbers. Since habitat was created for additional species without the loss of any common species, overall bird diversity increased and the number of species counted per year was higher after the fire. Overall about twice as many bird species increased after the fire than decreased, similar to the results found after fire in northwestern Montana (Smucker *et al.* 2005).

The relative abundance of most common bird species was assumed to be relatively static in the 11 years prior to the fire because there were no major habitat changes. It will be difficult to show any effect of fire on species such as seed-eating finches whose local abundance may fluctuate markedly on an annual basis. However, the annual abundance of most other species tended to be relatively stable in this study prior to the fire.

Relative abundance of some species such as the House Wren, MacGillivray's Warbler and Spotted Towhee were not static and were changing at a comparatively quick pace after the fire. As the habitats change with natural post-fire succession, the abundance of many other bird species will also be expected to change. Future analyses of the count data will have to take increases and decreases with habitat succession into account in regression and trend analyses, rather than the relatively simple comparisons of before and after presented here.

Hutto (1995) identified bird species relatively restricted to early post-fire conditions as Olive-sided Flycatcher, American Three-toed Woodpecker, Black-backed Woodpecker, Clark's Nutcracker and Mountain Bluebird. Clark's Nutcracker was just as common in the park before and after the fire so would not appear to be an early post-fire specialist. Each of the other species increased significantly in the park after the fire, or in the case of Black-backed Woodpecker and Mountain Bluebird, were found only after the fire.

Saab *et al.* (2005) summarized fire response of 66 species from eight other studies in the Rocky Mountains; Hannon and Drapeau (2005) summarized response of 69 species from five other studies in the boreal forest; Huff *et al.* (2005) summarized the response of 26 species from three other studies in Pacific maritime forests. In general, the results matched those of this study (Table 2) as discussed below. However these cross-study comparisons must be interpreted with caution because when species show different responses to fire in different studies, this is more likely to be a response to different fire severity or time since fire in different studies (Smucker *et al.* 2005).

Of the 14 park species with significant increases in this study, and for which >1 study was cited in Table 2, 11 were in general agreement, *i.e.* most studies indicated the species increased after fire. For the three species for which there was no agreement, the fault appeared to be in the length of the studies. Short-term studies of <4 years after fire tended to indicate only a few species significantly increase after fire (*e.g.* Hutto 1995). However, longer term studies such as this one indicate a much wider variety of species increase after fire, in particular as shrub regrowth creates new habitat. For example, species such as Warbling Vireo, Dusky Flycatcher, and MacGillivray's Warbler can be very abundant in dense 2–3 m tall deciduous shrubs in regenerating clearcuts (Gyug 2000) and these all exhibited increases after the fire in the park. However, if a post-fire study does not last long enough for the shrubs to reach 2–3 m tall, then no effect will likely be shown.

Of the five park species with significant decreases in this study, and for which there was >1 study (Table 2), three were in general agreement with none of those species showing increases after fire. Only for Townsend's Warbler was no decrease shown in any of those studies after fire. In the park Townsend's Warbler relative abundance decreased to 21% of the pre-fire abundance. There was no doubt about the sensitivity to fire as the few places with Townsend's Warblers were almost always remnant forest patches. Red-naped Sapsuckers showed no response to fire in two of three studies, and a negative response in one. The response in this study was negative as most aspen patches were burned over but any unburned aspen patches did tend to retain sapsuckers.

Of the 27 park species for which no fire effect was shown in this study, and for which >1 study was cited by any of those three papers (Table 2), 22 were in general agreement, with either no response shown, mixed responses, or different responses in different studies, *i.e.* particular site effects may be stronger than the any response to fire for those species. Of the five species that did not match, the effects of fire tended to be positive for Mourning Dove, Downy Woodpecker, Tree Swallow and Cassin's Finch, and the effects tended to be negative for Mountain Chickadee, but no effects could be shown on these species in this study.

