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Effects of fuel reduction on bird density and reproductive success in riparian areas of mixed-conifer forest in southwest Oregon

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ABSTRACT

Studies in southwest Oregon suggest that riparian areas within mixed-conifer forests historically burned with frequencies and intensities similar to upland areas and that fire played an important role in maintaining both of these ecosystems. Currently, most fuel reduction projects do not include riparian, due to the perception that these riparian areas are negatively affected by anthropogenic disturbance. However, there is very little information on the ecological consequences of including riparian areas in fuel reduction projects. We compared the effects of non-commercial thin and handpile treatments followed by prescribed burns in riparian areas of intermittent and perennial streams that were treated to the streamside (unbuffered), to the typical prescription in which sites were treated only in the adjacent upland (buffered). Unbuffered fuel reduction treatments have the potential to affect bird density and reproductive success differently than buffered treatments by altering (1) available nest habitat, (2) predator and nest parasite abundance, and (3) food availability in riparian areas. This study assessed whether unbuffered fuel reduction treatments yielded similar bird response as buffered treatments by quantifying differences in density and reproductive success of five bird species, vegetation structure, the frequency of occurrence of predators and a nest parasite, and arthropod biomass. Density was greater for the shrub and tree-nesting Pacific-slope Flycatcher in buffered streams post treatment. Reproductive success showed a minimal, near-term effect for the shrub-nesting Black-headed Grosbeak. For potential causal factors, we found differences between buffered and unbuffered streams only for available nest habitat in the upper-ground strata and frequency of occurrence of raptors. Overall, results suggest that fuel reduction in riparian areas as compared with typical upland treatments with buffers had a small effect on bird density and a near-term effect on reproductive success. Additional study of fuel reduction in riparian areas is warranted because of its effectiveness in reducing the risk of unnaturally severe wildfire and, correspondingly, the potential benefit to bird communities over the long-term.

1. Introduction

The Klamath Province in southwest Oregon has a hot and dry climate and in the past, the influence of climate and topography in the region contributed to the regular occurrence of mixed-severity wildfires (Agee, 1993; Huff et al., 2005). However, a century of fire suppression has caused a shift in current fire patterns extending return intervals and increasing severity (Agee, 1993; Agee and Skinner, 2005; Odion et al., 2004; Olsen and Agee, 2005). In an effort to reduce the risk of severe wildfires and return ecosystems to historic conditions, the Bureau of Land Management and other land management agencies are implementing fuel reduction across western landscapes and in the Klamath Province (US Committee on Resources, 2003; USDA and USDI, 2006). However, in many situations, the implementation and efficacy of these treatments is limited by a lack of information on their ecological effects (Alexander et al., 2004; Huff et al., 2005).

There has been no clear consensus on whether or not riparian areas should be included in fuel reduction projects (Arkle and Pilliod, 2010; Bisson et al., 2003). Historically, fire was an important component of riparian ecosystems (Dwire and Kauffman, 2003; Olsen and Agee, 2005). Fire regimes in riparian habitat are linked to the regimes of adjacent upland areas (Everett et al., 2003) and historical records in the Klamath Province indicate that riparian ecosystems burned with similar frequency as upland systems (Olsen, 2000; Taylor and Skinner, 1998). Evidence suggests that vegetation in hardwood and conifer-dominated riparian areas recover rapidly after wildfire, suggesting that riparian plant communities are resilient to disturbance events (Halofsky and Hibbs, 2009).

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Riparian areas provide unique habitat characteristics as the interface between aquatic and terrestrial ecosystems and have high diversity of plants and animals (Sanders and Edge, 1998), supporting diverse bird communities (Knopf et al., 1988; Rich, 2002). In southwestern Oregon, riparian areas surrounding perennial and intermittent streams are typically buffered within fuel reduction projects, to protect both the physical and biological health of the stream and the surrounding biological diversity, as called for in the Northwest Forest Plan (USDA and USDI, 1994). There is concern that the high number of stream buffers (e.g. 7.1 miles of stream per square mile) in any given landscape may diminish the intended effect of fuel reduction by creating stringers of vegetation that carry fire between untreated areas (Agee, 1993; Taylor and Skinner, 1998). Therefore, the need for riparian buffers must be considered in the context of both ecological integrity and effectiveness of fuel reduction.

