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Assessing Home-range Size and Habitat Needs of Black-backed Woodpeckers in California

Report for the 2013 Field Season

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Above: Capturing a Black-backed Woodpecker as it emerges from its nest. Photo by K. Hein.

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Summary

The Black-backed Woodpecker is a designated Management Indicator Species (MIS) for snags in burned forest across ten national forest units of the Pacific Southwest Region of the USDA Forest Service (USDA Forest Service 2007). Effective management of recently burned forest in California that also meets the conservation needs of the Black-backed Woodpecker requires better information on the resource requirements that support Black-backed Woodpecker occupancy and reproduction in California forests.

During 2011 and 2012 we radio-tracked Black-backed Woodpeckers nesting in 3 forested areas of California that burned between 2 and 5 years before the initiation of tracking. Among 15 individuals with robust tracking data, we found that home-range size varied by an order of magnitude, from 24.1 to 304.1 hectares, as measured by movement-based kernel estimation. Using an information theoretic approach, we evaluated the strength of sex, age, and years since fire as covariates with average snag basal area to explain home-range variation. We found that snag basal area alone best predicted home-range size, explaining 54 to 62 percent of observed variation. As snag basal area increased, home-range sizes exponentially decreased. This relationship held true both with and without the inclusion of three individuals that nested in burned forest yet foraged predominantly outside the fire perimeter in unburned forest. We described a quantitative relationship between home-range size and snag density that forest managers can use to predict Black-backed Woodpecker pair density in burned forests, and assess the likely population consequences of specific harvest treatments.

One of the surprising results we reported in Tingley et al. (2014) was that time since fire added no explanatory power to our model of Black-backed Woodpecker home-range size. This is in marked contrast to work by Dudley and Saab (2007) and Rota et al. (2014), which indicate a strong positive relationship between time since fire and home-range size. Among the birds we studied during 2011 and 2012, snag basal area was far more important than time since fire in driving home-range size, and, in fact, we did not find any evidence of a positive relationship between time since and home-range size. However, a limitation of our 2011-2012 work was that

time since fire was perfectly confounded with study site – we assessed home ranges of birds at three different sites, each with a different number of years having elapsed since fire. While we were able to conclude that any affect of time since fire was insubstantial compared to the effect of variation in snag basal area across the sites, without studying the same site in multiple years, we were left with an unresolved question about whether home ranges enlarge with years since fire. This question has important implications for predicting the area and foraging resources needed by breeding Black-backed Woodpeckers, and how those change with time.

Home-range size and foraging habitat selection in 2013

Here we report on efforts in 2013 to estimate home-range size and assess foraging habitat selection at the 2007 Wheeler Fire, where we worked previously in 2012. Our primary purpose was to assess directly the effect of time since fire on home-range size, without the confounding effect of different study sites. During the 2013 breeding season, we captured and radio-tagged 13 Black-backed Woodpeckers, and were able to obtain enough foraging data to estimate home range of 9 of them using Brownian bridge kernel estimation. In total we completed 154 bouts of radio-tracking, comprising 1342 foraging events at 1216 unique foraging locations. Data on foraging substrate and local stand conditions were collected at all of these foraging locations, and at 1011 "background" grid points within home ranges of the tracked birds. Two of the birds radio-tracked in 2013 had been tracked in 2012, and one bird was the current mate of a bird who had been tracked in 2012. Nests of all birds were found to be within the fire perimeter, and home ranges were also consistently within fire perimeter boundaries, except that one bird foraged occasionally outside but near the fire perimeter.

Home ranges of birds tracked in 2013 varied greatly in size. As expected, MCPs yielded larger estimates of home-range size (100% HR range 27 – 415 ha) than did kernels (95% HR range 19 – 173 ha). With the exception of one bird that frequently foraged outside the fire perimeter, all birds had mean snag basal areas above 15 m^2/ha, and mean live basal areas below 20 m^2/ha within both core and full kernel home ranges. The one woodpecker that foraged substantially outside the fire perimeter had the second highest home range observed in 2013.

We used the 2013 home-range estimates to test the predictive model we developed based on data from 2011 and 2012. Using the full kernel metric, 4 of the home ranges estimated in 2013 fell below the 95% bootstrapped prediction interval defined by the previously parameterized model, and one fell above the interval. For both core and full kernels, four home ranges in 2013 were smaller than expected based on their mean snag basal area. Despite this weaker than expected predictive ability, however, the model was only very slightly changed by the subsequent inclusion of the 2013 results, which did not result in a qualitatively different fit.

In the aggregate, home ranges of birds studied at the Wheeler Fire in 2013 differed little in size from those of birds studied at the same fire in 2012. Mean home-range size increased slightly, but not significantly (Table 6), whereas median home-range size decreased slightly. Rather than any substantial change in aggregate home-range size, the additional year since fire underscored the high degree of variability across individuals in home range size, presumably a strong function of habitat quality. Of the two individual birds' whose home-ranges we estimated in both 2012 and 2013, both shifted areas of usage substantially between years, with nest locations shifting by 350 m and 423 m, respectively. However neither bird exhibited a dramatic change in home-range size; one bird's s home-range increased slightly while the other's decreased slightly.

We evaluated whether background habitat conditions within the study area changed between 2012 and 2013, and found that live tree and snag basal area in portions of the fire areas that fell within observed MCPs in both years decreased significantly. Despite these changing conditions in available foraging substrate, or perhaps because the numbers of both live trees and snags changed in concert with one another, selection of foraging substrate within areas used by focal individuals in both years did not change appreciably (Table 6). Interestingly, while we did not find that birds traveled farther from nests in 2013, they did on average travel farther between successive foraging relocations, spending less time foraging on any single tree. Thus, Black-backed Woodpeckers in our study area appear to have been able to adapt behaviorally to declining food resources over a one-year period. We hypothesize that over longer periods of time, individual woodpeckers would expand their home range size, population density would decrease, and habitat would become increasingly marginal.

Selection of night-time roost sites

A secondary study objective was to use utilize radio-tagged birds to learn something about selection of roost sites by Black-backed Woodpeckers in burned forest, which had never been studied. We found 14 roost locations (other than nests) during 20 night-time searches for 5 individual birds. In six cases, we found birds roosting at sites where we had found them roosting on previous nights. In all cases, the tree in which the bird was roosting was definitively determined by radio-tracking, but description of the particular micro-site on the tree that the bird used was impossible during five instances in which the bird could not be visually located by observers. At the nine roosting locations that were visually confirmed, none of the birds roosted in excavated cavities. Rather, we found birds roosting in the crook of a forked trunk (1 instance); wedged between adjacent trunks of two closely spaced trees (1 instance); in a deep, natural bark furrow (1 instance); clinging to a trunk directly above a horizontal branch (1 instance); and in sheltered spaces within burned out hollows of trunks (5 instances). At the five locations where the roosting bird was not visually located, inspection of the roost trees during the day did not reveal any excavated cavities that could have been used for roosting. The 14 roost locations varied greatly in distance from the roosting bird's nest (range = 110 – 874 m) and averaged 428 m (SD = 241 m). The four instances in which we found locations of birds that still had nestlings in their nests (e.g., the young had not fledged yet) included the roost that was closest to the roosting bird's nest (117m), as well as the roost that was farthest from the roosting bird's nest (874 m). All 14 of the roost sites were within stands that had burned at medium or high severity. Three of the 14 roost sites were in live trees, whereas the remaining 11 were in fire-killed snags. Trees used for roosting averaged 37.0 (16.1) cm dbh and 12.3 (5.5) m tall. Most of the roost sites had few or no live trees within a 10-m radius circle centered on the roost tree (range = 0-17 live trees with dbh> 10 cm) whereas local abundance of dead trees with the 10-m radius varied greatly (range = 1-89 dead trees with dbh>10 cm). Based on these results, we provide recommendations for factoring habitat needs for roosting in to snag retention efforts for Black-backed Woodpeckers.

Breeding phenology and nest success

As we document in Appendix 1, during 2013 were able to monitor 9 Black-backed Woodpecker nesting attempts, all of which succeeded. Since 2011, we have now monitored nesting attempts of 30 pairs of Black-backed Woodpeckers, where nesting attempts are defined as nesting efforts during which we are certain eggs were laid. Estimated dates for the initiation of incubation ranged from April 20 to June 26. Observed and estimated fledging dates of nestlings ranged from May 27 to July 25. The latest-starting nest we observed failed for unknown reasons during the nestling phase, but had it succeeded, we estimate that the nestlings would have fledged August 2. Trees used for nesting were all heavily charred snags that appeared to have been killed by the recent fire, with mean dbh = 33.9 cm (SD = 8.1 cm).

Of the 30 nests we have observed, 25 (83%) were confirmed or strongly believed to have fledged at least one young, and five failed to fledge any young. These results are based on a naive nest success rate that did not consider exposure period or length of time the nest was observed. We intend to collect additional data on Black-backed Woodpecker nest phenology and nest success rate during summer 2014, as part of a project conducted under separate funding. Once these additional data are collected, we anticipate conducting a more thorough analysis incorporating all of our nesting data.

Spatially extensive occupancy surveys at 2012 fires prior to any post-fire forest treatments

Black-backed Woodpecker abundance and reproductive success have been shown to be reduced by post-fire forest management actions that remove large numbers of snags from otherwise suitable habitat. However, the specific number and arrangement of fire-killed trees removed can vary greatly among and across projects, depending on the site-specific ecological context and the management objectives. As documented in Appendix 2, in 2013 we initiated a multi-Forest study to assess the effects of different intensities, extents, and landscape configurations of post-fire forest treatments on Black-backed Woodpecker occupancy. We identified six fires that burned on National Forests in potential Black-backed Woodpecker habitat across the species' range in California during 2012 (Barry Point fire on Modoc NF, Bear fire on Sierra NF, Chips fire on Lassen and Plumas NFs, George Fire on Sequoia NF, Ramsey fire on Stanislaus NF, and

Reading fire on Lassen NF). During the 2013 breeding season, a little under a year after the fires had burned, we conducted extensive Black-backed Woodpecker occupancy surveys across each fire area. Except for some limited hazard-tree removal projects along roadways, none of the surveyed stands had yet been salvage-logged or treated with other post-fire management actions that remove substantial numbers of snags. In total, we conducted broadcast surveys at 710 survey stations across the six fires. One or more Black-backed Woodpeckers were detected at 215 of the stations. During the 2014 breeding season we will attempt to again conduct broadcast surveys at all of the stations we surveyed in 2013, permitting an analysis of the effects of post-fire forest treatments on occupancy rates of Black-backed Woodpeckers.

Introduction

The Black-backed Woodpecker is a designated Management Indicator Species (MIS) for snags in burned forest across ten national forest units of the Pacific Southwest Region of the USDA Forest Service (USDA Forest Service 2007). At this writing US Fish and Wildlife Service is also evaluating two populations of the species (including the birds in California) for candidacy under the federal Endangered Species Act. Effective management of recently burned forest in California that also meets the conservation needs of Black-backed Woodpecker requires better information about Black-backed Woodpecker home-range size and the factors that drive variation in home-range size.

During 2011 and 2012 we radio-tracked Black-backed Woodpeckers nesting in 3 recent fire areas on Plumas and Lassen National Forests that burned between 2 and 5 years before the initiation of tracking (Siegel et al. 2013, Tingley et al. 2014). Among 15 individuals with robust tracking data, we found that home-range size varied by an order of magnitude, from 24.1 to 304.1 hectares, as measured by movement-based kernel estimation. Using an information theoretic approach, we evaluated the strength of sex, age, and years since fire as covariates with average snag basal area to explain home-range variation. We found that snag basal area alone best predicted home-range size, explaining 54 to 62 percent of observed variation. As snag basal area increased, home-range sizes exponentially decreased. Snag basal area, unlike other potential influences on home range size, is an attribute that forest managers can influence. We described a quantitative relationship between home-range size and snag density that forest managers can use to predict Black-backed Woodpecker pair density in burned forests, and assess the likely population consequences of specific harvest treatments. We subsequently used that relationship in the development of a Black-backed Woodpecker habitat suitability model (Tingley et al. 2014) that is being used by Forest Service personnel to evaluate the possible effects of post-fire treatments on forests that burned in 2013.

One of the surprising results from Tingley et al. (2014) was that time since fire added no explanatory power to our model of Black-backed Woodpecker home-range size. This is in marked contrast to work by Dudley and Saab (2007) and Rota et al. (2014), which indicate a strong positive relationship between time since fire and home-range size. As populations of wood-boring beetle larvae decrease during the years after fire (McCullough et al. 1998), it is suggested that Black-backed Woodpeckers require larger home ranges to provide enough food. Yet among the birds we studied during 2011 and 2012, snag basal area was far more important than time since fire in driving home-range size, and, in fact, we did not find any evidence of a positive relationship between time since and home-range size.

However, a limitation of our 2011-2012 work was that time since fire was perfectly confounded with study site – we assessed home ranges of birds at three different sites, each with a different number of years having elapsed since fire. While we were able to conclude that any affect of time since fire was insubstantial compared to the effect of variation in snag basal area across the sites, without studying the same site in multiple years, we were left with an unresolved question about whether home ranges enlarge with years since fire. This question has important implications for predicting the area and foraging resources needed by breeding Black-backed Woodpeckers, and how those change with time. In 2013 we therefore again estimated home-range size and assessed foraging habitat selection at the Wheeler Fire, where we had worked in 2012. Our primary purpose was to assess directly the effect of time since fire on home-range size, without the confounding effect of different study sites.

We also continued to amass a data set on Black-backed Woodpecker nesting phenology, nest-site selection, and nest success rates. As a final objective, we also sought to characterize habitat used for night-time roosting by the woodpeckers. Little is known about habitat selection for roosting in Black-backed Woodpeckers, because of the inherent difficulty of finding the birds at night. Nevertheless, the availability of suitable roosting opportunities could be an important component of overall habitat quality. Although no studies of Black-backed Woodpecker roosting habits or habitat has ever been published in peer-reviewed literature, Goggans et al. (1989) described twenty roost sites in an unburned forest in Oregon with large numbers of dead and drying trees due to a mountain pine beetle outbreak. Most of the roosts they found (87%) were in live Lodgepole Pines. It is unclear how relevant these findings might be to Black-backed Woodpeckers in burned mid-elevation forests of California, so we searched for, and characterized, night-time roost sites of Black-backed Woodpeckers we had marked with radio transmitters.

Methods

Study area

During the 2013 breeding season, we studied Black-backed Woodpeckers occupying the footprint of the Wheeler fire (alternately referred to as the 'Antelope Complex' fire) on Plumas National Forest (Figure 1) in the northern Sierra Nevada mountains of California. This was also the site of telemetry work during the 2012 breeding season during which we captured and robustly tracked 9 Black-backed Woodpeckers (Siegel et al. 2013, Tingley et al. 2014). Sampling in 2013 was conducted to gain additional inference on space-use by woodpeckers in the Wheeler fire and in particular to better assess how space-use changes across years.

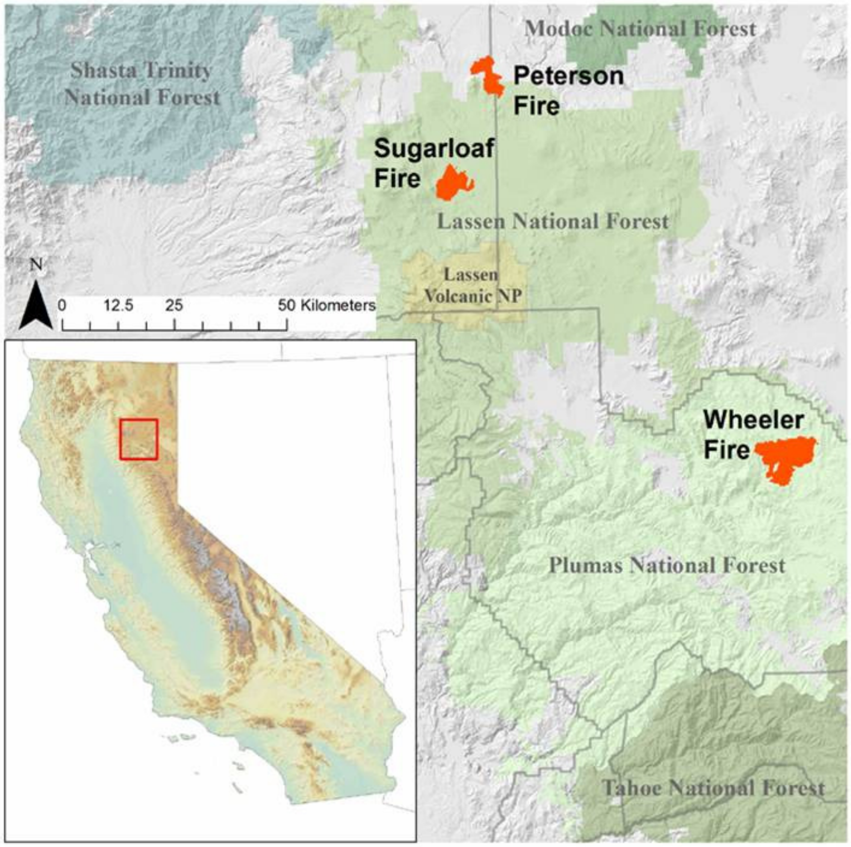

Figure 1. Location of the Wheeler fire, where we studied Black-backed Woodpeckers during the 2012 and 2013 breeding seasons, and the Peterson and Sugarloaf fires, where we studied Black-backed Woodpeckers during 2011.

