Lake Tahoe Upland Fuels Research Project: 2006-2007 Results

Report to
Nevada Division of State Lands
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INTRODUCTION

Mechanical and prescribed fire treatments are used to reduce fuels and change forest structure and reduce the potential size and intensity of wildfires. The relative effectiveness of treatment combinations in meeting various objectives, such as reducing fire risk or meeting biological resource objectives, is still uncertain. Of particular interest are the individual and combined effects of mechanical and burning treatments. Fuel levels are at unprecedented high levels in the basin as a result of timber harvest in the late 1800s resulting in single-aged stands, and fire suppression since the early 1900s. Desired conditions for forests in the basin are: 1) reduce the risk of catastrophic fire, and 2) restore the health and ecological integrity of forests. The restoration of the natural fire regime, if possible, is likely to be the most effective approach to achieving desired conditions for forests in the basin. However, many obstacles make this impossible. Instead, managers are exploring options for manipulating vegetation using a variety of tools to move forests toward desired conditions.

There is little doubt that fuel treatments can modify wildfire behavior, but support is lacking for the widely held belief that simply reducing tree density reduces fire hazard. Substantial evidence supports the effectiveness of prescribed fire, but there is no scientific consensus on the specifics of how treatments are implemented and the relative effectiveness of different prescriptions. Research that addresses effects on biodiversity, wildlife populations, and ecosystem function are virtually nonexistent. The notion that mechanical thinning, or a combination of mechanical thinning and prescribed fire reduces the incidence of catastrophic fire should be regarded as a working hypothesis. Therefore, fuel treatment programs should include a robust experimental design that provides a scientific basis for the design, implementation, and evaluation of fuel treatments. As the amount of money spent on fuels treatment programs increases every year, a comparable investment should be made in scientific and applied research in order to optimize a higher return on future investments.

Fuel treatments are likely to affect wildlife populations and habitat, particularly species that have narrow habitat tolerances in association with features such as canopy cover, understory structure, herbaceous plants (e.g., seed eaters and understory foraging species), fungi, and standing and downed woody debris (Manley *in press*). Fuel treatments are typically designed to achieve short-term (1-2 years) change in forest structure, and to a lesser extent a change in composition. Any substantial manipulation of vegetation will result in a myriad of short and long-term effects on the composition and structure of plants and animal communities and populations (Bigelow and Manley *in press*, Manley *in press*).

Existing studies in urban-wildland interface zones in the basin are finding that species responses to changes in forest conditions vary within and among taxonomic groups (Manley et al. 2006, Schlesinger et al. 2008, Sanford et al. *in press*). Some species appear to be sensitive to site disturbance (e.g., presence of people and equipment), whereas others are highly sensitive to vegetation structure, and still others are well adapted to a wide variety of environmental conditions. Short-term effects on animals are difficult to predict because the response of species to the disruption will vary depending on the timing and intensity of activities and the sensitivity of each species. Longer-term changes in animal communities and populations resulting from treatments are more predictable once a successional trajectory is modeled because then habitat correlates can be used to make inferences about animal responses.

BACKGROUND

This report presents the cumulative results from the Upland Fuels Research Project. The science team represents a collaboration between University of Nevada, Reno (UNR), Pacific Southwest Research Station (PSW), and BMP Ecosciences (a research consultant). The principle investigators in this project are Dennis Murphy (UNR), Patricia Manley (PSW), and Bruce Pavlik (BMP).

Previous grants from the Southern Nevada Public Lands Management Act (Round 5) paid for pre-treatment data collection in 2006 on six pairs of sites on the west shore. Documents summarizing results for 2006 were prepared (Manley 2006, Stanton and Dailey 2007). This grant from the Nevada State License Plate Funds paid for pre-treatment sampling in 2007 on two additional sites located on Nevada State Lands and a second year of sampling on the west shore sites. A second year of pre-treatment sampling was conducted on two pairs on sites on the west shore in order to establish inter-annual variation of the sampling variables, especially the understory vegetation and animal species responses. Treatments were completed on two sites on the west shore over the fall and winter of 2006 and post-treatment sampling was conducted on these sites in 2007. At the close of the 2007 field season, the sample includes 8 pairs of sites (16 sites total).

OBJECTIVES

The objective of this project was to evaluate interim results in the study of the effects of different fuel reduction treatments on vegetation composition and structure, fuel loading, select wildlife species, and wildlife habitat. Given the short-term nature of the data and the limited sample size, the results reported here are preliminary and inconclusive; however, they do represent mounting evidence as to the effects of standard fuel treatments on wildlife, plants, and forest structure. Animal species studied were small mammals, songbirds, and ants.

STUDY AREA AND SAMPLING DESIGN

The study was conducted in the Lake Tahoe basin on Nevada State Lands, California State Lands, and National Forest System lands. A Before-After-Control-Impact (BACI) design is being used with a sample size of eight paired treatment/control sites. Twelve sites (six pairs) were installed on the west shore in 2006 and four sites on the east shore in 2007(Fig. 1). Study sites were located in the montane zone because the majority of fuels management treatments in the basin are expected to occur in proximity to the wildland-urban intermix (WUI) zone, which occurs primarily at lower elevations around Lake Tahoe. The west shore mixed conifer forests are dominated by white fir, with varying proportions of red fir, incense cedar, Jeffrey pine, and sugar pine. The east shore montane zone consists of Jeffrey pine with red and white fir. Understory vegetation is varied, ranging from grass to shrub dominated with various amounts of herbaceous cover. The western portion of the basin receives a higher precipitation and higher water balance than the northern and eastern portions of the basin, resulting in higher plant and animal species richness.

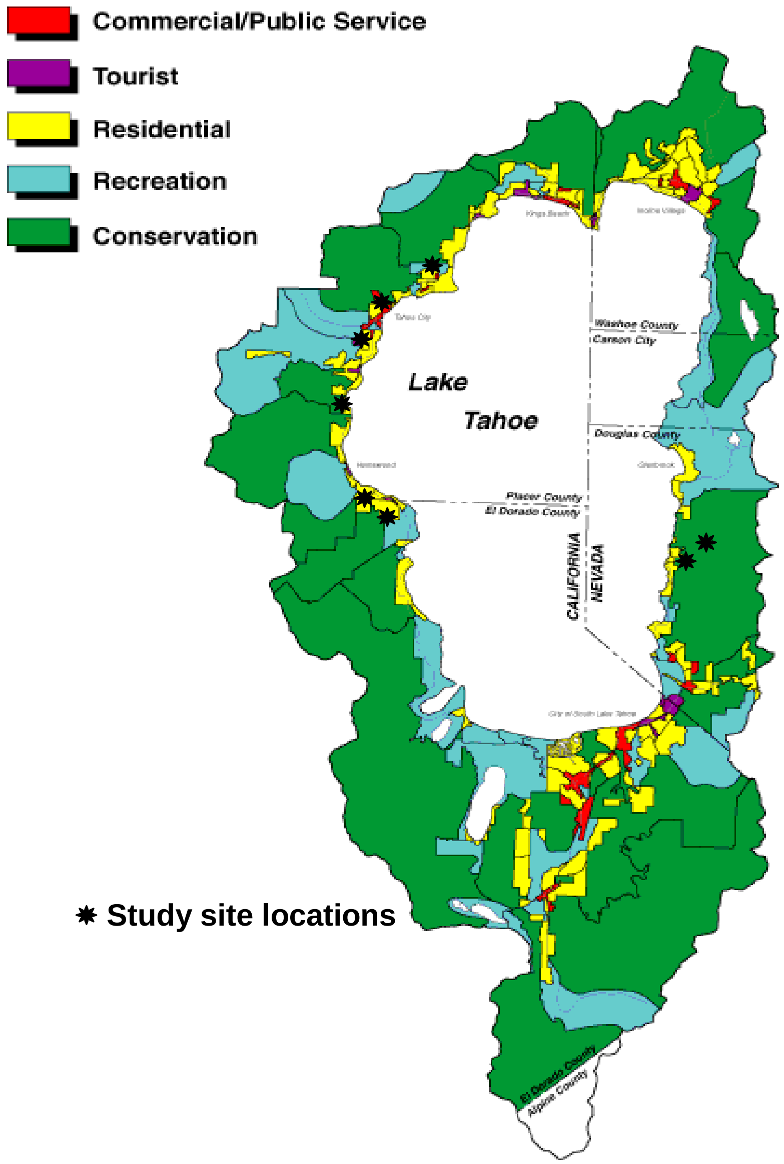

Figure 1. Study area and sample site locations.

The 12 sites on the west shore were located in four different watersheds, and the four sites on the east shore were located in the same watershed (Table 1). Site elevation ranged from near lake elevation at 6,300 feet to over 7,700 feet. Slopes varied from 5 to over 40%. The units will be referred to by either the unit number or the site code.

Table 1. Location and characteristics of treatment (T) or control (C) sample units.

Unit	Veg type	HUC7 watershed	Slope (%)	Elevation (ft)	Aspect	Site code
BLK 1-4 T	Mixed conifer	Blackwood Cr	17	6,479	S	BLKW
BLK 1-4 C	Mixed conifer	“	21	6,542	E	DEDO
MCK13-1 T	Mixed conifer	Eagle Rock-Madden Cr-Homewood-Quail	11	6,827	NW	CHNQ
MCK 13-1C	Mixed conifer	“	10	6,471	E	TMBW
MCK 13-3T	Mixed conifer	“	26	6,609	SE	MULL
MCK 13-3 C	Mixed conifer	“	24	6,350	E	HOME
TWC3 T	Mixed conifer	Lower Truckee R.	6	6,871	S	DANY
TWC3 C	Mixed conifer	“	11	6,916	S	ARND
WRD 20-16T	Mixed conifer	Ward Cr Frontal	11	7,048	flat	BOTA
WRD 20-16C	Mixed conifer	“	11	7,115	flat	CALC
WRD 20-9 T	Mixed conifer	“	5	6,972	NW	BOAA
WRD 20-9 C	Mixed conifer	“	5	7,008	flat	SKTR
RED T	Jeffrey pine/ red fir	North Canyon	35	7,759	W	REDS
RED C	Jeffrey pine/ red fir	“	42	7,644	W	ROLS
WLD T	Jeffrey pine/ red fir	“	21	7,635	S	NUTH
WLD C	Jeffrey pine/ red fir	“	14	7,585	W	WILD

Standard fuel reduction prescriptions are designed to reduce surface and ladder fuels in order to modify fire intensity and limit the potential for crown fire spread. The prescriptions utilize hand and mechanical treatments including: chainsaw thinning, cut-to-length forwarder/processor thinning, piling, pile burning, mastication, and chipping. With hand thinning, the slash is piled and the piles are scheduled for burning within 1-3 years. Some prescriptions call for an additional understory burn after the piles are gone. Hand treatments are generally required on units with slopes greater than 30%, but hand treatments are also conducted on slopes less than 30% if there are other limitations on machine access. With mechanical treatment, machine mastication of the slash in place results in residual woody material that is irregularly shaped and generally in excess of 3 inches diameter. Chipping results in more regular pieces of residual woody material that are generally less than 3 inches diameter.

The details of the prescriptions vary among Lake Tahoe basin agencies. On National Forest lands within the LTBMU, the USFS utilizes three types of thinning prescriptions: 1) standard hand thinning of trees up to 14in DBH with piling of the slash; 2) standard mechanical removal of trees up to 30in DBH with a cut-to-length forwarder/processor system with mastication or chipping of the slash; and 3) site-specific prescriptions for units located within the boundaries of protected activity centers (PAC) that are prepared in consultation with wildlife biologists. Within the Lake Tahoe Nevada State Park, the NDSL utilizes project-specific prescriptions that may utilize a combination of treatments.

Of the eight treatment unit pairs, 3 have hand thin prescriptions and five have mechanical prescriptions (Table 2). Spotted owl protected activity centers (PAC) for Goshawk and Spotted Owl were located in three treatment units. The specialized prescriptions in Blackwood and Twin Crags on the west shore called for higher remnant basal area and canopy cover than typical in standard mechanically treated stands. The hand thin unit in Ward Creek was governed by an older prescription that limited tree removal to 10in DBH or less, instead of the standard 14in DBH. In the North Canyon RED unit, the diameter limit on hand thinning was extended up to 24in DBH because the steep slopes make it inaccessible for machinery. The prescription in North Canyon WLD unit specifies a combination of hand thinning and machine removal of trees up to 24in DBH, although select trees over 30in DBH may be removed on an individual basis.

Table 2. Fuels reduction prescriptions on 8 treatment units on the west and east sides of the Lake Tahoe basin.

Unit	Ownership	Treatment Rx
West shore:		
Ward Ck Unit 20-16	USFS	PAC, hand thin to 10", pile/burn
McKinney Ck Unit 13-1	USFS	Hand thin to 14", pile/burn
McKinney Ck Unit 13-3	USFS	Mechanical to 30”, masticate
Ward Ck Unit 20-9	USFS	Mechanical to 24", masticate
Blackwood Ck Unit 1-4	USFS	PAC, mechanical to 24", masticate
Twin Crags Unit 3	USFS	PAC, mechanical to 24", masticate
East shore:		
North Canyon Reds	NV	Hand to 24”, pile/burn
North Canyon Wildcat	NV	Combination hand/mechanical to 24”, pile/burn

The treatment schedule and sampling schedule extends into 2011 (Table 3). Funding from the SNPLMA Round 8 science granting process will provide some funding through 2010. Treatments are implemented within a complex regulatory and funding environment and therefore delays are expected. On USFS in particular, the implementation of mechanical treatments is limited by the number of contractors available to do the work. Currently, only one contractor is being used. The method is limited by its low profitability and complex regulations.

Table 3. Treatment and sampling schedule for the eight treatment sites in the Lake Tahoe Basin.

Unit Name and #	Treatment year	1 yr post-sample	2 yr post-sample
Ward Ck Unit 20-16	2007	2008	2009
McKinney Ck Unit 13-1	2006	2007	2008
McKinney Ck Unit 13-3	2009	2010	2011
Ward Ck Unit 20-9	2008	2009	2010
Blackwood Ck Unit 1-4	2006	2007	2008
Twin Crags Unit 3	2008	2009	2010
North Canyon Reds	2007	2008	2009
North Canyon Wildcat	2008	2009	2010

METHODS

Field Data Collection

An integrated sampling design was used to collect data on vegetation structure and fuel loads, small mammals, birds, and invertebrates. A macroplot of 150 x 330 m was established in a relatively homogeneous and representative portion of each unit (Fig. 2). The macroplot provided the grid for 72 wildlife trapping stations, point bird counts, and 10 randomly selected vegetation plots. A paired BACI sample design is critical for separating treatment effects from the myriad of environmental factors that can influence plant and animal community composition and structure over time. Two-year pre-treatment sampling is required to establish inter-annual variation of the sampling variables, especially the understory vegetation and animal species responses. Together these data will set a baseline for the longer monitoring period (minimum of 5 years) that is required to address longer-term conditions resulting from treatments and whether they are meeting desired conditions for forest health, wildlife habitat, and the maintenance of acceptable predicted fire behavior.

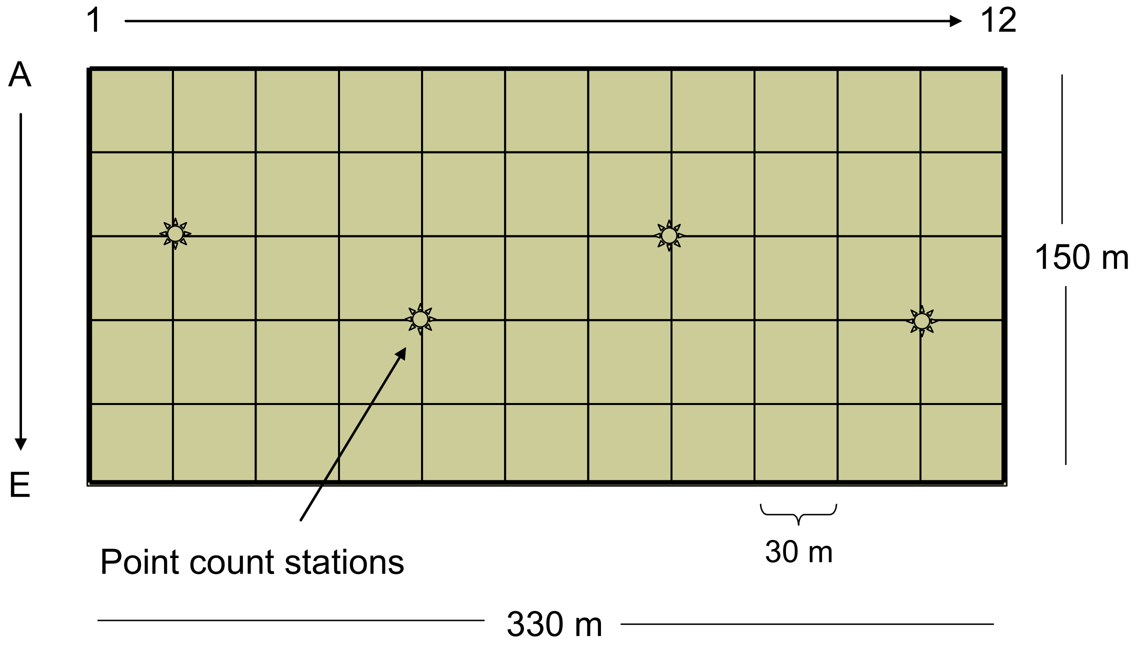

Figure 2. Integrated sample plot design, with 72 sample points occupying a 12.4 ha area.

Vegetation and Fuels

Vegetation sampling focused on forest structure, understory composition, and fuel loads. Vegetation plot lay-out and sampling protocols were developed in collaboration with the USFS Adaptive Management Services Enterprise Team (AMSET, located on the Tahoe National Forest) and the LTBMU and were based primarily on FIREMON, the Fire Effects Monitoring and Inventory System (Lutes et al 2006). FIREMON is an Access database software tool that is specifically designed to facilitate analysis of changes in plant communities and fuel loadings in response to management activities over time. The resulting sampling protocols have been used by AMSET to monitor other fuels treatment sites elsewhere in the basin. Thus, the protocols used in this project are accepted by management agencies in the basin and promise to become the primary system to be used for fuels treatment monitoring and associated data management across multiple agencies in the basin (see www.fire.org).

Vegetation was measured in 8 to 10 randomly selected plots centered on the macroplot grid. Plots were fixed-radius circular areas with a 58 ft (17.84 m) radius encompassing 0.25

acres (0.1 ha). Every tree and snag ≥ 6in (15cm) diameter at breast height (DBH) was tagged with a unique number and the following information recorded: species, diameter at breast height (DBH), total height, decay class (snags), height to live crown base, live crown ratio, crown position, and observed damage. Seedings and saplings (trees < 6in DBH) were recorded in a smaller sub-plot of 0.025 acres (0.01ha). Canopy cover was measured using a GRS site-tube densitometer. Surface and ground fuels were sampled on four, 20m transects in each inventory plot using the line-intercept method (Brown, 1974). Herb and shrub percent cover, height, and nested frequency were measured in five $0.25m^2$ quadrats along each transect. Detailed data collection parameters for vegetation and fuels may be found in Appendix A.

Birds and Small Mammals

Birds and small mammals were the primary focus of vertebrate sampling – they are directly affected by treatments and have complementary sensitivities to the effects of fuels treatments. They also serve as the primary prey for upper trophic level species of special status in the basin, namely the California spotted owl, Northern goshawk, and American marten. Small mammals are closely tied to the local conditions, they are highly dependent upon overstory and understory vegetation, and they primarily are year-round residents. Birds are more mobile, but most species have relatively narrow environmental conditions in which they can successfully breed, and they are also dependent upon both overstory and understory conditions.

Point Counts

Bird point count stations were located at four locations located near the center of the sample plot (C2, D5, C8, D11). In addition, birds were recorded as observers walked between stations in a zig-zag manner between B2 and B11 (e.g., B2 to C2, C2 to E2, E2 to E5, E5 to D5, D5 to B5, B5 to B8, etc.). Point counts were conducted three times at each sample plot from late May to early July. Each count consisted of a 10 minute count during which all birds, Douglas squirrels, and tree frogs were recorded. All detections were recorded as to whether they occurred during the first or second 5 minutes of the count, and distance from the count station was recorded in 20 m increments. Paired sites were sampled within two days of one another, and the two observers were rotated among visits across sites. Counts begin at least 15 min after sunrise and are completed before 9:30 a.m. Counts are not conducted during windy or rainy conditions.

