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Western Gray Squirrel Distribution in the Upper Methow Valley, Washington 2010-2014 Report

Pacific Biodiversity Institute

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Western Gray Squirrel Distribution

in the Upper Methow Valley, Washington

2010-2014 Report

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Executive Summary

Western gray squirrels are the largest native tree squirrel in Washington and are ecologically important as fungi dispersers, tree seed dispersers, and food for predators.
The western gray squirrel (*Sciurus griseus*) is currently listed as Threatened in the state of Washington, however, it is currently being evaluated and may be updated to State Endangered. Very little is known about its northern range. Historically in Washington, western gray squirrels inhabited the Columbia River gorge and low- to mid-elevations on the east and west sides of the Cascade Mountains in Washington. The primary objective of the study Pacific Biodiversity Institute (PBI) has conducted is to determine regions used by western gray squirrels in the northern-most portion of their range to aid in their recovery. Our study is unique in two ways; we concentrated our survey efforts in the northern part of the Methow Valley where information is least available and we utilized volunteers to set up and conduct the study.

Using the design and methodology from previous studies, we made hair-snag tubes to collect rodent hair samples. Analyzing these samples allowed us to identify western gray squirrel hair and therefore, identify areas which the squirrels were living. We utilized citizen scientists to help make, distribute and check tubes. This, along with fieldtrips and informational presentations, promotes community engagement and education. We have also compiled a sighting database, recording where members of the public have seen live western gray squirrel and road-killed specimens; some of which DNA was collected and were sent to a laboratory for genetic mapping. Community support for this animal is a key component of its protection.

The use of volunteers also has allowed for more tubes to be placed and checked on both public and private land. PBI both re-sampled the more southern western gray squirrel population WDFW (lower Methow Valley) and expanded the study area north (upper Methow Valley). Particular focus was given to a persistent population in the lower Chewuch watershed. A total of 767 tubes have been placed since the project's start in 2010, yielding 88 positive western gray squirrel hair results. Many of these areas had little to no previous positive results. Of the areas re-sampled, positive results indicated the populations persistence, even after the 2014 wildfire. An in-depth analysis of the effects the wildfire had on western gray squirrels and wildlife in general was done as well (Carlton Complex Fire Report, in progress). Wildlife trail cameras and vegetation records have been used in both the burned areas as well as other sites to supplement hair tubes. Our locations for hair-tube sampling are determined by sightings, previous studies, and are built on each year as opposed to being systematically determined. This allows for more specific focuses on known sights, but not randomly sampled over an extended area.

Introduction

The western gray squirrel (*Sciurus griseus*) is currently listed as Threatened in the state of Washington, however, it is currently being evaluated and may be updated to State Endangered. Very little is known about its northern range. It currently inhabits mixed oak and conifer forests in Washington, Oregon, and California. To aid in conservation and recovery efforts, it is necessary to determine fundamental information such as the species distribution. Historically in Washington, western gray squirrels inhabited the Columbia River gorge and low- to mid-elevations on the east and west sides of the Cascade Mountains in Washington (Figure 1; Dalquest 1948; Ingles 1965). Currently, the western gray squirrel is known to exist in only three

isolated remnant populations in Washington: 1) Puget Trough, 2) South Cascades, and 3) North Cascades.

Causes of threatened status

Habitat loss has been determined to be the largest factor contributing to declines in the Washington population of western gray squirrels. Habitat losses have occurred from urbanization (Rodrick 1986), logging removing large, mast producing trees and eliminating an interconnected canopy (Noss et al. 1995; Vander Haegen et al. 2004), fire exclusion (Kertis 1986), and overgrazing (Weaver 1961) natural disturbance events such as natural fires. Additionally, road-kill deaths (Ingles 1947; Verts and Carraway 1998; Weston 2005), mange (Bryant 1921; Shannon 1922), and competition with non-native squirrels (Byrne 1979) have also led to western gray squirrel population declines. *Sciurus niger* and *Sciurus carolinensis* are introduced tree squirrels which compete with the western gray squirrel for resources (Byrne 1979). An additional threat to population recovery of the three remnant populations is low genetic diversity (Warheit 2003).