The general management practice of the Bureau of Land Management in this region is to buffer riparian areas within fuel reduction treatments in mixed-conifer forest. Because of concerns about both the ecological integrity and the effectiveness of upland treatments, land managers are questioning whether or not to continue universally buffering riparian areas. This study was designed to compare the common practice of upland fuel reduction, which incorporates riparian buffers, with an alternative practice of upland and riparian fuel reduction treatments. Assessing overall ecological effects of upland treatments is beyond the scope of this study. Results from this study will inform decisions about treating fuel accumulation in mixed-conifer forests and associated intermittent and perennial streams on public land in the west, and can also be applied to private timberlands and non-commercial ownerships.

Information on how bird populations respond to fuel reduction and wildfire, and the driving factors of change, is limited (Huff et al., 2005). For managers to make decisions about conducting fuel reduction in riparian areas, information on how and why these activities influence bird communities is needed. Postfire changes in bird communities have been associated with vegetation structure (Saab et al., 2007; Seavy, 2006), nest site availability (Hutto, 1995), food availability (Alexander et al., 2004; Apfelbaum and Haney, 1981; Bolger et al., 2005), and predator and nest parasite abundance (Alexander et al., 2004; Martin, 1988).

To provide more information on the ecological effects of fuel reduction in riparian areas, we compared bird density and reproductive success within riparian areas that were treated to the streamside (unbuffered), with the typical prescription in which sites were treated only in the adjacent upland (buffered). Unbuffered fuel reduction treatments have the potential to affect bird density and reproductive success differently than buffered treatments by altering (1) available nest habitat, (2) predator and nest parasite abundance, and (3) food availability in riparian areas. This study assessed whether unbuffered fuel reduction treatments yielded similar bird response as buffered treatments by quantifying differences in bird density and reproductive success of five species, along with vegetation strata cover, frequency of occurrence of predators and a nest parasite, and arthropod biomass. The desired management outcome is that density and reproductive success in unbuffered streams would be greater than or not different from buffered streams during and following treatment.

2. Methods

2.1. Study area

This study was conducted in Jackson County, Oregon within the Klamath Province. The vegetation ranges from mixed-conifer to mixed-conifer/hardwood forest. The habitat type is characterized by Huff et al. (2005) as a lower montane ecosystem. The vegetation in the overstory strata is dominated in the upland by Douglas-fir (*Pseudotsuga menziesii*), Ponderosa Pine (*Pinus ponderosa*), Incense Cedar (*Calocedrus decurrens*), White Fir (*Abies concolor*), Pacific Madrone (*Arbutus menziesii*), Canyon Live Oak (*Quercus chrysolepis*), California Black Oak (*Quercus kellogii*), and Oregon White Oak (*Quercus garryana*). In riparian areas, Big-leaf Maple (*Acer macrophyllum*) also contributes to the overstory strata. The understory strata in the upland is dominated by Buckbrush (*Ceanothus cuneautus*) and Manzanita (*Arctostaphylus* spp.) with added riparian composition including Mock Orange (*Philadelphus lewisii*), Hazelnut (*Corylus cornuta*), and Oceanspray (*Holodiscus discolor*).

This area historically was characterized by fire return intervals ranging from <10 years in dry areas to 50 years in areas with greater moisture, and a low to moderate mixed-severity fire regime (Agee, 1991, 1993; Huff et al., 2005; Taylor and Skinner, 1998). Low severity fires typically result in small scale even-age stands (<0.4 ha), whereas moderate severity fires result in patchiness on the landscape and uneven age stands (Agee, 1998). Fire severity is influenced by topography with greater severity upslope and on south facing slopes (Alexander et al., 2006; Huff et al., 2005). Areas dominated by larger trees (Alexander et al., 2006), located on lower slopes, or within riparian habitat (Taylor and Skinner, 1998) in the lower montane ecosystem burn at low severity resulting in complex forest structure.