Small Mammal Trapping

Sampling methods targeted small mammal species presence and abundance, with an emphasis on squirrels. Flying squirrels are expected to be a strong integrator of the range of treatments associated with fuel reduction activities because they are associated with the canopy (nesting and cover), as well as the ground (foraging). Small mammals were sampled with a combination of extra long and extra large Sherman live traps (4 x 4.5 x 15 in; 10 x 11.5 x 38 cm) and tomahawk traps (5 x 5 x 16 in; 12.5 x 12.5 x 40 cm;). One tomahawk trap and one extra large Sherman live trap were placed at each of 72 trap stations (6 x 12 stations 30 m apart = 150 x 330 m grid = 5 ha area) (Fig. 1). Tomahawk traps were placed in trees 1.5-2.0 m above ground on the trunk of a tree > 50 cm DBH that was not marked for removal. Traps were attached to trees with nails. Trees were as close to the trap station as possible, and within 5 m if at all possible. Tomahawk traps were covered with a tarp around the outside, attached with duct tape, and a nest box (10 x 10 x 6 cm cardboard) is placed at the back of the trap with some polystyrene for warmth. Sherman traps were placed at the base of trees or along larger logs or under shrubs. Traps were solidly placed such that they did not rock or move when an animal enters. Traps are covered with natural materials (or chloroplast if none are available) to insulate traps from the sun and rain, and polystyrene placed in the back of the trap for warmth. All traps were baited with a mixture of oats, bird seed, and raisins. We attempted to include peanut butter and molasses, following the general formula used by Carey et al. (1991), but bear damage was so great that we were forced to eliminate these ingredients from the bait. A small amount of bait was placed at the entrance of the trap and a larger amount at the back of the trap.

Traps were set, baited, and locked open for a minimum of 3 nights before trapping began, then opened for four nights, starting with traps being set in the late afternoon/early evening prior to the first trap evening (just before dusk). The traps were checked twice per day, with afternoon checks occurring in the late afternoon/early evening. The morning after the fourth night, the traps were removed.

All individuals captured were identified to species and marked in both ears with uniquely numbered ear tags, and data on sex, age (juvenile or adult), weight, and reproductive status (males: testes enlarged; females: vagina perforate, nipples swollen, enlarged, reddened, lactating, pregnant) were recorded. Ear, leg, or tail measurements were taken on individuals whose identification is in question.

Mammalian Carnivores

Baited camera stations were established at the center of each sample site to determine the presence of mammalian carnivores. Cuddyback or Leafriver digital cameras were set approximately 1 m above the ground on a large diameter tree. At a nearby opposing tree, ½ a raw chicken was fastened to the tree inside a wrap of chicken wire. In addition, a turkey feather was dangled above the bait but outside the range of the camera lens to attract cats (bobcat and mountain lion). Cameras were set for 10 days and checked every other day to ensure that bait was still present, cameras were operational and flashcards were not full. No attractant was used at camera stations to reduce any potential bias associated with drawing in animals from long distances outside the sample site. Sites were sampled from June through August.

Ants and Butterflies

Invertebrate herbivores are mostly monophagous or narrowly polyphagous on plant species that will be variously impacted by proposed treatments; thus, the combined responses of plants, vertebrates, and invertebrates provide rich information about ecological conditions. We sampled ground-dwelling ants at 12 sites in 2006 and 2007. At each site, we established three, 40-m transects within the macroplot located at B2, C6, and E11. Each transect consisted of four pit-fall traps separated by 10 m. Ant pit-fall traps consisted of 6.5-cm diameter (120 ml) plastic cups. Traps contained approximately 25 ml of propylene glycol and remained open for seven days. All sites were sampled one time during each summer of 2006 and 2007.

We also sampled butterflies for 10 minutes within each of five circular plots (10-m diameter) within each site. One butterfly sampling plot was located at the center of the site at C6, and the other four butterfly plots were located within a forest opening nearest the corners of the grid (B2, E2, B11, and E11). All sites were sampled three times during each summer in June, July, and August in 2006 and 2007.

Data Analysis

Vegetation and Fuels

The FIREMON system has been designed to characterize forest structure by generating values for the following variables: quadratic mean diameter (QMD), percent canopy closure, tree density, tree basal area, snag density, shrub height, and the amount of coarse woody debris (logs). We calculated tree density by species and diameter class to assess species composition and vegetation structure.

The composition and cover of herbaceous and shrub species were also characterized and included in estimates of fuels. Understory vegetation is a critical component of wildlife habitat and it can strongly influence fire behavior. Herb and shrub species richness were calculated as the mean number of species present in each plot across a unit. Average cover was calculated for each plant species by status (live or dead). Frequency of occurrence was calculated for each of four frame sizes (1:25:50:100 cm) by dividing the number of quadrats in which a species is present by the total number of quadrats.

Measured surface fuel loads were calculated by FIREMON in tons per acre for three different components: litter and duff, fine woody debris (1, 10, and 100 hr fuels), and coarse woody debris (1000 hr fuels). Biomass is calculated based on equations in the Handbook for Inventorying Downed Woody Material (Brown 1974). Non-slash, composite values are used to calculate QMD, non-horizontal correction, and specific gravity of fine woody debris. Decay classes 1-3 are sound with a specific gravity of 0.40. Decay classes 4-5 are rotten and assigned a specific gravity of 0.30. Loading of litter and duff is calculated using bulk densities of 2.75lbs/ft^3 and 5.5 lbs/ft^3, respectively. Biomass of live and dead shrubs and biomass are calculated using the equation:

$$B=H*C*BD$$

where B is biomass (tons/acre), H is height (ft), C is percent cover/100, and BD is bulk density (lbs/ft^3). Bulk densities used for the herbaceous and shrub components are 0.8 kg/m^3 and 1.8kg/m^3 respectively.

All variables for vegetation and fuels are presented as means for each unit. At this time, no statistical analysis was conducted to determine significant difference between pre-treatment conditions in paired treatment/control units because of the small sample size ($n = 2$) at the close of 2007. It will be possible, however, to conduct this analysis with the addition of the 2008 data.

Habitat

Habitat was characterized based on the California Wildlife Habitat Relationships (CWHR) program (CDFG 2002). The CWHR database characterizes habitat based on two parameters: tree diameter and canopy cover (Table 4). The CWHR database identifies vegetation, tree diameter, and canopy cover conditions as having low, moderate or high suitability for each vertebrate species in California. We calculated the predicted changes in species richness based on habitat changes at treated sites and compared these predictions to observed changes in species richness.

Table 4. California Wildlife Habitat Relationships forest habitat classification.

Tree Size (diameter)			**Canopy Closure**		
WHR	**Size Class**	**DBH**	**WHR**	**Closure Class**	**Canopy Closure**
1	Seedling Tree	<1"	**S**	Sparse Cover	10 to 24%
2	Sapling Tree	1" to 6"	**P**	Open Cover	25 to 39%
3	Pole Tree	6" to 11"	**M**	Moderate Cover	40 to 59%
4	Small Tree	11" to 24"	**D**	Dense Cover	60 to 100%
5	Med/Large Tree	>24"			
6	Multi-Layered Tree	Size class5 trees over a distinct layer of class3 or 4 trees, total canopy >60%			

Animals

Small mammal and bird data provided a description of species composition, richness, and abundance for all species detected. Small mammal abundance was calculated using the number of first captures per 100 trap days, and dominance was calculated using the Berger-Parker dominance index (max abundance per species/total abundance). Trap effort was corrected for traps rendered unavailable for some (0.5) or all (1.0) of the trap day as a result of disturbed, sprung, destroyed, or missing traps.

Bird richness and abundance metrics were calculated for each site. Bird species richness was based on all species encountered over the course of all three visits. Bird abundance was calculated as the average number of individuals detected across all four count stations and three visits (12 counts total). Dominance was evaluated using the Berger-Parker dominance index. Bird species abundance was also calculated for each of several species groups representing associations with the primary habitat characteristics expected to change with fuel treatments: old forest associates, early seral associates, log and snag associates, and primary cavity nesters (Appendix B).

The presence of carnivores as evidenced by photos was reported. No corrections for probability of detection were conducted because no statistical analyses were used. Additional detections acquired in the course of conducting other standardized data collection efforts were also noted.

Species composition, richness, and relative abundance of ants and butterflies were calculated for each site. Three service-providing units (SPU) were identified for ants to help interpret the ecological meaning of changes in ant community composition and structure: aerators, decomposers, compilers. Remaining species were considered generalists.

The analysis for all species groups was limited to simple summaries, given the small number of sites that have received treatments (n = 2). The primary analysis conducted was a comparison of variation in species composition and abundance between years at sites with no treatment are compared to the variation observed between years for the two treatment sites. Sites on the east shore were not included in this analysis because only one year of data was available for these sites.

Variations in detections between years can be a function of multiple factors, including observers, timing of surveys, and actual changes in the bird community. For bird point counts, the same sample periods and the limited variation in observers (two observers in each year, one consistent between years) suggests that observed variation reflects real change. For small mammal trapping, timing of samples per site can result in differences in abundance but not composition. No sampling bias is expected to affect detections of ants or mammalian carnivore data.

Funding has been secured for a third year of data collection in 2008, and at that time four sites will have received treatments, with three more sites being treated in 2008. In future years, statistical analyses will be possible and appropriate.

RESULTS

Vegetation and Fuels

Pre-treatment conditions in 2006 for vegetation and fuel in the west shore units have been previously reported (Stanton and Dailey, 2007). Select results from that report are reproduced here to provide contrast with the east shore units installed in 2007. Pre-treatment conditions for forest structure, herbaceous and shrub species, and fuel loads are presented for the west shore units followed by the east shore units. A comparison of pre-and post treatment conditions for the two units that were treated in 2007 on the west shore is presented.

Pre-treatment conditions

Forest Structure

Pre-treatment habitat conditions in the 12 west shore units were typed as 4M and 4D (Table 5). Average tree size was small (11 to 24 in) in all units. Mean canopy closure ranged from 48% to 72%, indicating moderate to dense stands. The density of trees >1 inch ranged from a low of 157 to a high of 244 trees per acre. Mean basal area varied considerably, with values ranging from 147 to 309 ft^2/acre. Snag density was also variable, but generally quite high, with mean values ranging from 25 to 114 snags/acre. The mean number of down logs per acre ranged from 10 to 26 in all units except MCK 13-3 where high fuel loads translated to 35 and 57 logs/acre in the control and treatment unit, respectively. Mean live shrub height ranged from 0.9 to 2.4 feet.

Pre-treatment conditions in 2007 in the four east shore units in Nevada were characterized by fewer trees per acre and more open canopies (Table 6). However, the CWHR types were comparable to the west shore, with all east shore units classified as having small trees (<24 inches) and moderate canopy closure (<50%). Fewer mature trees meant lower basal areas, but the number of snags and logs per acres were comparable.

Table 5. Average forest structure and habitat conditions in the 12 west shore units prior to treatment in 2006. CWHR = California Wildlife Habitat Relationship class; QMD= Quadratic Mean Diameter.

Unit	Treat or Control	CWHR type	Trees/Acre (>1")	SE	Canopy Closure (%)	SE	QMD (inch)	SE	Basal Area (ft^2/acre)	SE	Snag/ Acre	SE	Logs/ Acre (>3")	SE	Shrub Height (ft)	SE
BLK 1-4	**C**	4M	151.3	13	48.4	3	16.1	2	190	12	25.1	5	23.6	1	2.4	0.3
BLK 1-4	**T**	4D	222.9	19	67.6	4	16.5	1	299.5	26	44.5	6	18.4	1	1.3	0.2
MCK 13-1	**C**	4M	197.9	22	57.2	4	15	2	221.4	21	34.4	16	25.2	2	1.8	0.2
MCK 13-1	**T**	4M	173.5	28	56.2	7	13.3	1	146.8	14	35.5	12	26.2	1	2	0.2
MCK 13-3	**C**	4D	212.4	20	72.4	4	17.1	1	304.8	15	114.1	16	34.8	3	1.2	0.3
MCK 13-3	**T**	4M	205.1	21	57.6	8	15.7	1	263.4	23	79.7	16	57.6	2	1.9	0.5
TWC 3	**C**	5D	206.8	25	60.2	7	17.4	2	305.1	27	36.4	11	18.4	2	1.6	0.1
TWC 3	**T**	4M	171.9	19	47.6	4	15.5	3	191.4	19	38.1	6	22	1	1.4	0.2
WRD 20-16	**C**	4D	239.9	16	71.6	11	15	1	264	5	26.7	7	10	1	0.9	0.1
WRD 20-16	**T**	4M	163.2	14	56	9	16	1	218.8	18	30.6	4	20.8	1	1.4	0.2
WRD 20-9	**C**	4D	194.6	25	62.9	9	15.3	1	227	27	26.7	5	11.6	1	1.2	0.1
WRD 20-9	**T**	4M	185.7	20	49.8	7	14.9	1	215.1	21	34	6	15.6	1	1.2	0.1

Table 6. Average forest structure and habitat conditions in the four east shore units prior to treatment in 2007. CWHR = California Wildlife Habitat Relationship class; QMD= Quadratic Mean Diameter, 75th percentile.

Unit	Treat or Control	CWHR type	Trees/Acre (>1")	SE	Canopy Closure (%)	SE	QMD (inch)	SE	Basal Area (ft^2/acre)	SE	Snags/Acre	SE	Logs/Acre (>3")	SE	Shrub Height (ft)	SE
RED	**C**	4M	94.1	9	43	1	17.7	1	155.5	11	40.9	11	13.5	1	2.2	0.3
RED	**T**	4M	89.1	16	50	2	17.1	1	131.3	18	45.1	10	29.5	1	2.9	0.2
WLD	**C**	4M	63.7	10	41.5	4	22.4	1	158.5	21	25.8	6	14	2	1.8	0.2
WLD	**T**	4M	108.1	21	49	2	17.4	1	157.7	26	28.3	12	36.5	1	1.5	0.2

Six tree species characteristic of lower montane mixed conifer forests were recorded in the west shore units: white fir (*Abies concolor*, ABCO); red fir (*Abies magnifica*, ABMA), incense cedar (*Calocedrus decurrens*, CADE); lodgepole pine (*Pinus contorta*, PICO); Jeffrey pine (*Pinus jeffreyi*, PIJE); and sugar pine (*Pinus lambertiana*, PILA). All units on the west shore were heavily dominated by white fir. Three out of every four trees tagged was a white fir. White fir was present in every sample plot (100 % frequency) and mean tree densities (trees/acre, > 1 inch) of ABCO were greater than the other conifer species by an order of magnitude (Table 7). The mean basal area of the different conifer species reflected the same pattern (data not shown).

On the east shore, the forest was dominated by Jeffrey pine and mixed red/white fir. White fir was most dominant in the RED control unit, while red fir was dominant in the RED treatment unit. Jeffrey pine was most dominant in both WLD units (Fig. 3).

Table 7. Mean density (trees/acre) of trees greater than one inch of six conifer species in the west shore units in 2006.

Unit	ABCO	ABMA	CADE	PICO	PIJE	PILA	Total
BLK 1-4 C	126	8	11		2	10	157
BLK 1-4 T	178	10		4	42		233
MCK 13-1 C	142	14	16	13	21	9	215
MCK 13-1 T	127	7	9	28	20	10	201
MCK 13-3 C	191	17		4	4	6	223
MCK 13-3 T	190	15			10	6	221
TWC3 C	168	33	4		8	6	219
TWC3 T	128	2	38		8	7	183
WRD 20-16 C	226	12			6		244
WRD 20-16 T	130	27		3	5		164
WRD 20-9 C	103	42		49	13	4	211
WRD 20-9 T	101	55		31	8	4	199

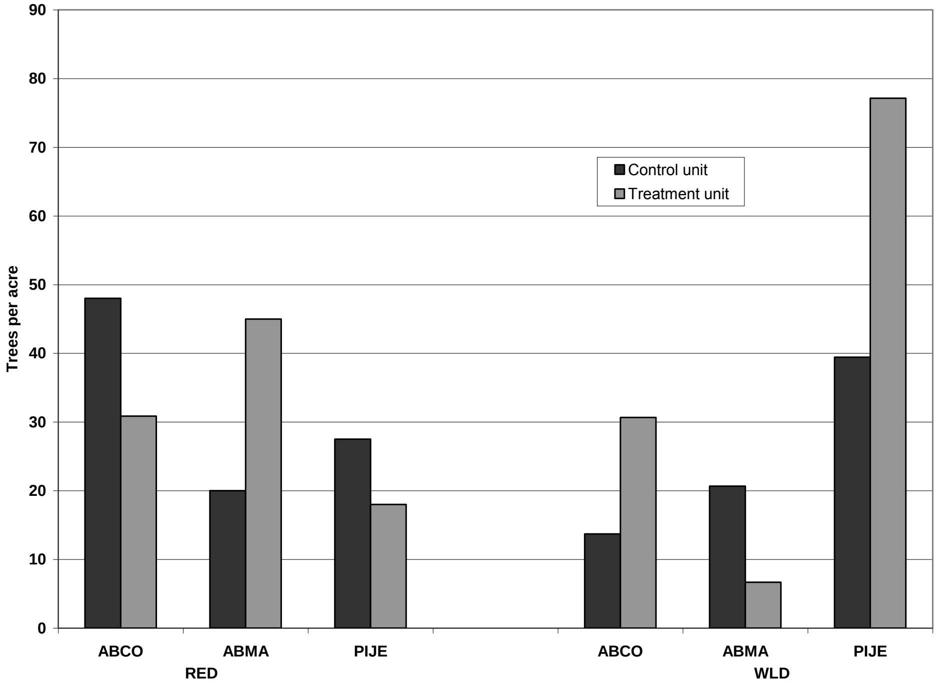

Figure 3. Pre-treatment conditions in the two east shore unit pairs: mean tree density for each of three conifer species; ABCO (white fir), ABMA (red fir), and PIJE (Jeffrey pine).

Average tree size was small on both sides of the lake. Pole size trees (6-12”) and/or small trees (12-24”) were dominant across every west shore unit (data not shown). Saplings (1-6”) were uncommon with fewer than 20 per acre and there were only 4 or fewer large trees (>36”) per acre. Although tree density was less in the east shore units, pole and small trees dominated in all units but the WLD control unit (Fig. 4). Saplings were less uncommon on east shore sites than west shore sites, but a similarly small number of large trees was present (≤ 4 large trees/ac).

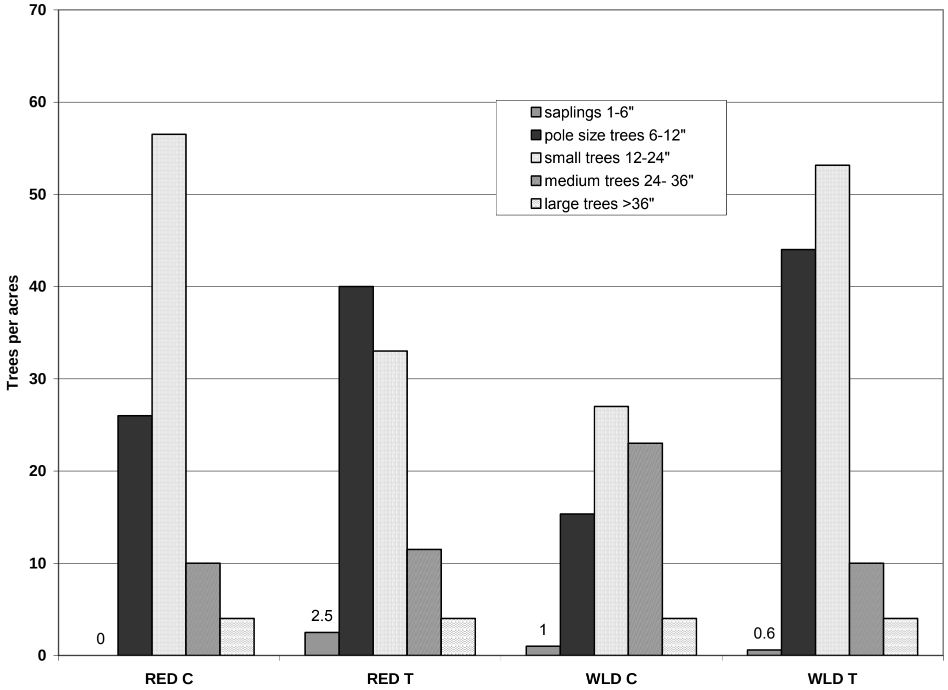

Figure 4. Pre-treatment conditions in the two east shore unit pairs: mean tree density (trees per acre) of saplings, and small, medium, large diameter classes.