The Wheeler Fire burned in 2007, affecting 9265 ha of mostly Sierra Mixed Conifer forest

(California Department of Fish and Game 2005) on Forest Service land. Forest Service mapping efforts based on Landsat Thematic Mapper data before and after the fire classified 52.6% of the area inside the fire perimeter as high-severity, 28.3% as mid-severity, 13.4% as low-severity, and 5.7% as unchanged. No post-fire logging occurred on Forest Service land within our study area, but a few private inholdings within and adjacent to the study area were clear-cut after the fire, and post-fire wood-cutting for firewood by the public was pervasive along roads throughout much of the study area on Forest Service land. Much of the study area encompassed large, continuous stands of medium- or high-severity burned forest (Figure 2). The burned area extends from 4650 to 7015 ft above sea level.

Figure 2. Representative views of the Wheeler fire on Plumas National Forest.

Data collection

Finding and catching birds. In late April of 2012 and 2013 we began searching for Black-backed Woodpeckers, using a combination of broadcast surveys (loosely following the survey methods described in Saracco et al. 2011) and passive observation. Once we located birds, we attempted to catch them in mist nets (Figure 3) using more broadcasts and a wooden carving of a Black-backed Woodpecker that served as a lure. We caught the majority of our focal birds this way, but when we were unable to catch some individuals in this manner (generally because they tended to remain too high in the trees to be caught in mist nets when agitated by the lure and broadcast vocalizations), or when nests of unmarked birds were discovered later in the breeding season, we instead caught birds with hoop nets as they exited their nest cavities (Figure 2). Other researchers (Jennifer Pierson, personal communication) report that Black-backed Woodpeckers may abandon their nests if caught while exiting nest cavities during the incubation phase or before nestlings turn 4 days old; we therefore closely monitored nesting activity and did not attempt to catch birds with this method until at least 5 days after eggs hatched. Hatching dates and/or age of nestlings were inferred from parental behavior and auditory detection of nestlings.

Figure 3. Black-backed Woodpeckers were captured with mist nets (left) or in a hoop net as they exited their nest (right).

Attaching radio-transmitters. Various methods for attaching transmitters to woodpecker-sized birds have been described (e.g., Raim 1978, Rappole and Tipton 1991, J. Tremblay personal communication). We attached Model BD-2 radio-transmitters supplied by Holohil Systems, Ltd. to the dorsal surface of one of the inner rectrices. Transmitters were custom-modified by the manufacturer with a hole drilled into the large end, through which we could feed monofilament. Transmitters, including batteries, weighted ca. 2.0g. We used ethyl cyanoacrylate (available commercially as ‘Superglue’) to glue transmitters to a feather shaft and then additionally attached them with two loops of monofilament tied around the feather shaft (Figure 4).

Figure 4. Attaching a radio-transmitter to a woodpecker's tail feather using (left) ethyl cyanoacrylate and (right) monofilament.

When we caught woodpeckers, in addition to attaching transmitters we also:

- banded the birds with uniquely numbered aluminum leg bands supplied by the USGS Bird Banding Laboratory.
- measured wing length and collected other morphometric data.
- made a preliminary assessment of the bird's age, based on plumage and evidence of past molts (Pyle 1997).
- collected photographs of open wings for after-the-fact determination of bird age.
- collected feather samples for genetic analysis.

In some cases the birds spontaneously molted an adequate number of body feathers during processing that no further feather collection was necessary; when this did not happen, we collected additional feathers by taking a small 'pinch' of feathers from the back of the bird – generally yielding 3-5 small feathers. Feathers collected from each bird were stored in a labeled and sealed paper envelope. Later in the field season some of the birds shed the tail feather on which we mounted the transmitter – with the functioning transmitter still attached. In these instances we collected the shed tail feather and added it to feather samples we collected during in-the-hand processing. After the field season, all feather samples were shipped to Dr. Michael Schwartz, Conservation Genetics Team Leader at the U.S. Forest Service Rocky Mountain Research Station, for DNA extraction and analysis.

In-the-hand processing generally lasted about 15 minutes, after which all birds were released in apparently good condition. When we caught birds exiting their nests, we released them onto their nest trees or even into their nest cavities when possible, in an attempt to minimize the likelihood of nest abandonment relating to capturing birds at their nests.

Monitoring nesting attempts of focal birds. We located Black-backed Woodpecker nests by following unmarked or radio-tagged birds to their nests, or by cueing in to the sounds of nest excavation or begging nestlings. Once we discovered a nest, we attempted to visit it at least every four days to observe parental behavior and/or listen for hatchlings. We were generally unable to observe nest contents directly, but we were nevertheless able to construct a timeline for each nesting attempt, based on direct observations of parental behavior and nestlings (when they were mature enough to be audible from ground level or to peer out of the cavity entrance), and published information on the expected duration of each nesting interval. We occasionally used a borescope with a flexible probe for looking into nest cavities, but most of the nests were too high to use this technique without climbing the nest tree – which we chose not to do out of safety concerns and a desire to minimize disturbance to nesting efforts. Following Ehrlich et al. (1988), when our direct observations were equivocal we assumed that egg laying lasted 5 days, incubation lasted 13 days, and the nestling period (hatching to fledging) lasted 25 days.

Radio-tracking and marking foraging locations. Once birds were marked with radio-transmitters emitting signals at unique frequencies, we attempted to track them approximately every second day, although intended tracking bouts were sometimes missed due to inclement weather or other logistic reasons. Alternately, when the crew had time, we sometimes tracked birds daily. Each pair of crew members usually had time to find and track two birds per day (including the substantial time needed to describe foraging substrate and habitat at observed foraging points – see below), so for each individual bird we strove to alternate whether it was the first (generally tracked during mid-morning) or second (generally tracked during early afternoon) bird tracked in a day, in case activity patterns varied substantially with time of day.

We used radio receivers and Model RA-7 antennas supplied by Telonics Telemetry Consultants and AVM Instruments Company, Ltd. to locate and track marked birds (Figure 5). Radio-tracking generally required a team of two people working together. The team would return to the home range of a marked bird and use a receiver and antenna to find a signal and use the homing method (Mech 1983, White and Garrott 1990) to approach and find the bird. Sometimes this process was rapid, but because the birds often moved too quickly to be followed on foot over large distances, it sometimes required as long as 2 hours to visually locate a bird prior to initiating the collection of foraging observations. Black-backed Woodpeckers were very unwary of human observers, consistently allowing trackers to approach within 3-4 m without obviously altering their behavior, as has been reported from the boreal forest (Tremblay et al. 2009).

Figure 5. Using a receiver and antenna to assess the direction of a transmitter signal.

Once a bird was visually located, the team would follow it for at least one hour of continuous tracking, or until at least 20 foraging locations were marked. One member of the team – the 'tracker' – would use the receiver, antenna, and binoculars to find and follow the bird, and a stopwatch to measure the time the bird spent on each tree. The other person – the 'scribe' – would carry a GPS unit, clipboard with data sheet, and at least 20 pre-numbered vinyl pin flags. Upon sighting the bird alight on a tree and begin foraging (defined as touching its bill to the tree), the tracker would start the stopwatch and time the period from the initiation of foraging until the bird left the tree. The tracker would also call out which of four height ranges (<1 m above ground, 1-3 m, 3-10 m, >10 m) on the tree the bird foraged within, and which foraging methods it used (peck, flake, excavate, glean). The scribe would record the tracker's observations and the elapsed time (also called out by the tracker), collect a GPS waypoint, and plant a pin flag at the base of the tree (generally waiting until the bird departed, unless it was foraging high enough on the tree not to be flushed by the observer). When the bird departed from the tree, the team would follow it, and record the next foraging event in a similar manner.

Describing foraging substrate and habitat at foraging locations. After completing each bout of tracking a focal bird, the tracking team used their GPS waypoints to return to each pin flag and collect information on the foraging substrate as well as habitat data within a 10-m and a 50-m radius plot centered on the tree.

For the foraging substrate, the data collected included:

- Identification of substrate as live tree, snag, log, or stump
- Height (length for logs)
- Whether any needles were present
- How much bark was retained
- Diameter at breast height (dbh; max width for logs)
- Broken or intact top
- Percent retained live foliage (live trees only)
- Percent trunk scorched
- Number of wood-boring beetle holes <1 m above ground
- Number of woodpecker excavations <1m above ground

For the 10-m plot, the data collected included:

- Aspect
- Linear extent of logs >10 cm thick
- Number of live trees > 10 cm dbh
- Number of cut stumps
- Number of snags in each of three size classes (10-30 cm, 31-60 cm, >60 cm dbh)

For the 50-m plot, the data collected included:

- Dominant fire severity (none, low, medium, or high, determined by visual inspection)
- Apparent pre-fire CWHR habitat type
- Basal area of snags and live trees (assessed with a 'Cruiser's Crutch')

Locating radio-tagged birds at night-time roosts. In 2013 we attempted to find night-time roosting locations of radio-tagged Black-backed Woodpeckers approximately every ten days, or opportunistically when the crew was able to visit the study site at night. In Black-backed Woodpeckers, males are known to primarily roost in the nest cavity until late in the nestling period (Short 1974). After confirming this by finding one of our radio-tagged males roosting in the nest on May 14 with nestlings, we searched for roosts of males only after their nestlings had fledged. We looked for night-roosts of radio-tagged females opportunistically throughout the field season, though for logistic reasons most of our roost-searching effort occurred later in the season after most nestlings had fledged.

Working in pairs or small groups, crew members used the homing method (Mech 1983, White and Garrott 1990) to find roosting birds at night. Searching never began until at least three stars were visible in the night sky, and crews would generally begin homing from somewhere near the nest of the bird they were seeking. Locating roosts generally required between 15 and 90 minutes of homing. In many cases we were able to visually confirm the locations of roosting birds with a flashlight, but sometimes the birds were obscured by vegetation or otherwise impossible to see in the dark. We collected gps coordinates at roost sites and also marked them with flagging, and then returned during daylight hours to collect habitat information on roost substrate and the surrounding habitat.

Describing available habitat at systematic points across each bird's home range. Near the end of each field season we used the radio-tracking data to construct preliminary minimum convex polygons (MCPs) describing 100% of each marked bird's observed home range. Within each home range we defined a systematic grid of points 100 m apart, and then conducted vegetation survey at each of these points, to describe 'available' habitat within each bird's home range.

At each of the systematic grid points we conducted a vegetation assessment similar to what we did at the observed foraging locations. For information on available foraging substrate, we collected our foraging substrate data (see Describing foraging substrate and habitat at foraging locations, above) at the nearest snag and live tree within 50 m of each systematic point. 10-m plot data and 50-m plot data were collected identically to what we did at the observed foraging locations, but rather than collecting these data at every grid point as we did for the foraging substrate information, these data were only collected at alternating grid points.

Data analysis

Data preparation. Data collected from radio-tracking can be divided into three classes: 1) GPS points taken from sightings of known birds prior to tagging and radio-tracking; 2) GPS points taken during radio-tracking where foraging trees were later measured; and 3) GPS points taken during radio-tracking where foraging trees were not measured (primarily late in the field season when vegetation measurements were limited by crew availability). For the calculation of home range sizes, only GPS points collected during radio tracking (regardless of whether foraging trees were measured) were used.

All data analyses were conducted in R (R Development Core Team 2013) and made use of the home range estimation packages AdehabitatHR and AdehabitatLT (Calenge 2006). Subsequent spatial manipulations and area estimations used ArcGIS (ESRI 2011), and the R packages PBSmapping (Schnute et al. 2010), raster (Hijmans and van Etten 2011), and sp (Bivand et al. 2008).

Home-range estimators. Home range can be estimated using various methods depending on assumptions, data type, and data quality. Classically, home range has been estimated by simply circumscribing all tracked points, which results in the Minimum Convex Polygon (MCP; Mohr 1947). If this is done around all points, it yields the 100th percentile MCP. Although MCPs are known to overestimate home ranges due to the inclusion of areas of low use within the convex polygon, to keep consistent with past studies of Black-backed Woodpeckers we present the 100th percentile MCP in this report along with other home range metrics.

The joining of home range and use led to the conceptualization of a home range as consisting of an area with varying degrees of usage, and that within the home range there may be patches that are more heavily used and less heavily used. This usage pattern is termed the Utilization Distribution (UD; van Winkle 1975) and can be modeled as a bivariate probability density distribution. Here we use a home range method called Brownian bridge kernel estimation which accounts for temporal autocorrelation in the woodpecker radio-tracking data and explicitly uses both the path taken between consecutive relocations as well as the amount of time between observations at successive foraging points to estimate a Utilization Distribution (Bullard 1999, Horne et al. 2007). Unlike fixed kernel methods (i.e., where each fix is treated as independent), the Brownian bridge method assumes that the area between consecutive relocations is part of the 'home range' and that the degree with which this in-between area is used is related to the amount of time spent traveling between two fixes (relative to the speed of the animal). Thus, parameterization of Brownian bridge kernel home ranges requires the specification of two variables: sig1, which relates to the speed of the animal and defines the width of Brownian bridges; and sig2, which relates to the imprecision of the relocations and defines the width of kernels around known locations. Brownian bridge kernel estimation works best when the time between consecutive locations is relatively constant, thus lumping 'bouts' (i.e., series of radio-tracking) collected across multiple days or weeks into a single continuous movement trajectory invalidates model assumptions. To avoid this problem, kernel-based home ranges were modeled for individual observation bouts (consisting of 1 to 60 foraging relocations; median = 10), and then all bout-specific UDs for a single bird were averaged to create a composite utilization distribution for an entire bird's home range (Tingley et al. 2014). The parameter sig1 can be empirically estimated using data for a single bout (Horne et al. 2007), but given that sig1 has meaning as a bird-specific rather than bout-specific property, we averaged empirical estimates of sig1 across all bouts for a single bird and used this single mean sig1 value for home range estimation with all bouts of an individual. The parameter sig2 was set to 5 (meters) for all birds, consistent with the approximate uncertainty of field-based GPS units used in this study. Kernel home range areas were calculated for multiple percentiles. Consistent with previous studies, we utilize the 95th percentile to represent the full home range ('full kernel'), and the 50th percentile to represent the 'core' home range (Anich et al. 2012, Tingley et al. 2014).

It should be noted that all methods include assumptions and biases that sometimes lead to wildly different “home range” estimates, often depending on different inherent ideas of what a “home range” actually is. However, movement-based kernel-based estimates have been shown to consistently minimize Type I and Type II errors versus other home range estimation methods, including the MCP method (Cumming and Cornélis 2012). Nevertheless, our overall goal is to present results using multiple methods so as to maximize comparability to other studies of home range size in Black-backed Woodpeckers, thus MCP estimates are also presented.

Determination of Adequate Sample Size Per Bird. How many geographic locations are necessary to robustly estimate a home range has long been a key question in spatial ecology (Odum and Kuenzler 1955). Although radio-tracking study designs aim to gather adequate sample sizes for all individuals, many factors can contribute to why insufficient sample sizes are collected. For example, transmitters can fall off or stop signaling, tracking teams may need to spread their effort across many individuals, and sometimes animals simply disappear. There is little consensus on how a “robust” sample size for home range estimation should be measured (Seaman et al. 1999, Anich et al. 2009). Here, we follow the method of Tingley et al. (2014), using a boostrap resampling procedure to check for robust sample sizes adequate for MCP estimation as well as kernel estimation.

The bootstrap procedure draws increasing numbers of random relocation points for birds, and estimates an MCP at each consecutive draw. For each bird, 5 points were randomly drawn at the start of the sequence, and sample sizes increased incrementally until all sample points (n) were drawn. Following Odum and Kuenzler (1955), we then calculated the incremental change in home range size, with each successive sample point. For each bird, the random drawing of points was repeated 5,000 times, thus allowing the calculation of means and 95% confidence intervals around the incremental change in home range size with increasing samples. We decided on a conservative cut-off of having 95% confidence intervals converge to less than 2% incremental change in estimated area.

Results

We captured and radio-tagged 13 Black-backed Woodpeckers during the 2013 breeding season, adding to the 12 Black-backed Woodpeckers tracked at the Wheeler fire during the 2012 field season. Getting the transmitters to remain affixed to the birds continued to pose difficulties. In several cases, even though the transmitter held fast to the feather, the woodpecker shed its entire feather, thereby ending our tracking efforts prematurely. Of the 13 caught birds in 2013, only 11 provided any tracking data. Nevertheless, we were still able to accomplish substantial radio-tracking: 154 bouts comprising 1342 foraging events at 1216 unique foraging locations. Data on foraging substrate and local stand conditions were collected at all of these foraging locations. In addition, on-the-ground habitat data were collected at 1011 “background” grid points within MCP boundaries. Two of the birds radio-tracked in 2013 had been tracked in 2012, and one bird was the current mate of a bird who had been tracked in 2012.