For some species 2003 may have coincided with another event causing long-term decreases or increases in population abundance that might confound the results of this study. However, with the exception of Canada Goose, the possibility of any such single event significantly affecting abundance to a greater degree than the major effects of the fire on habitat were likely to be small. Examination of an 18-year period will tend to account for both inter-annual fluctuations that add statistical noise to the analysis and for long and steady declines or increases in abundance. On the longer term trend and regression analysis will be required for many species to determine how post-fire successional patterns affect abundance. However, over the 18-year term of this study, the strongest effects on abundance before and after 2003 were likely to be those of the fire alone.

The forests of the park are going to be continually changing for many years in the course of natural succession as young conifers and aspens grow into forests again and particularly as these overtop the current shrub growth that is very dense in many places. If continued, this annual count will provide an excellent long-term record of the changes in bird populations in response to those habitat changes. Whether the park will ever again get to the rather unnatural state where older conifer forests dominate the entire area will depend on any habitat management that might go on within the park and, of course, when fires may strike again. If some fires happen within the park relatively soon, they may not sweep over the whole park as happened in 2003 because fuels in general have been reduced. The results may be a mosaic of open and closed forests at lower elevations more resembling the forests prior to widespread fire suppression and with bird communities to match.

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Appendix 1. Relative abundance (number tallied per 100 party-hours) of 75 bird species considered not sufficiently common for meaningful statistical analyses (i.e. average <3 per year, or recorded on <60% of counts either before or after fire) in Okanagan Mountain Provincial Park before and after the 2003 fire. Species sorted by taxonomic order. Totals are those counted on all counts, summed over all years.

Species	Before Fire (1993–2003)		After Fire (2006–2011)	
	Total tallied on 11 counts	Number tallied / 100 party-hours	Total tallied on 5 counts	Number tallied / 100 party-hours
Gadwall	1	0.2	1	0.3
American Wigeon	1	0.3	0	0.0
Blue-winged Teal	8	1.8	0	0.0
Cinnamon Teal	0	0.0	1	0.4
Green-winged Teal	7	1.2	2	0.7
Lesser Scaup	2	0.3	2	0.8
Bufflehead	16	2.6	15	5.7
Common Goldeneye	34	6.3	0	0.0
Barrow's Goldeneye	152	28.4	34	16.3
Hooded Merganser	3	0.5	3	1.2
Ruddy Duck	8	1.5	28	12.5
Chukar	1	0.1	1	0.3
Ring-necked Pheasant	1	0.1	0	0.0
Spruce Grouse	4	0.7	0	0.0
Dusky Grouse	5	0.7	4	1.5
Pacific Loon	1	0.1	0	0.0
Common Loon	25	4.2	4	1.5
Pied-billed Grebe	0	0.0	3	1.8
Horned Grebe	1	0.1	0	0.0
Red-necked Grebe	28	4.7	0	0.0
Western Grebe	12	1.9	0	0.0
Double-crested Cormorant	1	0.1	0	0.0
Bald Eagle	30	5.0	12	4.4
Northern Harrier	3	0.5	1	0.3
Sharp-shinned Hawk	11	1.8	3	1.1
Cooper's Hawk	13	2.2	6	2.3
Northern Goshawk	2	0.3	3	1.2
Swainson's Hawk	2	0.3	0	0.0
Rough-legged Hawk	2	0.3	0	0.0
Golden Eagle	5	0.9	1	0.3
Merlin	5	0.8	5	1.8