Understory Species

A total of 142 understory plant species were identified in the west shore units including 22 shrubs, 3 sub-shrubs, 14 grasses, and 103 herbs. A sub-shrub is distinguished from a shrub by its ground-hugging stems and lower height, with overwintering perennial woody growth typically less than 20 cm tall. The total number of species found within a single plot ranged from zero in several plots in MCK 13-3 to 41 species in a plot in WRD 20-09. Total mean richness per 0.25 ac plot ranged approximately from 4 to 30 species (Fig. 5). The mean number of herb species per plot ranged from 1 to 20, with the most common herbs being dogbane (*Apocynum androsaemifolium*), milk kelloggia (*Kelloggia galioides*), mountain pennyroyal (*Monardella odoratissima)*, little prince's pine (*Chimaphila menziesii*), and wirelettuce (*Stephanomeria lactucina*). The mean number of shrub species per plot ranged approximately from 2 to 7. The most common shrub by far was whitethorn (*Ceanothus cuneatus*), and other common shrub species included greenleaf manzanita (*Arctostaphyllos patula*), huckleberry oak (*Quercus vaccinifolia*), and bush chinquapin (*Chrysolepis sempervirens*). The mean number of sub-shrub and grass species per plot ranged approximately from 0 to 3. Common grasses included squirrel tail (*Elymus elymoides*), western needlegrass (*Acnatherum occidentalis*), and native bromes (*Bromus spp.).*The three sub-shrubs, pinemat manzanita (*Arctostaphylos nevadensis*), creeping snowberry (*Symphoricarpos mollis*), and squaw carpet (*Ceanothus prostratus*) were all quite common. No exotic plant species were detected.

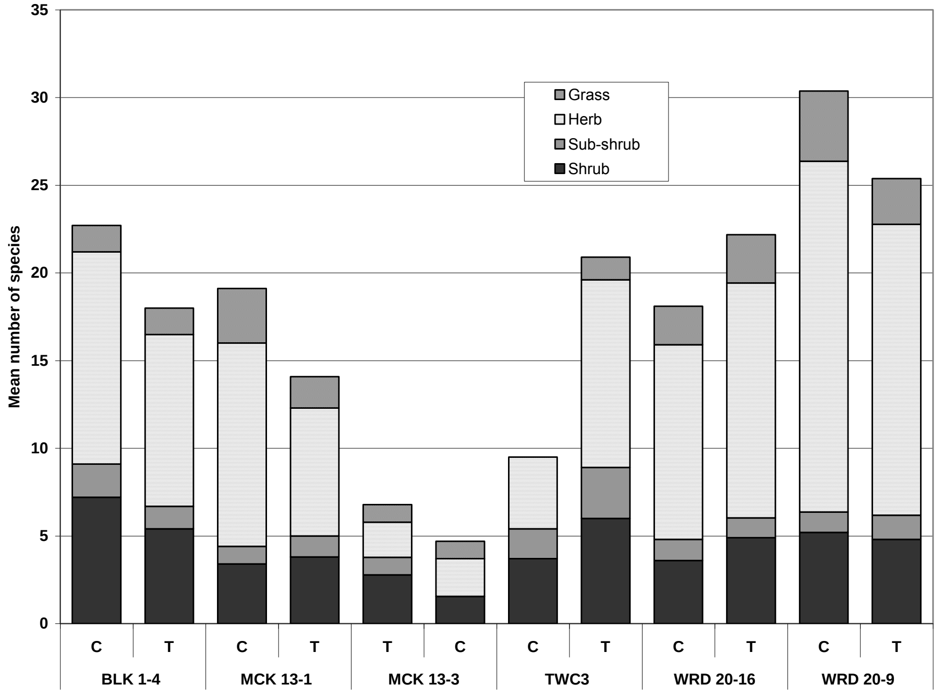

Figure 5. Mean species richness by lifeform in the west shore units in the basin in 2006.

Fewer species were encountered in the drier forest in the eastside units. A total of 56 species were detected, including 41 herbs, 8 shrubs, and 6 grasses, and 1 sub-shrub. Although there was less diversity, values for richness, cover, and frequency in the east shore units were all within the range of variation seen on the west shore. Total mean richness per plot (size of 0.25 ac) ranged from just under 14 to 22 species (Fig. 6). The mean number of herb species per plot ranged from 7 to 12 and the most common herbs were mountain pennyroyal (*Monardella odoratissima)*, slender penstemon (*Penstemon gracilentus*), and gayophytum (*Gayophytum diffusum var. parviflorum*).The mean number of shrub species per plot ranged from less than 4 to 7. The most common shrubs were tobacco bush or snowbrush (*Ceanothus velutinus*) and bush chinquapin (*Chrysolepis sempervirens*). The mean number of grass species per plot ranged from 1 to 3, with squirrel tail (*Elymus elymoides*) being the most common. Only one sub-shrub was present- pinemat manzanita (*Arctostaphylos nevadensis*). The only non-native species recorded was cheatgrass (*Bromus tectorum*).

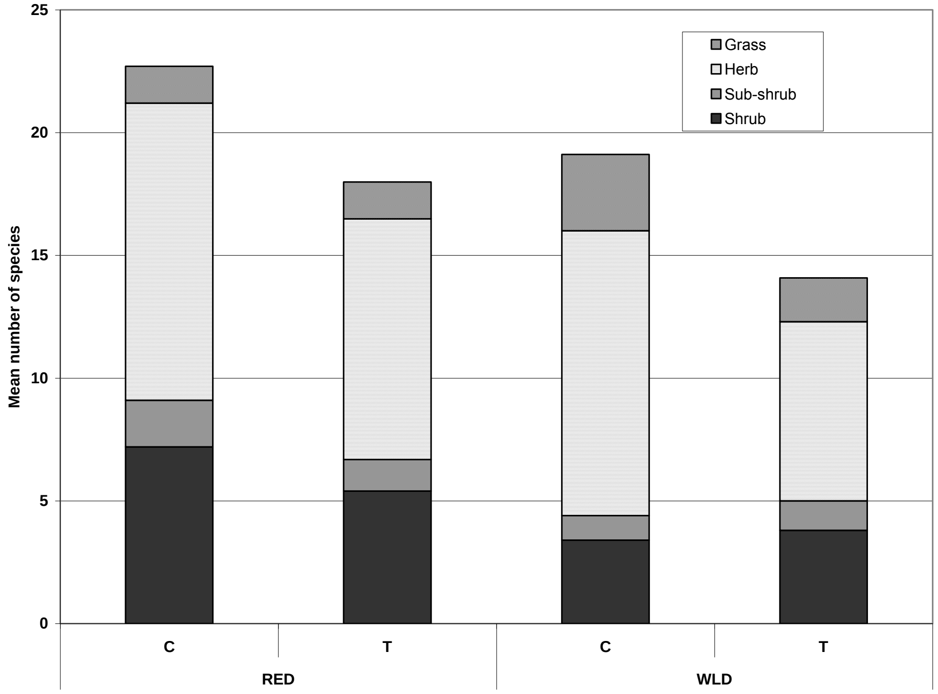

Figure 6. Mean species richness by lifeform in the east shore units in 2007.

Understory vegetative cover in the west shore units was moderate, ranging from 15-25% in most units (Fig. 7). While local cover in shrub patches could be quite high, in general, the understory vegetation is patchily distributed across the landscape. At the extremes, the lowest mean cover (<3%) was in MCK 13-3 T, a unit with the highest fuel load, while the highest mean cover (45%) was in TWC 3 T, a unit with the lowest canopy cover. Shrubs and sub-shrubs constituted the majority of understory plant cover in all units, while grass and herb cover ranged from absent to 12%.

Understory plant cover in the east shore units was similar, ranging from 12-40% (Fig. 8). The units in WLD did not appear to be well matched in the characteristics of the understory. The control unit lacked any measurable herb or grass component, while the treatment unit was dominated by herbs and grasses. Likewise, the treatment unit in RED had much greater vegetative cover than the control unit.

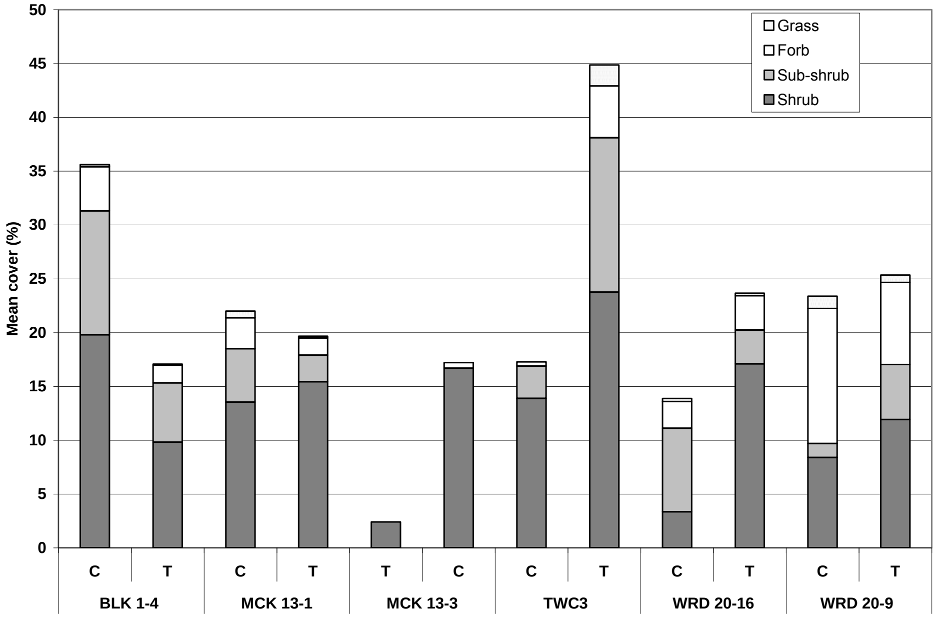

Figure 7. Mean percent cover by lifeform in the west shore units in 2006.

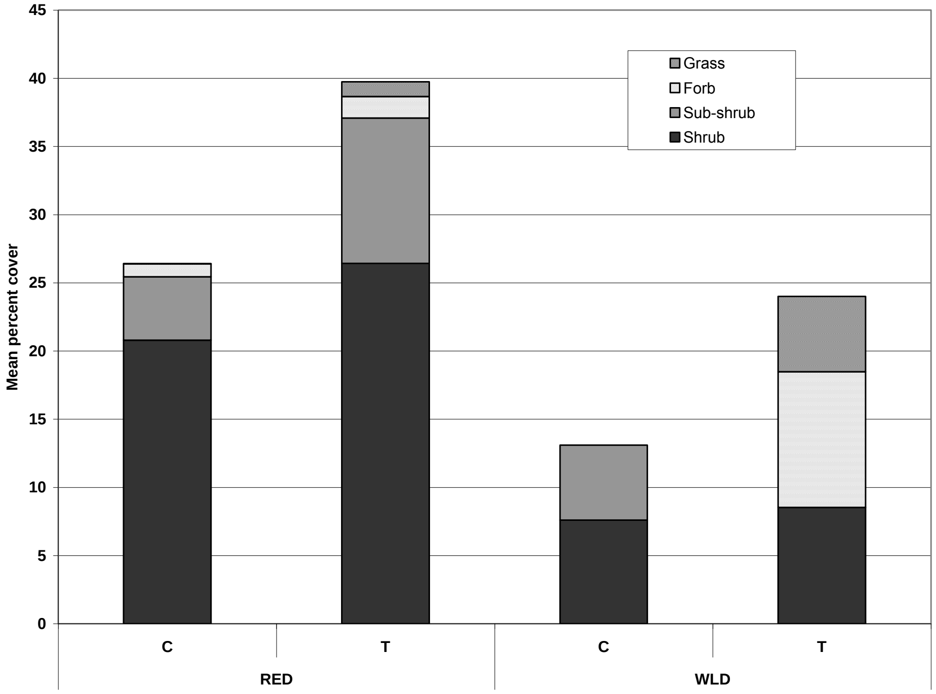

Figure 8. Mean percent cover by lifeform in the east shore units in 2007.

It should be noted that the quadrat method used to assess cover is most suited to plants less than 3 ft (1m) in height. Although the dominant shrub (whitethorn) in the west shore units was generally less than 3 ft tall, several of the other shrub species (Greenleaf manzanita and tobacco bush) often exceeded this height. This may have biased the total shrub cover values to be lower than they would have been using a line intercept method.

Frequency describes the abundance and distribution of species. It is calculated as the number of times a species occurs in the total number of sampled quadrats, usually expressed as a percent. In the west shore units, sub-shrubs constituted the most frequently encountered lifeform in most units with mean frequency ranging from 10 to 38% in the units where they occurred (Fig. 9). Shrubs were less frequently encountered in come units, with average frequencies ranging from 9 to 19%. The mean frequency of herbs and grasses was similar with ranges from 5 to 16 % and 6 to 19%, respectively.

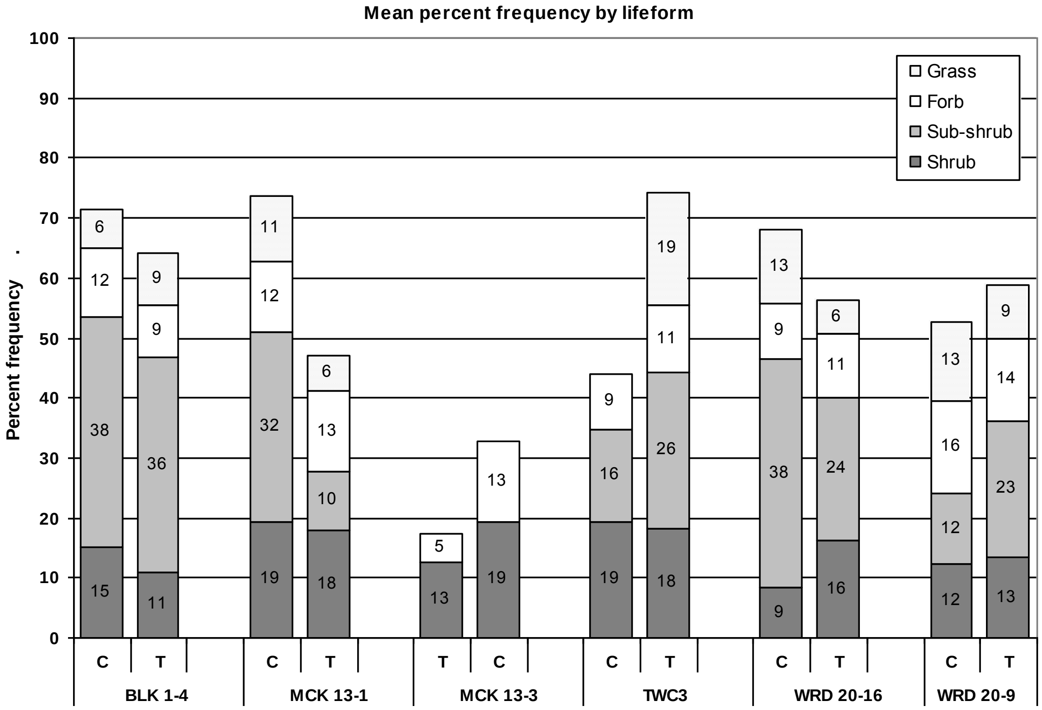

Figure 9. Mean percent frequency by lifeform for west shore units in 2006.

In the east shore units, mean frequency of all lifeforms combined ranged from 25 to 55% (Fig. 10). Shrubs were only slightly less frequently encountered than in the west shore units, but herbs and grasses were encountered less often in all units except WLD T, where the grass squirrel tail (Elymus elymoides) was the most widespread species.

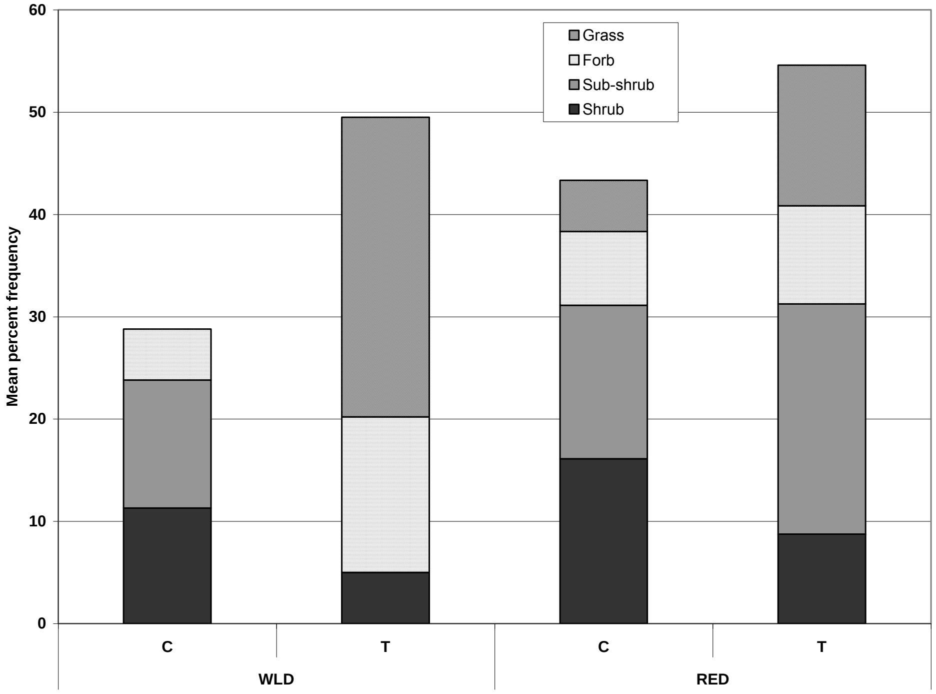

Figure 10. Mean percent frequency by lifeform in the east shore units in 2007.

Fuel loading

Measured surface fuel loads were quantified as three different components: litter and duff, fine woody debris (1-100 hr fuels), and coarse woody debris (1000 hr fuels). Pre-treatment vegetative fuel loading of live and dead shrubs and herbs was also calculated. For the west shore units, total mean surface fuel loads were high, ranging from 28 tons/acre in the WRD 20-16 control unit to 62 tons/acre in the MCK 13-3 treatment unit (Fig. 11). The number of logs >3 inches on the ground (coarse woody debris) was moderate to high, ranging from 10 to 57 (Table 5).

The biomass of live and dead vegetation is strongly associated with fire behavior and crown fire potential. FIREMON uses volume estimates derived from percent cover and height values from the fuels transect to calculate fuel loads of live and dead shrubs and herbs. Live shrubs comprised over 75% of the total mean vegetative fuel loading in all units, which ranged from 1 to 4.6 tons/acre (Fig. 12). The live shrub component was dominated in various proportions across the units by whitethorn (*Ceanothus cuneatus*), greenleaf manzanita (*Arctostaphyllos patula*), huckleberry oak (*Quercus vaccinifolia*), or bush chinquapin (*Chrysolepis sempervirens*). These species are all highly flammable due to extensive dead branch retention and the presence of volatile resins and oils in the leaves or other plant parts.

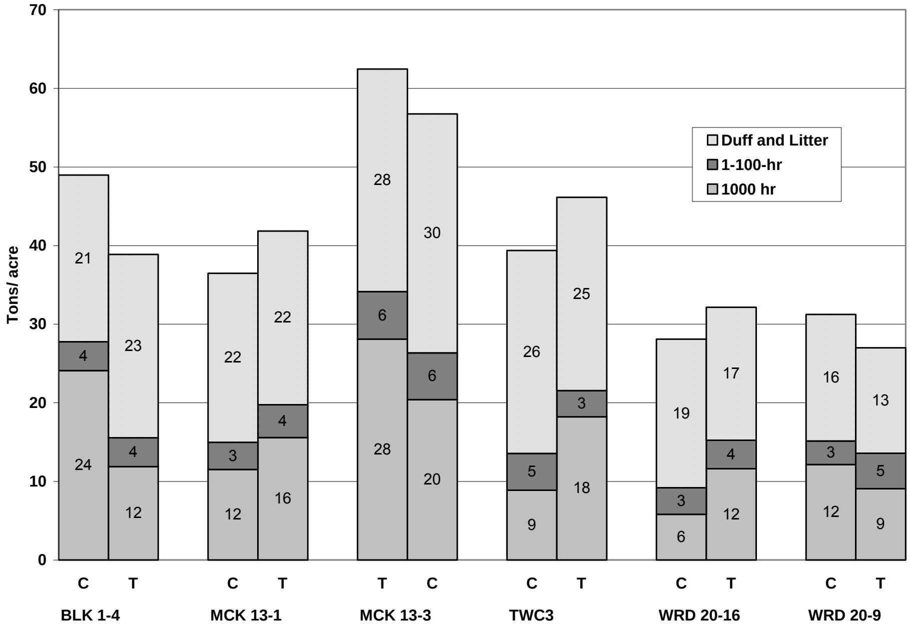

Figure 11. Mean fuel loading (tons/acre) of duff and litter, fine woody debris (1-100hr), and coarse woody debris (1000hr) in the west shore units.