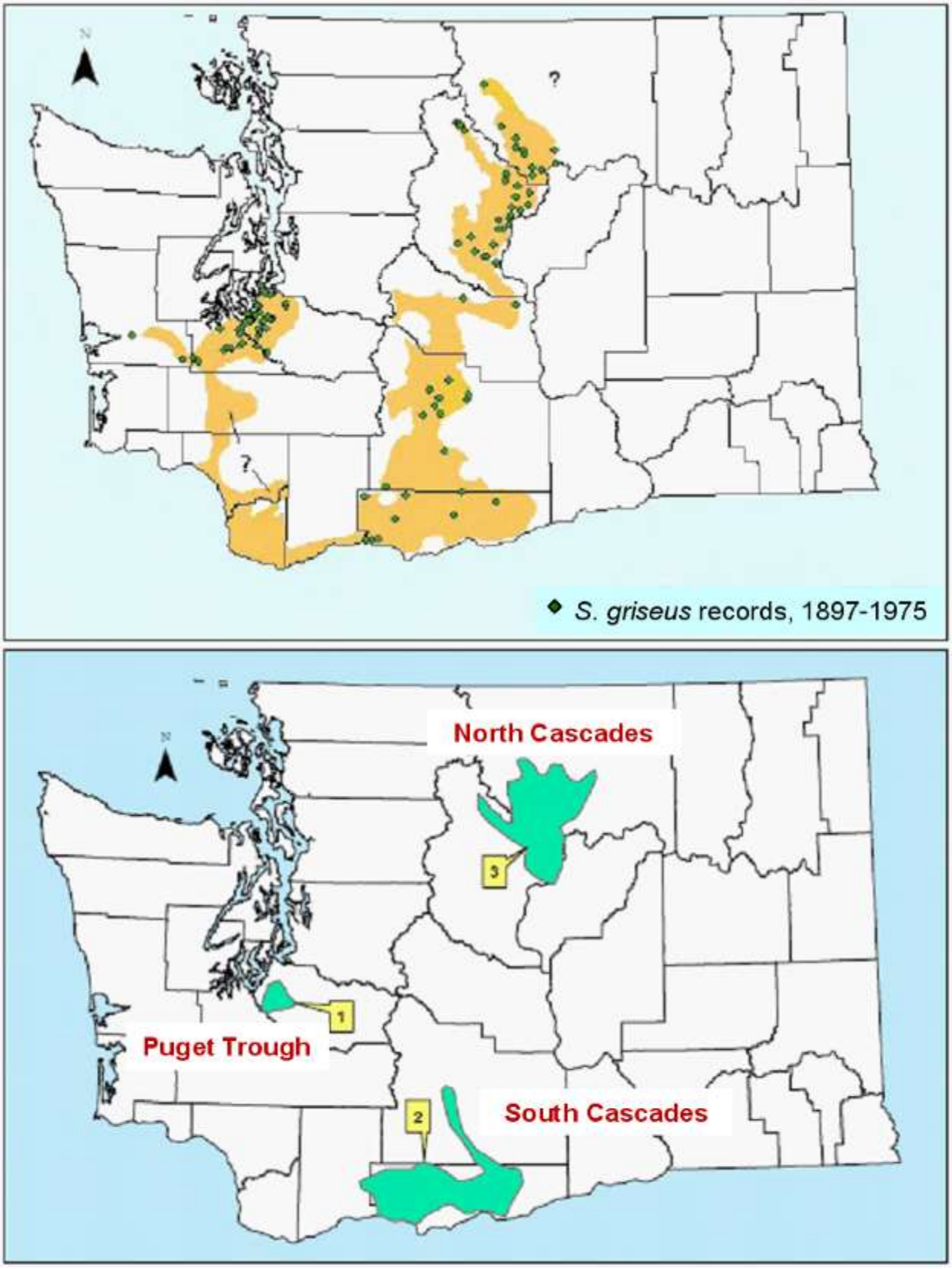


Figure 1. Historical (upper map) and current (lower map) western gray squirrel distribution in Washington state.

Ecological importance

Western gray squirrels are the largest native tree squirrel in Washington and are ecologically important as fungi dispersers, tree seed dispersers, and food for predators. One major food source for western gray squirrels is hypogeous fungi which are mycorrhizal and increase water and nutrient uptake with roots of associated trees (Stienecker and Browning 1970; Asserson 1974; Maser et al. 1981). Western gray squirrels disperse fungal spores as they defecate. Western gray squirrels also tend to be scatter hoarders which leads to them aiding tree seed dispersal by burying individual pine and fir cones and acorns away from the parent tree (Smallwood et al. 2003). Predators of western gray squirrels include red-tailed hawks, northern goshawks, golden eagles, coyotes, bobcats, fishers, and house cats (Carraway and Verts 1994; Zielinski et al. 1999; Vander Haegen et al. 2005).

Western gray squirrel species description

Western gray squirrels (*Sciurus griseus*) are mammals of the order Rodentia, suborder Sciurognathi, and family Sciuridae. *S. griseus* has uniformly silvery-gray fur on its back and white fur on its belly. It also has large ears and a long, plumose tail (Bailey 1936; Hall 1981). *S. griseus* has a body length (not including the tail) of 265-323 mm and a tail length 240-309 mm (Crase 1973; Ingles 1965; Nelson 1899). Mass may be between 520-942 g (Crase 1973; Hall 1981; Ingles 1965).

Methow Valley Squirrel Types

Tree squirrels

Red squirrel

Western gray squirrel

Ground squirrels

Yellow-pine chipmunk

Townsend's chipmunk

Yellow-bellied marmot

Hoary marmot

Columbian ground squirrel

Cascade Golden-mantled ground squirrel

Flying squirrel

Northern flying squirrel

Figure 2. Squirrels and squirrel-like rodents of the Methow Valley.

Western Gray Squirrel	Red Squirrel	Eastern Gray Squirrel
		
• Head and body = 9-12 inches • Tail = 10-12 inches • Has large, gray body; tail is bushy; belly is white with solid border • Tends to be quiet	• Head and body = 6-8 inches • Tail = 4-6 inches • Has small, rust-red to grayish-red body and tail; belly is white or grayish • Noisy, aggressive and territorial	• Head and body = 9-12 inches • Tail = 7-9 inches • Body has rufous color on face, back and tail; ears are shorter; tails are narrower • more frequently seen in urban areas

Figure 3. General differences between western gray squirrels (left), red squirrels (middle) and eastern gray squirrels (right).

Western gray squirrel behavior

S. griseus is mostly arboreal and tends to be wary (Cross 1969). Spherical stick nests (shelter nests), platform stick nests, and cavity nests are used by western gray squirrels as predator protection and shelter (Vander Haegan et al. 2004), in addition to being a location to raise young. *S. griseus* spherical stick nests consists of a few concentric layers with the largest sticks on the outside and sequentially smaller and insulating layers lining the inside (Merriam 1930; Cross 1969). Western gray squirrels tended to select larger diameter trees, interconnected canopies, and trees with mistletoe when making nests in Black Canyon in the lower Methow Valley, Washington (Gregory et al. 2010). Western gray squirrels are active year round. Their activity peaks a couple hours after sunrise (Cross 1969), and is documented to change seasonally in the North Cascades area during winter months (per comm. Katy Stuart). When disturbed, western gray squirrels may "freeze" in place. If the danger does not seem high, they may bark, "chewnnk-chewnnk-chewnnk", while foot-stamping and tail-flicking (Cross, 1969; Ingles 1947). However they are more known to be a quiet and passive squirrel species, often times not making any sounds; this is evident in comparison to the vocal red squirrel (*Tamiasciurus hudsonicus*) which inhabits similar habitat in Washington State (pers comm. Katy Stuart). Typically, western gray squirrels eat cones by cutting them off the tree, letting the cone fall, then retrieving the cone on the ground. Then the squirrel will carry individual cones to a branch, hold the cone in its forefeet, and remove conescales to eat the pinenuts (Grinnel and Storer 1924). They are typically known to eat ponderosa pine and Douglas-fir seeds in the North Cascades region (pers. comm. Katy Stuart; Gregory 2005).