2.2. Study design

The study design included data collection before and after treatment, within a paired stream approach. The study was conducted over three years: year one was pre-treatment, year two was post-thinning and handpile, and year three was post-underburn.

The study design incorporated four basins with paired streams in each. Within basins, the paired streams were similar in elevation, aspect, slope, vegetative composition, and size of fuel reduction project, but characteristics among the 4 basins differed. Elevation of the study sites ranged from 436 to 1451 m. For each pair of streams, one stream was treated in the upland with the standard 7.62 m riparian buffer on each side of intermittent stretches and 15.24 m on each side of perennial stretches (hereafter referred to as “buffered”). The other stream was treated in both the riparian and upland (hereafter referred to as “unbuffered”). Stream treatments were assigned randomly within the paired streams (except in one instance because of downstream water rights). The stream basins and corresponding treatment areas ranged in size from 33 to 271 ha.

Within each of the eight stream reaches two study plots were randomly selected; areas were excluded from the study for safety (slope > 30°) and logistics (travel on foot >1.5 h). Plots were situated along a 300 m stretch and extended 50 m upslope on both sides of the stream.

2.3. Fuel reduction treatment

Fuel reduction consisted of non-commercial thin and handpile followed by pile burning and then broadcast underburn. Treatment included direct hand cutting, piling, and burning of non-riparian shrub species and small diameter conifers (<20.32 cm diameter). Thinning was limited to areas that were determined by fuels specialists to need treatment.

Thinning and handpiling were completed from 24 November 2006 to 12 June 2007. While thinning and handpiling in one study unit continued into June, treatment within our study plots was completed by the end of April. Pile burning was completed from 27 November 2007 to 15 February 2008. Underburn treatments were completed in 2008 from 7 April to 7 May. One treatment unit was not underburned due to weather constraints.

Buffered riparian areas remained largely unburned and unbuffered riparian areas showed evidence of low intensity fire (DeJuilio and Martin, 2009). While the majority of uplands burned with moderate severity, the majority of unbuffered riparian areas exhibited lower severities. Fire behavior in both riparian and upland areas differed with micro-site characteristics and fuel loading (DeJuilio and Martin, 2009).

2.4. Data collection

2.4.1. Bird density and reproductive index

We evaluated density and reproductive success for five species with varying habitat requirements. The species included a ground nester; Dark-eyed Junco (*Junco hyemalis*, Nolan et al., 2002), a shrub nester; Black-headed Grosbeak (*Pheucticus melanocephalus*, Hill, 1995), a general shrub and tree nester; Pacific-slope Flycatcher (*Empidonax difficilis*, Lowther, 2000), and two tree nesters; Western Tanager (*Piranga ludoviciana*, Hudon, 1999) and Cassin's Vireo (*Vireo cassinii*, Goguen and Urson, 2002). Surveys were completed using standardized spot-mapping methodology (Ralph et al., 1993) combined with behavioral observation. We used a reproductive index from Vickery et al. (1992) to determine reproductive success, using only rankings for a single-brood because surveys did not cover the entire nesting cycle of double brooders. Each bird territory was assigned a reproductive index score based on presence and/or observed behavior (1 = territorial male present 4+ weeks, 2 = territorial male and female present 4+ weeks, 3 = pair found nest building, laying or incubating eggs or giving distraction display, 4 = adults carrying food presumed to nestlings, 5 = evidence of fledging success). Each plot was visited 10 times annually from 2006 to 2008 between 3 May and 26 July and visits on average lasted 180 min.

During each visit, the five species were mapped and reproductive indices were recorded for each territory. Density of adult males was calculated for each plot based on territory delineations. A territory was counted as zero if it was ≤25% on plot, 0.5 if it was >25% and ≤75%, and one if it was > 75% on plot. Mean reproductive indices were generated for each of the five species for each study plot by year using territories that were ≥50% on plot.