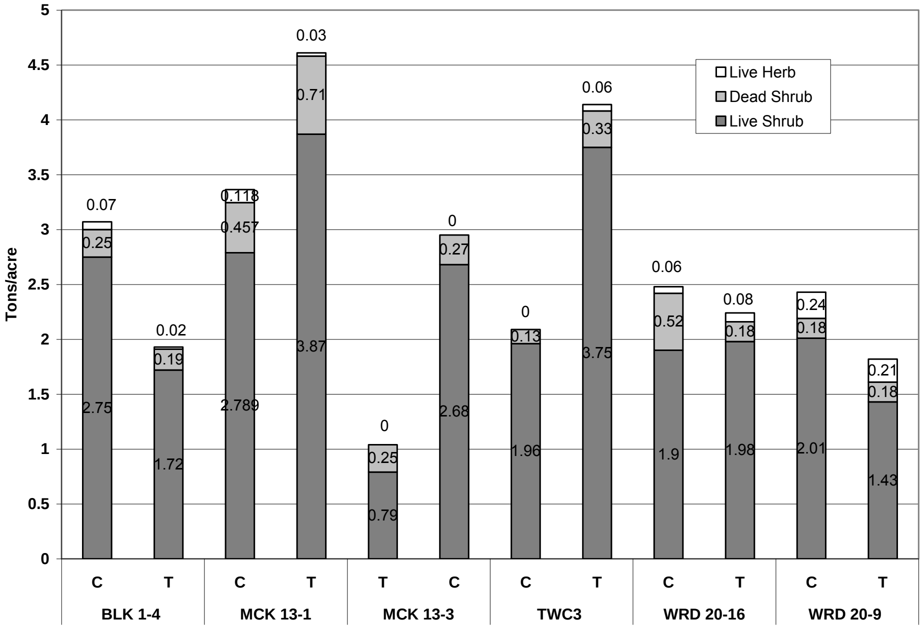

Figure 12. Mean fuel loading (tons/acre) of live and dead herbs and shrubs in the west shore units.

In the east shore units, fuel loadings of litter and duff, fine woody debris (1-100 hr fuels), and coarse woody debris (1000 hr fuels) were comparable in range and magnitude to the west shore units, ranging from a total of 22 tons per acre in RED C to 46 tons per acre in WLD T (Fig. 13). The biomass of live and dead vegetation contributed a small amount to the total fuel load. Live shrubs comprised over 90% of the total mean vegetative fuel loading in both units, which ranged from 1.8 and 1.9 tons/acre in RED T and C, respectively to only 0.7 tons/acre in the WLD units (data not shown). The live shrub component was dominated in various proportions across the units by whitethorn (*Ceanothus cuneatus*), greenleaf manzanita (*Arctostaphyllos patula*), or bush chinquapin (*Chrysolepis sempervirens*).

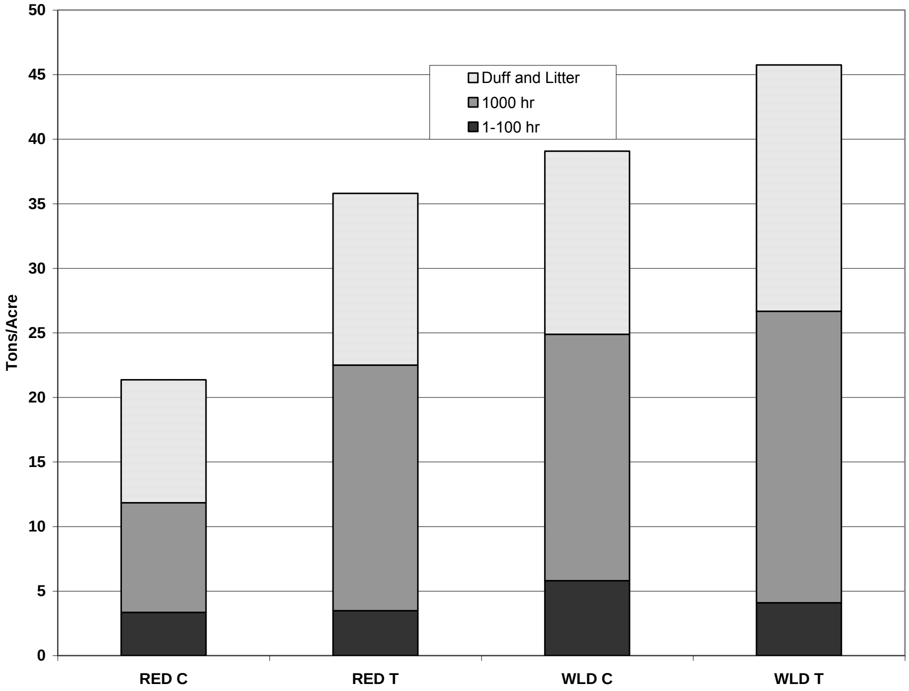

Figure 13. Mean fuel loading (tons/acre) of duff and litter, fine woody debris (1-100hr), and coarse woody debris (1000hr) in the east shore units.

Treatment Effects

The unit in the McKinney Creek watershed (MCK 13-1) received the standard USFS hand thinning to 14” with the slash piled. The unit along Blackwood Creek (BLK 1-4) received a specialized USFS fuels reduction designed for the Spotted Owl/ Goshawk PAC within the unit boundary. The unit was harvested with a cut-to-length forwarder system with a John Deere 300LC excavator fitted with a Bullhog Fecon masticator head.

Forest Structure

Forest structure and wildlife related habitat conditions at treatment sites changed substantially as a result of treatments, with the mechanical treatment in BLK 1-4 resulting in greater changes than those observed at MCK 13-1 (Table 8). In MCK, there was a 57% decline in tree density to only 69 trees per acre. Average tree diameter increased by only 3in and canopy cover was reduced by only 14%, so CWHR type did not change from 4M. In BLK, mean tree size increased by 4.5 inches and canopy closure was reduced by almost 25 %, resulting in a change in CWHR type from dense (D) to moderate (M). The 63% decline in tree density in BLK was accompanied by a 49% reduction in basal area. Density of snags > 6in declined by over 60% on both sites, declining from 44 to 18 and 32 to 10 snags/ac on Blackwood and McKinney, respectively. Log density also declined substantially at both units, reduced by 15-20 logs/ac to 36-64 logs/ac in BLK and MCK, respectively. Although some thinning of shrubs was employed in both treatment types, residual shrub height did not change at either site.

Average white fir density declined by almost 60% in MCK, but it still comprised 65% of the residual tree species (Fig. 14). Modest declines were observed in other conifers, with almost no reduction in sugar pine, a species targeted for retention.

Table 8. Pre and post-treatment forest structure and habitat conditions in two sites sampled in 2006 (pre-treatment) and 2007 (post-treatment). CWHR = California Wildlife Habitat Relationship class; QMD= Quadratic Mean Diameter.

Unit	**Year**	**CWHR**	**QMD (inches)**	**Canopy Closure (%)**	**Trees/Acre (>6 in DBH)**	**Basal Area (ft^2/acre)**	**Snags/Acre**	**Logs/Acre (>3 in)**	**Shrub ht (ft)**
MCK13-1	2006	4M	13.5	56.2	161.4	149.5	32.9	26.2	2.0
MCK13-1	2007	4M	16.6	42.2	69.3	106.8	9.6	6.4	2.0
BLK 1-4	2006	4D	16.7	67.6	207.6	309.3	44.5	18.4	1.3
BLK 1-4	2007	4M	21.2	44.4	77.3	189.8	18.2	3.6	1.3

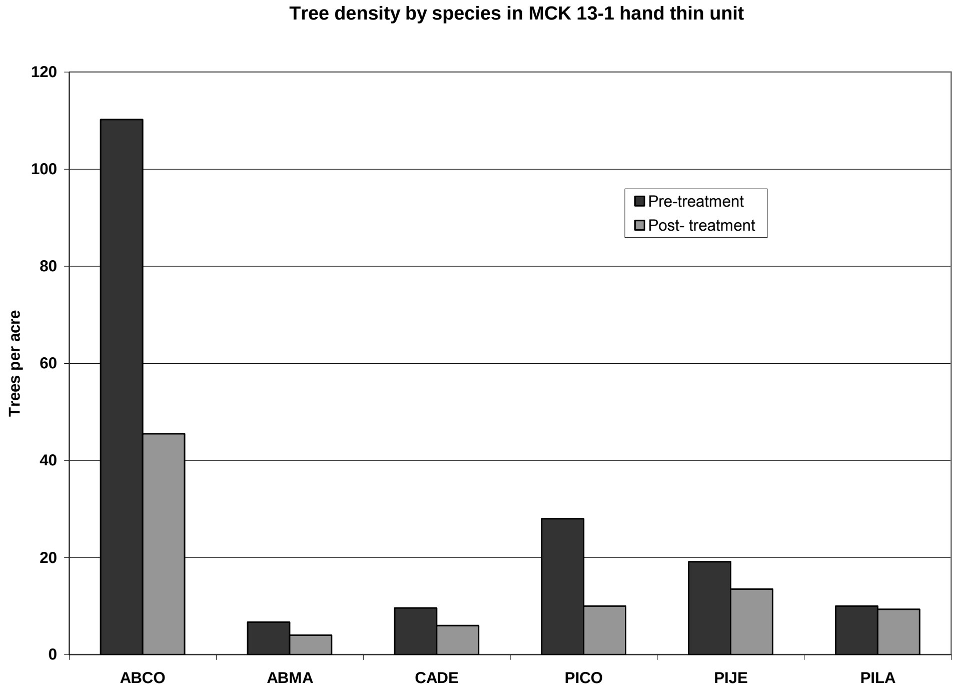

Figure 14. Pre and post-treatment mean tree density (trees/acre) of 6 conifer species in the MCK 13-1 hand thin unit. ABCO (white fir), ABMA (red fir), CADE (incense cedar), PICO (lodgepole pine),PIJE (Jeffrey pine), and PILA (sugar pine).

In BLK, the mechanical thinning reduced average white fir density by 68%, but it still comprised 57% of total tree density (Fig. 15). Jeffrey pines comprised almost 30% of the residual trees, so although two desired species (incense cedar and sugar pine) that were likely present historically are still missing, the species composition is shifting closer toward the desired mixed conifer type.

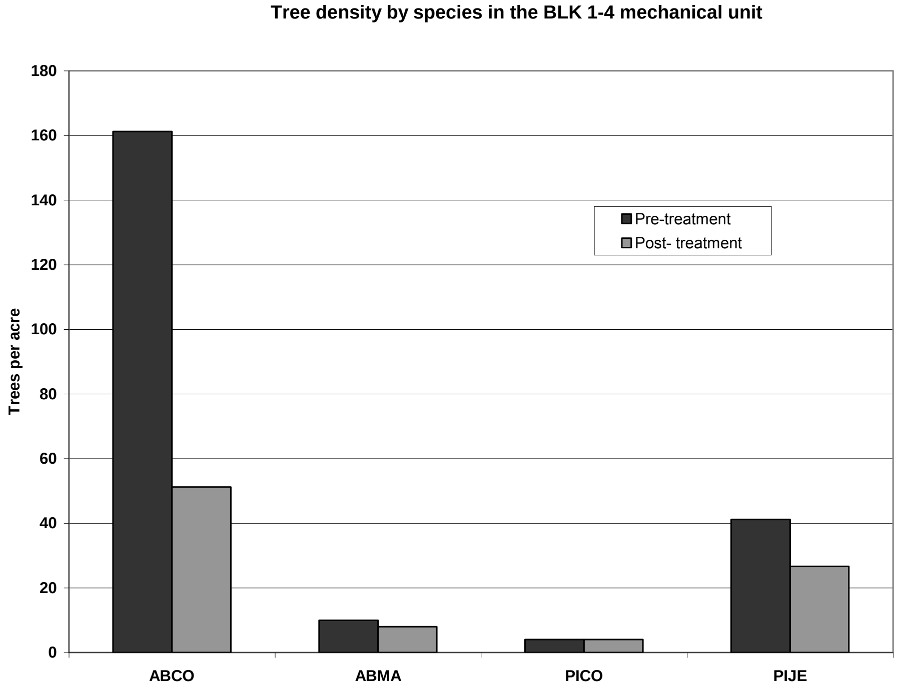

Figure 15. Pre and post-treatment mean tree density (trees/acre) of 4 conifer species in the BLK mechanically treated unit. ABCO (white fir), ABMA (red fir), PICO (lodgepole pine), PIJE (Jeffrey pine).

In MCK the hand thinning was limited to trees up to 14”, so almost all trees that were removed were pole size (6-12”). Consequently, the size class distribution of residual trees shifted from being dominated by pole size trees to a more even mix of pole, small (12-24”), and medium (24-36”) trees (Fig. 16). A similar pattern was observed at BLK, where the majority of trees removed were also pole size (Fig. 17). The mechanical thinning operation was capable of removing trees up to 24”, so there was also a 54% decline in small trees. At both sites, the small reduction in medium size trees was likely the result of natural mortality. Saplings were eliminated (BLK) or reduced to only 1 per acre (MLK) because they were all white fir and retaining them would inhibit efforts to promote pine regeneration.

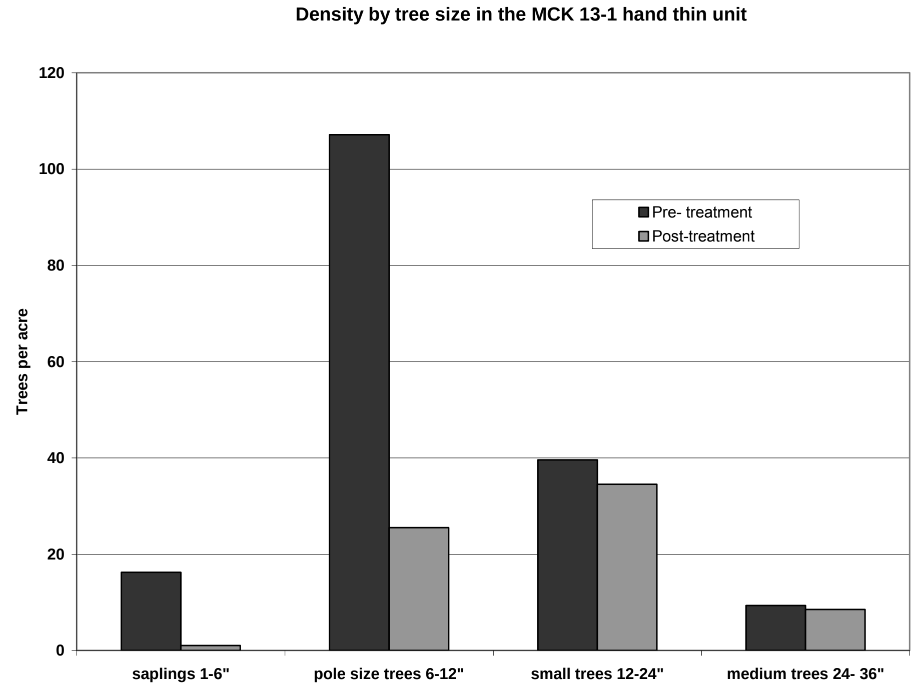

Figure 16. Pre and post-treatment mean tree density (trees/acre) of four diameter classes in the MCK 13-1 hand thin unit.

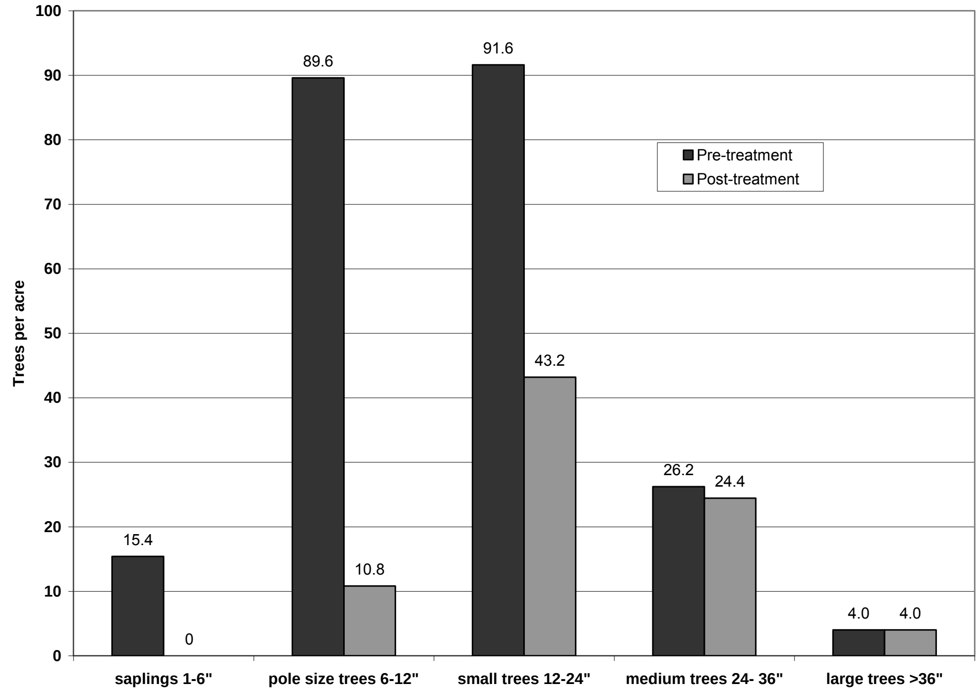

Figure 17. Pre and post-treatment mean tree density (trees/acre) of four diameter classes in the BLK 1-4 hand thin unit.

Snags and down logs provide valuable wildlife habitat; however, their high pre-treatment density reflected decadent stand conditions resulting from high insect and pathogen mortality, drought, and lack of fire. The treatments at both sites reduced total snag density by over 60%, with the greatest reduction occurring in the smallest diameter class (Fig. 18). Most of the large diameter (> 24in) snags, which provide the highest quality habitat for wildlife, were retained. The density of down logs was also greatly reduced with both treatments, but log volume increased in MCK, the hand thin unit (Table 9). The control units experienced only slight changes in both log density and volume.

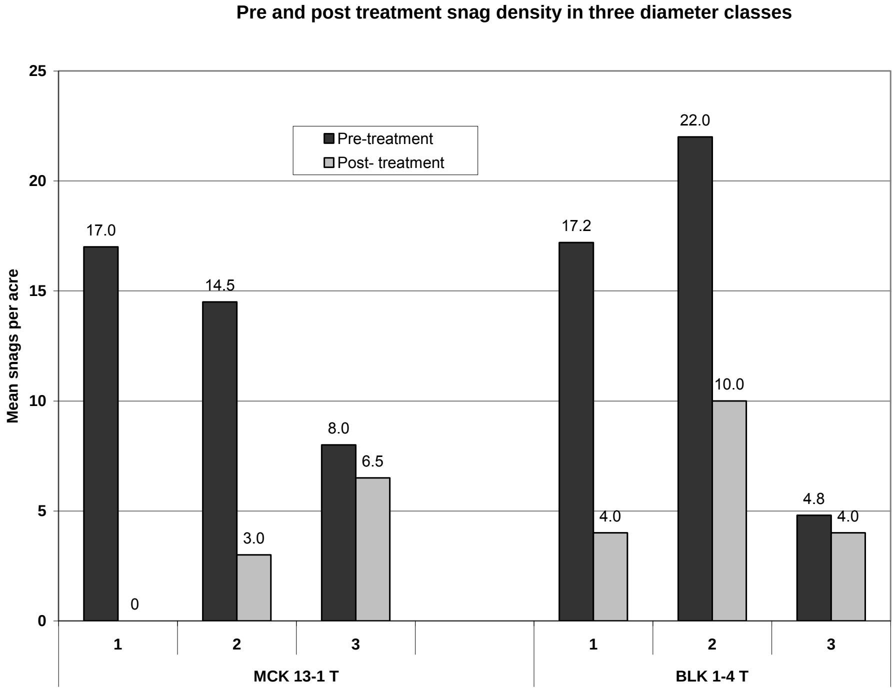

Figure 18. Pre and post-treatment mean snag density (dead trees/acre) in three diameter classes: 1= (3-12in); 2= (12-24in); and 3= (>24in).