Gaps in knowledge of the North Cascades population of western gray squirrels

The North Cascades population and ecosystem differ from the populations and habitats other remnant populations of western gray squirrels in Washington State. The North Cascades population inhabits the northern-most extent of the western gray squirrel's range, which lacks oaks, is a primarily dry forest ecosystem, and experiences harsher winters (Gregory et al. 2010). The least is known about the North Cascades remnant population of western gray squirrels compared to the Puget Trough (Fimbel & Freed 2008; Ryan & Carey 1995; Vander Haegen et al. 2007; Vander Haegen and Orth 2009) and South Cascades populations (Cornish et al. 2001; Linders et al. 2004; Vander Haegen et al. 2004; Vander Haegen et al. 2005). The South Cascades population occurs where oak and pine forests merge (Linders and Stinson 2007); the Puget Trough population occurs in areas primarily of Oregon white oak and Douglas-fir (Linders and Stinson 2007). Acorns make up much of the western gray squirrel diet in the South Cascades and Puget Trough (Verts and Carraway 1998). The North Cascades ecosystem lacks oaks and the western gray squirrels occur in ponderosa pine and Douglas-fir forests (Bartels 1995; Gregory 2005; Hamer et al. 2005). The North Cascades population of western gray squirrels experiences a much harsher winter than either the Puget Trough or South Cascades population (Table 1). The northern habitat of the North Cascades population (our focal region) is colder and snowier in the winter than the southern region of the North Cascades, Puget Trough, or the South Cascades ecosystems.

Within the North Cascades population, the southern extent of the western gray squirrel population has received attention over the last decade (Gregory 2005; Hamer et al. 2005; Gregory et al. 2010; Bartels 1995; Bartels 2000), however little is known about the western gray squirrels inhabiting the northern portion of the North Cascades. The Methow Valley is located in this area. It is composed of approximately 75% coniferous forest and 14% shrub steppe. As part of the coniferous forest, 4% of the Methow Valley is ponderosa pine forest which may provide the best western gray squirrel habitat. The upper Methow Valley has an average minimum temperature of -12.0 °C in January and an average maximum temperature of 30.4 °C in July. This region also has an average annual precipitation of 36 cm and an average total annual snowfall of 180 cm (104-yr averages; Western Regional Climate Center 2010). The southern area of the North Cascades population, where the majority of previous work has been conducted (lower Methow Valley), has an average minimum temperature of -8.4 °C in January and an average maximum temperature of 31.3 °C in July. This region has an average annual precipitation of 32 cm and an average total annual snowfall of 108 cm (40-yr averages; Western Regional Climate Center 2010). In contrast, the Puget Trough area has an average minimum temperature of 2.2 °C in December and an average maximum temperature of 25 °C in August. Average annual precipitation in the Puget Trough is 100 cm and average total annual snowfall is 1 cm (28-yr averages; Western Regional Climate Center 2010). The South Cascades region has an average minimum temperature of -4.9 °C in January and an average maximum temperature of 29.8 °C in August. The average annual precipitation in the South Cascades is 44 cm and the average total annual snowfall is 65.3 cm (105-yr averages; Western Regional Climate Center 2010). Understanding more about western gray squirrels in the upper Methow Valley will aid in the effectiveness of recovery efforts for squirrels living in this unique habitat at their northern-most distribution.

Table 1. Regional differences in climate for western gray squirrel habitats based on weather logging stations.

Region	City	Avg. Minimum Temperature (°C)	Avg. Maximum Temperature (°C)	Avg. Annual Precipitation (cm)	Avg. Total Annual Snowfall (cm)	# of Years Averages Are Based On
North Cascades	Winthrop	-12	30	36	180	104
North Cascades	Methow	-8	31	32	108	40
North Cascades	Stehekin	-5	28	87	314	104
South Cascades	Goldendale	-5	30	44	65	105
Puget Trough	Tacoma	2	25	100	1	28

Study objectives

The primary objective of the study Pacific Biodiversity Institute (PBI) has conducted is to determine regions used by western gray squirrels in the northern-most portion of their range to aid in their recovery. The upper Methow Valley has different ecosystem qualities than the other areas where much of the research has been conducted on western gray squirrels. Therefore, increasing the knowledge base of this northern-most extent of the species distribution will provide needed information to help in recovery efforts where western gray squirrels experience a different habitat that lacks oaks and has harsher winters. We focused our efforts on the upper Methow Valley to cover a larger area and add to previously gathered western gray squirrel distribution sampling data from Okanogan County from 2006-2009 by the Washington Department of Fish and Wildlife (Figure 4a). Survey areas were chosen within habitats dominated by ponderosa pine habitats.

Education and outreach are essential goals of the western gray squirrel project. Beginning in 2010, PBI has sponsored workshops, fieldtrips and media events to share information with the public. Community outreach to engage volunteers, landowners, and the public was also a large component of this western gray squirrel project. Our study is unique in two ways; we concentrated our survey efforts in the northern part of the Methow Valley where information is least available and we utilized volunteers to set up and conduct the study. The use of volunteers allowed more locations to be monitored over a larger area than would have been possible without volunteer participation. The northern part of the Methow Valley was chosen because it has not yet received systematic squirrel surveys despite having high quality ponderosa pine habitat. We conducted a hair-sampling tube distribution survey to determine western gray squirrel occurrence, in addition to recording nest and sighting information. Because the western gray squirrel is vulnerable to habitat loss and low genetic diversity, a better understanding of areas where they occur is needed to help managers protect critical habitats.

In addition, we engaged in a related comparison trial of different sampling tube diameters and lengths. This study was begun after discovering damage to some sampling tubes caused by squirrels nibbling the tubes. The purpose of this study was to determine the most efficient tube design for collecting hair samples. In this study we also used a motion triggered remote video cameras at sample tube test locations to observe squirrel behavior as they interacted with the various types of comparison hair tubes. The resulting videos also became useful as a tool for education and outreach for this project.

The initial WDFW surveys recorded squirrel sightings (Figure 4a and 4b) and hair tube sampling (Figure 5a and 5b) largely in the lower Methow Valley. However, very few data points were collected north of Winthrop and none along the Chewuch River. These became the primary focus areas of PBI's study.