2.4.2. Vegetation sampling

We collected vegetation data using a relevé technique (Ralph et al., 1993) to describe vegetation composition and structure. We established three 50 m radius vegetation plots to quantify vegetation within each 100 m × 300 m survey plot. Four strata of vegetation were defined based on height: overstory (>5 m), understory (>0.5 m and <5 m), upper-ground (>0.1 and <0.5 m), and ground (<0.1 m). Within each stratum, we quantified percent vegetation cover into five categories (0–5%, 5–25%, 25–50%, 50–75% and 75–100%). For the analysis, we converted categorical cover variables to percentages using the midpoint percent cover for each cover class. Mean overstory, understory, upper-ground, and ground cover value were calculated for each study plot by year.

2.4.3. Predator and nest parasite sampling

Total count for all predators and the parasitic Brown-headed Cowbird (*Molothrus ater*) were recorded during each spot-mapping/reproductive index survey. For the analysis, predators were grouped as corvids [Common Raven (*Corvus corax*), American Crow (*Corvus brachyrhynchos*), Steller's Jay (*Cyanocitta stelleri*), and Western Scrub Jay (*Cyanocitta cristata*)], squirrels [Douglas Squirrel (*Tamiasciurus douglasii*), Western Gray Squirrel (*Sciurus griseus*), and Golden-mantled Ground Squirrel (*Spermophilus lateralis*)], raptors [Red-tailed Hawk (*Buteo jamaicensis*), Cooper's Hawk (*Accipiter cooperii*), Sharp-shinned Hawk (*Accipiter striatus*), American Kestrel (*Falco sparverius*), owls [Northern Pygmy Owl (*Glaucidium gnoma*), Western Screech Owl (*Otus kennicottii*)], and lizards [Alligator Lizard (*Elgaria multicarinata*), Western Fence Lizard (*Sceloporus occidentalis*)]. For analysis, the frequency of occurrence (percentage of surveys in which a species was detected) of each predator group and the nest parasite was calculated for each study plot by year.

2.4.4. Arthropod sampling

Sweep netting, a direct collection method, was used to sample foliage dwelling arthropods in low vegetation (New, 1998). Arthropods were collected using 10 sweeps of vegetation between 0.5 and 2 m in height. Seven samples were collected twice annually from each plot at points every 50 m along the stream. Specimens were collected and preserved in 95% ethanol, and later identified in the lab to order and measured to the nearest millimeter. Arthropod length was converted to dry mass, using a length–weight equation (Rogers et al., 1976). Total biomass was calculated by summing all individuals for each study plot by year for *Hemiptera* (true Bugs, aphids, leafhoppers), *Hymenoptera* (ants, bees, wasps), *Arachnida* (spiders), *Diptera* (flies), and *Coleoptera* (beetles). Of total arthropods collected, 90% were comprised of these 5 orders. All other arthropods were combined into an additional group, referred to as Other [*Collembola* (springtails), *Psocoptera* (bark lice), *Acarina* (mites), *Thysonoptera* (thrips), *Lepidoptera* (butterflies and moths), *Neuroptera* (snakeflies), *Archeognatha* (bristletails), *Orthoptera* (crickets and cockroaches), *Plecoptera* (stoneflies), *Tricoptera* (caddisflies), *Opiliones* (harvestmen and daddy long-legs), *Isoptera* (termites), *Odonata* (dragonflies and damselflies), and unidentified nymphs and larvae].

2.5. Statistical analysis

Using the paired design, we calculated the difference between density, mean reproductive index, vegetation strata cover, predator and nest parasite frequency of occurrence, and total insect biomass on buffered and unbuffered streams (difference equal buffered values minus unbuffered values). The difference between paired streams is the metric used in all analyses. Normality of residuals was assessed with a Shapiro–Wilk test. Reproductive indices were normally distributed; all other data had a non-normal distribution. We used R Project for Statistical Computing (R Development Core Team, 2008) for all analyses.