Table 9. Pre and post-treatment mean log volume and density in the control (C) and treatment (T) units in MCK and BLK.

	Log volume (cubic feet)		Logs/acre	
Unit	**2006**	**2007**	**2006**	**2007**
BLK 1-4 C	110.8	79.6	23.6	16.4
BLK 1-4 T	43.2	7.0	18.4	3.6
MCK 13-1 T	29	51.9	26.2	6.4
MCK 13-1C	23.8	33.0	25.2	20.4

Understory Species

Both the mechanical and hand thinning treatments reduced canopy cover and overstory tree density. The resulting increase in light reaching the forest floor would be expected to eventually lead to an increase in early seral species in the understory. In the first year, however, total species richness declined post-treatment in both units. BLK lost approximately 5 species including several herbs and shrubs, while MCK lost 2 species of herbs and 1 shrub species (Table 10). The declines were mirrored in the control units with both losing an average of 4 species each (data not shown). Total plant cover declined from 17% to only 7% with the mechanical treatment in BLK, while the hand thin barely reduced cover by 1% (Fig. 19).

Table 10. Pre and post-treatment mean species richness in two treatment sites on the west shore of the basin, sampled in 2006 and 2007.

		Mean no. species per unit				
		Herb	**Grass**	**Shrub**	**Sub-shrub**	**Total**
BLK 1-4	Pre	9.8	1.5	5.4	1.3	18.0
	Post	7.3	1.0	3.3	1.1	12.7
MCK 13-1	Pre	7.3	1.8	3.8	1.2	14.1
	Post	5.3	1.4	2.9	1.2	10.8

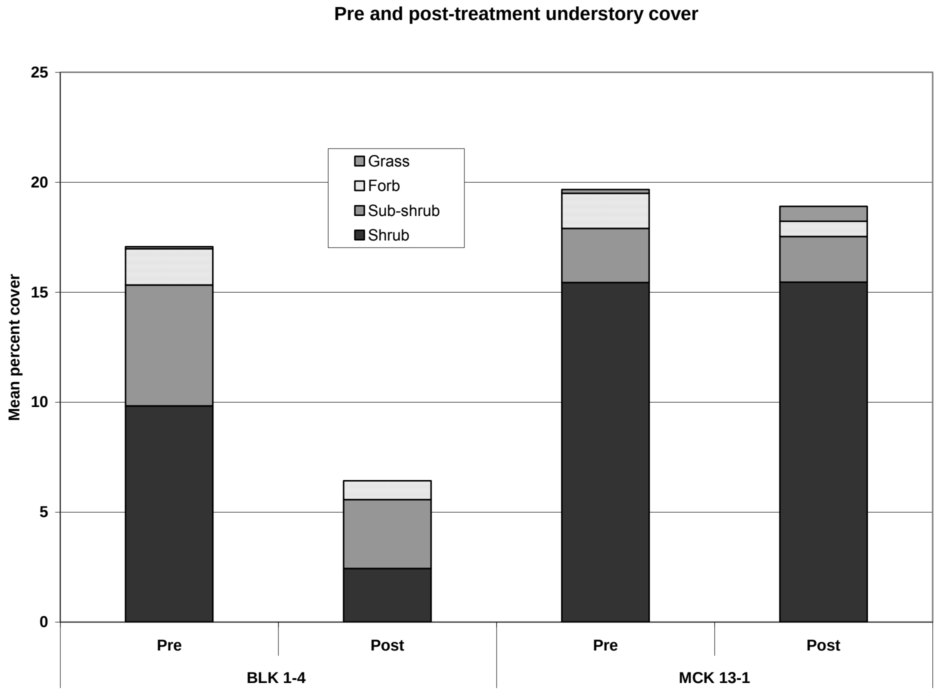

Figure 19. Pre and post-treatment mean understory species cover on two treatment sites on the west shore of the basin, sampled in 2006 and 2007.

Frequency is a very useful measure for comparing differences between two plant communities or detecting change in a single community over time. Plants with frequencies between 20 and 80% result in the greatest sensitivity to change. Total average frequency declined by 12% with the treatment in BLK and by only 3% in MCK (Fig. 20).

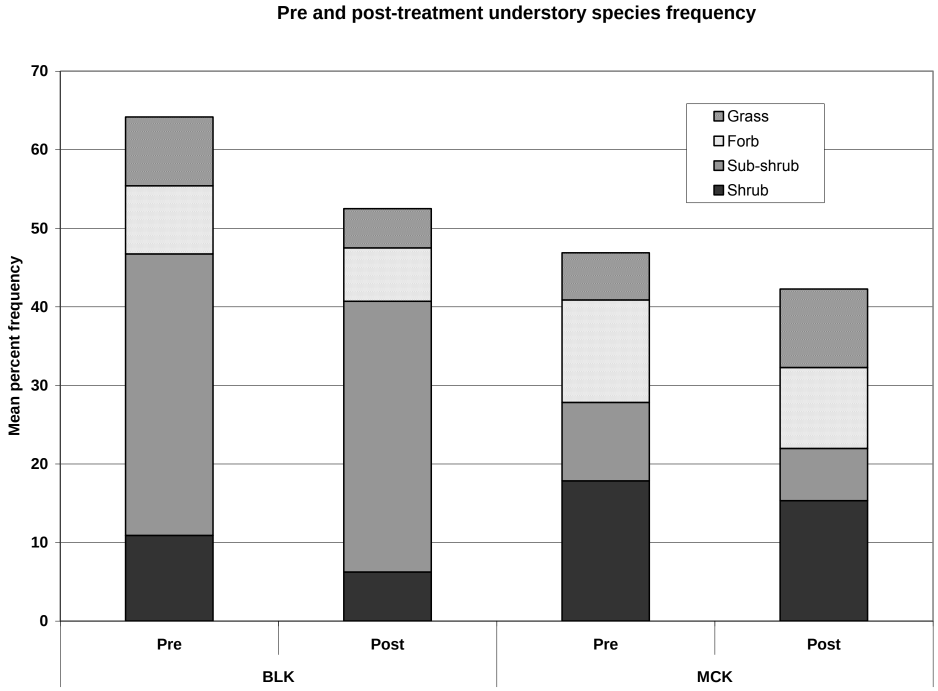

Figure 20. Pre and post-treatment mean understory species frequency in two treatment sites on the west shore of the basin, sampled in 2006 and 2007.

Fuel loading

Total fuel loads changed very little in the hand thin treatment (Fig. 21). A slight increase in fine fuels (1-100hr) and duff and litter was accompanied by a decline in coarse woody debris (1000hr CWD). In contrast, the mechanical treatment reduced total fuel loading by 35% (Fig. 22). Most of the reduction came from a decline in CWD that was probably masticated and the decline in duff and litter from masticated debris being piled on the surface.

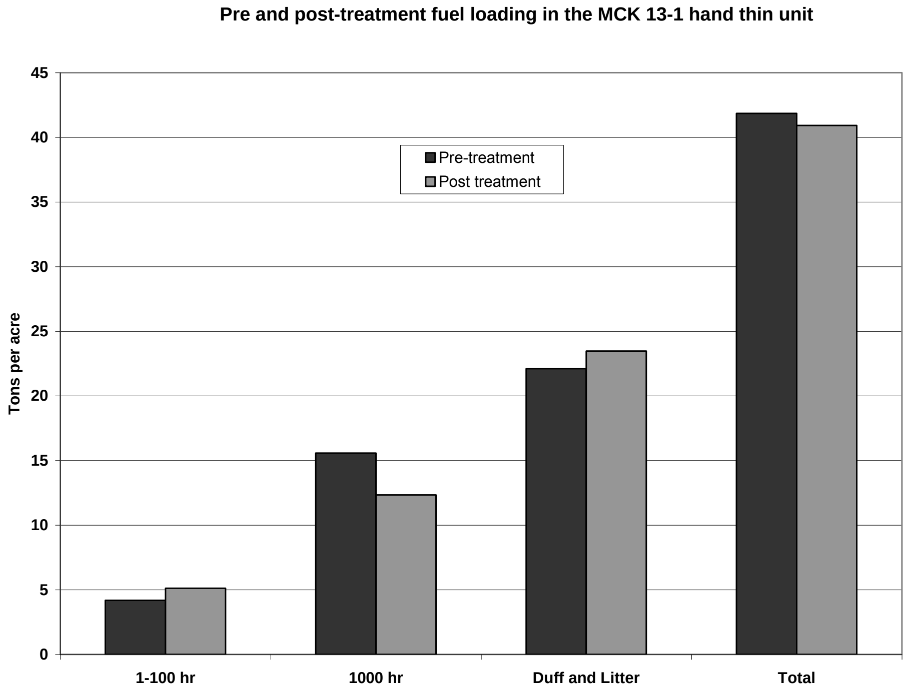

Figure 21. Pre and post-treatment mean fuel loading (tons/ac) in the McKinney 13-1 hand thin unit.

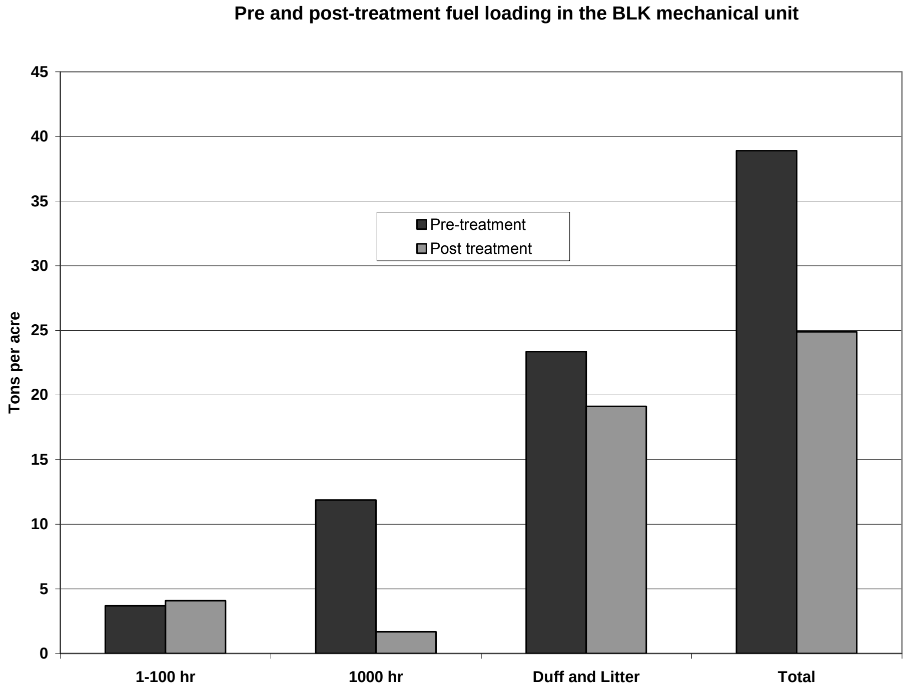

Figure 22. Pre and post-treatment mean fuel loading (tons/ac) in the Blackwood 1-4 mechanical unit.

Small Mammals

A total of 16 species of small mammals, plus American marten, were captured across the 16 sample sites (Table 11). The most frequently occurring species were deer mouse, long-eared chipmunk, and shadow chipmunk. Douglas squirrel was captured at 11 sites, but detected during point counts at all 16 sites. Trap effort varied among sites as a primary result of disturbance by bears (Table 12). Species richness estimates could be negatively biased by reduced trap effort, but we found no evidence of a relationship between changes in trap effort and species richness (r = -0.495) based on untreated sites with sampling in sequential years.

A few species were uniquely or primarily detected on the east-shore sites. Pinon mouse, least chipmunk, and golden-mantled ground squirrel were only detected on the east-shore sites. The pinon mouse and least chipmunk are likely to have a limited distribution beyond the east-shore, but the golden-mantled ground squirrel is known to occur in other locations in the basin. Two other species were detected infrequently and/or at lower abundances on the west-shore compared to the east-shore sites: lodgepole chipmunk and yellow-pine chipmunk.

Species richness ranged from 3 to 10 species across sites and years (Table 12). Gains and losses in species richness across the eight sites with sequential sampling ranged from -3 to +4, with treatment sites showing no change in species richness the first year following treatment. Abundance ranged widely from 1.55 to 11.10 animals per 100 trap days (Table 12). Between-year abundance also varied widely from -4.29 to +6.59, with one treated site showing little change (-0.64), and the other (McKinney 13-1) showed an intermediate degree of decline in abundance (-2.34). Dominance ranged from 0.16 to 0.65 across all sites and years, and treatment sites showed little change in dominance following treatment (+/- 0.10) relative to the non-treated sites (Table 12).

Table 11. Mammal species detected during live trap sampling at 16 sites in 2006 and 2007 in the Lake Tahoe basin. Sherman live traps (n = 72) and tomahawk traps (n = 72) were open for five nights at each site.

Scientific name	Common name	Code	Freq (n = 16)
Rodentia			
Glaucomys sabrinus	Northern flying squirrel	GLSA	8
Spermophilus beecheyi	California ground squirrel	SPBE	7
Spermophilus lateralis	Golden-mantled ground squirrel	SPLA	5
Neotamias quadrimaculatus	Long-eared chipmunk	TAQU	15
Neotamias senex	Shadow chipmunk	TASE	15
Neotamias speciosus	Lodgepole chipmunk	TASP	7
Tamias amoenus	Yellow-pine chipmunk	TAAM	10
Tamias minimus	Least chipmunk	TAMI	2
Tamiasciurus douglasii	Douglas squirrel	TADO	11
Microtus longicaudus	Long-tailed vole	MILO	1
Peromyscus maniculatus	Deer mouse	PEMA	16
Peromyscus truei	Pinon mouse	PETR	6
Peromyscus boylii	Brush mouse	PEBO	1
Insectivora			
Sorex trowbridgii	Trowbridge's shrew	SOTR	6
Sorex vagrans	Vagrant shrew	SOVA	3
Carnivora			
Martes Americana	American marten	MAAM	4

Table 12. Small mammal trap effort, species richness, relative abundance, and dominance at 16 sites sampled in 2006-2007 in the Lake Tahoe basin.

	Trap effort (trap days)			Species richness			Relative abundance (100 trap nights)			Dominance (Berger-Parker)		
Site	2006	2007	Gain/ loss	2006	2007	Gain/ loss	2006	2007	Gain/ loss	2006	2007	Gain/ loss
Treated - pre and post:												
BLKW	586.5	620.3	33.8	8	8	0	5.97	6.61	0.64	0.31	0.41	0.10
CHNQ	501.0	582.3	81.3	5	5	0	9.38	7.04	-2.34	0.55	0.45	-0.10
Untreated - repeat sample:												
TMBW	540.8	602.0	61.3	7	6	-1	11.10	6.81	-4.29	0.32	0.45	0.13
DEDO	592.3	619.8	27.5	8	7	-1	9.29	6.62	-2.67	0.40	0.52	0.12
BOAA	627.3	633.3	6.0	10	7	-3	3.99	6.47	2.49	0.16	0.47	0.31
BOTA	585.0	507.5	-77.5	6	8	2	5.81	8.08	2.27	0.38	0.46	0.08
CALC	542.8	448.3	-94.5	5	6	1	2.58	9.15	6.57	0.36	0.31	-0.04
SKEET	643.5	605.0	-38.5	4	8	4	1.55	6.78	5.22	0.50	0.51	0.01
Untreated - single yr:												
ARND	632.0			9			5.70			0.50		
DANY	625.0			7			6.24			0.26		
HMWD	594.8			4			4.37			0.65		
MULL	541.5			3			4.62			0.52		
NUTH		622.5			8			6.59			0.38	
REDS		602.3			9			6.81			0.51	
ROLS		614.3			8			6.67			0.44	
WCAT		627.5			7			6.53			0.36	

Birds

Point counts were conducted from late May to early July in 2006 and 2007. Sixty-seven bird species were observed within 100 m of count stations, but only 53 native and one exotic species were detected on plots (within 60 m of count stations) across all sample sites (Appendix B). In addition, Douglas squirrel was regularly detected during point counts. In 2007, total bird abundance within 60 m across all 4 counts and 3 visits ranged from 71 to 208 individuals, equating to an average of 5.9 and 17.3 individuals per count. Richness and abundance on the four east-side sites were not unusual relative to the spread of values observed on west-side sites, with richness ranging from 21 to 33 species and abundance ranging from 112 to 155 individuals. A few species were uniquely detected on east-side sites (within 60 m of count stations), including Ruby-crowned Kinglet, Mountain Quail, Green-tailed Towhee, Calliope Hummingbird, Cooper's Hawk, and Clark's Nutcracker; only the Ruby-crowned Kinglet is unique to the east-shore based on other survey data. Species missing from the east-shore sites that were observed on at least two west-shore sites include Brown-headed Cowbird, Black-headed Grosbeak, Northern Flicker, Red Crossbill, Warbling Vireo, Western Wood Peewee, and

Williamson's Sapsucker. The lack of Brown-headed Cowbird on the east shore sites could be significant ecologically since this species, where present, can reduce nest success. Red Crossbill, Western Wood Peewee, and Williamson's Sapsucker are commonly associated with more mesic forests and may be rare on the east-shore.

Bird species richness and abundance were lower on sites following treatments than any changes in abundance observed between years on non-treatment sites (Fig. 23). Bird species richness varied between years on non-treatment sites from an increase of seven species to a decrease of two species, whereas treatment sites showed declines of three and four species. Bird species abundance varied between years on non-treatment sites from an increase of 39 individuals to a decrease of 24 individuals, whereas treatment sites showed declines of 26 and 36 species. Between-year variance in bird community dominance on treatment sites did not fall outside the range of variation observed among non-treatment sites.

Old forest bird species richness and abundance followed the same pattern as observed for all species: richness and abundance on treatment sites fell below the range of variability observed across non-treatment sites (Fig. 24). The richness of old forest species ranged from no change to a gain of 4 species between years on non-treatment sites, whereas treatment sites showed no decline and a loss of two species. The abundance of old forest species showed an increase on all but one untreated site, ranging from a gain of 26 species to a loss of two species, whereas treatment sites showed losses of one and eight old-forest species.

Early seral species did not show a concomitant increase as one might expect given the loss of old-forest species (Fig. 25). Between-year variation in species richness on treatment sites was within the range of variation observed among non-treatment sites. The abundance of early seral species actually declined by 20 individuals at one of the two treatments sites, greater than was observed across the non-treatment sites, which ranged from an increase of 16 individuals to a decrease of 14 individuals.

The richness of snag and log associates showed no change and a decline of two species between years on sites with treatments, whereas sites without treatments showed either no change or an increase of up to three species (Fig. 26). The abundance of snag and log associates varied greatly on treatment sites, from a gain of 15 to a loss of 10 individuals, but these changes were not outside the range of variation observed on non-treatment sites (Fig. 26).

The number of primary cavity nester species per site ranged from one to four. Primary cavity nester richness declined by two species on one treatment site, and the other showed no change, whereas non-treatment sites only varied from a gain of two to a loss of one species (Fig. 27). Primary cavity nester abundance did not show a response on treatment sites that was outside the range of variation observe across non-treatment sites (Fig. 27).