Previous data and PBI's efforts

Hair Tube Sampling

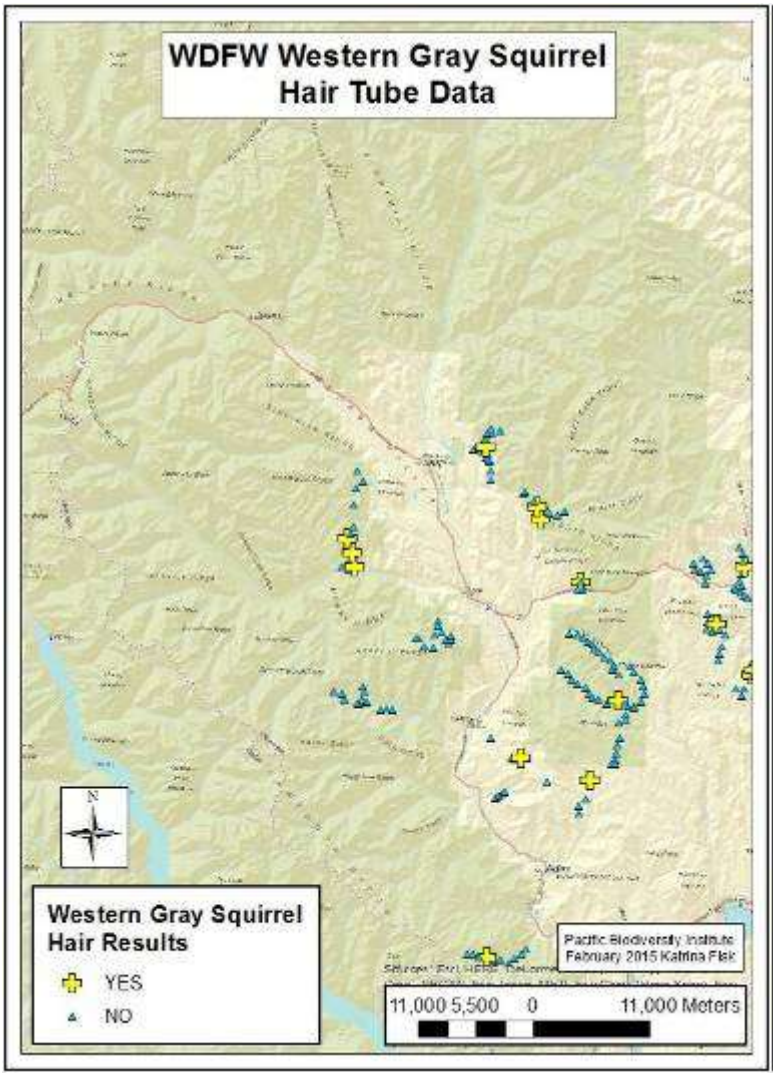


Figure 4a. Western gray squirrel hair-sampling tube distribution surveys from 2006-2009 by WDFW and historical sightings in Okanogan County.

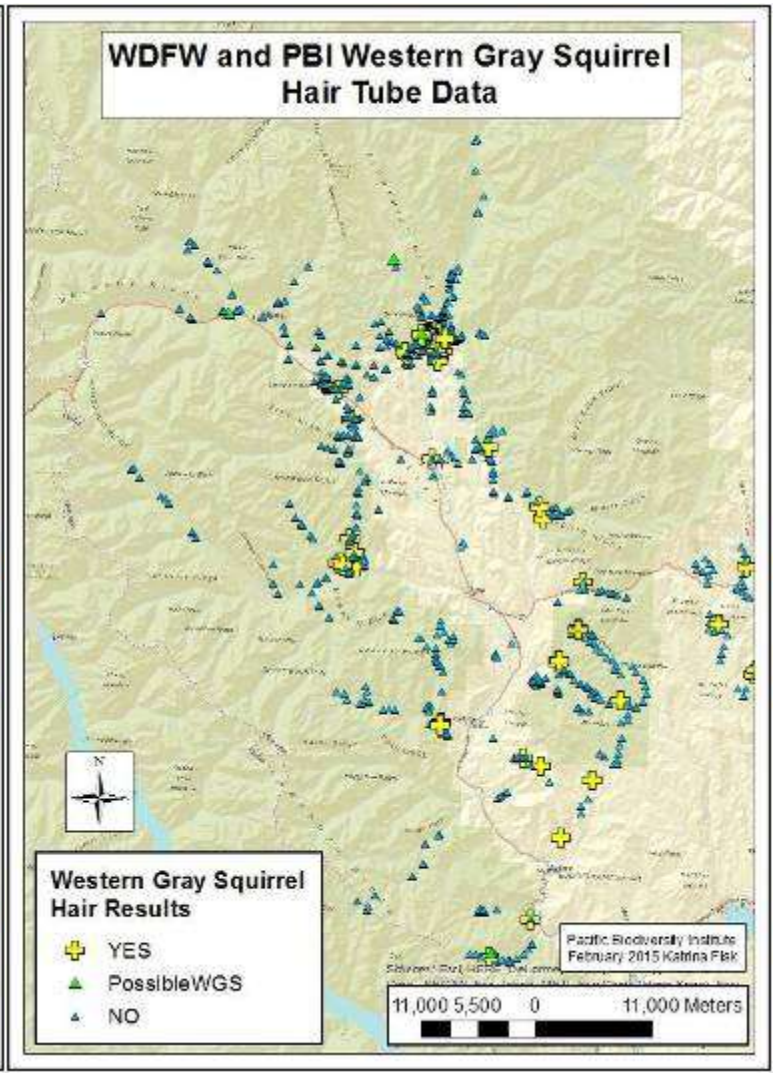


Figure 4b. Western gray squirrel hair-sampling tube distribution surveys from WDFW and PBI's 2010-2014 surveys.