Home-range size estimates

Of 11 Black-backed Woodpeckers with radio tracking data, 9 were males and 2 were females. All 11 birds attempted to nest during the study. Nests of all birds were found to be within the fire perimeter (Figure 6). Home ranges were also consistently within fire perimeter boundaries. One bird, SD-13, foraged occasionally outside of the fire perimeter, although this bird did not travel extensively away from his nest.

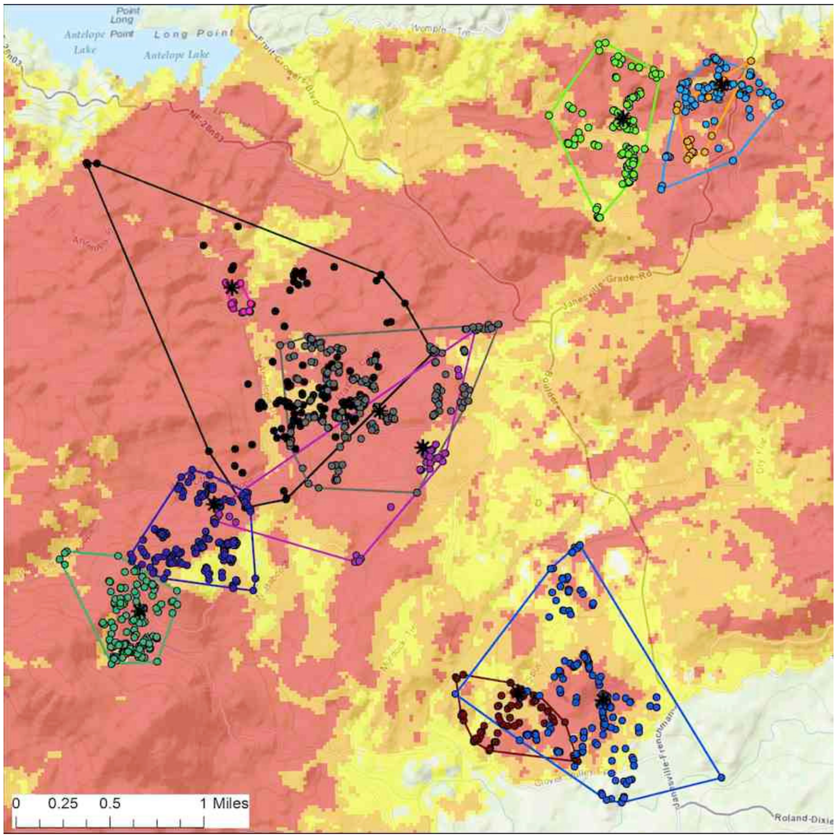

Figure 6. Observed foraging locations (points), nests (asterisks) and full MCP boundaries for individual Black-backed Woodpeckers (each represented with a unique color) radio-tracked at the Wheeler fire in 2013. The birds denoted with black and gray, respectively, were a mated pair. Burn severity is shown from low (yellow) to high (red).

Sample Size Analysis. Prior to formal home-range size estimation, it was necessary to limit analysis to only those individual birds for which we had collected enough relocation data. The number of radio-tracked relocations per bird ranged from 13 (GP-13) to 208 (RR-13) with a median of 147. Based on the results of our bootstrapped home range analysis (Figure 7), we excluded 2 birds, GP-13 and JU-13 (note that the last two characters of the bird identifier indicate the sampling year: 12=2012 and 13=2013), from formal home range size analysis due to a lack of convergence of home range size. In 2012, we excluded analysis of one bird (CG-12), leaving 9 birds with robust tracking data (Siegel et al. 2013). Across the two years of sampling at the Wheeler fire, we have 16 individual birds with robust tracking data, of which 2 birds were sampled in both years (i.e., 18 year-specific home ranges).

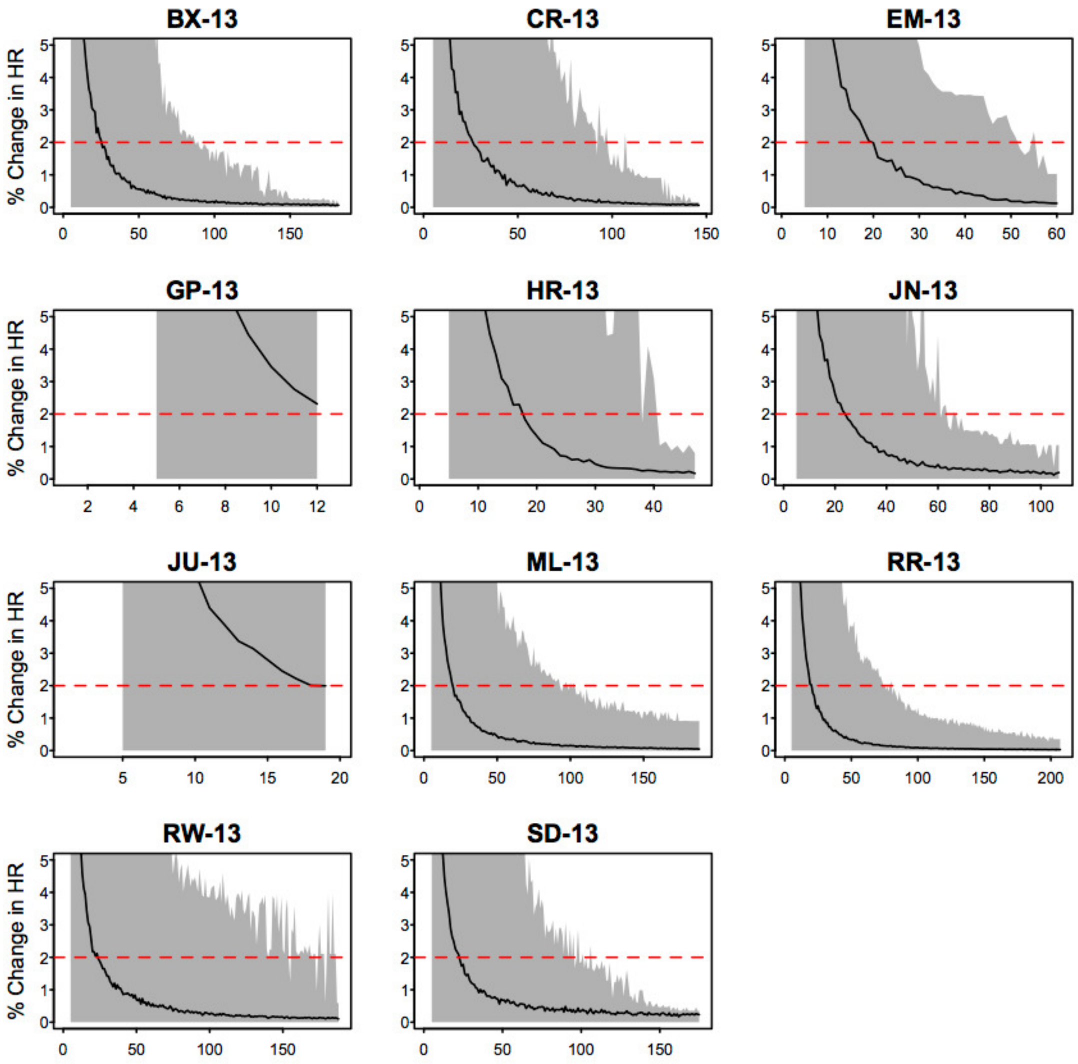

Figure 7. Mean (black line) and 95% credible interval (gray) of incremental change in MCP home range size for increasing random draws of n relocation points (x-axis) for each radio-tracked Black-backed Woodpecker in 2013. Plots were assessed for evidence of home range convergence to less than 2% (red dotted line).

Home-range Size. Home ranges were modeled using both the MCP and Brownian bridge kernel method (Figure 8). MCPs were evaluated at the 100th percentile (utilizing all relocation points), while kernels were measured at the 95th (‘full’) and 50th (‘core’) percentile level.

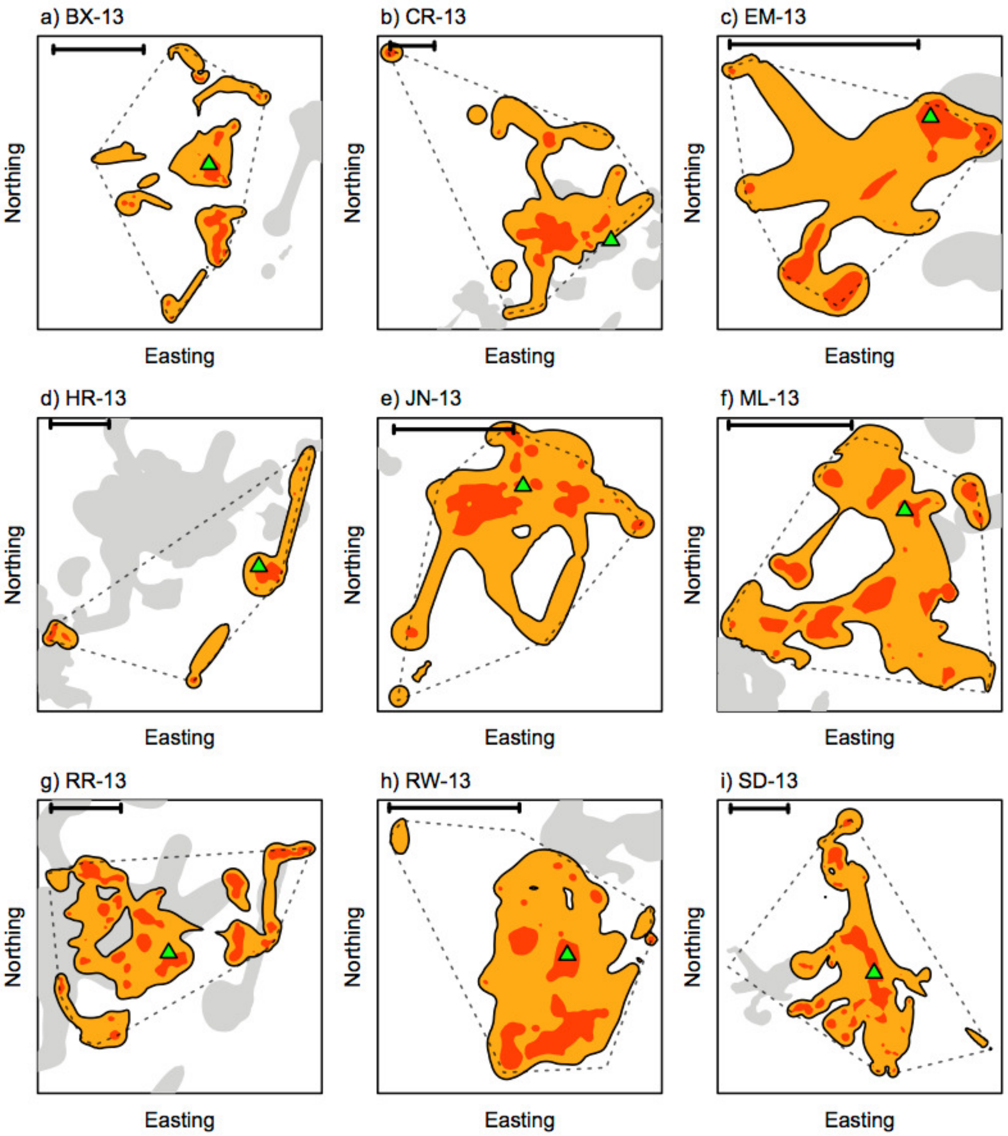

Figure 8. Home-range maps for robustly-tracked birds at the Wheeler fire in 2013 as estimated by MCP (dotted outline) and Brownian bridge kernels (colors: 95^{th} % = orange, 50^{th} % = red). Maps additionally indicate 95th percentile home ranges of other nearby radio-tracked birds in 2013 (gray background) and nest locations (green triangles). Scale bars represent 500-m increments.

Using both estimators (MCP and Brownian bridge kernel), home-range size was calculated across a range of percentiles for each of the 9 robustly-tracked Black-backed Woodpeckers (Table 1). MCPs gave larger estimates of home range size (100% HR range 27 – 415 ha) while kernels gave more conservative home range sizes (95% HR range 19 – 173 ha), particularly for large home ranges. Independent of estimation method, there was a wide range in home range sizes, with one bird in particular (CR-13) exhibiting a home range 2-3 times greater than the overall mean. Home range estimates were not significantly related to the total number of relocation points used for each individual ($\rho = 0.30$, $p = 0.44$).

Table 1. Home range size estimates for each of 9 Black-backed Woodpeckers tracked at the Wheeler fire in 2013.

Bird	Core home range (ha)	95th kernel home range (ha)	MCP home range (ha)
BX-13	4	26	84
CR-13	27	173	415
EM-13	3	19	27
HR-13	5	35	181
JN-13	7	43	66
ML-13	9	48	77
RR-13	17	86	170
RW-13	7	38	62
SD-13	18	105	251

Home range characteristics. Through analysis of habitat characteristics within Black-backed Woodpecker home ranges, we sought to estimate the total basal area of snags and live trees within the home ranges of each bird. Basal area estimates (converted to m^2/ha) were made for stands surrounding foraging snags and live trees identified during radio-tracking, and across the grid of background points. These data provided the foundations for interpolating a constant surface of snag and live tree basal area within each of the three fire areas. Using the Spatial Analyst extension of ArcGIS 9.3 (ESRI 2011), we interpolated continuous basal area using the Inverse Distance Weighting method parameterized with the nearest 10 points and a maximum distance of 500 m to create a 50 x 50 m resolution surface (Siegel et al. 2013).

Interpolated surfaces were subsequently used to estimate the mean basal area density within the home range of each bird tracked in 2013. With the exception of one bird (SD-13), all birds had mean snag basal areas above 15 m^2/ha, and mean live basal areas below 20 m^2/ha within both core and full kernel home ranges (Table 2). The average ratio of total snag basal area to total live tree basal area was greater than 1 (indicating greater basal area of snags than live trees) for 7 of the 9 birds (Table 2). For full kernel home ranges, this ratio reached a maximum of 5.9:1 for JN-13. Of the two birds with ratios <1 (EM-13 and SD-13), SD-13 foraged extensively outside the fire perimeter and had the second highest home range size (Table 1). The other bird, EM-13 had a ratio <1 within its full kernel home range but >1 within its core home range. While ratios >1 often indicate foraging outside of burned areas, EM-13's full kernel was entirely within the burn perimeter – it just foraged in low burn severity patches with large numbers of live trees.

Table 2. Mean basal area (m^2/ha) of snags and live trees and ratios of snags to live trees within home ranges of Black-backed Woodpeckers, as measured by full and core kernel home ranges.

	Full Kernel Home Range			Core Kernel Home Range		
Bird	Mean snag density	Mean live tree density	Ratio of snags:live trees	Mean snag density	Mean live tree density	Ratio of snags:live trees
BX-13	20.34	6.9	2.95	21.99	6.5	3.38
CR-13	22.16	5.8	3.81	21.21	10.0	2.12
EM-13	15.74	18.6	0.85	28.12	14.3	1.96
HR-13	15.13	10.7	1.42	19.00	13.3	1.43
JN-13	15.81	2.7	5.86	17.10	1.4	12.33
ML-13	24.68	6.5	3.79	28.30	4.1	6.88
RR-13	17.97	5.8	3.12	18.98	3.2	5.84
RW-13	30.48	6.1	4.99	31.15	8.1	3.85
SD-13	8.57	16.8	0.51	10.85	15.6	0.70

In previous analyses of Black-backed Woodpecker home-range size (Siegel et al. 2013, Tingley et al. 2014) we identified a strong, exponential relationship between mean snag basal area and home range size. In other words, small home ranges were found in areas of high snag basal area, and large home ranges were found in areas of low snag basal area. Using the modeled relationship previously established (Tingley et al. 2014), we tested how well the additional data from 2013 fit within this previous model (Figure 9). At least half of home ranges estimated in 2013 fell within a 95% bootstrapped prediction interval defined by the previously parameterized model. For both core and full kernels, four home ranges in 2013 were smaller than expected based on their mean snag basal area. Overall, however, the model appeared to remain robust with the inclusion of new data. Updating the model with new data from 2013 did not result in a qualitatively different fit (Figure 10).