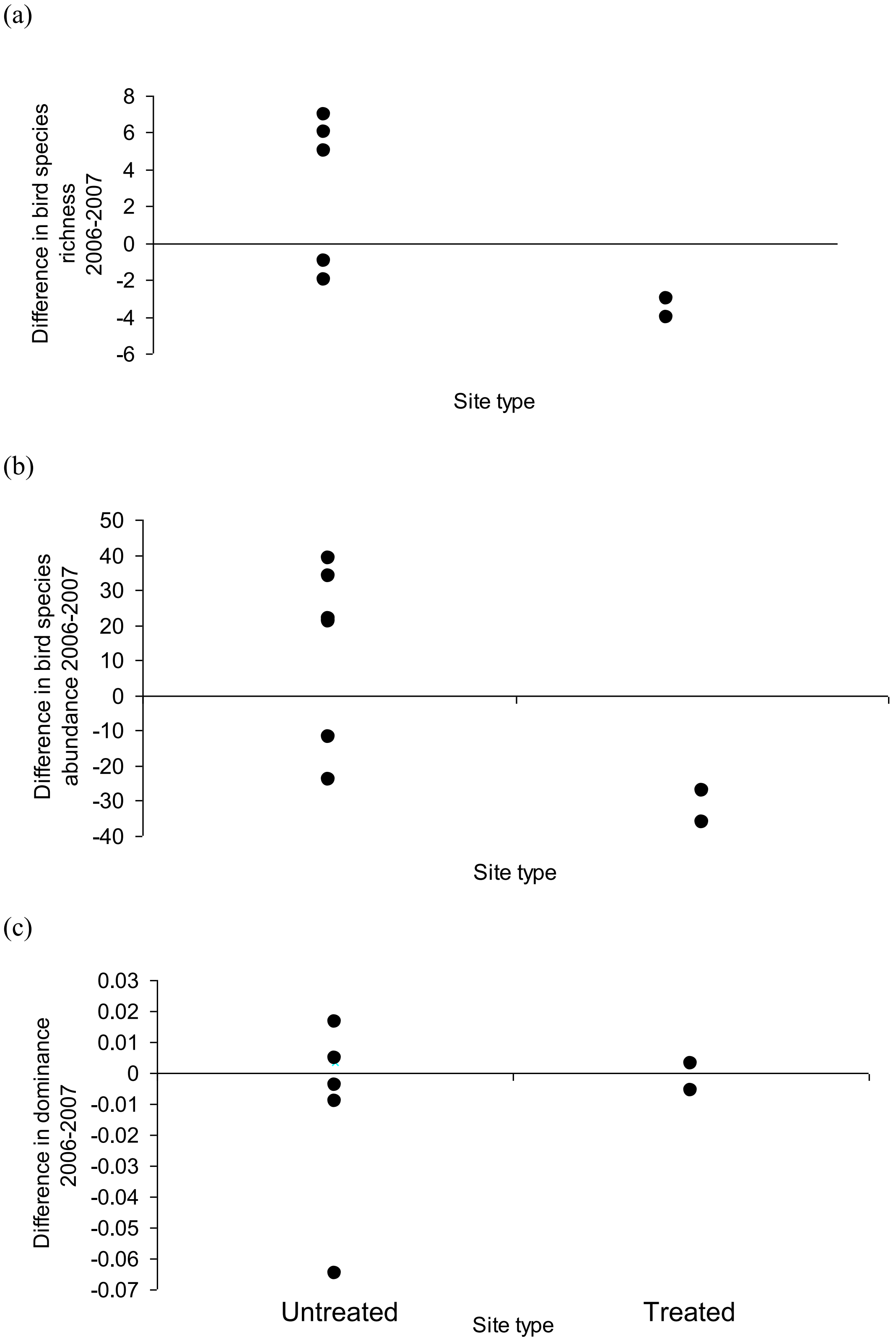

Figure 23. Bird species richness (a), abundance (b), and dominance (c) between year variation at sties with and without intervening fuels reduction treatments.

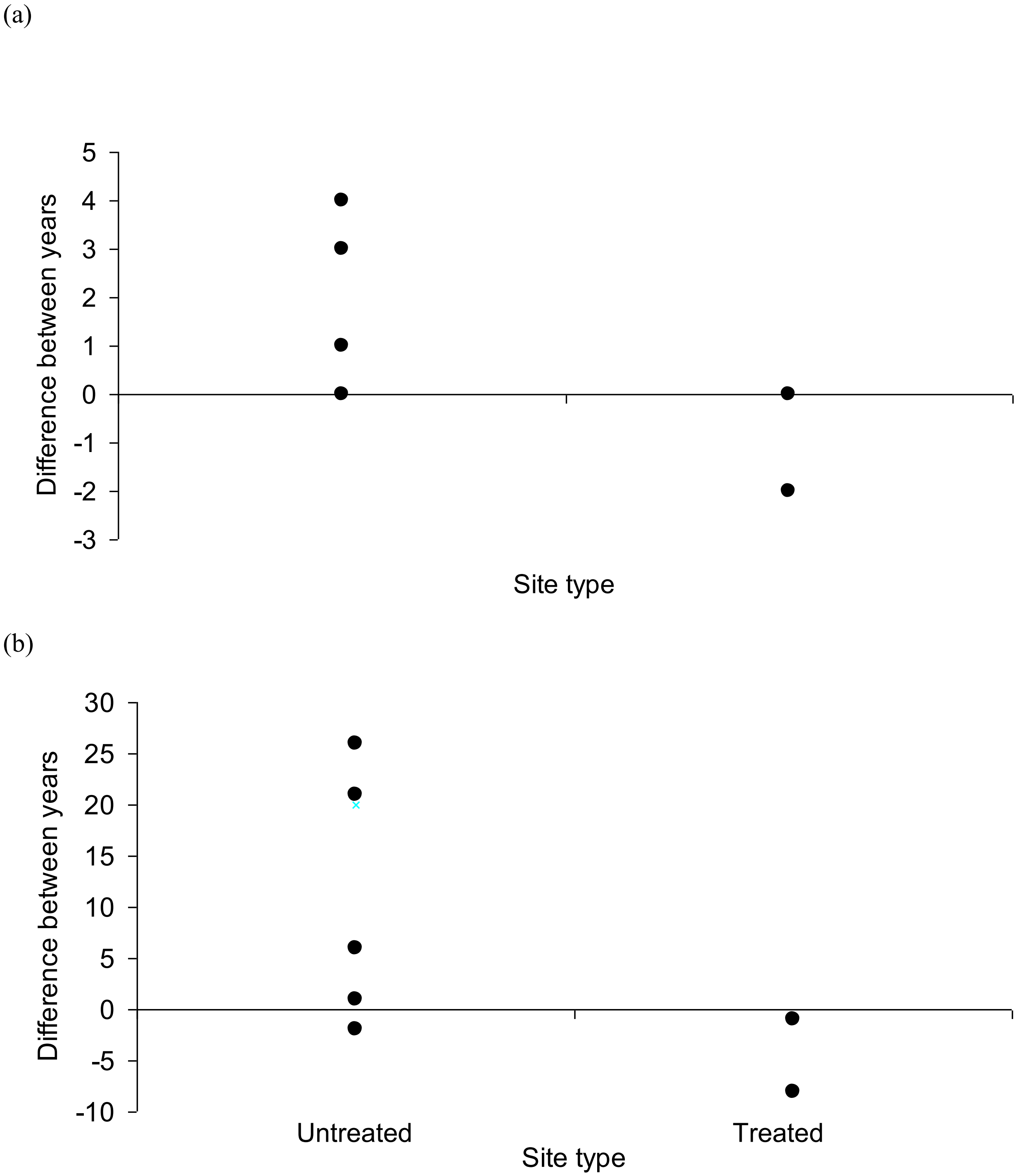

Figure 24. Old-forest associated bird species richness (a) and abundance (b) variation between years (2006-2007) for untreated (left) and treated (right) sites.

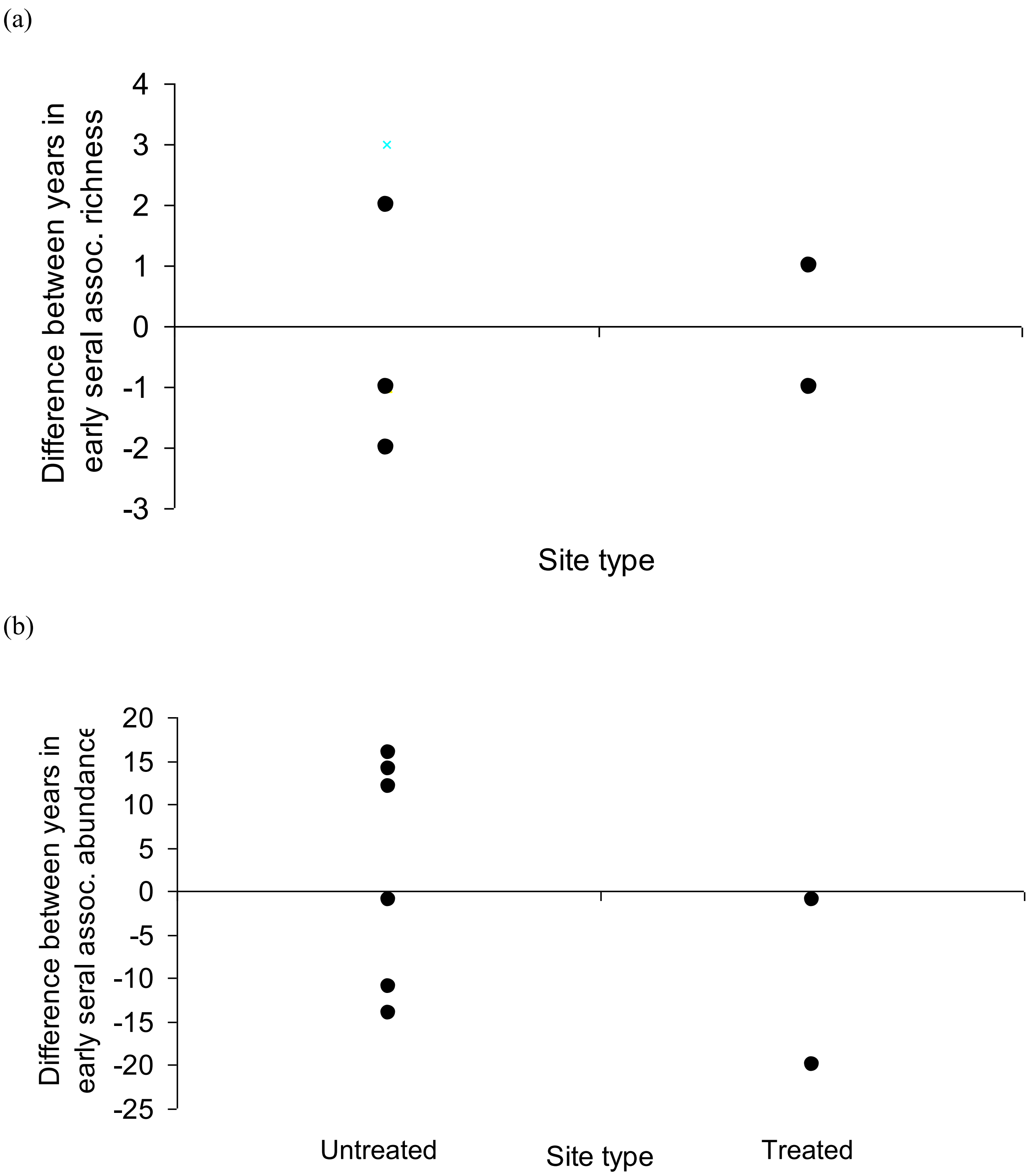

Figure 25. Early seral associates richness (a) and abundance (b) between year variation iwith and without intervening fule reduction treatments.

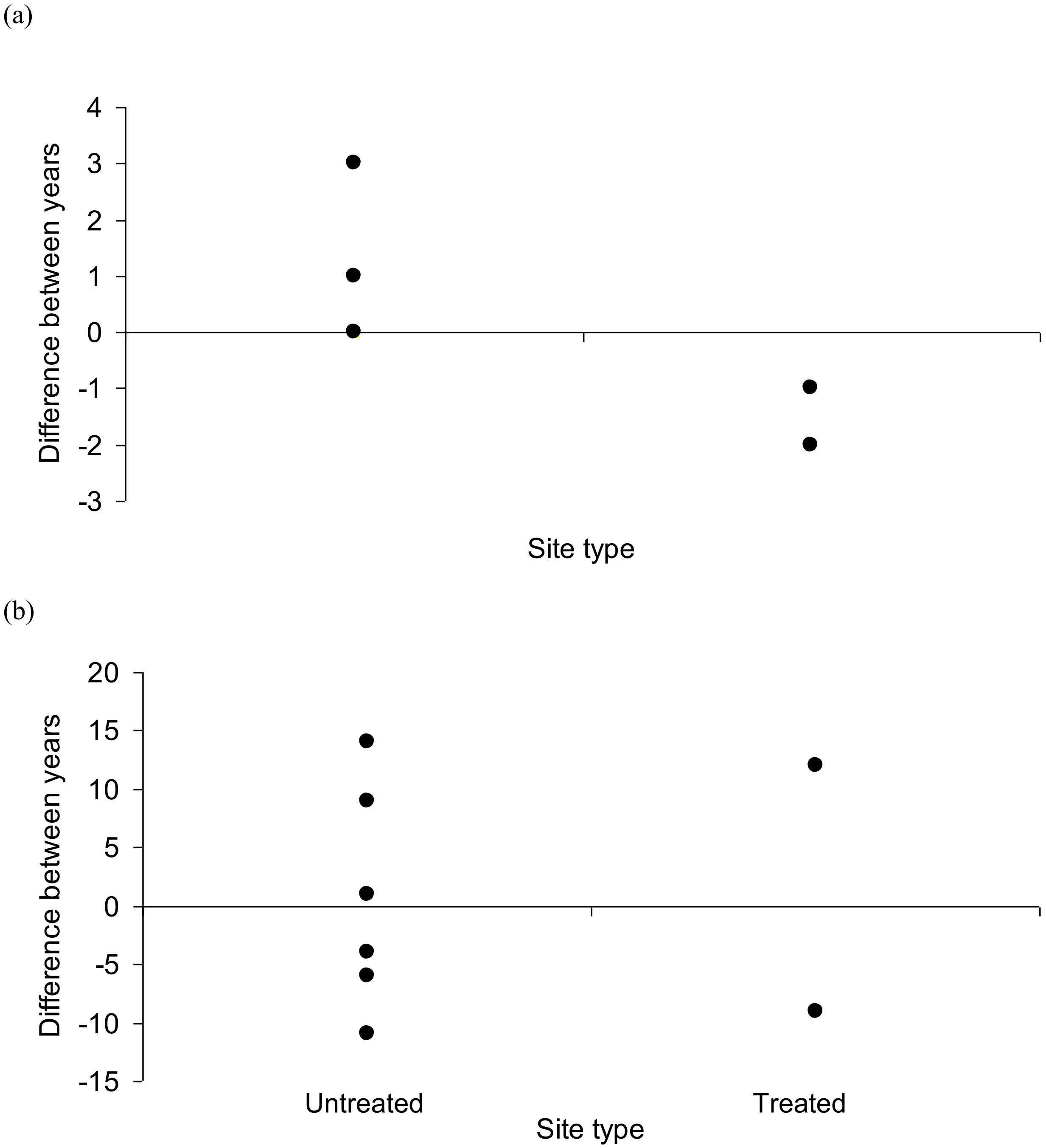

Figure 26. Snag and log associated bird species richness (a) and abundance (b) between-year differences at sites with and without fuel reduction treatments.

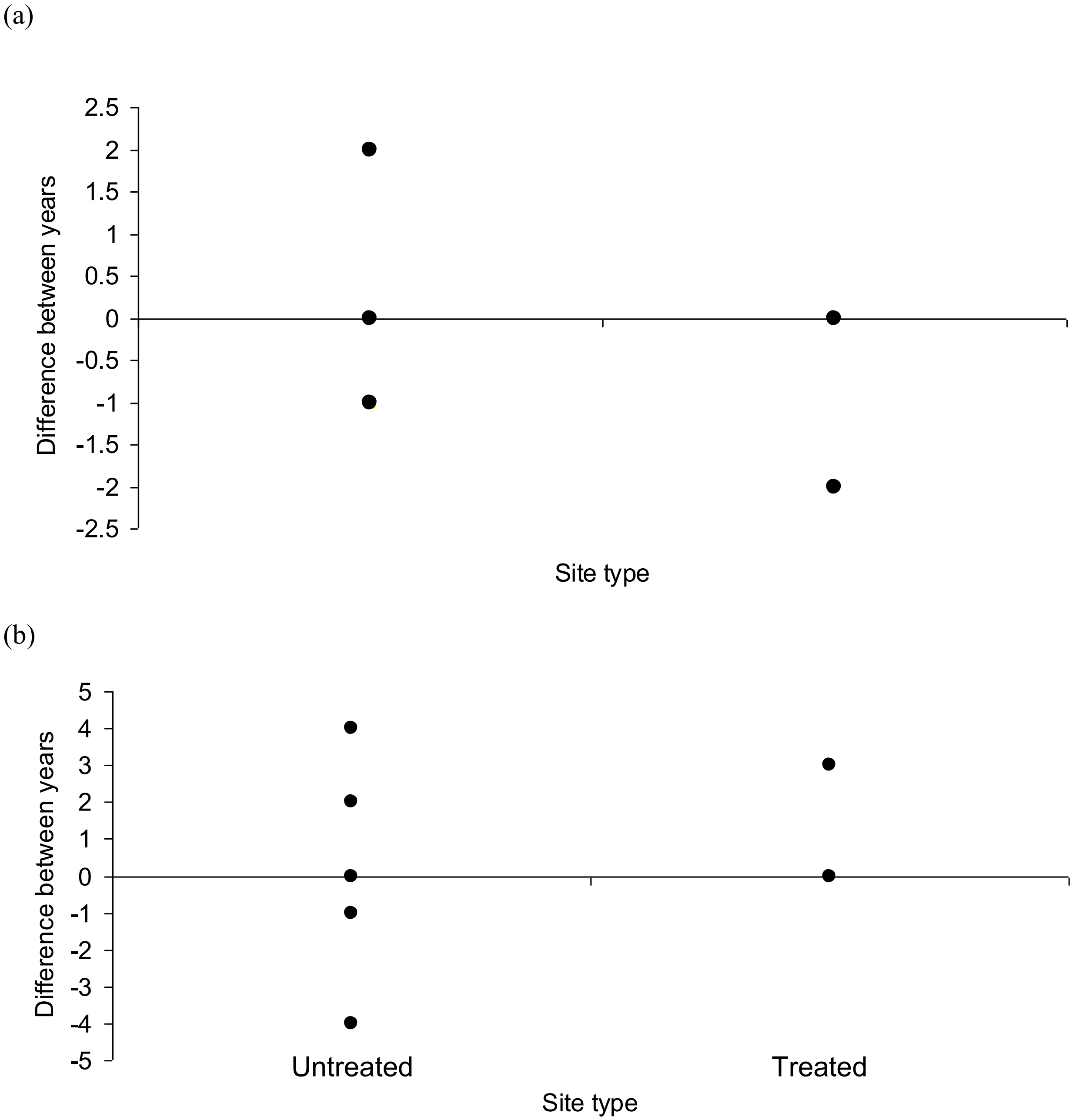

Figure 27. Primary cavity nester richness (a) and abundance (b) between year variance with and without intervening fuels reduction treatment.

Carnivores

Carnivore surveys detected three native and one domestic species of carnivores (Table 13). In addition, cameras detected five species of rodents and black-tailed deer (*Odocoileus hemionus*). Only one species, black bear, was detected in both years at one of the treatment sites, Blackwood 1-4 (Table 14). In the other treatment site, McKinney 13-1 (CHNQ), black bear was also detected in both years, but black-tailed deer and marten were detected in 2006 but not in 2007, and conversely, coyote was only detected in 2007 (Table 14). Detections on untreated sites were fairly consistent between years (Table 14).

Table 13. Carnivores detected on 16 samples sites sampled in 2006 and/or 2007 in the Lake Tahoe basin.

Scientific name	Species code	Common name	2006	2007
Carnivores:				
Martes americana	MAAM	American marten	8	6
Ursus americanus	URAM	Black bear	9	8
Canis latrans	CALA	Coyote	0	1
Canis familiaris	CAFA	Domestic Dog	1	1
Non-carnivores:				
Spermophilis beecheyi	SPBE	California ground squirrel	1	1
Spermophilis lateralis	SPLA	Golden-mantled ground squirrel	0	2
Tamaisciurus douglasii	TADO	Douglas' squirrel	1	1
Glaucomys sabrinus	GLSA	Northern flying squirrel	0	1
Tamias sp.	TASP	Chipmunks	2	1
Odocoileus hemionus	ODHE	Black-tailed deer	1	0

Table 14. Carnivore and deer detections on the eight sites sampled in two consecutive years

	2006					2007				
Site	**CAFA**	**CALA**	**MAAM**	**URAM**	**ODHE**	**CAFA**	**CALA**	**MAAM**	**URAM**	**ODHE**
Treated:										
BLWD				X					X	
CHNQ			X	X	X		X		X	
Untreated:										
BOAA			X	X				X		
CALC			X					X	X	
DEDO			X	X				X	X	
SKET			X	X				X	X	
TBWF	X		X	X		X		X	X	
BOTA				X				X		

Ants and Butterflies

Ants

We observed a total of 3761 individual ants representing 25 species from 2006 and 2007 (Appendix C). Over 60% greater abundance of ants was observed in 2006 compared to 2007, but with nearly the same number of species observed. No species were uniquely observed on the east-side sites. Variation in richness and abundance on treated sites was variable, and no particular pattern of change was associated with treatment (Fig. 28). Richness declined the most on a treated site (McKinney 13-1), showing a loss of six species, however the other treated site showed one of the greatest increases in richness (gain of three species). Five of the six species lost on McKinney 13-1 were aerators. Conversely, the only site showing an increase in abundance was on a treated site (Blackwood 1-4), showing a gain of 57 species; the remaining treated and untreated sites showed a decline of 19 to 160 individuals. Aerators showed the greatest variation in abundance between years (-239 to +56), but they were also the most abundant SPU overall, with a total of 1850 individual aerators captured. Compilers and decomposers were the next most variable, with similar variation observed among years (-41 to +131 and -109 to +51), but compilers were less than half as abundant as decomposers (536 and 1254 individuals, respectively), so variation in compilers represents a more significant effect on ecosystem services. Generalists were not very speciose (4 and 5 species captured in 2006 and 2007, respectively) or abundant (n = 121 individuals in 2006 and 2007 combined) relative to other groups, and were not highly variable between years (-4 to +7).