## ◀ Appendix 1

Species	Before Fire (1993–2003)		After Fire (2006–2011)	
	Total tallied on 11 counts	Number tallied / 100 party-hours	Total tallied on 5 counts	Number tallied / 100 party-hours
Sora	7	1.0	5	2.1
Killdeer	13	2.3	10	3.7
Long-billed Curlew	1	0.2	0	0.0
Wilson's Snipe	1	0.1	9	4.1
Bonaparte's Gull	2	0.5	0	0.0
Herring Gull	8	1.5	1	0.4
Parasitic Jaeger	2	0.3	0	0.0
Rock Pigeon	11	1.7	0	0.0
Great-horned Owl	1	0.1	3	1.1
Northern Pygmy-Owl	1	0.2	1	0.4
Barred Owl	3	0.5	1	0.4
Great gray Owl	1	0.1	0	0.0
Common Nighthawk	3	0.5	31	14.6
Common Poorwill	2	0.4	1	0.4
Black Swift	10	1.7	2	0.7
Black-chinned Hummingbird	2	0.5	0	0.0
Belted Kingfisher	13	1.9	2	0.7
Lewis' Woodpecker	4	0.8	0	0.0
Willow Flycatcher	8	1.3	10	4.7
Least Flycatcher	1	0.1	2	0.8
Gray Flycatcher	3	0.4	0	0.0
Western Kingbird	3	0.6	7	2.7
Eastern Kingbird	5	0.9	14	6.3
Red-eyed Vireo	20	3.1	11	3.9
Cliff Swallow	1	0.1	7	2.4
Boreal Chickadee	17	2.5	1	0.4
Brown Creeper	18	3.3	0	0.0
American Dipper	2	0.4	0	0.0
Varied Thrush	24	5.0	0	0.0
American Pipit	1	0.2	0	0.0
Magnolia Warbler	3	0.5	0	0.0
American Redstart	1	0.1	1	0.6
Common Yellowthroat	3	0.5	8	3.6
Clay-colored Sparrow	0	0.0	1	0.3
Lark Sparrow	1	0.1	0	0.0
Savannah Sparrow	3	0.6	1	0.3
Golden-crowned Sparrow	1	0.1	0	0.0
Black-headed Grosbeak	27	4.8	12	4.5
Western Meadowlark	3	0.6	5	1.7
Yellow-headed Blackbird	1	0.2	0	0.0
Pine Grosbeak	20	3.7	5	1.9
White-winged Crossbill	1	0.1	0	0.0
House Sparrow	3	0.6	0	0.0

## Appendix 2. Scientific names of birds mentioned in the text.

English name	Scientific name	English name	Scientific name
Canada Goose	<i>Branta canadensis</i>	California Quail	<i>Callipepla californica</i>
Gadwall	<i>Anas strepera</i>	Chukar	<i>Alectoris chukar</i>
American Wigeon	<i>Anas americana</i>	Ring-necked Pheasant	<i>Phasianus colchicus</i>
Mallard	<i>Anas platyrhynchos</i>	Ruffed Grouse	<i>Bonasa umbellus</i>
Blue-winged Teal	<i>Anas discors</i>	Spruce Grouse	<i>Falcapennis canadensis</i>
Cinnamon Teal	<i>Anas cyanoptera</i>	Dusky Grouse	<i>Dendragapus obscurus</i>
Green-winged Teal	<i>Anas crecca</i>	Pacific Loon	<i>Gavia pacifica</i>
Ring-necked Duck	<i>Aythya collaris</i>	Common Loon	<i>Gavia immer</i>
Lesser Scaup	<i>Aythya affinis</i>	Pied-billed Grebe	<i>Podilymbus podiceps</i>
Bufflehead	<i>Bucephala albeola</i>	Horned Grebe	<i>Podiceps auritus</i>
Common Goldeneye	<i>Bucephala clangula</i>	Red-necked Grebe	<i>Podiceps grisegena</i>
Barrow's Goldeneye	<i>Bucephala islandica</i>	Western Grebe	<i>Aechmophorus occidentalis</i>
Hooded Merganser	<i>Lophodytes cucullatus</i>	Double-crested Cormorant	<i>Phalacrocorax auritus</i>
Common Merganser	<i>Mergus merganser</i>	Turkey Vulture	<i>Cathartes aura</i>
Ruddy Duck	<i>Oxyura jamaicensis</i>	Osprey	<i>Pandion haliaetus</i>