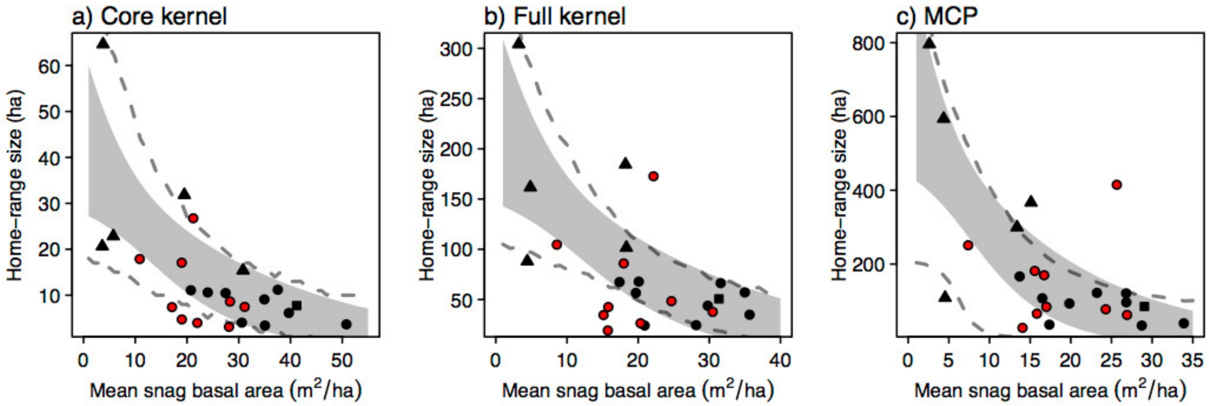

Figure 9. Relationship between mean snag basal area and home range size for each of three home range estimations. The generalized linear model was fit on the 15 home ranges fit to data collected during 2011 and 2012 (black points: circles = Wheeler, triangles = Peterson fire, squares = Sugarloaf fire), with new data from Wheeler in 2013 overlaid (red circles). Model shown as both a 95% confidence interval (solid gray area) and 95% bootstrapped prediction interval (dotted lines).

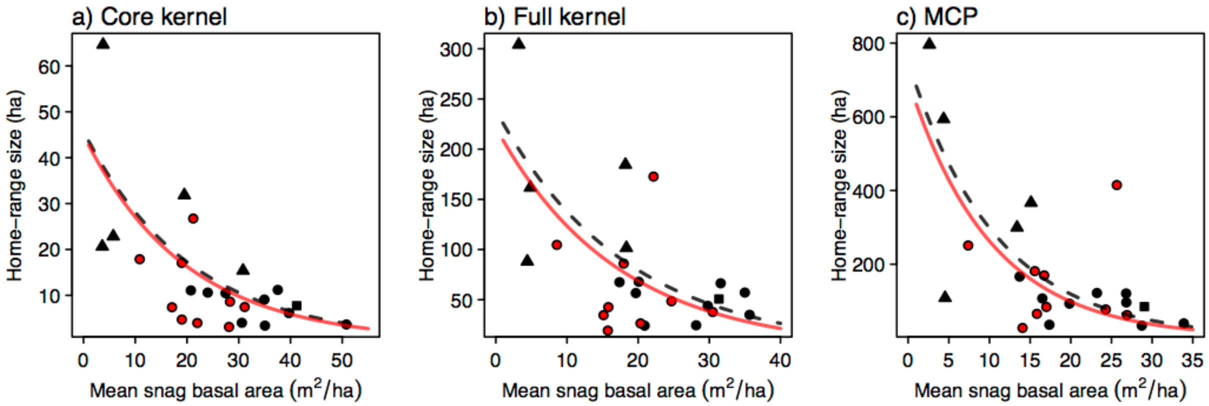

Figure 10. Change in modeled relationship between mean snag basal area and home-range size based on the addition of 2013 data. Mean predicted relationships from Tingley et al. (dotted gray line) compared against modeled relationship updated with 2013 data (red line). Point symbology follows Figure 9.

Changes to Woodpecker Habitat at Wheeler: 2012 to 2013

As burned forests age, the number of snags available is expected to change on a yearly basis, as snags deteriorate and fall, and in some cases, live trees that were injured but not immediately killed by the fire die and become snags. We used our background habitat grid, sampled in both years, to estimate changes in habitat at the Wheeler fire between 2012 and 2013. In 2012, 451 points representing available habitat within the study area were sampled with 50-m radius plots in the Wheeler fire, and in 2013, 506 such points were sampled. As sampling of available habitat was only conducted within home ranges of woodpeckers tracked during the same year, the two samples of background points did not fully overlap (Figure 11). To test for changes in habitat, we restricted our comparison to only those background points that occurred in portions of home range of tracked birds during both years (Figure 11). This limited our sample to 217 background points from 2012, and 200 background points from 2013.

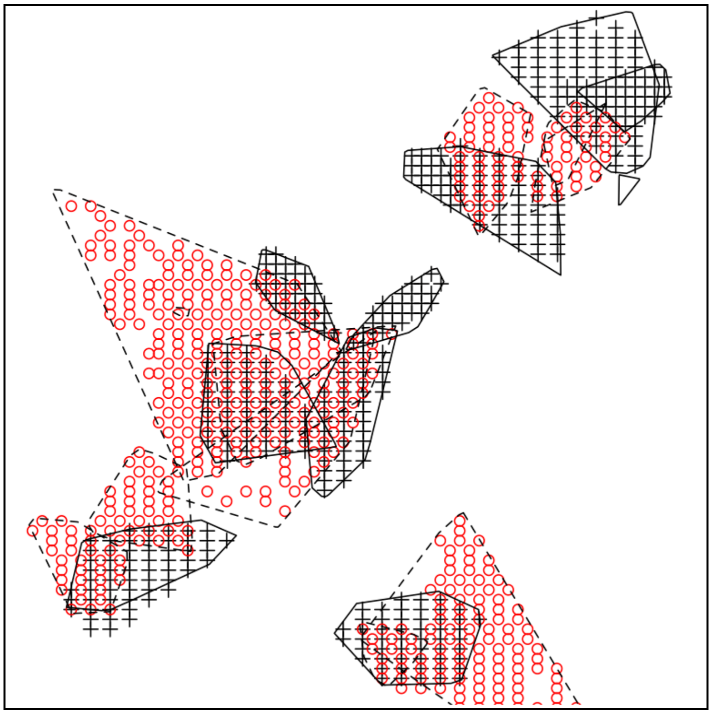

Figure 11. Spatial arrangement of MCP home ranges and background habitat points sampled in 2012 (black solid lines and crosses) and 2013 (dashed line and red circles). Only in areas where MCPs overlapped were background points compared.

Assessing only habitat points from the same sampling regions across both years, we compared the snag and live tree basal areas (Figure 12). Between 2012 and 2013, both snag basal area and live tree basal area significantly declined (snags t-test: t = 2.8, p = 0.005; live t-test: t = 2.6, p = 0.009). Although plots had greater snag basal area than live tree basal area, both snags and live trees declined on average by about 2 m^2/ha over the 1-year period.

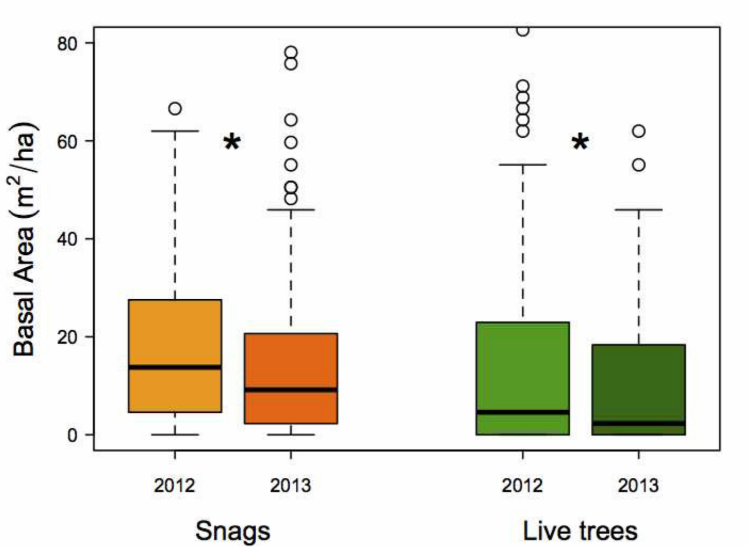

Figure 12. Changes in basal area for snags and live trees between 2012 and 2013 as measured at systematic background points. Asterisk (*) denotes a t-test with significance at $p = 0.05$.

The decline in snag basal area was significant ($p < 0.05$) only for areas classified as low or moderately burned (Figure 13). Although high severity burn areas showed a decrease in average snag basal area, it was not significant ($t = 1.58$, $p = 0.12$).

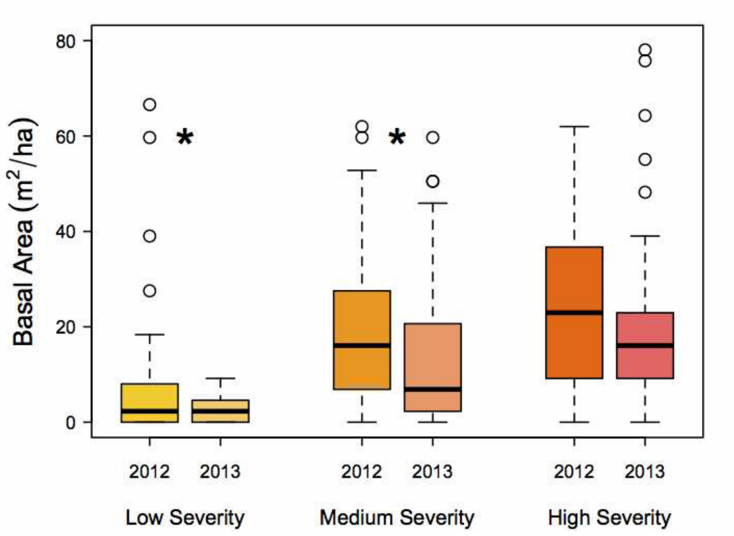

Figure 13. Measured changes in snag basal area between 2012 and 2013, by burn severity. Asterisk (*) denotes a t-test with significance at $p = 0.05$.

Changes in Home-range Location and Size, 2012 to 2013

One of the key questions we wanted to address with our 2013 telemetry work is how home range size in Black-backed Woodpeckers changes within the same fire from year to year. We assess several different aspects of home range change, focusing on both average changes and paired changes. As previously described, 9 Black-backed Woodpeckers were robustly tracked at the Wheeler fire in both 2012 and 2013. Although these birds inhabited similar regions of the Wheeler fire, there was substantial turnover among individuals. Only two birds, "EM" (EM-12 and EM-13) and "RR" (RR-12 and RR-13), were tracked in both years. Additionally, for one bird tracked in 2012, SP-12, we tracked its mate in 2013, RW-13. Thus, to compare home range changes across the two years, we present broad inference on all individuals as well as more focused results for these three pairs of birds.

Changes in Home-range Size. Across all robustly tracked birds, there was no significant change in home-range size for any metric (Figure 14). Mean home ranges increased from 2012 to 2013 for all metrics (although medians decreased) but variability was high enough within each year that none of these changes was significant (t-tests, core kernel: p = 0.32; full kernel: p = 0.42; MCP: p = 0.21). Although means increased, for each home range metric 2013 had both smaller and larger home ranges observed than in 2012 (Figure 14). Linear models for home range size (similar to Figure 10) of birds at the Wheeler fire that included both mean snag basal area and year found no significant effect of year.

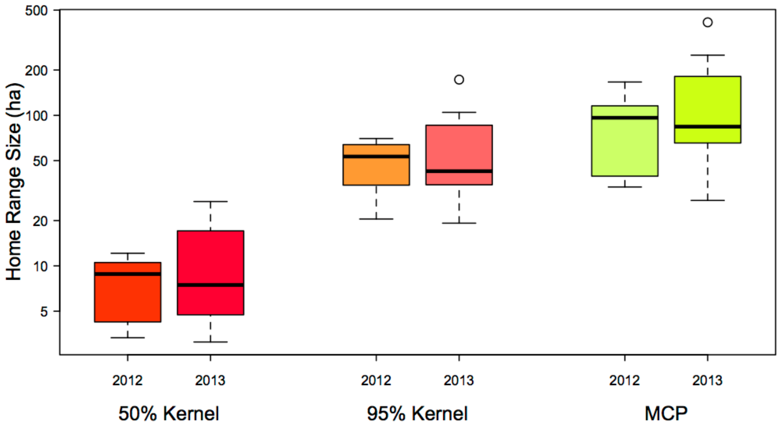

Figure 14. Boxplots of home-range size estimates for all birds at the Wheeler fire, by year. Boxes bound 25th and 75th percentiles, whiskers show data range (minus outliers), and thick lines show median.

Given that birds tracked in 2013 were not in exactly the same areas as birds in 2012 (Figure 11), comparing home ranges of all tracked birds is not a perfect test of year-to-year effects on home-range size. However, the three matched pairs of birds sampled in both years provide little additional inference (Figure 15). Of the three pairs, EM-13 decreased home-range size, RR-13 increased home-range size, and RW-13's home range was smaller than SP-12's home range (Table 3). Both EM-13 and RR-13 moved nest sites by a considerable distance – 350 m and 423 m, respectively – while RW-13 nested within 66 m of SP-12's nest.

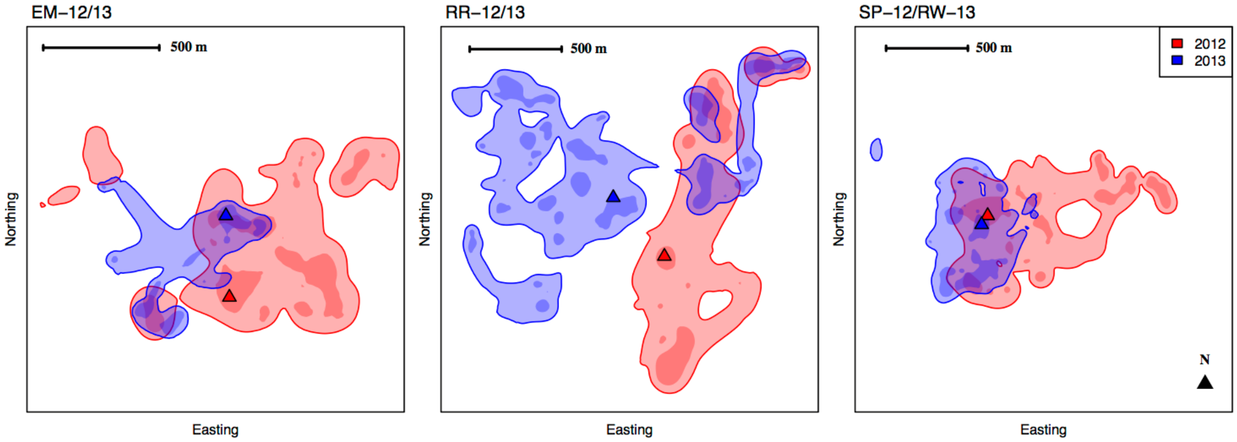

Figure 15. Full (light color) and core kernel (dark color) home ranges for three pairs of birds sampled in both 2012 (red) and 2013 (blue). Triangles show locations of nest trees in each year.

Potential inference on change in home range can be made in a spatial context (Figure 15) by examining overlap of home ranges (Table 4). In this context, EM-13 and RW-13 occupied smaller home ranges that heavily overlapped with western portions of their 2012 home ranges (or their mate's home range, in the case of RW-13). RR-13, in comparison, overlapped only a small portion of its 2012 home range and largely established a new home range several hundred meters to the west (Figure 15).

Table 3. Comparisons of home-range size over time for three pairs of birds sampled in both 2012 and 2013.

Bird / Pair	2012 full kernel size (ha)	2013 full kernel size (ha)	% change (core kernel)	% change (full kernel)	% change (MCP)
EM	53	19	29%	36%	25%
RR	67	86	162%	128%	182%
SP-12/RW-13	70	38	62%	54%	65%

Table 4. Overlap statistics between 2012 and 2013 home ranges for birds tracked in both years.

Overlap Metric	EM	RR	EP-12/RW-13
VI	0.21	0.13	0.29
UDOI	0.15	0.05	0.31

Birds may expand or contract home ranges over time due to interactions with neighboring territorial individuals. While our sampling of all neighboring territories was incomplete, both EM-13 and RR-13 show movement out of 2012 occupied home ranges and replacement within those formerly occupied areas by other birds in 2013 (Table 5). EM-12's home range overlapped with its 2013 home range (Table 4) just as much as it overlapped with another bird (SD-13) in 2013 (Table 5). RR-12's home range overlapped more with a different bird in 2013 (HR-13) than it did with itself or its mate (CR-13). In comparison, SP-12's home range overlapped marginally with another bird in 2013 (ML-13), but not nearly as much as it did with RW-13 (Table 4).

Table 5. Maximum overlap between 2012 home ranges of focal birds with all non-self 2013 home ranges.