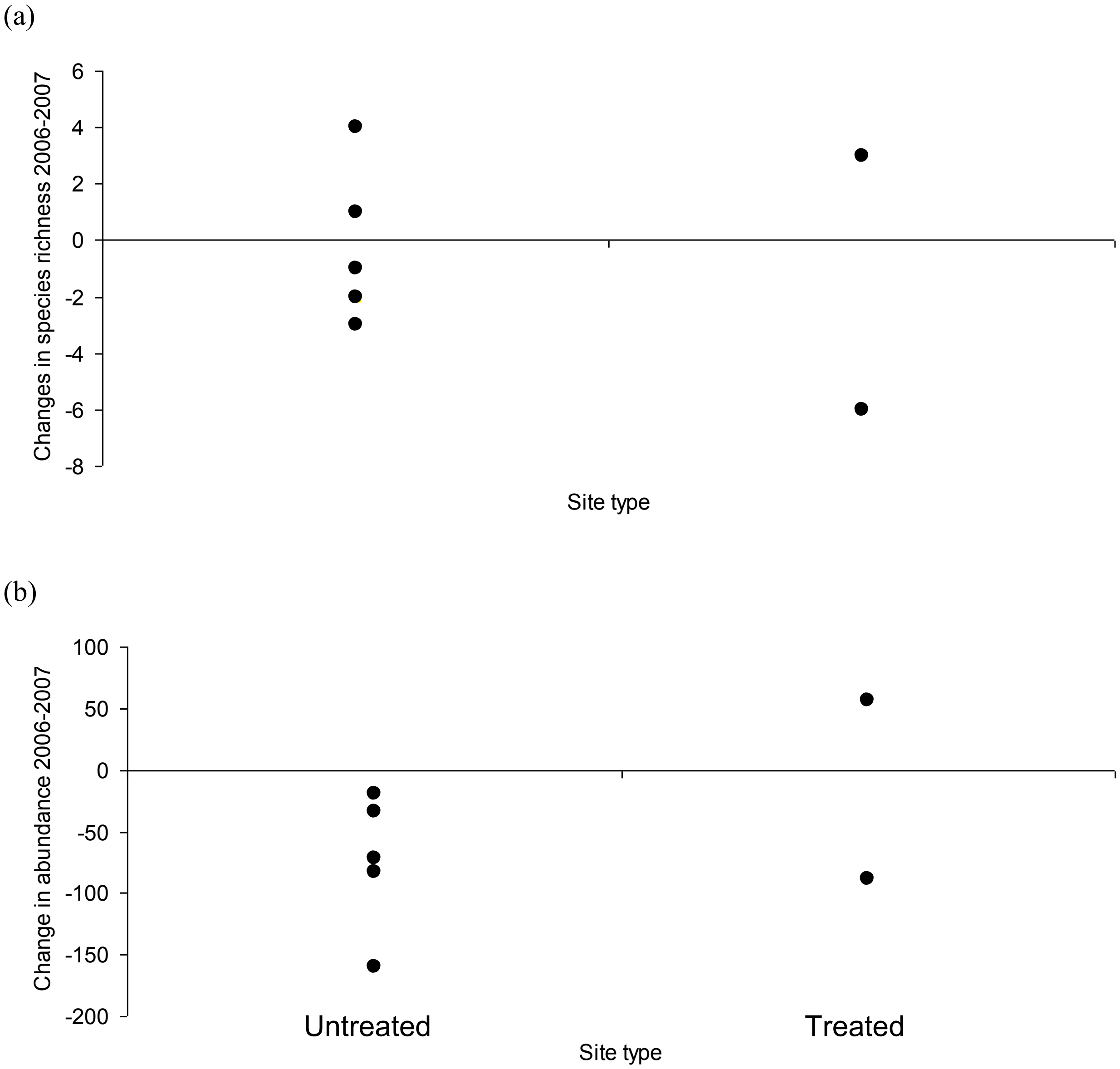

Figure 28. Gains and losses in total ant richness (a) and abundance (b) between years (2006-2007) on untreated and treated sites in the Lake Tahoe basin.

Butterflies

We observed a total of 612 individual butterflies representing 41 species from 2006 and 2007 (Appendix C). In 2006, we observed 443 individuals from 30 different species, whereas in 2007 we observed 169 individuals and 26 species. One butterfly species was only observed on east-shore sites, *Callophrys spinetorum.* All but one site experienced no change or a decline in species richness from 2006 to 2007, including a decline in both treatment sites (Fig. 29). Similarly, abundance declined on all sites from 2006 to 2007, with treated sites showing limited declines compared to untreated sites.

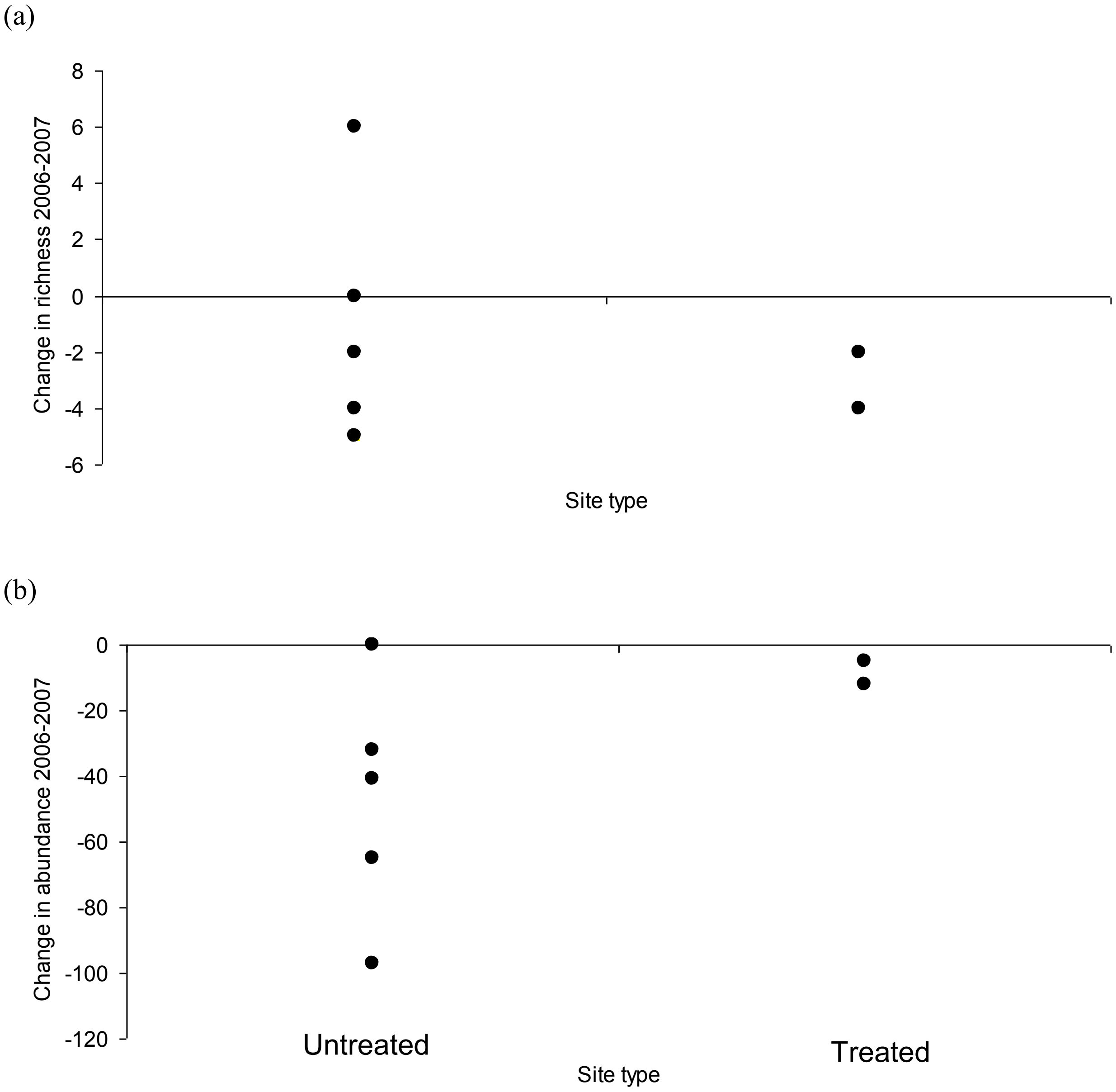

Figure 29. Gains and losses in total butterfly richness (a) and abundance (b) between years (2006-2007) on untreated and treated sites in the Lake Tahoe basin.

CWHR Wildlife Habitat Predictions

Despite substantial changes in forest structure, habitat conditions as per CWHR changed little, indicating that the CWHR database would not predict many changes in species composition. Since only canopy cover class changed, our analysis evaluated species changes based on habitat changes from 4D (medium diameter trees, dense canopy cover) to 4M (medium diameter trees, moderate canopy cover). For birds and mammals, CWHR estimates that fewer species of birds and mammals find high canopy cover conditions to be moderate or highly suitable habitat. In contrast, we observed either no change or a decrease in species richness in birds, small mammals, and mammalian carnivores (Fig. 30). Both treatment sites experienced a decline in bird species richness, whereas CWHR predicted species richness to be 3 times higher than observed, and that species richness would increase with the decline in canopy cover at Blackwood. Similarly, no changes were observed in species richness of small mammals or mammalian carnivores, but CWHR predicted richness to increase with the decrease in canopy cover and predicted the richness of 4M stands to be approximately 3 times greater than we observed. We don’t expect that our sampling for large mammals had high probability of detection for all mammalian carnivores, but probability of detection for our sampling effort is high for birds and small mammals, and similar degrees of commission occurred in these species groups. Small mammal composition changed slightly, with loss of the Brush mouse and the gain of the California ground squirrel occurring in both treatment sites

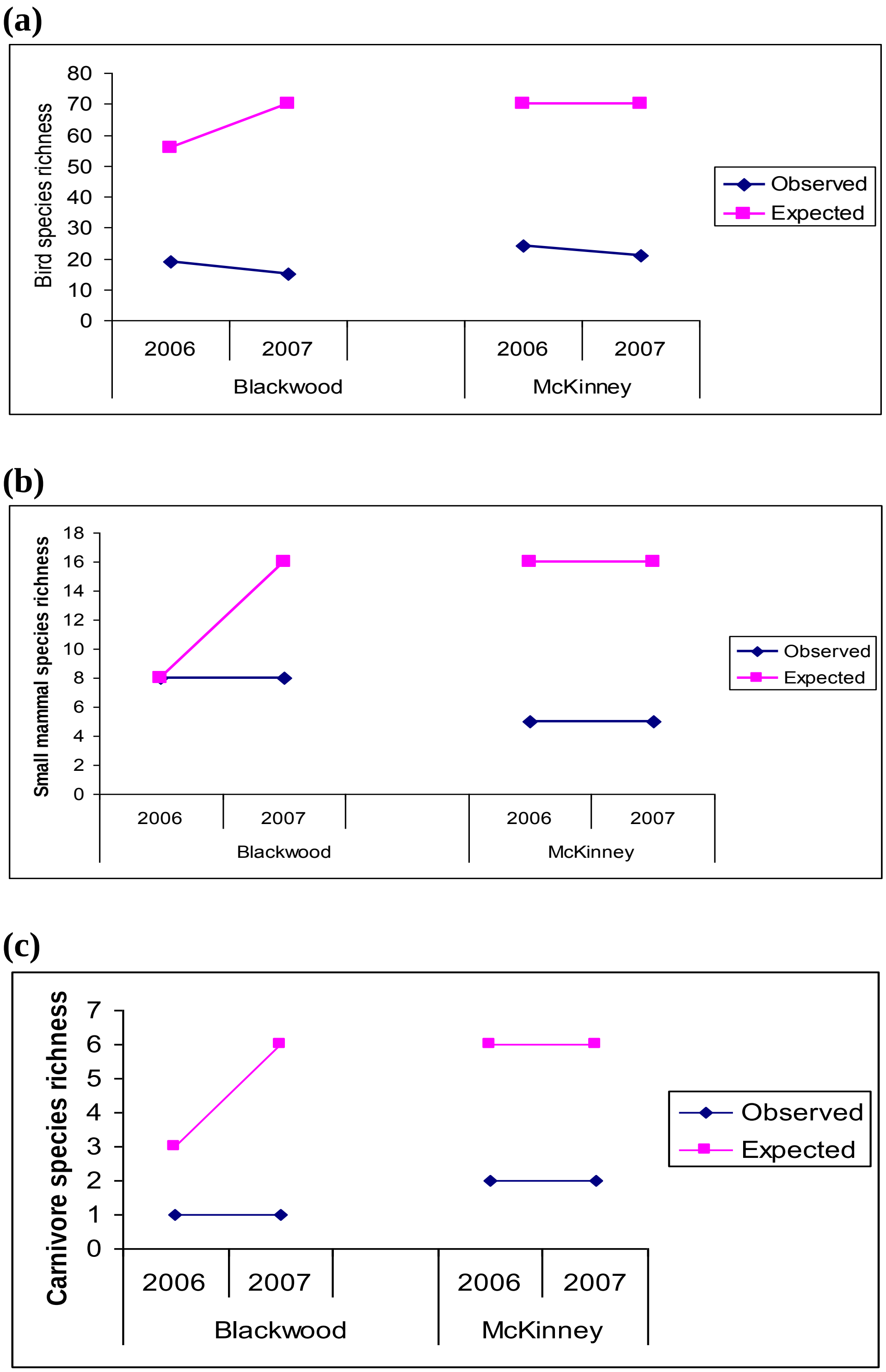

Figure 30. Predicted vs. observed changes in songbird (a), small mammal (b) and mammalian carnivore species (c) based on habitat changes on two sites treated to reduce forest fuels in the Lake Tahoe basin. Predictions based on California Wildlife Habitat Relationships database (CDFG 2002) and observed based on field data collection.

DISCUSSION

Vegetation Condition and Fuel loading

Thinning treatments on both treatment sites accomplished target objectives in terms of final tree density, basal area, and canopy cover. Target objectives were based on changing fire behavior. Additional objectives set for forest management is to move forests closer to historic conditions, with the assumption that those conditions represent a healthier forest; however conditions that meet this broader set of forest health objectives have not been set. The hand thinning and mechanical treatments carried out on the west shore reduced tree densities to 69 and 77 trees/ac, respectively. The mixed conifer forests on the west and east shore are far from the historic range of conditions that existing prior to Comstock logging and European settlement of the Lake Tahoe basin. Paintner and Taylor (2006) used stump data to develop a reconstruction of historic conditions of mixed conifer forests in Yosemite and concluded that pre-settlement forests had an average density of only 54 trees/acre, a BA of 187 ft^2/acre, and a QMD of 27in, based on trees > 4in DBH. In the present study, mean tree density and average basal area on the west shore appear greater, and QMD appears smaller on west shore mixed conifer units. Historic conditions in Jeffrey pine/white fir forests on the east shore were reconstructed and estimated to have an average tree density of 28 trees/acre, a BA of 113 ft^2/acre, and a QMD of 26in (Taylor et al. 2004). In the contemporary forests on the east shore in this study, mean tree density appears three times greater, average basal area similar, and mean QMD approximately 5in smaller.

Reference conditions are not available for fuel loadings, but current fuel loads in both the east and west shore sites are at extreme levels as the result of extensive logging, fire suppression, and insect and pathogen infestations. Fuel loads of 30 to 60 tons per acre on the west shore are beyond the threshold for active crown fire (Stanton and Dailey 2007). Crown fire potential was not predicted for the east shore units, but fuel loading exceeded 40 tons/ac except in the WLD control.

The more open conditions on the east shore compared to the west shore are the result of naturally lower precipitation on the east side. In addition, most units on the west and east shores were treated over the past 50 years. For example, all four units have received treatments in the past. The RED unit was treated to an unknown degree as recently as 2000 (Roland Shaw per. comm.). The WLD control unit lies on the east side of north Canyon road, adjacent to the RED units, and it has certainly been treated in the past, although there is no documentation. Stumps were observed on the site, tree density was one third lower than the other east side units, tree size was 5 inches greater, and fuel loading was about 40% less.

Although no response was observed in the understory one year post treatment, we expect to see changes in the understory resulting from fuels reduction treatments over time. While the immediate vegetation response to is likely to be dramatic and fairly easy to compare among treatments, longer term responses pose more of a challenge. Fuel reduction treatments necessarily alter the successional trajectory of a stand in a number of ways. For example, thinning the overstory and opening the canopy increases light penetration to the forest floor, which would not only favor the regeneration of more shade-intolerant conifers like pine, it may also promote the release of nitrogen-fixing species like ceanothus and lupine, alter shrub composition and density, and promote perennial bunch grasses.

The addition of post-treatment data from additional sites and additional post-treatment years from the 2008 field season will enable a more detailed analysis of vegetation change and response to treatment, including quantitative comparisons of treatment and control sites.

Small Mammals

Sampling successfully described the small mammal communities. Sampling was designed to intensively sample, so although the disturbance that traps experienced due to bears was significant, sampling was still sufficient to characterize small mammal community. Much of the information available from sampling cannot be extracted from the data until additional post-treatment sampling is completed. A few insights are provided here based on results to date. Extra large Sherman traps were equally successful in capturing squirrels compared to Tomahawk traps, however we captured over twice as many northern flying squirrels in Tomahawk traps as Sherman. The use of controls will be important for determining changes in small mammals resulting from treatments because of the high annual variability of populations. No dramatic changes in species composition, richness, or abundance were observed as a result of treatments in the first year following treatment; however, we did observe that shadow chipmunk (understory specialist) appeared to be sensitive to fuel treatments and that treatments may increase habitat suitability for California ground squirrel (a generalist).

Birds

We expected changes in the bird community to occur in response to the treatments because of the diversity of species and their habitat associations. We observed high annual variability in bird species composition and abundance, increasing the caution to be applied to the interpretation of the limited sample size reflected in this report. We observed declines in bird species richness and abundance, driven largely by species associated with old-forest conditions, meaning large diameter trees, higher canopy closure, complex vegetation structure, and dead wood (standing and downed). We did not see concomitant increases in early seral species, which is not surprising considering that stand structure was not similar to an early seral stage – understory vegetation was sparse and overstory cover was near 40%. Old forest associated species are likely to have declined even more in Blackwood if the plot had not included two riparian leave strips – most old-forest associates that remained on that site were located in riparian areas.

Carnivores

We took the opportunity to document the presence of carnivores at sample sites even though this data collection was not required as part of the project. Bear and marten were commonly occurring in these sites on the west side of the basin. Based on sampling associated with other studies, the west side of the basin appears to have a higher density of bears – almost every site had an abundance of sign that bears were consistently using sites for denning, resting, and/or foraging. Fuel treatments were predicted to reduce the quality of habitat for black bear and marten through the reduction of vertical diversity of vegetation, overstory canopy cover, and ground-based food resources (shrubs) and cover (logs and shrubs). Given the small size of plots, we consider the results of this sampling to be indicative, but not definitive in the response of mammalian carnivores to fuels treatments. We saw no change in species detected on one treatment site, but the indication of a swap of an old-forest associate (marten) to a generalist (coyote) on the other site. Sites with multiple years of before and after treatment data will be needed to determine what effects fuels reduction treatments have on these carnivores.