Sightings

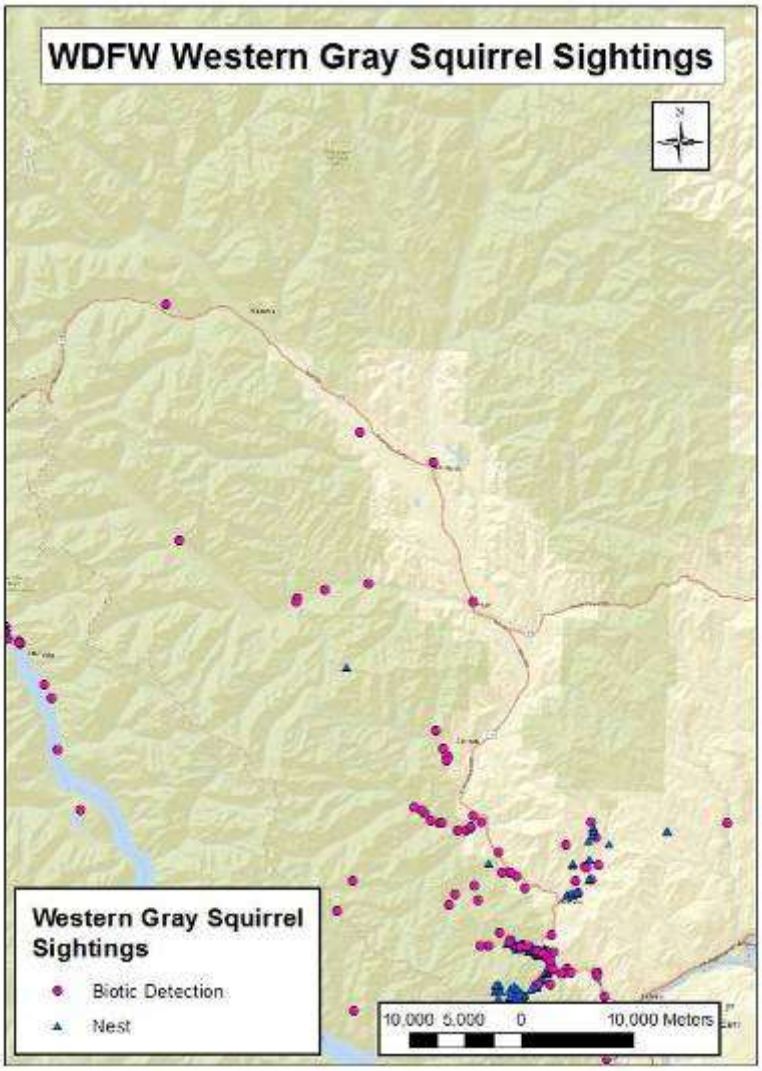


Figure 5a. Western gray squirrel sighting database by WDFW. Observations and nest surveys from 1978 to 2008.

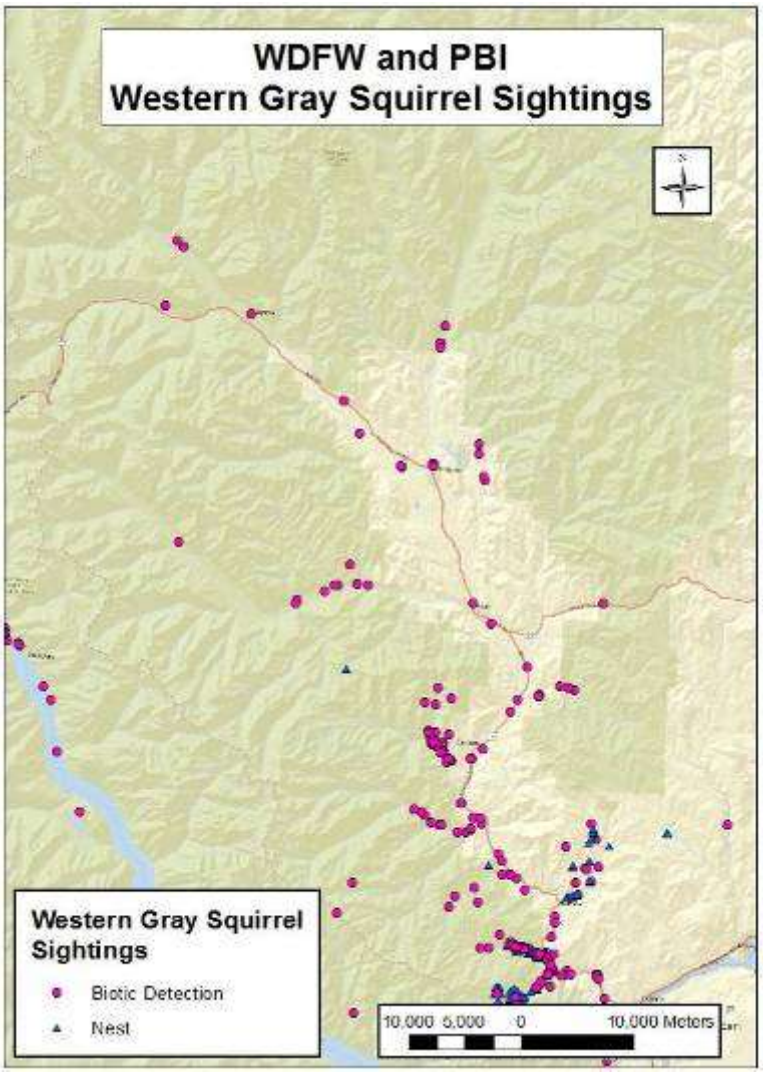


Figure 5b. Western gray squirrel sightings database by WDFW and PBI's sighing database from 2002 to 2014.

Utilizing volunteers to monitor western gray squirrels in the upper Methow Valley

PBI sought volunteers to assist with western gray squirrel surveys in the Methow Watershed during the field season (March-October). Local volunteers, including some landowners with western gray squirrel habitat on their property, were involved in conducting distribution and nest count surveys.

Hair-sampling tubes for distribution surveys

Hair-sampling tubes were used to study the distribution of western gray squirrels between March and October. This methodology has been previously used in western gray squirrel studies to determine presence at specific locations (Fimbel & Freed 2008; Vander Haegen & Orth 2009). This is a low cost, noninvasive sampling technique, which allows for more sites to be monitored compared to other sampling techniques such as trapping. If a hair-sampling tube is positive for western gray squirrels, we can conclude that a western gray squirrel was in the area, but we cannot determine whether this region is part of the squirrel's home range territory or if it was a dispersing individual. Similarly, hair-sampling tubes do not allow us to quantify squirrels in an area or determine western gray squirrel densities. Additionally, if hair is not collected in a hair-sampling tube, we cannot conclude that there are no squirrels in the area; the squirrel may not have found the hair-sampling tube and entered it.

Sampling tubes were constructed with the aid of volunteers (Figure 6). The hair-sampling tube is a 7.6cm diameter, 45.7cm (18 in.) or 38.1cm (15 in.) long pipe of black ABS (Acrylonitrile Butadiene Styrene) tubing. We used nontoxic glue to secure one English walnut in the center of the tube to the inner wall. The walnut is glued to the "bottom" of the tube (side to be placed on the ground).

Hair Tubes Construction

Sanding edges and drilling holes

Adding walnut, hardware, & sticky tape

Finished hair-tube

Hair-tube deployed

Figure 6. Construction of sampling tubes by volunteers in 2010.