We used a repeated measure ANOVA to test a null hypothesis that the difference in reproductive indices between paired buffered and unbuffered streams would not change over treatment years (Bolker, 2008). For significant results, we used a post hoc Tukey HSD (Honestly Significantly Different) to determine which treatment years were significantly different from one another. To test a null hypothesis that the difference in density, vegetation strata cover, predator and nest parasite frequency of occurrence, and total insect biomass between paired buffered and unbuffered streams would not differ by treatment year we used a Friedman test, which accommodates non-normal data distribution. For all analyses, treatment year was considered a significant effect when $P \leq 0.05$.

3. Results

3.1. Bird density

There was no evidence that the difference in density between buffered and unbuffered streams differed by treatment year for Black-headed Grosbeak, Cassin's Vireo, Dark-eyed Junco, or Western Tanager (Friedman test, P always >0.08, Table 1). Only the difference in density of Pacific-slope Flycatcher differed by year,

Table 1
Sample size; mean density, vegetation strata cover, predator and nest parasite frequency of occurrence, and total arthropod biomass; and standard error on buffered and unbuffered streams in each treatment year. The difference (Diff.) between means [buffered – unbuffered] is presented. Results from a Friedman test indicate whether the difference between paired buffered and unbuffered streams differed between treatment years.

	N	2006 Pre-treatment					2007 Post-thinning and handpile					2008 Post-underburn					*P*
		Buffered		Unbuffered		Diff.	Buffered		Unbuffered		Diff.	Buffered		Unbuffered		Diff.	
		Mean	Std Error	Mean	Std Error		Mean	Std Error	Mean	Std Error		Mean	Std Error	Mean	Std Error		
Avian density																	
Black-headed Grosbeak	8	2.38	0.31	2.81	0.39	−0.44	2.19	0.44	2.69	0.37	−0.50	3.38	0.31	2.50	0.40	0.88	0.08
Cassin's Vireo	8	0.38	0.26	0.31	0.16	0.06	0.69	0.25	0.50	0.16	0.19	0.75	0.25	0.88	0.40	−0.13	0.89
Dark-eyed Junco	8	3.00	0.25	2.38	0.36	0.63	2.56	0.37	2.13	0.52	0.44	2.81	0.37	2.25	0.35	0.56	1.00
Pacific-slope Flycatcher	8	1.50	0.42	1.81	0.60	−0.31	1.38	0.53	1.38	0.45	0.00	2.25	0.56	1.75	0.53	0.50	0.05
Western Tanager	8	2.25	0.47	1.88	0.34	0.38	1.00	0.31	1.38	0.45	−0.38	1.81	0.27	2.00	0.37	−0.19	0.76
Vegetation cover																	
Overstory	24	0.42	0.04	0.44	0.05	−0.02	0.42	0.03	0.44	0.04	−0.02	0.39	0.02	0.45	0.04	−0.06	0.50
Understory	24	0.23	0.03	0.30	0.04	−0.07	0.15	0.02	0.18	0.03	−0.03	0.09	0.02	0.08	0.01	0.01	0.40
Upper-ground	24	0.24	0.03	0.28	0.04	−0.04	0.23	0.03	0.32	0.03	−0.10	0.13	0.04	0.21	0.04	−0.08	0.04
Ground	24	0.32	0.04	0.36	0.04	−0.04	0.29	0.04	0.42	0.04	−0.13	0.17	0.04	0.23	0.04	−0.06	0.08
Predator/parasite functional group																	
Brown-headed Cowbird	8	0.15	0.03	0.10	0.07	0.05	0.21	0.09	0.06	0.04	0.15	0.20	0.08	0.20	0.11	0.00	0.53
Corvid	8	0.74	0.05	0.81	0.06	−0.08	0.70	0.09	0.71	0.10	−0.01	0.83	0.05	0.83	0.08	0.00	0.27
Lizard	8	0.03	0.02	0.04	0.02	−0.01	0.11	0.04	0.13	0.05	−0.01	0.24	0.05	0.24	0.07	0.00	0.96
Owl	8	0.00	0.00	0.01	0.01	−0.01	0.01	0.01	0.10	0.09	−0.09	0.00	0.00	0.04	0.03	−0.04	0.58
Raptor	8	0.01	0.01	0.03	0.02	−0.01	0.09	0.06	0.09	0.05	0.00	0.13	0.04	0.03	0.02	0.10	0.03
Squirrel	8	0.31	0.04	0.31	0.07	0.00	0.28	0.07	0.25	0.08	0.03	0.28	0.03	0.31	0.06	−0.04	0.91
Arthropod biomass																	
Arachnida	8	7.77	1.58	9.93	1.38	−2.17	5.50	1.19	5.15	0.98	0.35	9.51	1.23	8.96	1.64	0.55	0.61
Coleoptera	8	7.21	1.17	9.94	3.30	−2.73	3.41	0.67	3.99	1.07	−0.58	11.69	3.14	8.45	1.35	3.24	0.69
Diptera	8	8.59	1.52	8.91	2.51	−0.32	2.75	0.99	1.92	0.53	0.83	11.98	2.50	11.37	1.85	0.61	0.61
Hemiptera	8	17.07	4.22	50.88	35.82	−33.81	32.45	10.57	35.16	21.15	−2.71	11.38	2.24	10.59	2.32	0.79	0.61
Hymenoptera	8	13.64	1.97	14.36	2.86	−0.73	14.09	2.33	19.72	6.62	−5.64	32.92	6.92	23.95	2.71	8.98	0.61
Other	8	13.54	2.01	11.47	1.67	2.07	6.71	1.20	4.35	1.07	2.36	15.06	1.17	10.68	1.23	4.38	0.61