## ◀ Appendix 2

English name	Scientific name	English name	Scientific name
Bald Eagle	<i>Haliaeetus leucocephalus</i>	Barn Swallow	<i>Hirundo rustica</i>
Northern Harrier	<i>Circus cyaneus</i>	Black-capped Chickadee	<i>Poecile atricapillus</i>
Sharp-shinned Hawk	<i>Accipiter striatus</i>	Mountain Chickadee	<i>Poecile gambeli</i>
Cooper's Hawk	<i>Accipiter cooperii</i>	Boreal Chickadee	<i>Poecile hudsonicus</i>
Northern Goshawk	<i>Accipiter gentilis</i>	Red-breasted Nuthatch	<i>Sitta canadensis</i>
Swainson's Hawk	<i>Buteo swainsoni</i>	White-breasted Nuthatch	<i>Sitta carolinensis</i>
Red-tailed Hawk	<i>Buteo jamaicensis</i>	Pygmy Nuthatch	<i>Sitta pygmaea</i>
Rough-legged Hawk	<i>Buteo lagopus</i>	Brown Creeper	<i>Certhia americana</i>
Golden Eagle	<i>Aquila chrysaetos</i>	Rock Wren	<i>Salpinctes obsoletus</i>
American Kestrel	<i>Falco sparverius</i>	Canyon Wren	<i>Catherpes mexicanus</i>
Merlin	<i>Falco columbarius</i>	House Wren	<i>Troglodytes aedon</i>
Sora	<i>Porzana carolina</i>	Pacific Wren	<i>Troglodytes pacificus</i>
American Coot	<i>Fulica americana</i>	American Dipper	<i>Cinclus mexicanus</i>
Killdeer	<i>Charadrius vociferus</i>	Golden-crowned Kinglet	<i>Regulus satrapa</i>
Spotted Sandpiper	<i>Actitis macularius</i>	Ruby-crowned Kinglet	<i>Regulus calendula</i>
Long-billed Curlew	<i>Numenius americanus</i>	Western Bluebird	<i>Sialia mexicana</i>
Wilson's Snipe	<i>Gallinago delicata</i>	Mountain Bluebird	<i>Sialia currucoides</i>
Bonaparte's Gull	<i>Chroicocephalus philadelphia</i>	Townsend's Solitaire	<i>Myadestes townsendi</i>
Ring-billed Gull	<i>Larus delawarensis</i>	Veery	<i>Catharus fuscescens</i>
Herring Gull	<i>Larus argentatus</i>	Swainson's Thrush	<i>Catharus ustulatus</i>
Parasitic Jaeger	<i>Stercorarius parasiticus</i>	Hermit Thrush	<i>Catharus guttatus</i>
Rock Pigeon	<i>Columba livia</i>	American Robin	<i>Turdus migratorius</i>
Mourning Dove	<i>Zenaida macroura</i>	Varied Thrush	<i>Ixoreus naevius</i>
Great Horned Owl	<i>Bubo virginianus</i>	Gray Catbird	<i>Dumetella carolinensis</i>
Northern Pygmy-Owl	<i>Glaucidium gnoma</i>	European Starling	<i>Sturnus vulgaris</i>
Barred Owl	<i>Strix varia</i>	American Pipit	<i>Anthus rubescens</i>
Great Gray Owl	<i>Strix nebulosa</i>	Cedar Waxwing	<i>Bombcilla cedrorum</i>
Common Nighthawk	<i>Chordeiles minor</i>	Northern Waterthrush	<i>Parkesia noveboracensis</i>
Common Poorwill	<i>Phalaenoptilus nuttallii</i>	Orange-crowned Warbler	<i>Oreothlypis celata</i>
Black Swift	<i>Cypseloides niger</i>	Nashville Warbler	<i>Oreothlypis ruficapilla</i>
Vaux's Swift	<i>Chaetura vauxi</i>	MacGillivray's Warbler	<i>Geothlypis tolmiei</i>
White-throated Swift	<i>Aeronautes saxatalis</i>	Common Yellowthroat	<i>Geothlypis trichas</i>
Black-chinned Hummingbird	<i>Archilochus alexandri</i>	American Redstart	<i>Setophaga ruticilla</i>
Calliope Hummingbird	<i>Stellula calliope</i>	Magnolia Warbler	<i>Setophaga magnolia</i>