Alternative tube designs were tested during the 2011 season (Appendix B). On the opposite inner wall of the tube (top), approximately 3.8cm from the ends, flat aluminum bars (5.8 x 2.5cm) were secured into place with nuts and bolts. The metal bars were covered with a double-sided sticky tape (3M Double-Sided Foam Tape, 0.2 cm thick & 2.5cm wide). The walnut lures the squirrel into the tube and as it walks through, the squirrel will leave back and/or tail hair on the sticky tape. Each tube had a unique number associated with it to help keep track of individual tubes, which are recorded on each photopoint with number cards. Each location was given a unique identifying code. Each location could have different tubes at different times, since tubes were switched out during the sampling season.

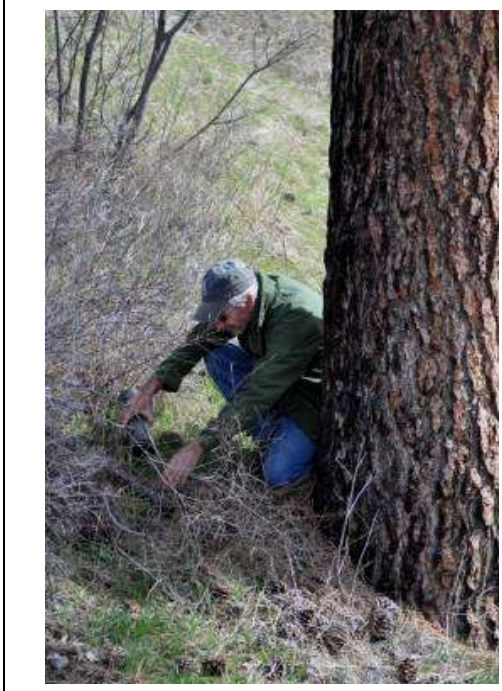
Hair-sampling tubes were placed at the base of a tree and the tree was flagged to aid in relocating it. Surveyors double-checked that the hair-sampling tube was placed flat with the sticky tape on top, walnut on bottom, and that both open ends of the tube were not obscured (Figure 7). Since the squirrel must enter the tube to reach the inner walnut and leave a hair sample, surveyors prevented the hair-sampling tube from moving by securing it with natural materials such as rocks and wood. One loose bait walnut was placed outside the tube by both openings (two walnuts total) to get the squirrel acclimatized to walnuts and to aid in luring the squirrel into the tube to get the third walnut. GPS locations were recorded for mapping and to help find the tube during revisits. Volunteers were advised in deciding where to place the hair-sampling tubes. They recorded the hair-sampling tube GPS location and site information, including drainage, dominant overstory, and dominant understory.

Beginning in 2010, vegetation plots were selected and classified into forest types and the percent of area covered by each forest type was calculated. In 2014, densitometer, estimated cover of tree, shrub, forb and grass percent cover and species were also recorded. All plant species within a 10m radius of the tube location were recorded with each plant type (tree, shrub, forb/herb and grass) and the percent cover recorded. Sites within the burned area after the Carlton Complex fire had additional records such as living/dead vegetation, needle cover, bare ground, charcoal, char and scorch heights and tree color/survival rates. Photos were also taken of each site. Some of this information was gathered by volunteers, others by PBI staff.

Previous studies in the lower Methow Valley had concluded that large diameter ponderosa pines, interconnected canopy, and an open understory were favored by western gray squirrels (Gregory 2010). Therefore, volunteers were directed to place hair-sampling tubes in areas with these preferences in mind. Volunteers were also trained to identify squirrel signs such as cut cones, cone scales, and dig holes to aid in finding potentially favorable squirrel habitats to place hair-sampling tubes. However, criteria were not strict since all preference criteria were difficult to meet, it can be difficult to tell the difference between red squirrel and western gray squirrel signs in the area, and we were not sure whether known habitat and behavioral preferences based on research conducted in the lower Methow Valley would be the same for squirrels in the upper Methow study area.

Hair-sampling tubes were placed on both public and private lands. Hair sampling tubes were only placed on private land after written permission was granted. Hair-sampling tubes were checked every three to four weeks to determine whether hair was collected on the sticky tape. Data collected during hair-sampling tube checks include: date deployed, date checked, observers, tube status, whether hair was collected, tube action, and notes. Additional data collected included whether the hair-sampling tube looked disturbed (e.g., rolled) and whether walnuts were missing or present (Appendix A). We replaced bait walnuts if they were missing. If hair was detected, the hair-sampling tube was removed and a replacement hair-sampling tube was put in the exact same place to replace it. Additionally, during each check, the stickiness of the sticky tape was checked

and if it feels less adhesive, the tape was replaced by attaching another tape layer to the metal bar (up to three layers).



Find a good tube location

Secure tube with rocks &/or sticks

Record location

Record habitat information & take photos

Figure 7. Diagram of deploying hair-sampling tubes by western gray squirrel distribution study volunteers.

The hair collected was visually analyzed to determine what animal it was from. The tape was removed from the aluminum bars and examined under a dissecting microscope at 30x magnification. Hair color patterns and hair size were used to categorize the hair into the following categories: western gray squirrel, red squirrel, yellow-pine chipmunk, bushy-tailed woodrat, or unknown. In order to heighten reliability, each sample had to contain at least 10 identifiable hairs (Matthew Vander Haegen, pers. comm.) If the hair samples appeared to fall into one of these identifiable categories but had less than 10 hairs present, we labeled them as "suspected" followed by the name of the suspected species. We compared our hair sample collected from the tubes with back, tail, and belly/chin hair collected from road-kill specimens. Hair samples were categorized by two people to reduce observer bias. We documented tube number, date, and location for each hair sample collected. Throughout the field season, GIS maps were updated with hair-sampling tube locations with and without western gray squirrel hair. Data forms were entered into a Microsoft Access Database. Sampling location coordinates recorded in the database were compared with those of GPS waypoints in order to ensure the data was correctly located.

Western gray squirrel sightings

In addition to utilizing hair-sampling tubes to determine western gray squirrel distributions in the upper Methow Valley, volunteers were asked to record any visual sightings of western gray squirrels (Appendices B & C). If a positively identified western gray squirrel was sighted, location notes were recorded along with whether it was an adult male, adult female, subadult, unknown, or young of year, time of detection, and behavior (i.e., nest building, perched on tree, perched in nest, perched on ground, perched on rock or stump, copulating, vocalizing, foraging, aggressive, defensive, courtship, excavating, playing, feeding, running on ground, and/or climbing in tree).