showing lower density in buffered streams pre-treatment (Year 1) and greater density post treatment (Year 3) (Friedman test, $P = 0.05$, Table 1).

3.2. Bird reproductive indices

Difference in reproductive indices between buffered and unbuffered streams did not differ by treatment year for the Dark-eyed Junco, Cassin's Vireo, Pacific-slope Flycatcher, and Western Tanager (ANOVA, P always >0.12, Table 2). For the Black-headed Grosbeak reproductive success was lower in unbuffered streams post-handpile (Year 2), compared with buffered streams. However, post-underburn (Year 3), reproductive success was greater in unbuffered compared with buffered streams (ANOVA $P = 0.05$, Tukey test Year 2 post-handpile/Year 3 post-underburn $P = 0.04$, Table 2).

3.3. Vegetation structure

There was no evidence that the difference in cover between buffered and unbuffered streams for the overstory, understory, and ground strata differed by treatment year (Friedman test, P always >0.08, Table 1). Difference in upper-ground strata cover did vary by year, with greater cover in unbuffered streams in year 2 and 3, as compared with buffered streams (Friedman test, $P = 0.04$, Table 1).

3.4. Predators and nest parasites

The difference in frequency of occurrence of most functional predator groups (corvids, squirrels, lizards, owls) and the one nest parasite (Brown-headed Cowbird) did not differ between treatment years (Friedman test, P always >0.27, Table 1). The difference in frequency of occurrence differed only for all raptors combined (Friedman test, $P = 0.04$, Table 1). This difference resulted from greater variance between buffered and unbuffered streams in year 2 and greater occurrence of raptors on buffered streams in year 3 (Table 1).

3.5. Arthropods

There was no evidence that the difference in biomass between buffered and unbuffered streams for the five most abundant orders (*Hemiptera*, *Hymenoptera*, *Arachnida*, *Diptera*, and *Coleoptera*) and other insects combined differed between treatment years (Friedman test, P always >0.61, Table 1).