Metric	EM-12	RR-12	SP-12
VI	0.20	0.16	0.10
UDOI	0.15	0.09	0.01

Foraging and Space Use Changes, 2012 to 2013

Previous analyses (Siegel et al. 2012, 2013) examined how Black-backed Woodpeckers used habitat within their home ranges as compared to background points. Given our 2013 sampling at the Wheeler fire, we were interested in how foraging location and space use may have changed between 2012 and 2013. Similar to analyses of background points (Figure 11), in order to make a valid comparison across years, we only compared foraging points in areas where MCP home ranges overlapped in both years (Figure 16). This condition restricted the comparison to 861 of 1475 (58%) foraging points in 2012 and 731 of 1246 (59%) foraging points in 2013.

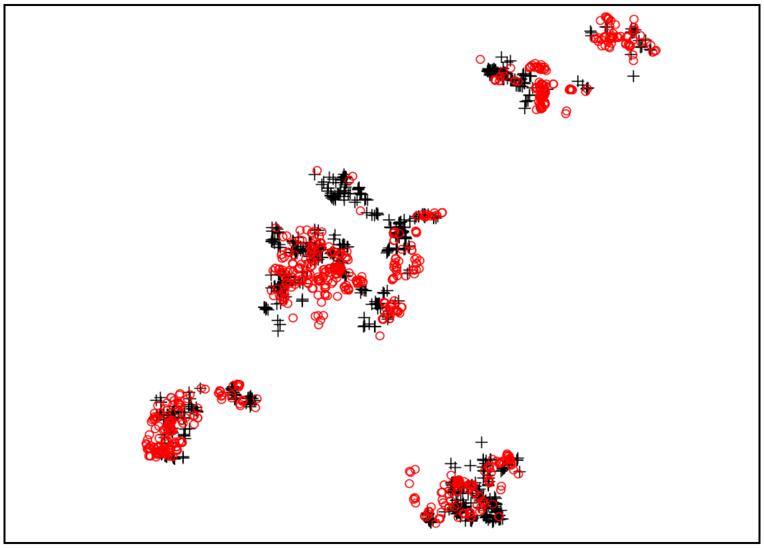

Figure 16. Locations of foraging points (red circles = 2013, black crosses = 2012) within portions of MCPs that overlapped across years at the Wheeler fire.

Across both years, foraging substrates remained highly similar. In 2012, 80% of foraging observations were on snags, 14% were live trees, 4% were cut stumps, and the remaining observations were on the ground or on logs. In 2013, 83% of observations were on snags, 14% were live trees, 1% were cut stumps, with the remaining observations on the ground or on logs. Thus, while the percentage of foraging observations on snags increased, this was at the expense of observations on cut stumps, not observations on live trees.

Choice of foraging tree species also remained relatively constant across year. From 2012 to 2013 the percentage of foraging observations on *Pinus spp*. (including *P. ponderosa, P. jeffreyi*, and a marginal amount of *P. contorta*) decreased from 50% to 47%. At the same time, the percentage of foraging observations on *Abies spp.* (including *A. concolor* and *A. magnifica*) stayed constant at 48%. Other changes included increases in foraging on Incense-cedar (*Calocedrus decurrens*) from 0.5% to 2% and Douglas-fir (*Pseudotsuga menziesii*) from 2% to 3%.

Despite small changes in substrate species for foraging, there was no change in the size of trees used for foraging (Figure 17). The average DBH of foraged trees in 2012 was 38.6 cm and in 2013 it was 39.0 cm (t = -0.46, p = 0.64). Both years showed a high degree of variability in foraging tree size, although in both years 50% of foraging observations were on trees between 27 and 45 cm DBH (Figure 17).

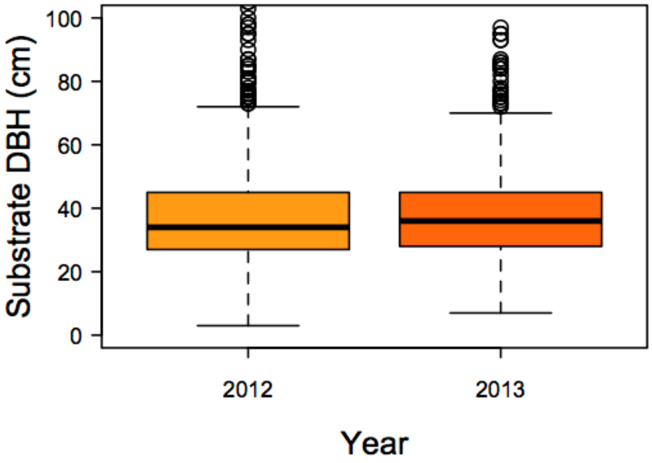

Figure 17. Boxplot of DBH of trees or snags used for foraging by Black-backed Woodpeckers in 2012 and 2013.

With the constancy of foraging substrate, birds in 2013 appeared to forage at similar distances from nest sites compared to birds in 2012 (Figure 18). Comparing all birds sampled in both years, tracked Black-backed Woodpeckers in 2013 traveled approximately similar distances from nests to foraging sites as tracked birds in 2012 (Wilcoxon rank sum test, p = 0.58). The median distance from nests to forage sites was 402 m in 2012 and 377 m in 2013. Of birds radio-tracked in both years, RR showed no difference in foraging distance from nest (Wilcoxon rank sum test, p = 0.27) while EM decreased foraging distance significantly (Wilcoxon rank sum test, p = 0.016).

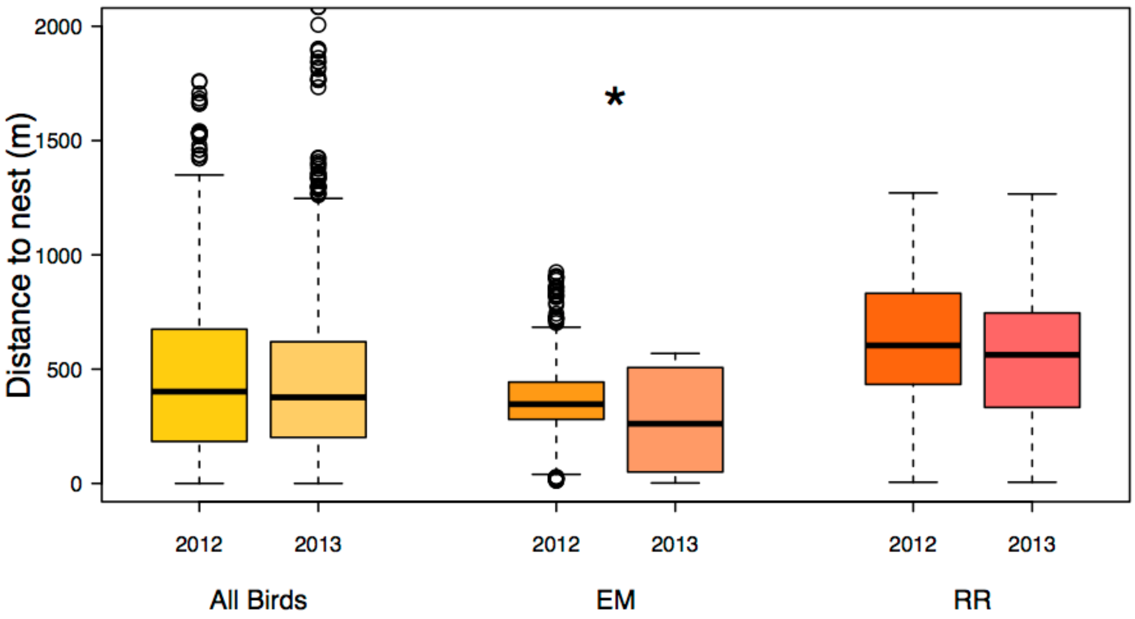

Figure 18. Boxplots of distance from nest sites to foraging observations, by year, for all birds and for the two birds tracked in both years. Asterisks (*) demark distance distributions that are significantly different ($p < 0.01$) by a Wilcoxon rank sum test.

While distance from foraging points to nests generally showed no change over the two years, the distance between consecutive foraging points during tracking increased for all tracked birds from 2012 to 2013 (Figure 19; Wilcoxon rank sum test, $p < 0.001$). The median distance traveled was 23 m in 2012 and 31 m in 2013, while the mean distance increased from 61 m to 80 m. Of birds radio-tracked in both years, EM showed no difference in travel distance (Wilcoxon rank sum test, $p = 0.14$) while RR increased distance significantly (Wilcoxon rank sum test, $p = 0.003$).

In comparison to both distance metrics, the amount of time birds spent foraging on trees decreased from 2012 to 2013 (Figure 20). The median amount of time spent foraging on each substrate across all birds was 76 seconds in 2012 and 68 seconds in 2013 (Wilcoxon rank sum test, $p = 0.008$). Of the two birds tracked in both years, EM showed a significant decrease in foraging duration ($p = 0.048$) but RR's decrease was not significant ($p = 0.14$).

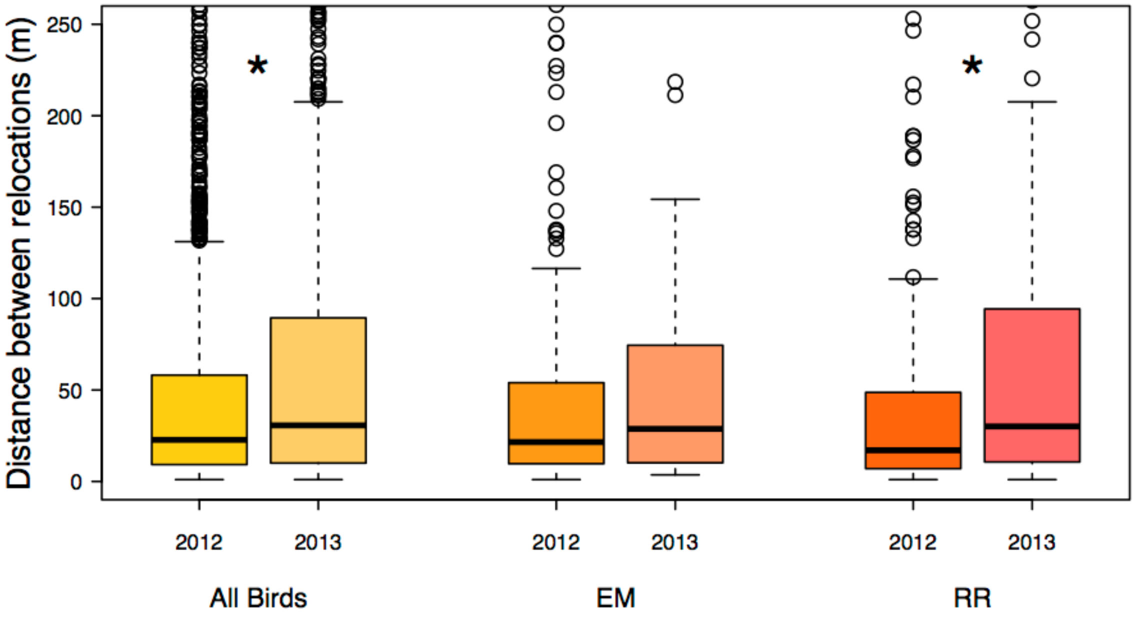

Figure 19. Boxplots of distance between consecutive relocation points, by year, for all birds and for the two birds tracked in both years. Asterisks (*) demark distance distributions that are significantly different (p < 0.01) by a Wilcoxon rank sum test.

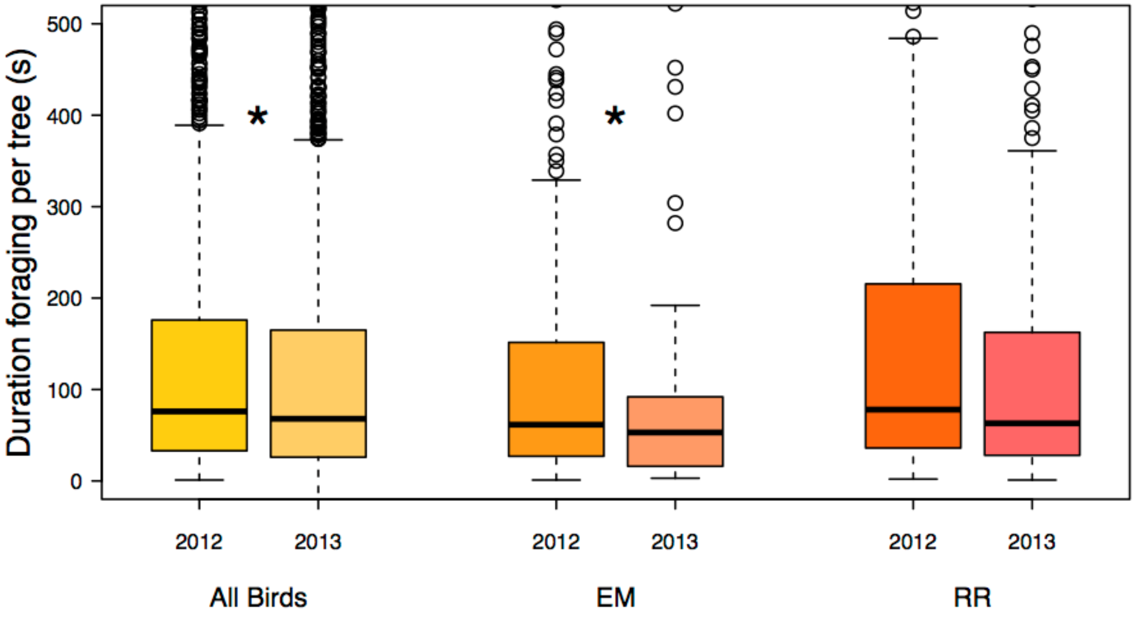

Figure 20. Boxplots of time spent foraging on each substrate, by year, for all birds and for the two birds tracked in both years. Asterisks (*) demark distance distributions that are significantly different (p < 0.01) by a Wilcoxon rank sum test.

Roost Locations

We found 14 roost locations (other than nests) during 20 night-time searches for 5 individual birds (Table 6). In six cases, we found birds roosting at sites where we had found them roosting on previous nights. In all cases, the tree in which the bird was roosting was definitively determined by radio-tracking, but description of the particular micro-site on the tree that the bird used was impossible during five instances in which the bird could not be visually located by observers. At the nine roosting locations that were visually confirmed, none of the birds roosted in excavated cavities. Rather, we found birds roosting in the crook of a forked trunk (1 instance); wedged between adjacent trunks of two closely spaced trees (1 instance); in a deep, natural bark furrow (1 instance); clinging to a trunk directly above a horizontal branch (1 instance); and in sheltered spaces within burned out hollows of trunks (5 instances) (Figure 21). At the five locations where the roosting bird was not visually located, inspection of the roost trees during the day did not reveal any excavated cavities that could have been used for roosting.

The 14 roost locations varied greatly in distance from the roosting bird's nest (range = 110 – 874 m) and averaged 428 m (SD = 241 m). The four instances in which we found locations of birds that still had nestlings in their nests (e.g., the young had not fledged yet) included the roost that was closest to the roosting bird's nest (117m), as well as the roost that was farthest from the roosting bird's nest (874 m). All 14 of the roost sites were within stands that had burned at medium or high severity. Three of the 14 roost sites were in live trees, whereas the remaining 11 were in fire-killed snags. Tree species used for roosting included Ponderosa and Jeffrey Pine, White Fir, and unidentified *Abies* (which could be White Fir or Red Fir), and Scrub Oak, and averaged 37.0 (16.1) cm dbh and 12.3 (5.5) m tall. Most of the roost sites had few or no live trees within a 10-m radius circle centered on the roost tree (range = 0-17 live trees with dbh> 10 cm) whereas local abundance of dead trees with the 10-m radius varied greatly (range = 1-89 dead trees with dbh>10 cm).

Table 6. Descriptions of locations where radio-tracked birds were found to be roosting at night.

Bird ID	Distance to Nest (m)	Burn Severity[a]	Roost Substrate					No. of Trees within 10 m (dbh>10 cm)		Dates Used[b]
			Roost Micro-site	**Tree Species**	**Live or Dead**	**Dbh (cm)**	**Tree Height (m)**	**Live Trees**	**Dead Trees**	
BX-13	372	H	Forked trunk	Yellow Pine	Dead	55	8.5	0	47	6/10
BX-13	281	M	Burned out hollow in trunk	*Abies* sp.	Dead	26	4.5	0	4	6/18
BX-13	427	H	Unseen	White Fir	Dead	31	13	0	89	6/26
BX-13	844	M	Deep bark furrow	Incense-Cedar	Dead	30	7	5	9	7/3, 7/10, 7/18
CR-13	177	H	On trunk above a branch	White Fir	Dead	33	12.5	0	18	6/11
CR-13	110	H	Burned out hollow in trunk	*Abies* sp.	Dead	30	8.5	0	37	6/21, /26, 7/3, 7/10, 7/18
EM-13	874	M	Wedged between two trunks	Scrub Oak	Dead	10	10	17	1	**4/30**
RR-13	641	H	Burned out hollow in trunk	Yellow Pine	Dead	38	13.5	0	19	**6/8**, 6/26
RR-13	280	M	Unseen	Jeffrey Pine	Live	32	19	3	40	6/19
RR-13	519	H	Burned out hollow in trunk	*Abies* sp.	Dead	26	7	0	22	7/10
RR-13	340	H	Burned out hollow in trunk	*Abies* sp.	Dead	42	10	0	28	7/18
SD-13	117	M	Unseen	Ponderosa Pine	Live	75	24	3	7	**5/14**
SD-13	503	M	Unseen	Yellow Pine	Dead	57	19	7	22	**6/21**
SD-13	505	M	Unseen	Yellow Pine	Live	33	15	4	8	6/26
Mean (SD)	**428 (241)**	**-**	**-**	**-**	**-**	**37.0 (16.1)**	**12.3 (5.5)**	**2.8 (4.7)**	**25.1 (23.1)**	**-**

[a] Burn severity (unburned, low, medium [M], or high [H] was assessed in the field for a 50-m radius circle centered on the roost location.