Wildlife Habitat

We found that CWHR, a commonly employed tool in the basin, was a poor predictor of changes in habitat suitability and species composition for birds and mammals. CWHR was not designed to be an incisive tool for determining forest management effects, but none-the-less it is used widely for assessing the potential effects of forest management on wildlife habitat. Its inclusive nature makes it a dull instrument at small scales. More importantly, though, is the fact that it is predicated on the concept of a linear progression of seral stages and the predicted values are based on the suite of stand characteristics that develop as a stand ages following a natural disturbance or stand replacing event. Fuels treatments do not mimic either, and they create stand conditions that CWHR is not capable of evaluating. Unfortunately, no other tool exists for the evaluation of the effects of forest management on multiple species for the California or Nevada portions of the basin.

Conclusions

Standard fuels reduction treatments are effective in achieving target objectives in forest structure designed to reduce the risk of crown fire. We found that fuel loads were not greatly reduced in these two treatment units; however we did not model fire behavior for these two sites, and changes in crown configurations could have contributed to reducing the risk of crown fire despite limited reductions in fuel loadings.

It is clear that a variety of other unintended ecological conditions are changing along with the risk of crown fire. Reductions in understory vegetation, logs, and snags resulting from hand and mechanical treatments suggest that post-treatment forests have reduced heterogeneity and habitat quality for a number of species. Species responses are consistent with this interpretation. These same habitat characteristics are the factors that commonly decline in remnant forests in more urban areas in the basin (Heckmann et al. 2008). Manley et al. (2006) found that many aspects of biological diversity declined as a result of losses of heterogeneity in remnant forests in more urban areas.

East shore sites are ecological different from west shore sites in tree composition and lower starting tree density; however, the same challenges exist in these forests in terms of conserving biological diversity and restoring ecological resilience while reducing the threat of catastrophic wildfire. The differences historic and current pre-treatment structure between east and west shore sites suggests that it would be beneficial to develop target ecological conditions based on historic conditions on their respective sides of the basin.

Target ecological conditions should take into consideration the relative risk of retaining forest elements that have high ecological value but are commonly reduced as the result of fuels reduction treatments. For example, large logs have a limited effect on fire behavior, but are typically greatly reduced by fuels reduction treatments. Current log densities and volumes are likely to be much higher than historic conditions, thus reductions may be warranted in pursuit of ecological restoration; however, target log densities to achieve multiple ecological objectives (fire behavior, soil productivity, wildlife habitat).

Additional work is needed to more fully evaluate the effects and effectiveness of fuel reduction treatments on target and non-target elements of forest ecosystems. The addition of data from 2008 and 2009 will greatly enhance our ability to inform forest management approaches to achieve multiple objectives.

ACKNOWLEDGEMENTS

The Nevada Division of State Lands provided funding for data collection in 2007 and made the continuation of this project in 2007 possible. Elizabeth Harrison (NDSL) worked closely with the science team to coordinate funding and negotiate complex logistics associated with access to Lake Tahoe State Park. Roland Shaw of Nevada Division of Forestry designed and implemented the treatments on the east shore sites. The addition of these sites to the study greatly enhanced the ability of the research to address the array of forest conditions on both sides of the lake, and in particular contribute more to the management of forested ecosystems on the east side of the basin. Multiple agency staff provided valuable assistance in the location and coordination of treatments in units, including Ray Machado (LTMBU), Scott Parsons (LTBMU), Judy Clot (CTC), and Juan Carlos (CTC). Previous years funding was received from the Southern Nevada Public Lands Management Act. Field team leaders and members did a fantastic job of implementing the study, with particular thanks to Kris McIntyre, Marchel Munnecke, Dan Moses, Matty Holdgate, Scott Appleby, Katie Heckendorn, and Haruka Furuya.

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Appendix A. Vegetation Data Collection Protocols

Initial Pre-Treatment Measurements

Vegetation was measured within a fixed 17.58 meter (58 ft) radius plot of 0.1 ha (0.25 ac). A random azimuth was selected for the first transect and then three additional transects were established at subsequent 90° angles with the 0 meter marks at the plot center. The four transects were the basis for sampling down woody debris (DWD), herbaceous and shrub cover and frequency, and duff and litter depths (Figure 2). Plots were monumented with five 2 foot pieces of rebar capped with yellow plastic caps imprinted with "USFS UPFU"; one at the plot center and one at the distal end of each transect.

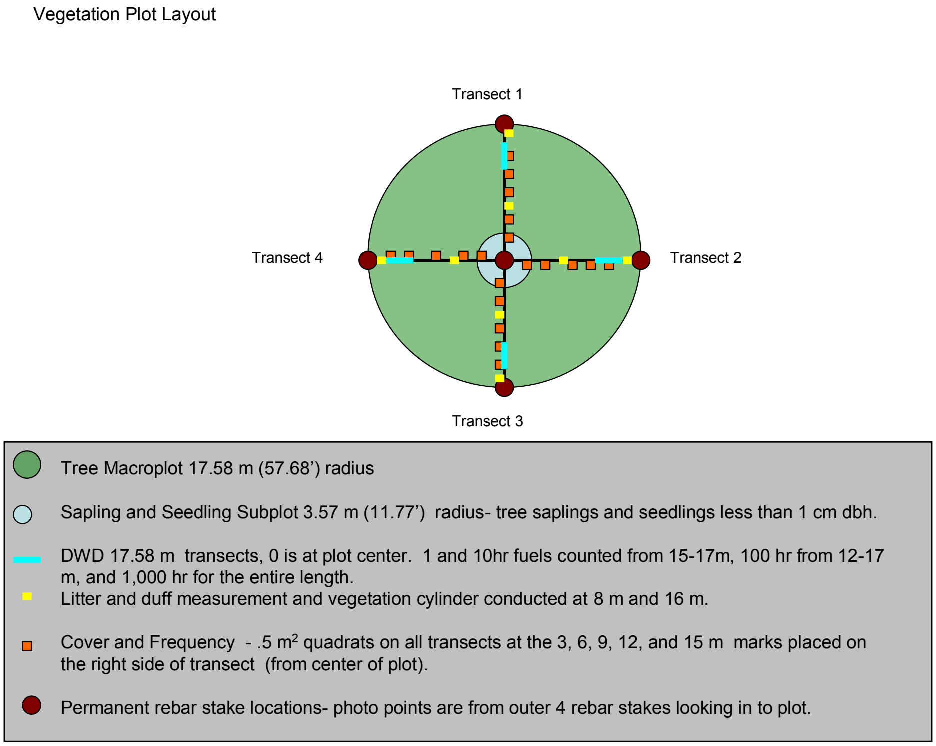

Figure A1-1. UPFU Vegetation plot lay-out.

Plot Description

Descriptive data collected in each plot included: UTM coordinate in NAD 27, slope, aspect, general landform, horizontal and vertical slope shape. The two most dominant species with greater than 10% canopy cover were recorded for three stratums; upper (> 3 m tall), mid (3 to 10 m tall), and low (< 1 m tall). A photo point was established at the distal end of each transect looking down the meter tape toward the plot center.

Tree Data

A breakpoint of 15 cm (6 in) diameter at breast height (DBH) was selected for sampling mature trees. The following data was recorded for all mature trees within the entire plot: species, DBH, total height, height to live crown base, live crown ratio, crown position, and observed damage. Snags were also sampled within the entire plot. Snag data included: species, DBH, total height, and decay class. Within a 3.57 m (11.7 ft) fixed radius subplot of 0.01 ac (0.004ha) nested at the plot center, the species, DBH, total height, and live crown ratio was recorded for all saplings greater than 1.37 m (4.5 feet) tall with a DBH less than the breakpoint. Saplings were categorized by 4 size classes based on DBH: 0-2.5, 2.5-5, 5-10, 10-15 cm. The number of all seedlings less than of 1.37 meters tall was recorded for each species. Seedlings were categorized by 5 height classes: 1-15, 15-30, 30-60, 60-100, and 100-140 cm. The midpoint values of size and height classes were used in calculations. Each mature tree and snag was permanently marked with an aluminum tree tag and nail. Canopy cover was measured at 25 points using a 5 m by 5 m grid using a GRS site-tube densitometer.

Fuels Data

Surface and ground fuels were sampled on all four transects in each inventory plot using the line-intercept method (Brown, 1974). One-hour (0-0.64 cm) and ten-hour (0.64-2.54 cm) fuels were tallied from 15-17 meters, 100-hour (2.54-7.62 cm) fuels from 12-17 meters, and 1000-hour (>7.62 cm) fuels were sampled along the entire length (17.58 meters) of each transect. The larger fuels (1000-hour) represent coarse woody debris (CWD) that has high value for many wildlife species, so the following information was collected for each CWD: species, diameter at the tape, diameter at each end, length, and decay class. Duff and litter depth (cm) was measured at the 8 and 16 meter marks.

At the same locations, the surveyors estimated the following within an imaginary 2m by 2m cylinder: live and dead tree/shrub cover, average tree/shrub height, live and dead herb cover, and average herb height. Measurements were conducted towards the distal ends of the transects to avoid the disturbance that was generally concentrated in the plot center.

Herbaceous and Shrub Cover/Frequency

Herb and shrub percent cover, height, and nested frequency were measured in five 0.25m^2 quadrats located at 3 meter intervals (3,6,9,12,15) along all four transects, for a total sample area of 1.25 m^2. Frequency describes the abundance and distribution of species and is very useful for comparing significant differences between two plant communities or detecting significant change in a single community over time. A reasonable sensitivity to change results from capturing frequencies between 20 and 80 percent, and therefore, a nested quadrat system was used to avoid problems resulting from using a single quadrat size. Nested quadrat sizes (5x5, 25x25, 25x50, 50x50 cm) corresponded to a nested rooted frequency ratio of 1:25:50:100.

Plant cover was measured as the vertical projection of foliage within a percentage of the quadrat and the percent value indicates the relative influence of each species on the community. A system of 12 cover classes, (0-1, 1-5, 5-15, 15-25, 25-35, 35-45, 45-55, 55-65, 65-75, 75-85, 85-

95, 95-100) was used to reduce human error and increase the consistency of estimates. Midpoint values were used for computation.

Height gives detailed information about the vertical distribution of plant species cover with in the plot. It allows calculations of 1) plant species volume (cover x height) and 2) biomass (height x cover x bulk density). FIREMON uses 0.8 kg/ m^3 for herbaceous BD and 1.8 kg/m^3 for shrubs.

Post-Treatment Data Collection Protocol

For one year post treatment plots with hand thin (MCK 13-1):

- Find Rebar- if rebar is missing re-install
- Lay out plot- if necessary run tapes incrementally between piles so that distance from plot center is correct
- Cover Freq- record data as possible, enter PILE and % cover when quad is under pile
- FWD,CWD, Veg cylinder- collect data as before on any point in the transect where there is not a pile
- Densitometer- take data as possible, assuming no hits directly above piles
- Tree Data- record status, LCBH, LCR,
- Snag Data- record status and decay class
- Seedlings and saplings- as before
- PILE DATA- Use the standard method to calculate the volume and biomass and estimate smoke production (Hardy 1996). For all piles positioned at least one half within the plot take the following data:
    - Shape- use shape codes 1-7
    - Take height and width measurements as specified by shape
    - Packing Ratio: choose estimate from .10, .15. 20, .25
    - Record 2 dominant tree species and % cover of each

For one year post treatment plots with mechanical mastication (BLK 1-4):

- All pre-treatment variables were re-measured.
- The protocol for masticated fine woody debris (FWD) follows Hood and Wu (2006).
- Find Rebar and lay out plot as possible- pieces will be missing, but only one is required to set up plot- re-install missing pieces
- Cover Freq- record all veg data,
- FWD- distinguish the cover class of natural (i.e round pieces) of FWD as WOOD and irregularly shaped masticated materials as MAST
- CWD- as before along entire transect
- Veg cylinder- as before at 8 and 16 m then: 1) use a 1m2 quadrat to determine the visual cover class of each of 3 fuel components on the surface: LITT, DUFF, WOOD/MAST and then 2) take 4 depth measures per quad and estimate the percent litt/wood/duff for each depth measurement. Use FIREMON cover classes.
- Densitometer- as before
- Tree Data- record status, LCBH, LCR,
- Snag Data- record status and decay class
- Seedlings and saplings- as before

Appendix B. Bird species detected during point counts conducted in June 2006 and 2007 across 16 sample sites in the Lake Tahoe Basin Management Unit. Asterisks indicate species not detected on plots (e.g., within 60 m of count station).

Common Name	AOU code	AOU number	Scientific Name	Old forest	Early seral	Snags/ logs	1° cavity
Osprey*	OSPR	*203*	*Pandion haliaetus*				
Sharp-shinned hawk	SSHA	*221*	*Accipiter striatus*	X			
Cooper's hawk	COHA	*223*	*Accipiter cooperii*				
Northern Goshawk	NOGO	*225*	*Accipiter gentilis*				
Red-shouldered Hawk	RSHA	*239*	*Buteo lineatus*				
Red-tailed Hawk*	RTHA	*247*	*Buteo jamaicensis*				
Blue Grouse*	BLUG	*298*	*Dendragapus obscurus*				
California Quail*	CAQU	*327*	*Callipepla californica*		X		
Mountain Quail	MOQU	*328*	*Oreortyx pictus*		X		
Virginia Rail*	VIRA	*338*	*Rallus limicola*				
Killdeer*	KILL	*379*	*Charadrius vociferus*		X		
Spotted Sandpiper	SPSA	*404*	*Actitis macularia*				
Band-tailed Pigeon	BTPI	*545*	*Columba fasciata*	X			
Mourning Dove	MODO	*558*	*Zenaida macroura*		X		
Calliope Hummingbird	CAHU	*870*	*Stellula calliope*				
Rufous Hummingbird	RUHU	*874*	*Selasphorus rufus*				
Red-breasted Sapsucker*	RBSA	*960*	*Sphyrapicus ruber*				
Williamson's Sapsucker*	WISA	*961*	*Sphyrapicus thyroideus*	X		X	
Hairy Woodpecker	HAWO	*967*	*Picoides villosus*	X		X	X
White-headed Woodpecker	WHWO	*970*	*Picoides albolarvatus*	X		X	X
Black-backed Woodpecker	BBWO	*972*	*Picoides arcticus*	X		X	X
Northern Flicker	NOFL	*981*	*Colaptes auratus*			X	X
Pileated Woodpecker	PIWO	*987*	*Dryocopus pileatus*	X		X	X
Olive-sided Flycatcher	OSFL	*1131*	*Contopus cooperi*	X			
Western Wood Pewee	WEWP	*1135*	*Contopus sordidulus*				
Dusky Flycatcher	DUFL	*1152*	*Empidonax oberholseri*		X		
Cassin's Vireo	CAVI	*1271*	*Vireo cassinii*	X			
Warbling Vireo	WAVI	*1277*	*Vireo gilvus*				
Steller's Jay	STJA	*1293*	*Cyanocitta stelleri*	X			
Clark's Nutcracker	CLNU	*1316*	*Nucifraga columbiana*				
Common Raven*	CORA	*1331*	*Corvus corax*				
Tree Swallow*	TRES	*1342*	*Tachycineta bicolor*				
Mountain Chickadee	MOCH	*1359*	*Poecile gambeli*			X	
Red-breasted Nuthatch	RBNU	*1370*	*Sitta canadensis*	X		X	
White-breasted Nuthatch	WBNU	*1371*	*Sitta carolinensis*	X		X	
Pygmy Nuthatch	PYNU	*1372*	*Sitta pygmaea*	X		X	
Brown Creeper	BRCR	*1374*	*Certhia americana*	X		X	
House Wren*	HOWR	*1410*	*Troglodytes aedon*				
Golden-crowned Kinglet	GCKI	*1425*	*Regulus satrapa*	X			
Townsend's Solitaire	TOSO	*1460*	*Myadestes townsendi*				
Hermit Thrush	HETH	*1483*	*Catharus guttatus*	X			
American Robin	AMRO	*1501*	*Turdus migratorius*	X	X		
European Starling	EUST	*1513*	*Sturnus vulgaris*				
Orange-crowned Warbler*	OCWA	*1567*	*Vermivora celata*				
Nashville Warbler	NAWA	*1568*	*Vermivora ruficapilla*		X		

Yellow Warbler	YWAR	*1576*	*Dendroica petechia*		
Yellow-rumped Warbler	YRWA	*1581*	*Dendroica coronata*		
Townsend’s Warbler	TOWA	*1583*	*Dendroica townsendi*		
Hermit Warbler	HEWA	*1584*	*Dendroica occidentalis*	X	
MacGillivray's Warbler	MGWA	*1615*	*Oporornis tolmiei*		
Wilson's Warbler	WIWA	*1630*	*Wilsonia pusilla*		X
Western Tanager	WETA	*1685*	*Piranga ludoviciana*		
Green-tailed Towhee	GTTO	*1780*	*Pipilo chlorurus*		X
Chipping Sparrow	CHSP	*1803*	*Spizella passerina*		X
Fox Sparrow	FOSP	*1823*	*Passerell iliaca*		X
Golden-crowned Sparrow	GCSP	*1831*	*Zonotrichia atricapilla*		X
Dark-eyed Junco	DEJU	*1833*	*Junco hyemalis*		X
Black-headed Grosbeak	BHGR	*1862*	*Pheucticus melanocephalus*		X
Red-winged Blackbird	RWBL	*1874*	*Agelaius phoeniceus*		
Brewer's Blackbird	BRBL	*1887*	*Euphagus cyanocephalus*		X
Brown-headed Cowbird	BHCO	*1897*	*Molothrus ater*		X
Pine Grosbeak*	PIGR	*1934*	*Pinicola enucleator*		
Cassin's Finch	CAFI	*1937*	*Carpodacus cassinii*	X	
Red Crossbill	RECR	*1939*	*Loxia curvirostra*	X	
Pine Siskin	PISI	*1944*	*Carduelis pinus*		
Evening Grosbeak	EVGR	*1959*	*Coccothraustes vespertinus*	X	

Appendix C. Frequency of occurrence for butterfly species observed on 12 sample sites sampled in 2006 and 2007 in the Lake Tahoe basin. Asterisk indicates species detected only on one or more of the four east-shore sites (sampled only in 2007).

Butterfly species	2006	2007	**Ant species**	2006	2007
Boloria epithore	3	0	*Aphaeno gasteruinta*	1	1
Callophrys augustus	1	2	*Camponotus laevigatus*	2	2
*Callophrys spinetorum**	0	2	*Camponotus modoc*	12	13
Celastrina argiolus	1	0	*Camponotus vicinus*	7	6
Chlosyne hoffmanni	8	4	*Formica accreta*	8	5
Chlosyne palla	7	0	*Formica argentea*	1	2
Colias eurytheme	0	1	*Formica aserva*	6	4
Erynnis pacuvius	4	0	*Formica cfsibylla*	12	13
Gaides xanthoides	0	2	*Formica fusca*	9	5
Glaucopsyche lygdamus	5	3	*Formica integroides*	1	0
Habrodais grunus	2	0	*Formica lasioides*	3	3
Limenitis lorquini	8	5	*Formica microphthalma*	10	10
Lycaena arota	0	1	*Formica neoclara*	5	3
Lycaena nivalis	1	0	*Formica neorufibarbis*	3	1
Neophasia menapia	0	2	*Formica oreas*	1	0
Nymphalis antiopa	1	0	*Formica propinqua*	5	3
Nymphalis californica	2	1	*Formica ravida*	2	5
Papilio eurymedon	4	1	*Formica sibylla*	1	4
Papilio rutulus	3	3	*Lasius pallitarsis*	5	6
Phycioides campestris	1	2	*Myrmica tahoensis*	3	7
Phycioides mylitta	3	0	*Polyergus breviceps*	0	1
Phycioides oreis	6	2	*Tapinoma sessile*	12	11
Pieris callidice	0	1	*Temnothorax nevadensis*	1	1
Plebejus icarioides	6	5	*Temnothorax nitiens*	3	2
Plebejus idas	4	3	*Temnothorax rugatulus*	3	3
Polites sonora	1	0			
Polities sonora	0	2			
Polygonia satyrus	1	0			
Polygonia zephyrus	6	0			
Pyrgus communis	7	1			
Satyrium behrii	1	0			
Satyrium californica	0	1			
Satyrium saepium	0	1			
Satyrium sylvinus	1	0			
Speyeria atlantis	5	10			
Speyeria coronis	2	1			
Speyeria mormonia	2	3			
Speyeria zerene	0	4			
Thorybes mexicana	1	0			
Thorybes pylades	1	0			