4. Discussion

Overall, we found relatively little evidence that fuel reduction in riparian areas negatively affected bird density or reproductive success in the context of upland treatments. Our results are similar to other studies in the western United States. Bêche et al. (2005), in a similar study in the Sierra Nevada, found that prescribed fire in the riparian had no or very near-term (<1 year) effect on abiotic and biotic parameters, including riparian vegetation and large woody debris. Saab et al. (2007) in a literature synthesis found a greater bird response to prescribed fire during the treatment year than in the following year, suggesting an immediate but short-term response.

4.1. Bird density

In our study, difference in density between buffered and unbuffered streams differed only for the Pacific-slope Flycatcher. Although the difference in shrub strata cover did not differ by treatment year, there was a general reduction in shrub

Table 2
Sample size, mean reproductive success, and standard error for five bird species on buffered and unbuffered streams in each treatment year. The difference (Diff.) between means [buffered – unbuffered] is presented. Results from an ANOVA indicate whether the difference in reproductive success between paired buffered and unbuffered streams differed between treatment years.

	2006 Pre-treatment							2007 Post-thinning and handpile							2008 Post-underburn							P
	Buffered			Unbuffered			Diff.	Buffered			Unbuffered			Diff.	Buffered			Unbuffered			Diff.	
	N	Mean	Std Error	N	Mean	Std Error		N	Mean	Std Error	N	Mean	Std Error		N	Mean	Std Error	N	Mean	Std Error		
Black-headed Grosbeak	21	1.95	0.34	24	1.92	0.29	0.04	19	3.16	0.36	21	2.38	0.30	0.78	30	2.77	0.29	23	3.35	0.29	−0.58	0.05
Cassin's Vireo	3	2.00	1.00	3	2.00	1.00	0.00	6	1.00	0.00	5	1.80	0.49	−0.80	6	2.83	0.60	7	2.57	0.65	0.26	0.49
Dark-eyed Junco	26	2.77	0.39	21	3.00	0.41	−0.23	20	3.65	0.35	16	2.94	0.34	0.71	24	3.33	0.37	19	3.74	0.31	−0.40	0.12
Pacific-slope Flycatcher	12	1.17	0.17	15	2.07	0.38	−0.90	11	1.91	0.39	12	2.33	0.53	−0.42	18	1.89	0.35	16	2.63	0.46	−0.74	0.67
Western Tanager	20	1.35	0.17	16	2.19	0.41	−0.84	9	2.11	0.39	12	1.75	0.22	0.36	16	2.63	0.46	16	3.44	0.33	−0.81	0.48

cover across study plots. We hypothesize that the retention of shrubs in the riparian area of the buffered stream was correlated with greater density of Pacific-slope Flycatchers on buffered streams, because of their affinity to riparian habitat in western forests (Canterbury, 2003) and nesting preference in shrubs and trees (Lowther, 2000).

Other species did not differ by treatment year, suggesting either density was not affected by thin and handpile treatments nor prescribed burning, that the affect of treatments was consistent in buffered and unbuffered streams, or that the affect of a buffer was overshadowed by an upland treatment effect. The latter may be the case because areas of mid-elevation streams can have similar vegetation composition and structure as the upland and exhibit similar species composition (Finch, 1989; Knopf and Samson, 1994; Lehmkuhl et al., 2007). Seavy and Alexander (2006) found that prescribed fire in mixed-conifer/hardwood habitats had minimal effect on shrub and canopy cover and little effect on bird abundance.

4.2. Bird reproductive indices

A year effect driving differences in reproductive success of the shrub-nesting Black-headed Grosbeak resulted from lower success in unbuffered streams post-handpile, as compared to buffered streams, followed by greater success in unbuffered streams following underburn. There was a trend of stable to increasing reproductive success in both buffered and unbuffered streams after completion of all treatments. We hypothesize that post-handpile, the retention of shrubs in the riparian of the buffered stream was correlated with greater reproductive success of Black-headed Grosbeaks, because of their affinity to riparian nest sites in dry forests (Lehmkuhl et al., 2007).