[b] All dates were during 2013. Dates indicated in bold type indicate that the bird's young had not yet fledged from the nest; regular type indicates that the bird's young had already fledged.

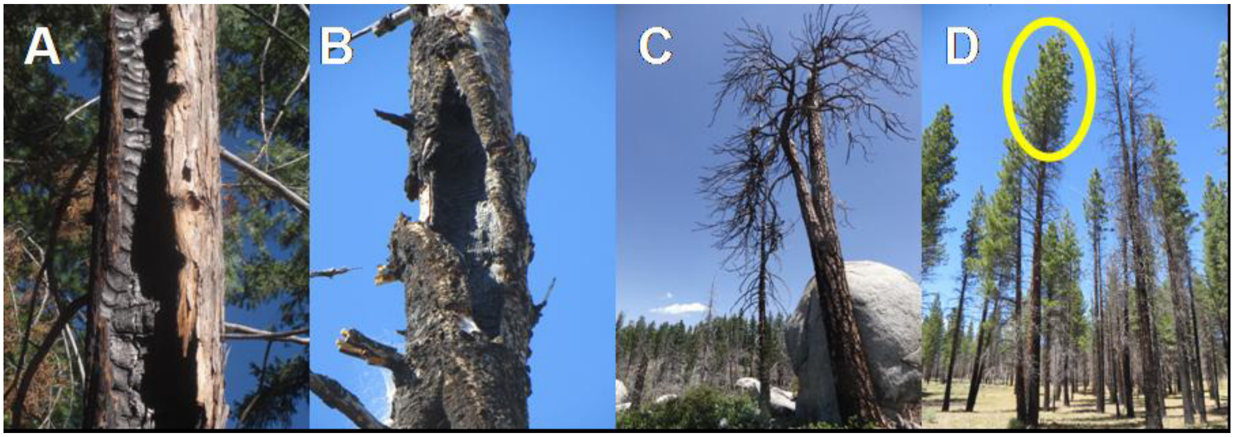

Figure 21. Examples of night-time roost locations in burned out hollows of trunks (A and B), the crook of a forked trunk (C), and obscured within thick live foliage indicated by the yellow oval (D).

Discussion

Understanding factors that predict home-range size in Black-backed Woodpeckers occupying recent fire areas is an important step in developing habitat management strategies that can effectively conserve the species, while still meeting other management objectives. The predictive model that we developed from data collected during 2011 and 2012 (Siegel et al. 2013, Tingley et al. 2014) is already being used in conservation planning efforts for the species (Tingley et al. 2014). A lingering question about this model was whether it adequately accounted for the effects of time since fire on home-range size. In contrast to two other studies outside California (Dudley and Saab [2007] which was based on a very small sample size in Idaho, and Rota et al. [2014] from South Dakota), results from our 2011 and 2012 field seasons suggested that time since fire added no explanatory power to our model of Black-backed Woodpecker home-range size. Among the birds we studied during 2011 and 2012, snag basal area was far more important than time since fire in driving home-range size, and, in fact, we did not find any evidence of a positive relationship between time since fire and home-range size. However, in our 2011-2012, time since fire was perfectly confounded with study site – we assessed home ranges of birds at three different sites, each with a different number of years having elapsed since fire. By assessing home ranges and foraging habitat selection in 2013 on the Wheeler Fire – the same fire where we worked in 2012 – we sought to assess directly the effect of time since fire on home-range size, without the confounding effect of different study sites.

Home ranges of birds tracked in 2013

Home ranges of birds tracked in 2013 varied greatly in size. As expected, MCPs yielded larger estimates of home-range size (100% HR range 27 – 415 ha) than did kernels (95% HR range 19 – 173 ha). With the exception of one bird that frequently foraged outside the fire perimeter, all birds had mean snag basal areas above 15 m^2/ha, and mean live basal areas below 20 m^2/ha within both core and full kernel home ranges. The one woodpecker that foraged substantially outside the fire perimeter had the second highest home range observed in 2013.

In previous analyses of Black-backed Woodpecker home-range size (Siegel et al. 2013, Tingley et al. 2014) we identified a strong, exponential relationship between mean snag basal area and home-range size, with smaller home ranges found in areas of high snag basal area, and larger home ranges found in areas of low snag basal area. We tested this predictive model using the home-range results from 2013. Using the full kernel metric, 4 of the home ranges estimated in 2013 fell below the 95% bootstrapped prediction interval defined by the previously parameterized model, and one fell above the interval. For both core and full kernels, four home ranges in 2013 were smaller than expected based on their mean snag basal area. However, the model was only very slightly changed by the subsequent inclusion of the 2013 results, which did not result in a qualitatively different fit, providing robust continuing support for the overall model relationship between snag basal area and home range size.

Changes at the Wheeler Fire, 2012 to 2013

In the aggregate, home ranges of birds studied at the Wheeler Fire in 2013 differed little in size from those of birds studied at the same fire in 2012. Mean home-range size increased slightly, but not significantly (Table 6), whereas median home-range size decreased slightly. The most marked effect of the additional year since fire on home-range size appears to have been an increase in variability across individuals, rather than any substantial change in aggregate home-range size. Of the two birds' whose home-ranges we estimated in both 2012 and 2013, both shifted areas of usage substantially between years, with nest locations shifting by 350 m and 423 m, respectively. However neither bird exhibited a dramatic change in home-range size; one bird's home range increased slightly while the other's decreased slightly.

We evaluated whether background habitat conditions within the study changed between 2012 and 2013, and found that live tree and snag basal area in portions of the fire areas that fell within observed MCPs in both years decreased significantly. This may seem like a puzzling result, but is explained by a) delayed mortality of trees that were injured by fire but not immediately killed (i.e., transitioning from live trees to snags), and b) an even greater number of snags (e.g., greater than the number recruited from the live tree population) falling due to deterioration and wind. Despite these changing conditions in available foraging substrate, or perhaps because the numbers of both live trees and snags changed in concert with one another, selection of foraging substrate within areas used by focal individuals in both years did not change appreciably (Table 6). What is intriguing about this analysis, however, is that despite a failure of birds to change their foraging substrate, their behavior did change – distance between foraging sites increased while foraging duration decreased. Unless birds were increasing capture efficiency simultaneously, these trends imply that Black-backed Woodpeckers were working harder to provision the same or less food. This behavioral adaptation would be expected if, over longer periods of time, burn areas slowly decline in habitat and food-provisioning quality.

Table 6. Summary of measured changes in Black-backed Woodpecker habitat, home range, and foraging at the Wheeler fire, from 2012 to 2013.

Class	Metric	Change, 2012 to 2013	Significant?
Habitat	Snag basal area	Decrease	yes
-	Live tree basal area	Decrease	yes
Home range	Size	Increased	no
Foraging	Foraging substrate (live or dead)	No change	-
-	Foraging tree species	No change	-
-	Foraging tree size	No change	-
-	Distance to nest from forage sites	No change	-
-	Distance between forage sites	Increase	yes
-	Foraging duration	Decrease	yes

Habitat used for night-time roosting

Our study provides the first ever information on Black-backed Woodpecker roost sites in burned forest. In unburned forest with high tree mortality induced by bark beetles, Goggans et al. (1989) reported finding the birds roosting primarily in live trees (87% of sites), whereas we found the opposite: 11 of 14 (79%) of the roost sites we found were in dead trees. However, an area of consistency between our two studies was that neither found any woodpeckers roosting in excavated cavities (except within the nest during incubation and brooding). Rather, at least during the nesting season, Black-backed Woodpeckers generally roost in semi-sheltered, unexcavated micro-sites, such as burned out hollows in fire-killed trees, tight spaces between forked trunks, and in at least one instance in our study, a portion of a trunk covered with dense, live foliage.

Several of our findings pertaining to roost sites may indicate important considerations for habitat retention intended to benefit Black-backed Woodpeckers:

- *Use of relatively large snags for roosting.* Black-backed Woodpeckers at the Wheeler fire roosted in relatively large trees (mean dbh = 37 cm [14.6 in]), indicating that forest stands of CWHR size class ≥4 (e.g., dominated by trees with dbh ≥ 11 in) may be most likely to provide adequate roosting opportunities.

- *Use of 'defect' snags for roosting.* Fire-killed trees with burned out hollows, forked trunks, or other relatively unusual structures were selected for roosting. Just as some forest management guidelines emphasize the retention of 'defect' trees during forest thinning operations in unburned forest (North et al. 2009), there may be added benefits to Black-backed Woodpeckers and other wildlife in post-fire forests of prioritizing retention of 'defect' snags when harvest operations are to be implemented.

- *Use of medium and high-severity burned stands for roosting.* All 14 of the roost sites we found were in stands that burned at medium or high severity, even though some of the birds had extensive low severity areas (and in the case of one individual, unburned areas) available within their MCP home ranges. Our past findings (Siegel et al. 2013) show that Black-backed Woodpeckers in burned forests of California preferentially select larger, dead trees in more severely burned areas for foraging; our findings here extend those same habitat selection criteria to another aspect of Black-backed Woodpecker habitat selection: roosting habitat.

- *Use of roosting habitat far from nests.* Our home-range size estimates (Tingley et al. 2014), as well as the new estimates in this report, document that California's Black-backed Woodpeckers have home ranges that can be many hundreds of meters across. Nevertheless we were surprised to find Black-backed Woodpeckers – including individuals that were still tending nests from which the young had not yet fledged – roosting up to 874 m (mean = 428 m) from their nest. The relatively long distances we found between nests and roost sites underscore the need for land managers to adopt a landscape perspective when thinking about habitat retention for Black-backed Woodpeckers.

Conclusions

Although variation in home-range size increased in 2013, our work this year largely corroborates our previous finding that time since fire has little if any effect on Black-backed Woodpecker home-range size, at least within the first 6 years after fire at the locations where we worked. Although the model we developed previously was not very effective at predicting individual birds' home-range sizes, this was due to increased variability in the sizes of home ranges that we estimated in 2013. In the aggregate, the model still performed well, and remains little changed with the inclusion of the 2013 results. This relationship should continue to be of use to land managers predicting effects of post-fire forest management actions on local populations of Black-backed Woodpeckers (Tingley et al. 2014, Tingley et al. 2014).

Other ancillary data and results from the 2013 field season should also be helpful for management of Black-backed Woodpecker habitat. Our description of roosting habitat provides a previously unknown (at least in burned forests) element of habitat usage by the species, and in particular our finding that birds frequently use 'defect' snags for roosting could be incorporated into 'marking' or snag retention criteria for partially harvested stands.

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Literature Cited

Anich, N. M., T. J. Benson, and J. C. Bednarz. 2009. Estimating Territory and Home-range Sizes: Do Singing Locations Alone Provide an Accurate Estimate of Space Use? The Auk 126:626–634.

Anich N. M., Benson T. J., Bednarz J. C. 2012. What Factors Explain Differential use Within Swainson's Warbler (*Limnothlypis swainsonii*) Home Ranges? The Auk 129:409-418.

Bivand, R. S., E. J. Pebesma, and V. Gomez-Rubio. 2008. Applied spatial data analysis with R. Springer, NY.

Bullard, F. 1999. Estimating the home range of an animal: a Brownian bridge approach. Johns Hopkins University. Master thesis.

Calenge, C. 2006. The package adehabitat for the R software: a tool for the analysis of spae and habitat use by animals. Ecological Modelling 197:516-519.

California Department of Fish and Game. 2005. California Wildlife Habitat Relationships (CWHR) version 8.1. California Department of Fish and Game, Interagency Wildlife Task Group, Sacramento, CA.

Cumming, G. S., & Cornélis, D. 2012. Quantitative comparison and selection of home range metrics for telemetry data. Diversity and Distributions 18:1057–1065.

Dudley, J. G., and V. A. Saab. 2007. Home range size of Black-backed Woodpeckers in burned forests of southwestern Idaho. Western North American Naturalist 67:593-600.

Ehrlich, P. R., D. S. Dobkin, and D. Wheye. 1988. The Birder's Handbook: a Field Guide to the Natural History of North American Birds. Simon & Schuster, Inc., New York.

ESRI. 2011. ArcGIS Desktop: Release 9.3. Environmental Systems Research Institute, Redlands, CA.

Goggans, R., R. D. Dixon, and L. C. Seminara. 1988. Habitat use by Three-toed and Black-backed Woodpeckers, Deschutes National Forest, Oregon. Oregon Dept. of Fish and Wildlife, USDA Deschutes National Forest, Nongame Project No. 87-3-02.

Hijmans, R. J., and J. van Etten. 2011. raster: Geographic aalysis and modeling with raster data. Pages R package version 1.8-27. http://CRAN.R-project.org/package=raster.

Horne, J.S., Garton, E.O., Krone, S.M. and Lewis, J.S. 2007. Analyzing animal movements using Brownian bridges. Ecology, 88, 2354–2353.

McCullough, D. G., R. A. Werner, and D. Neumann. 1998. Fire and insects in northern and boreal forest ecosystems of North America. Annual Review of Entomology 43:107–127.

Mech, L. D. 1983. Handbook of Animal Radio-Tracking. University of Minnesota Press, Minneapolis. 107 pp.

Mohr, C. 1947. Table of equivalent populations of North American small mammals. American Midland Naturalist 37:223-249.

North, M., P. Stine, K. O'Hara, Kevin, W. Zielinski, and S. Stephens. 2009. An ecosystem management strategy for Sierran mixed-conifer forests. Gen. Tech. Rep. PSW-GTR-220. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 49 p.

Odum, E. P., and E. J. Kuenzler. 1955. Measurement of territory and home range size in birds. The Auk 72:128–137.

Pyle, P. 1997. Identification Guide to North American Birds. Part 1. Slate Creek Press, Bolinas, CA. 742 pp.

R Development Core Team. 2013. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria.

Raim, A. 1978. A radio transmitter attachment for small passerines. Bird-Banding 49: 326-332.

Rappole, J. H., and A. R. Tipton. 1991. New harness design for attachment of radio transmitters to small passerines. Journal of Field Ornithology 62:335-337.

Rota, C. T., M. A. Rumble, J. J. Millspaugh, C. P. Lehman, and D. C. Kesler. 2014. Space-use and habitat associations of Black-backed Woodpeckers (*Picoides arcticus*) occupying recently disturbed forests in the Black Hills, South Dakota. Forest Ecology and Management 516 313:161–168.

Saracco, J. F., R. B. Siegel, and R. L. Wilkerson. 2011. Occupancy modeling of Black-backed Woodpeckers on burned Sierra Nevada forests. Ecosphere 2:1-17.

Schnute, J. T., N. Boers, R. Haigh, and A. Couture-Beil. 2010. PBSmapping: Mapping Fisheries Data and Spatial Analysis Tools. Pages R package version 2.61.69. http://CRAN.R-project.org/package=PBSmapping.

Seaman, D.E., J. J. Millspaugh, B. J. Kernohan, G. C. Brundige, K. J. Raedeke, and R. A. Gitzen. 1999. Effects of sample size on kernel home range estimates. Journal of Wildlife Management 63:739-747.

Short, L. L. 1974. Habits and interactions of North American three-toed woodpeckers (*Picoides arcticus* and *Picoides tridactylus*). Am. Mus. Novit. 2 547:1-42.

Siegel, R. B., M. W. Tingley, R. L. Wilkerson, and M. L. Bond. 2012. Assessing home range size and habitat needs of Black-backed Woodpeckers in California: 2011 Interim Report. Report to USFS Pacific Southwest Region. The Institute for Bird Populations, Point Reyes Station, CA.

Siegel, R. B., M. W. Tingley, R. L. Wilkerson, M. L. Bond, and C. A. Howell. 2013. Assessing home range size and habitat needs of Black-backed Woodpeckers in California: report for the 2011 and 2012 field seasons. Report to USFS Pacific Southwest Region. The Institute for Bird Populations, Point Reyes Station, CA.

Tingley, M. W, R. L. Wilkerson, and R. B. Siegel. 2014. Modeling expected density of Black-backed Woodpeckers at the Rim fire, California: a decision-support tool for post-fire management. Report to USFS Pacific Southwest Region. The Institute for Bird Populations, Point Reyes Station, California.