We also utilized wildlife trail cameras to augment the information obtained through hair-tube sampling. The wildlife cameras were used to help determine if squirrels were in a particular area and to study their behavior, especially in areas which had been burned by wildfire. The 256,108 acre Carlton Complex Fire caused a shift in focus from the northern population of gray squirrels to the better studied and established southern population. We assessed the survival of this population and its interaction and potential effects on the more northern metapopulation.

In 2014, a sighting database (Figure 11) was also formed, compiling previous year's data with current sightings, to continue to expand on mapping the population through the sightings themselves and adding to previous WDFW data (Figure 5a and 5b) as well as using them to identify potential hair tube locations for future study.

Western gray squirrel nest surveys

Nest detection indicates that an area was occupied by western gray squirrels. In 2010 we used the Black Canyon study area in the lower Methow Valley, where nests are known from radio-telemetry data (Gregory 2005), to test our methodology and nest identification skill. During our nest surveys, we systematically searched for western gray squirrel nests to gain information about areas that western gray squirrels occupy. Nest searches were conducted in areas where confirmed western gray squirrels have been sighted or positive western gray squirrel hair was collected in hair-sampling tubes this field season.

The procedure for conducting detailed nest surveys is as follows. First, we created a map of the target location with the best potential habitats clearly identified. We determined an approximate layout of nest search survey transects. Nest searchers stood 20-30 m apart (marked by paces) in a line, abreast, and in view of one another. Each person used a two-way radio for communication between observers. Nest searchers on either end of the search transect took a starting GPS reading. Nest searchers walked along a transect or contour of a steep slope using a compass bearing, walking for approximately five minutes while looking for nests and stopped for a more detailed search with binoculars (looking around 360 degrees) for one minute systematically, or a detailed search was coordinated via walkie-talkies when potential nest trees or complicated canopy was encountered. During this detailed search, nest searchers also realigned themselves. One person in the middle of the search line announced on the walkie-talkies when one minute of detailed searching had ended and the walking search continued. When a nest was located, all nest searchers marked their location (visually or with temporary flagging) and gathered to collect nest data and fill out vegetation sampling forms describing forest structure and habitat condition of the area. Nest searchers returned to their previous locations to resume the nest survey. Survey results are recorded on a form. Once a nest was found, the GPS locations were recorded.

Beginning in 2011, nest surveys were only conducted in areas where squirrels were located with sampling tubes during the field season. These surveys were less intensive and involved observers walking around the area where squirrel activity was observed while scanning the tree canopies for nests. One nest survey was conducted by tracking squirrels in fresh snow during late winter to locate the nest. In the following years, these searches were not conducted as systematically, but rather taken note of when they were observed in the field by staff or volunteers and marked with a GPS waypoint.

Community Educational Activities and Volunteer Involvement

Community education on western gray squirrels

Pacific Biodiversity Institute (PBI) provided several education and outreach opportunities for Methow Valley community members where the public could learn more about western gray squirrel identification, status, threats, and conservation needs. Attendants were provided with identification guides and background information (Figures 2 and 3), instructions on how to fill out datasheets (Appendix A1 and A2). Community education was conducted through: i) newspaper articles seeking volunteers and any western gray squirrel sighting information, ii) involving volunteers and private landowners in conducting the western gray squirrel distribution surveys, iii) a public talk open to community members interested in learning more about western gray squirrels and specifics of our project, and iv) several field trips that were open to the general public and our volunteers. We were interested in informing landowners about stewardship of the squirrels throughout the valley, since the increased knowledge may lead to greater interest in managing the landscape for western gray squirrels. Additionally, we encouraged community members to report western gray squirrel sightings and locations, especially if they were hit on the road.

2010 community education activities

We had a community field day on March 20, 2010 for training in western gray squirrel identification, survey methods, ecology, and conservation measures. The field day was attended by several dozen volunteers and members of the public.

Articles about the project were printed in the Wenatchee World newspaper and Methow Valley News. On October 5, 2010, we presented an hour and a half PowerPoint presentation in the Methow Conservancy First Tuesday Lecture Series at the Twisp Grange. This Methow Conservancy lecture series invites speakers to discuss nature-related topics of interest to local community members. For the talk, we partnered with Katy Stuart, a University of Washington graduate student working on western gray squirrels in the Squaw Creek watershed (lower Methow Valley) and Stehekin (adjacent to Lake Chelan in the lower Methow Valley).

There were approximately 50 people in attendance; we presented information on squirrels, adaptations, their ecological diversity, and specifically about the North Cascades western gray squirrels and their unique habitats found in the region.

Stuart presented her research and preliminary findings, while PBI presented their project scope and findings. Hands-on examples of western gray squirrel sampling equipment (radio collars, traps, and hair-sampling tubes) were on display, along with a WDFW western gray squirrel study skin, and hair samples of different small mammals for comparisons to the species of interest.

2011 community education activities

To provide information about western gray squirrels, Pacific Biodiversity Institute continually updated its website with a western gray squirrel project page (www.pacificbio.org/initiatives/wgs/gray_squirrel_background.html), volunteer advertisement (www.pacificbio.org/helpout/volunteer-western-gray-squirrel.html), and page for volunteers to access data sheets and sampling guides (www.pacificbio.org/initiatives/wgs/wgs-volunteer-page.html). These web pages link to videos we made showing western gray squirrel behavior.

Workshop activities were described on our website at http://www.pacificbio.org/initiatives/wgs/wgs-workshop-2011-june04.html. A gallery of notable photographs from the 2011 field season was documented in a photo gallery at http://www.pacificbio.org/initiatives/wgs/year-in-photos/index.htm.

Volunteers and the public attended an end of year get-together at the Pacific Biodiversity Institute on Thursday, December 1, to celebrate the 2011 western gray squirrel research season.

2012 community education activities

In spring of 2012, PBI's western gray squirrel study was the subject of a story in the Methow Valley News. This article also notified the public of upcoming field workshops.

2013 community education activities

George Wooten gave a talk in February at the Methow Valley Interpretative Center regarding western gray squirrels habitat and ecology.