4.3. Vegetation structure, predator and nest parasites, and arthropods

Because the study plots extended 50 m upslope, the upland areas which all underwent treatment comprised a considerable portion (>70%) of the study area. Thus, the difference between vegetation strata cover in buffered and unbuffered streams showed minimal difference; reduction of understory cover in the additional 30% of treated habitat in unbuffered was not substantial enough to result in significant differences within our study. A companion vegetation study was completed in conjunction with this study, which compared buffered and unbuffered vegetation within 7 m of the stream, identifying changes within the buffer area (DeJuilio, 2009). DeJuilio (2009) found that the greatest changes in cover occurred in the subcanopy of unbuffered streams and the reduction in subcanopy among unbuffered replicates was significantly more than the change in buffered streams. After thinning, shrub cover significantly decreased, by nearly 50% in all unbuffered streams and less so in buffered streams (DeJuilio, 2009).

We evaluated the frequency of occurrence of predators on study plots as a potential cause of changes in reproductive success following treatments, but overall differences in occurrence of raptors did not correspond with differences in reproductive success. Our results of predator abundance generally align with a study in similar habitat post wildfire, where Seavy (2006) found no evidence that predator abundance differed between burned and unburned areas three to four years post fire.

Results of our study suggest that insect availability was not a potential causal factor in differences of reproductive success after fuel reduction. Although no difference was found in insect biomass, it is important to note that our results did not encompass potential differences in canopy dwelling insects due to a limitation of sweep-netting field methods. In a study on wildfire within the Klamath Province, Seavy (2006) found increased insect abundance three to four years post fire, suggesting potential for affects after the completion of this short-term study.

4.4. Management implications

Pre-treatment fire behavior models were indicative of passive crown fire in riparian and upland areas within both buffered and unbuffered sites (DeJuilio and Martin, 2009). Both buffered and unbuffered fuel reduction treatments were effective in reducing predicted fire severity at a landscape level, indicating that both treatments met the goal of reducing wildfire risk (DeJuilio and Martin, 2009). However, post-treatment models indicated an increased probability of surface fire in both upland and riparian areas after unbuffered treatments, while the probability of passive crown fire in riparian areas remained high after buffered treatments (DeJuilio and Martin, 2009) suggesting that unbuffered treatments are even more effective. Ultimately, returning the system to a state which will burn at a severity similar to historic wildfires will better protect riparian areas and fauna associated with these areas, by reducing the risk of uncharacteristically high fire severity.

The results for the five 'focal' bird species studied can be used as indicators for the likely response of other birds that share their habitat preferences (Chase and Geupel, 2005). We hypothesize that the short-term effects on Black-headed Grosbeak reproductive success and Pacific-slope Flycatcher density, are likely indicators of the response of shrub nesting species with an affinity to riparian areas in this system, such as the Spotted Towhee *(Pipilo maculates)* (Contreras, 2003). Although fuel reduction treatment prescriptions called for retention of all riparian shrub species, we noticed the replacement of low growing riparian shrubs with herbaceous vegetation after treatments in unbuffered streams. Because treatments were completed primarily during winter months (late November to early June) shrubs were difficult to identify without foliage. Future treatments should either occur during times when shrubs are leafed out, or shrubs should be flagged, to assure their retention.

Overall, results suggest that fuel reduction in riparian areas as compared with typical upland treatments with buffers had a small effect on bird density and a near-term effect on reproductive success. Results should be interpreted cautiously in consideration of sample size limitations. Additional study of these treatments is needed to evaluate effects over the long-term. The riparian areas within this study, as is typical of dry mixed-conifer/broadleaf forests, are narrow and in many cases similar to uplands in vegetation structure and composition. Given this, it is likely that the effect of a buffer on density and reproductive success for some species would be washed out by the effect of treatment in upland areas. However, despite concurrence of minimal effects, studies have questioned whether fuel reduction and prescribed fire can mimic the natural conditions that result from wildfire, thus being effective as a tool for restoring ecosystem health (Arkle and Pilliod, 2010; Hurteau et al., 2008). Additional study of bird response to fuel reduction in the Klamath Province would inform future decisions on how both upland and riparian treatments could best meet bird conservation objectives.

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