Tingley, M. W., R. L. Wilkerson, M. L. Bond, C. A. Howell, and R. B. Siegel. 2014. Variation in home range size of Black-backed Woodpeckers (*Picoides arcticus*). The Condor: Ornithological Applications 116:325–340. DOI: 10.1650/CONDOR-13-140.1

Tremblay, J. A., J. Ibarzabal, C. Dussault, and J.-P. L. Savard. 2009. Habitat requirements of breeding Black-backed Woodpeckers (*Picoides arcticus)* in managed, unburned boreal forest. Avian Conservation and Ecology - Écologie et conservation des oiseaux 4.

USDA Forest Service. 2007. Sierra Nevada forests management indicator species: amendment FEIS. vol. R5-MB-159. USDA Forest Service, Pacific Southwest Region.

van Winkle, W. 1975. Comparison of several probabilistic home-range models. Journal of Wildlife Management 39:118-123.

White, G. C, and R. A. Garrott. 1990. Analysis of Wildlife Radio-Tracking Data. Academic Press, New York. 383 pp.

Appendix 1:
Summary of nest phenology, nest characteristics, and nest success rate data

Since 2011, we have monitored nesting attempts of 30 pairs of Black-backed Woodpeckers (Figure A1-1), where nesting attempts are defined as nesting efforts during which we are certain eggs were laid. In numerous cases we observed birds excavating more than one cavity and/or abandoning nest cavities during excavation, before the cavities were deep enough to be used. In a few cases nests in which excavation may have been completed were also abandoned, but if we were unable to confirm egg laying we did not consider it a failed nesting attempt. We were rarely able to see into nest cavities, making exact dates for the onset of incubation, hatching, and sometimes even fledging, difficult to collect. However, we were able to estimate the dates with a reasonable degree of accuracy by observing changes in behavior of parents and the behavior and appearance of chicks when they were old enough to beg for food at the nest cavity entrance. Estimated dates for the initiation of incubation ranged from April 20 to June 26 (Figure A1-1). Observed and estimated fledging dates of nestlings ranged from May 27 to July 25 (Figure A1-1). The latest-starting nest we observed failed for unknown reasons during the nestling phase, but had it succeeded, we estimate that the nestlings would have fledged August 2 (Figure A1-1).

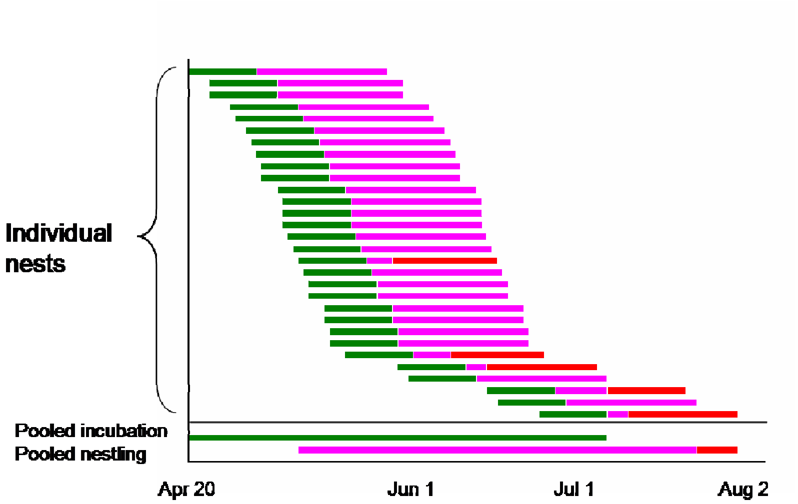

Figure A1-1. Nesting phenology of 30 Black-backed Woodpecker nests monitored in the Peterson, Sugarloaf, and Wheeler fire areas during the 2011, 2012, and 2013 breeding seasons. Green bars indicate the incubation stage, pink bars indicate the nestling stage, and red bars indicate the expected remainder of the nestling period for nests that failed during the nestling stage.

Of the 30 nests in which we are certain eggs were laid, 25 (83%) were confirmed or strongly believed to have fledged at least one young, and five failed to fledge any young. The nests that failed tended to have been initiated later in the season than the nests that succeeded (Figure A1-1) but this observation is based on naive nest success rates that do not consider exposure period or length of time the nest was observed (Shaffer 2004). All 5 observed nest failures occurred during the first half of the nestling phase (Figure A1-1). Causes of nest failure were unknown in 3 cases. In the 4th case, the nest cavity was clearly ripped open by a bear, as evidence by claw marks on the bark around the exposed nest. In the last case, observers returned to the nest after not having visited it for several days and observed chipmunks entering and leaving the cavity, with no sign of Black-backed Woodpeckers in the area, suggesting the young nestlings may have been predated by chipmunks. A bear apparently attempted to predate an additional nest, again as evidenced by stripped bark and obvious bear claw marks but the bear apparently was unable to completely expose the nest, and the nestlings eventually fledged.

Summary characteristics of Black-backed Woodpecker nests observed during 2013, and cumulatively from 2011-2013 are provided in Table A1-1. Because we occasionally observed Black-backed Woodpeckers excavate, but then not use, nest cavities, Table A-1 summarizes characteristics only of cavities in which we were certain eggs were laid. All of the nest trees we observed were dead, heavily charred, and appeared to have been killed by the recent fire. The vast majority of nests we found (22 of 30) were in Yellow Pine snags (4 of which were determined to be Ponderosa Pine, but observers were unable to determine if the remaining charred Yellow Pines were Ponderosa Pines or Jeffrey Pines). At least one nest was also found in snags identified as Lodgepole Pine, Incense-cedar, White Fir, and Abies sp. (which could have been White Fir or Red Fir). We will collect additional data on Black-backed Woodpecker nesting habitat, nesting phenology and nest success rate during summer 2014, as part of a project conducted under separate funding. Once these additional data are collected, we anticipate conducting a more thorough nest survival analysis incorporating all of our nesting data.

Table A1-1. Summary characteristics of Black-backed Woodpecker nests observed during the field 2013 field season only, and cumulatively from 2011-2013. Entries are presented as mean (SD).

Variable	2013 only	2011-2013 pooled
No. of nests assessed	9	30
Nest tree dbh (cm)	36.4 (5.5)	33.9 (8.1)
Tree height (m)	15.3 (5.2)	14.4 (5.3)
Cavity height above ground (m)	4.9 (3.0)	3.6 (2.2)

Appendix 2:
Spatially extensive occupancy surveys at 2013 fires prior to any post-fire forest treatments

Introduction

Black-backed Woodpecker abundance and reproductive success have been shown to be reduced by post-fire forest management actions that remove large numbers of snags from otherwise suitable habitat (summarized in Bond et al. 2012). However, the specific number and arrangement of fire-killed trees removed can vary greatly among and across projects, depending on the site-specific ecological context and the management objectives. In 2013 we initiated a study to assess the effects of different intensities, extents, and landscape configurations of post-fire forest treatments on Black-backed Woodpecker occupancy. We identified six fires (Fig. A2-1) that burned on National Forests in potential Black-backed Woodpecker habitat across the species' range in California during 2012, and then conducted extensive Black-backed Woodpecker occupancy surveys across them during the 2013 breeding season, a little under a year after the fires had burned. Except for some limited hazard-tree removal projects along roadways, none of the surveyed stands had yet been salvage-logged or treated with other post-fire management actions that remove substantial numbers of snags.

Beginning in late summer 2013 (after our surveys) portions of several of the burned areas were harvested, utilizing an array of harvest intensities and configurations. We will return to all six 2012 fires in during the 2014 breeding season, and survey the same areas again, after harvests have been completed. Once we have re-surveyed the same areas in 2014, we will assess the effects of the implemented forest treatments on Black-backed Woodpecker occupancy, in the manner of a 'natural experiment' rather than a designed experiment, since we did not have any control over the design of the treatments. This report simply summarizes our 2013 effort; analysis of the effects of post-fire forest treatments will be conducted after the 2014 field season.

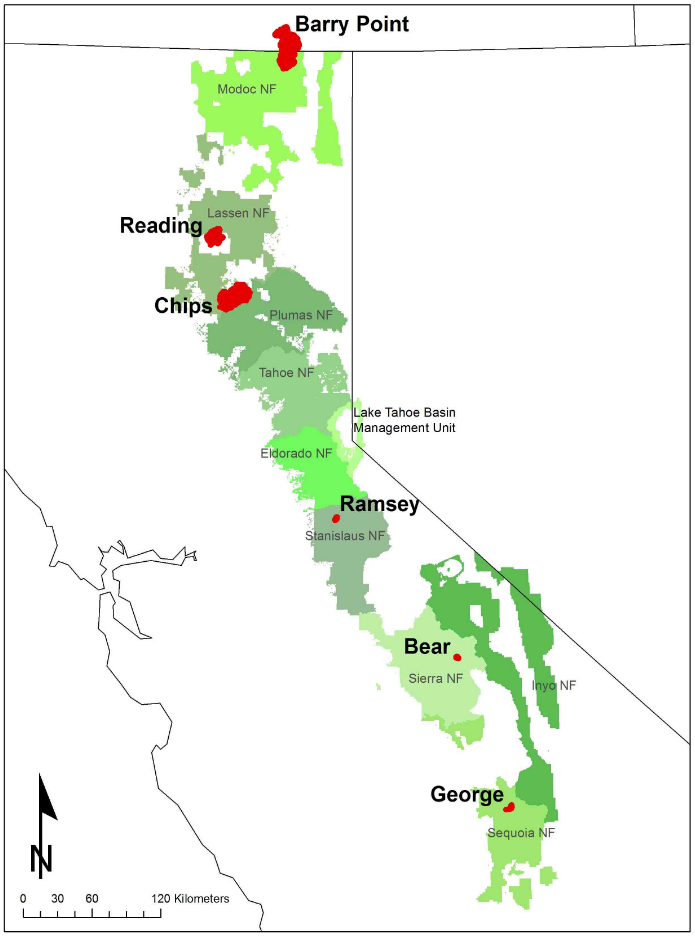

Figure A2-1. Locations of the six 2012 fires where we conducted Black-backed Woodpecker occupancy surveys during the 2013 breeding season.

Methods

During summer 2013 (May through early July) we established and surveyed of Black-backed Woodpecker survey stations across six fire areas that had burned during late summer or fall of 2012 (Table A2-1). Survey stations were established using GIS, and were defined as the vertices of a 500-m grid, based on cardinal directions and defined by a random starting point somewhere within the fire area. Survey stations were thus 500-m apart, and were arrayed irrespective of roads or trails. Using GIS, we discarded stations that fell in areas that were unforested prior to the fire, or were appeared to be located on dangerously steep slopes. Surveyors were given further latitude to discard stations in the field if they were dangerous to access for any reason.

Table A2-1. Fires that burned in 2012 and were then surveyed with extensive, systematically arrayed grids of call points during the 2013 breeding season. 'Area' indicates the total area of the fire footprint, in some cases including non-forest areas and/or lands not managed by the Forest Service.

Fire Name	National Forest(s)	Dominant Forest Type	Fire Size (ha)
Barry Point	Modoc	Eastside Pine	37,800
Bear	Sierra	Jeffrey Pine	397
Chips	Plumas, Lassen	Sierra Mixed Conifer	31,116
George	Sequoia	Sierra Mixed Conifer	720
Ramsey	Stanislaus	Sierra Mixed Conifer	502
Reading	Lassen	Sierra Mixed Conifer/Red Fir	11,424

Occupancy surveys were conducted using the same standard protocol for conducing Black-backed Woodpecker Management Indicator Species (MIS) surveys across the Region (Siegel et al. 2014). In brief, beginning within 10 min of official sunrise, surveyors located survey stations with handheld gps units, and then conducted 6-min broadcast surveys to elicit responses from Black-backed Woodpeckers. We used FoxPro ZR2 digital game callers to broadcast electronic recordings of Black-backed Woodpecker vocalizations and drumming. The electronic recording we broadcast was obtained from The Macaulay Library of Natural Sounds, Cornell Laboratory of Ornithology (G.A. Keller, recordist), and included the *scream-rattle-snarl* vocalization, *pik* calls, and territorial drumming.

We began the 6-min broadcast survey at each survey point by broadcasting the recording of Black-backed Woodpecker vocalizations and drumming for approximately 30 seconds at a standardized volume, and then quietly listening and watching for Black-backed Woodpeckers until two minutes had elapsed (including the 30-second broadcast period). At two minutes into the survey we again broadcasted the 30-second recording, and then quietly listened and watched until a total of four minutes had elapsed since the beginning of the survey, at which point we repeated the sequence of broadcasting and listening one more time, yielding three 2-min survey intervals. When Black-backed Woodpeckers were detected, we recorded their initial distance and bearing from the observer, whether species identification was confirmed visually, age (adult or juvenile) and sex (male, female, or unknown) of each bird, and whether the individual performed territorial drumming or vocalized. Black-backed Woodpecker surveys generally began within 10 min of official local sunrise, and were always completed by 10:30 a.m.

After completing broadcast surveys each day, observers returned to the survey points to collected cursory habitat data. They classified the habitat within a 50-m radius plot centered on the survey point, according to the California Wildlife Habitat Relationships (CWHR) habitat classification system (California Department of Fish and Game 2005). They also characterized the abundance and size of snags within the plot, and estimated basal area of snags and live trees using a using a slope-compensating angle gauge (SEC, Inc., Sedona, AZ).

Results and Discussion

During the 2013 field season we conducted broadcast surveys at 710 survey stations across the six fires (Table A2-1). One or more Black-backed Woodpeckers were detected at 215 of the stations. Locations of individual survey stations with and without Black-backed Woodpecker detections are indicated in Figs. A2-2 to A2-7.

During the 2014 breeding season we will attempt to again conduct broadcast surveys at all of the stations we surveyed in 2013, permitting an analysis of the effects of post-fire forest treatments on occupancy rates of Black-backed Woodpeckers.

Table A2-2. Summary results from grid-based broadcast surveys for Black-backed Woodpecker.

	No. of survey stations		
Fire Name	With Black-backed Woodpecker detections	Without Black-backed Woodpecker detections	Total
Barry Point	80	91	171
Bear	19	11	30
Chips	45	239	284
George	2	28	30
Ramsey	12	18	30
Reading	57	108	165
TOTAL	215	495	710

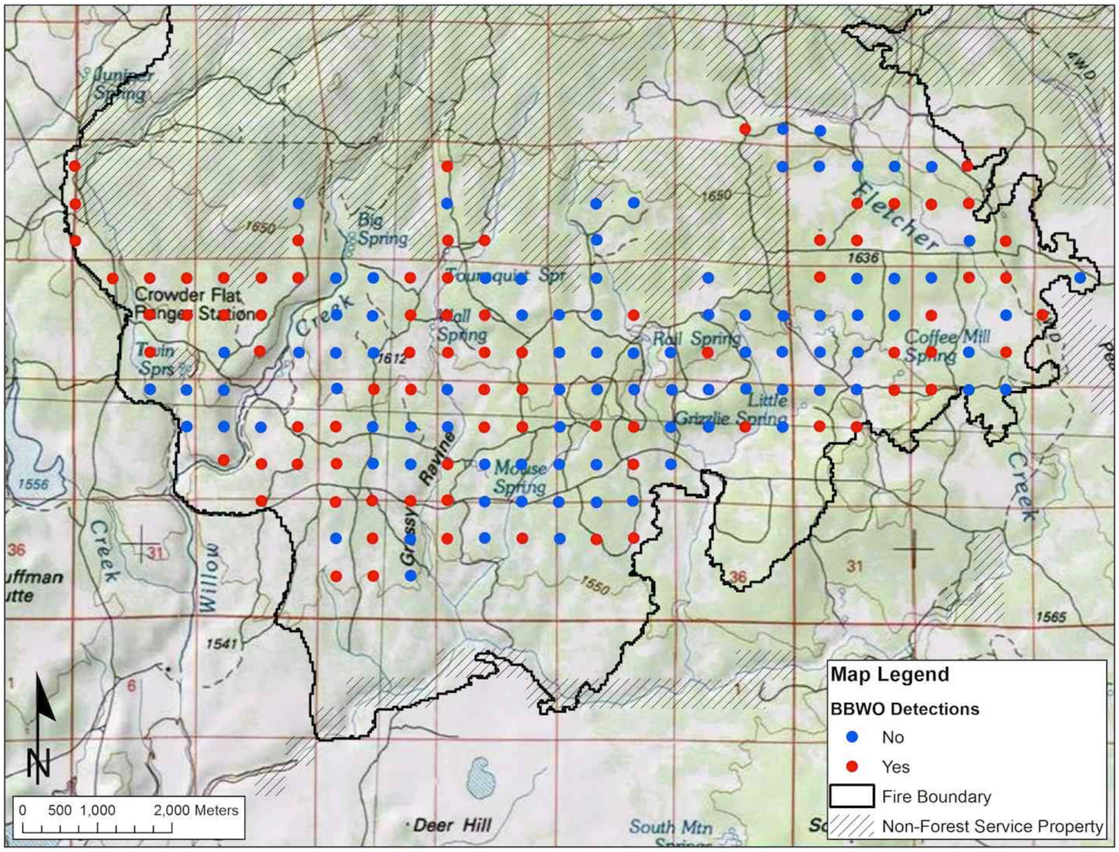

Figure A2-2. Survey stations with and without Black-backed Woodpecker detections at the Barry Point Fire on Modoc National Forest in 2013.