Rufous Hummingbird	<i>Selasphorus rufus</i>	Yellow Warbler	<i>Setophaga petechia</i>
Belted Kingfisher	<i>Megasceryle alcyon</i>	Yellow-rumped Warbler	<i>Setophaga coronata</i>
Lewis's Woodpecker	<i>Melanerpes lewis</i>	Townsend's Warbler	<i>Setophaga townsendi</i>
Red-naped Sapsucker	<i>Sphyrapicus nuchalis</i>	Wilson's Warbler	<i>Cardellina pusilla</i>
Downy Woodpecker	<i>Picoides pubescens</i>	Spotted Towhee	<i>Pipilo maculatus</i>
Hairy Woodpecker	<i>Picoides villosus</i>	Chipping Sparrow	<i>Spizella passerina</i>
American Three-toed Woodpecker	<i>Picoides dorsalis</i>	Clay-colored Sparrow	<i>Spizella pallida</i>
Black-backed Woodpecker	<i>Picoides arcticus</i>	Vesper Sparrow	<i>Poocetes gramineus</i>
Northern Flicker	<i>Colaptes auratus</i>	Lark Sparrow	<i>Chondestes grammacus</i>
Pileated Woodpecker	<i>Dryocopus pileatus</i>	Savannah Sparrow	<i>Passerculus sandwichensis</i>
Olive-sided Flycatcher	<i>Contopus cooperi</i>	Song Sparrow	<i>Melospiza melodia</i>
Western Wood-Pewee	<i>Contopus sordidulus</i>	Lincoln's Sparrow	<i>Melospiza lincolni</i>
Willow Flycatcher	<i>Empidonax traillii</i>	White-crowned Sparrow	<i>Zonotrichia leucophrys</i>
Least Flycatcher	<i>Empidonax minimus</i>	Golden-crowned Sparrow	<i>Zonotrichia atricapilla</i>
Hammond's Flycatcher	<i>Empidonax hammondii</i>	Dark-eyed Junco	<i>Junco hyemalis</i>
Gray Flycatcher	<i>Empidonax wrightii</i>	Western Tanager	<i>Piranga ludoviciana</i>
Dusky Flycatcher	<i>Empidonax oberholseri</i>	Black-headed Grosbeak	<i>Pheucticus melanocephalus</i>
Pacific-slope Flycatcher	<i>Empidonax difficilis</i>	Lazuli Bunting	<i>Passerina amoena</i>
Say's Phoebe	<i>Sayornis saya</i>	Red-winged Blackbird	<i>Agelaius phoeniceus</i>
Western Kingbird	<i>Tyrannus verticalis</i>	Western Meadowlark	<i>Sturnella neglecta</i>
Eastern Kingbird	<i>Tyrannus tyrannus</i>	Yellow-headed Blackbird	<i>Xanthocephalus xanthocephalus</i>
Cassin's Vireo	<i>Vireo cassinii</i>	Brewer's Blackbird	<i>Euphagus cyanocephalus</i>
Warbling Vireo	<i>Vireo gilvus</i>	Brown-headed Cowbird	<i>Molothrus ater</i>
Red-eyed Vireo	<i>Vireo olivaceus</i>	Bullock's Oriole	<i>Icterus bullockii</i>
Gray Jay	<i>Perisoreus canadensis</i>	Pine Grosbeak	<i>Pinicola enucleator</i>
Steller's Jay	<i>Cyanocitta stelleri</i>	Cassin's Finch	<i>Carpodacus cassinii</i>
Clark's Nutcracker	<i>Nucifraga columbiana</i>	House Finch	<i>Carpodacus mexicanus</i>
Black-billed Magpie	<i>Pica hudsonia</i>	Red Crossbill	<i>Loxia curvirostra</i>
American Crow	<i>Corvus brachyrhynchos</i>	White-winged Crossbill	<i>Loxia leucoptera</i>
Common Raven	<i>Corvus corax</i>	Pine Siskin	<i>Spinus pinus</i>
Tree Swallow	<i>Tachycineta bicolor</i>	American Goldfinch	<i>Spinus tristis</i>
Violet-green Swallow	<i>Tachycineta thalassina</i>	Evening Grosbeak	<i>Coccothraustes vespertinus</i>
Northern Rough-winged Swallow	<i>Stelgidopteryx serripennis</i>	House Sparrow	<i>Passer domesticus</i>
Cliff Swallow	<i>Petrochelidon pyrrhonota</i>		