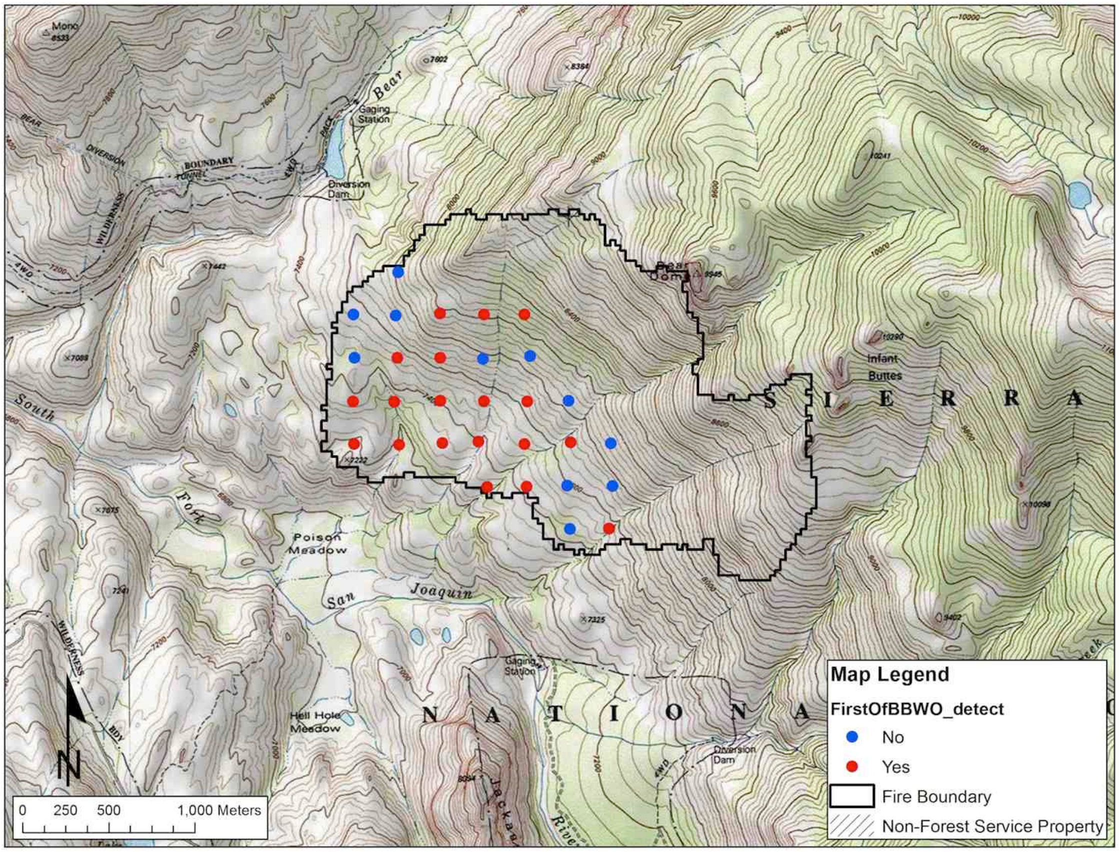

Figure A2-3. Survey stations with and without Black-backed Woodpecker detections at the Bear Fire on Sierra National Forest in 2013.

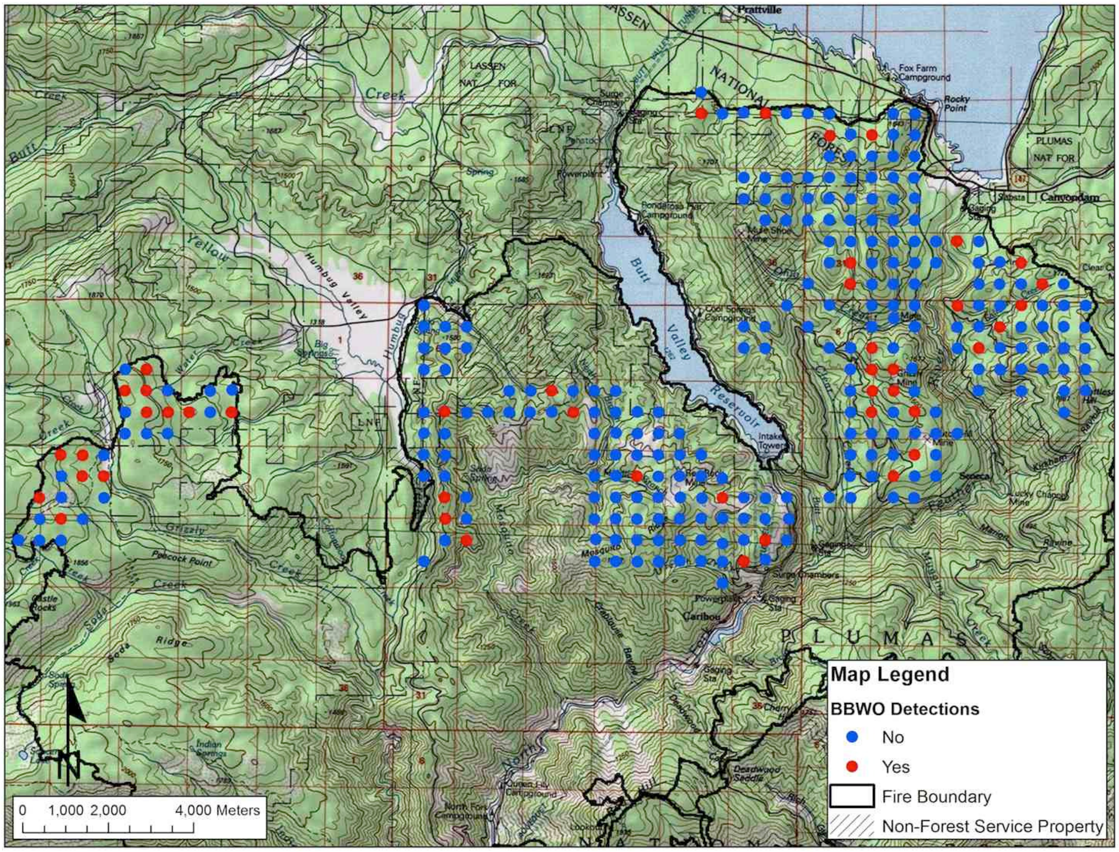

Figure A2-4. Survey stations with and without Black-backed Woodpecker detections at the Chips Fire on Lassen and Plumas National Forests in 2013.

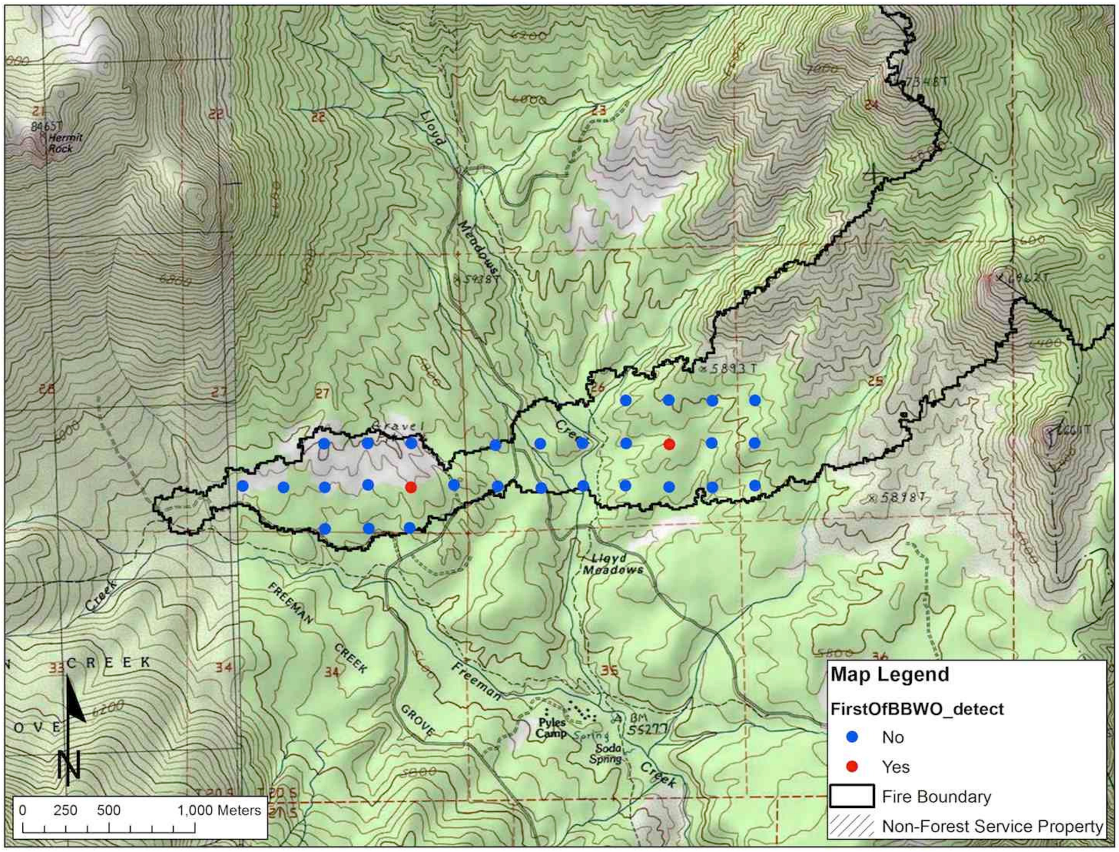

Figure A2-5. Survey stations with and without Black-backed Woodpecker detections at the George Fire on Sequoia National Forest in 2013.

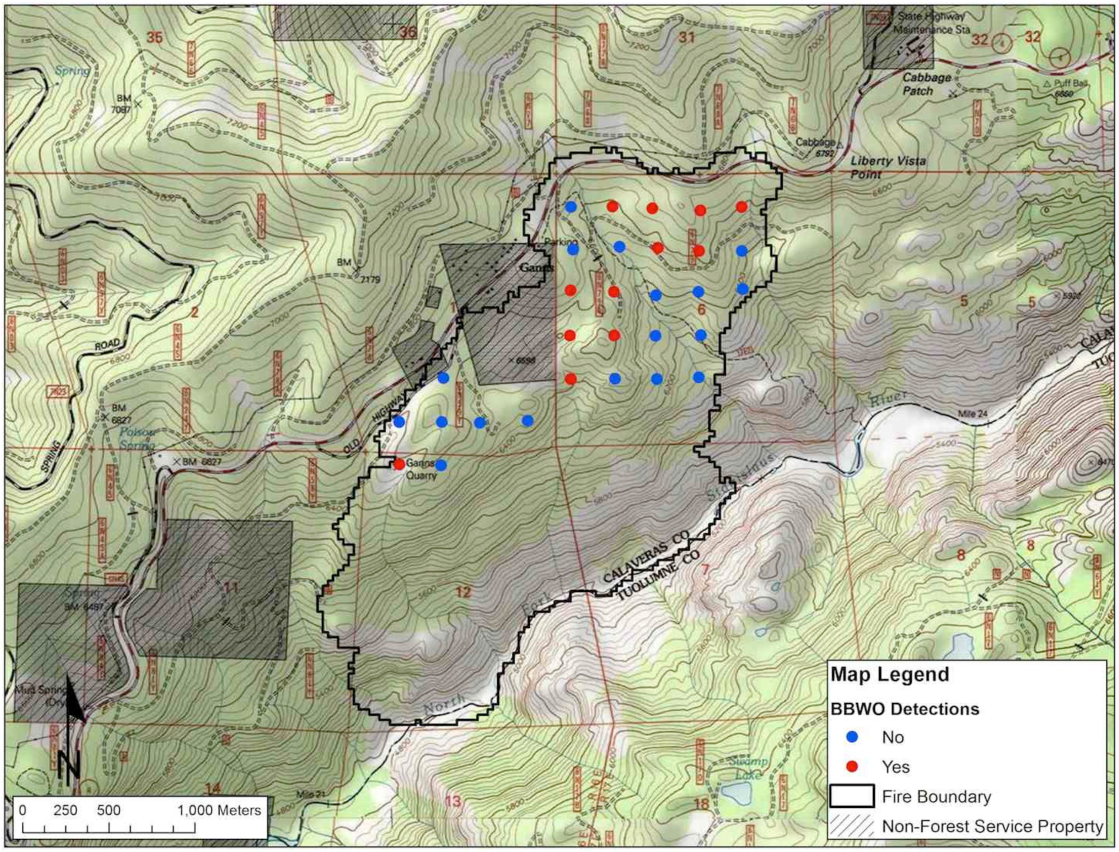

Figure A2-6. Survey stations with and without Black-backed Woodpecker detections at the Ramsey Fire on Stanislaus National Forest in 2013.

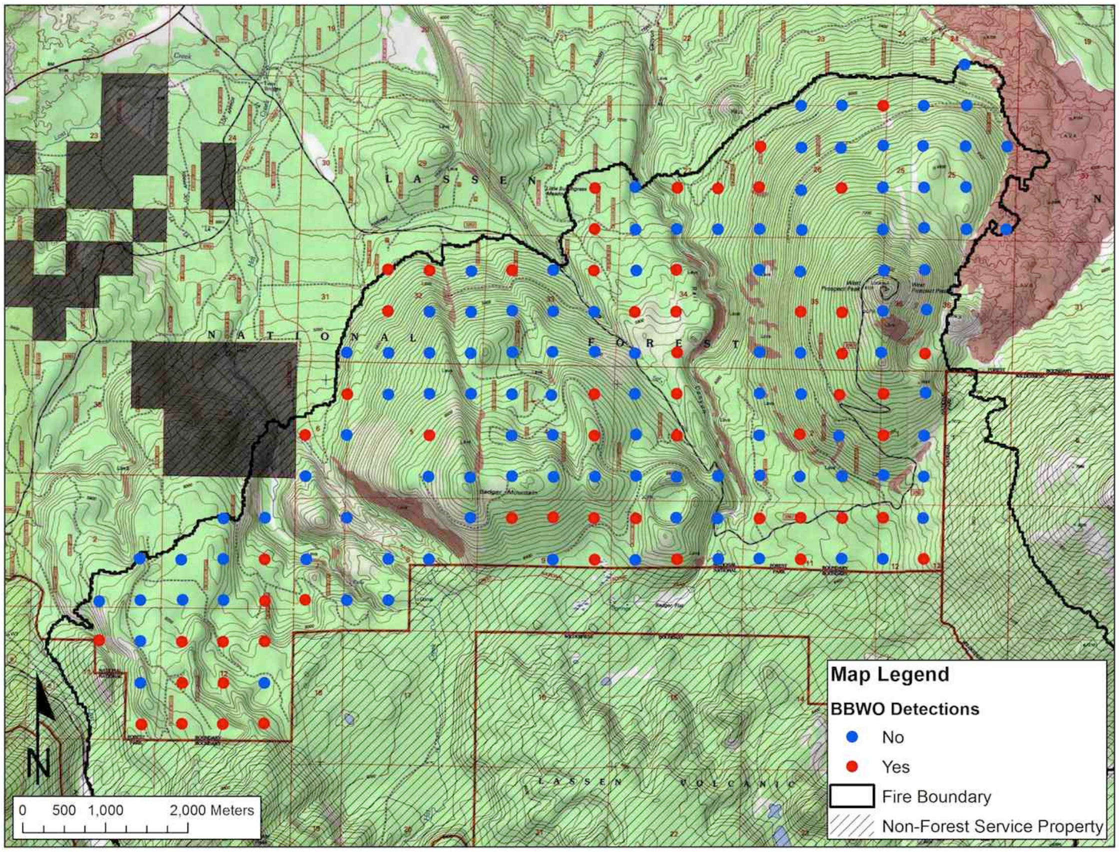

Figure A2-7. Survey stations with and without Black-backed Woodpecker detections at the Reading Fire on Lassen National Forest in 2013.

Literature Cited in Appendix 2

Bond, M. L., R. B. Siegel, and D. Craig, editors. 2012. A conservation strategy for Black-backed Woodpecker (*Picoides arcticus*) in California. Version 1.0. The Institute for Bird Populations and California Partners in Flight. Point Reyes Station, California.

California Department of Fish and Game. 2005. California Wildlife Habitat Relationships (CWHR) version 8.1. California Department of Fish and Game, Interagency Wildlife Task Group, Sacramento, California.

Siegel, R. B., M. W. Tingley, and R. L. Wilkerson. 2014. Black-backed Woodpecker MIS Surveys on Sierra Nevada National Forests: 2012 Annual Report. Report to USFS Pacific Southwest Region. The Institute for Bird Populations, Point Reyes Station, California.