2014 community education activities

In August, PBI lead a free field trip to Alta Lake State Park to investigate how the 2015 Carlton Complex affected the native ecosystems of the park and how the western gray squirrels and their habitat in the park were affected by the fire.

On September 13th, PBI lead a free field trip open to the public to explore the 2015 Carlton Complex burned area and educate the public on how the fire affected western gray squirrels and other wildlife in the area.

Katrina Fisk held an interactive talk on October 6th to a group of 5th graders at Alta Lake State Park summer camp educating them on the threatened species in their back yard. Western gray squirrels are known to inhabit the park. This talk was designed to excite and enlighten the children and hopefully inspire them to care about this threatened animal they have the rare opportunity to observe in the wild.

A talk at the Mercer Slough Environmental Education Center for the City of Bellevue's Natural Resource Department will be held March 15th 2015. This "Guest Speaker" series is a free, educational event is free and open to the public, Katie Stewart, a PBI contact, will be presenting on western gray squirrels and their importance to the environment, as well as their interaction with the more well-known, invasive eastern gray squirrel.

2010 volunteer activities

On March 5, 2010, volunteers helped build 200 non-invasive hair-sampling tubes to collect hair that can be used to identify the species (Figure 4). Fourteen volunteers participated in a second workshop on May 5, 2011 to learn about gray squirrels and to reconstruct the hair-sampling tubes.

At the workshops, volunteers were trained how to recognize the difference between the more rare western gray squirrel and the common red squirrel (Figure 4), determine good habitat for the species, deploy and check non-invasive hair-sampling tubes, and help conservation of the North Cascade western gray squirrel population. Additionally, volunteers were trained to recognize the type of preferred habitat and visually identify western gray squirrel nests and signs (e.g., feeding, hoarding). In 2010 we used the lower Methow Valley Black Canyon study area as a control site, where ongoing studies have been conducted by WDFW and research studies were conducted by University of Washington graduate student Sarah Gregory in 2005, to test methodologies and nest identification skills. Once the volunteers had placed their first set of hair-sampling tubes, a PBI intern/volunteer went out to the tube locations to address any concerns community volunteers might have had and also suggested better and/or other locations to place hair-sampling tubes. The PBI intern/volunteer also regularly updated community volunteers on project progress and provided further assistance in the field when necessary.

During 2010, volunteers put in 1,782 hours of time. A volunteer appreciation evening was held on November 4, 2010 at the Pacific Biodiversity Institute office to show appreciation to all volunteers involved in the western gray squirrel distribution study and to discuss their experiences working on the project.

2011 volunteer activities

In 2011, volunteer activities began at the Pacific Biodiversity Institute office on June 4. Workshop activities were similar to those of the 2010 workshop. The workshop included an introduction to the project, followed by a sampling tube reconditioning session, and then in the afternoon, a visit to a known squirrel activity center.

In 2011, fourteen volunteers put in a total of 1993 hours. On December 1, about 15 volunteers and members of the public attended an end of year get-together at the Pacific Biodiversity Institute to celebrate the 2011 western gray squirrel research season, to watch entertaining videos about western gray squirrels and to receive achievement awards.

2012 volunteer activities

We held a western gray squirrel field workshop on July 14 for interested public attendants and citizen science volunteers. This workshop emphasized the need to study gray squirrels in the context of ponderosa pine forests of the Methow Valley.

On November 29, we recognized the contributions of citizen science volunteers at an awards gathering at the Twisp Pub.

2013 volunteer activities

(In progress)

2014 volunteer activities

Help from previous volunteers as well as people new to the project helped place over 150 hair tubes across Mazama, up to the mid-Chewuch river and as far south as Black Canyon Creek. Some of these locations were identified as prime western gray squirrel habitat because of sightings in these areas.

Taking volunteer's sighting information allowed us to establish new population locations and bolster known ones. Especially after the wildfire, sightings became important both to establish squirrel survivability and movement. Several sightings of squirrels in areas far from previously known populations were reported in the months after the fire.

During our October field trip, volunteers helped place hair tubes in the burned area, learned the techniques for placement of tubes, cameras and data collection. Several expressed interest in future field trips and volunteering in future field seasons.

While road-killed specimens were previously identified and mapped, in 2014 we took this a step further. Volunteers reported and even collected road-killed individuals. DNA samples were sent to Matt Vander Heagen who aids in creating a genetic map to identify breeding movement within populations.

Results

2010 Hair-sampling tube distribution results

In 2010, volunteers placed hair-sampling tubes in a total of 176 locations in the upper Methow Valley. Of the 176 locations, hair-sampling tubes from 17 locations collected western gray squirrel hair. Some of the hair-sampling tubes that were positive for western gray squirrel hair were concentrated in the same region, resulting in eight regions occupied by western gray squirrels. After comparing our distribution data with previously gathered data by Washington Department of Fish and Wildlife staff, we found that our study produced five new areas that previously were not known to have western gray squirrels (Figure 8).

Some locations collected hair on more than one occasion. We collected a total of 134 hair samples from tubes, 17 of which were western gray squirrel hair. 61 samples were identified as "unknown" since they were not comparable to our reference hair samples. 55 samples were identified as red squirrel, and 11 were identified as yellow-pine chipmunk. There appears to be no obvious patterns between western gray squirrel locations and red squirrel and/or yellow-pine chipmunk locations.

Six volunteers had both live and road-kill western gray squirrel sightings. One volunteer had three separate observations in the Benson Creek region. During his first sighting, the western gray squirrel was chased by a red squirrel down a ponderosa pine tree. A western gray squirrel was seen climbing a ponderosa pine and investigating a manmade structure previously used as a nest by a red squirrel. The third sighting involved two western gray squirrels running together. Also in the Benson Creek watershed, another volunteer regularly saw a western gray squirrel frequently visit his bird feeders. In the Libby Creek watershed, a volunteer saw a western gray squirrel climb down a ponderosa pine and eventually run down a hill. Within the Little Bridge Creek region, a volunteer observed a western gray squirrel foraging and running on the ground. Two separate sightings were made, also in the Little Bridge Creek region. A western gray squirrel was also seen by a volunteer running across a Highway153 near the town of Methow. During the span of this year's study, there were also four road-kill western gray squirrels brought in to our office and locations were recorded.

In 2010, nest surveys were completed in two separate areas. First, we conducted a nest survey in the Chewuch River drainage, where we had many hair-sampling tubes that had collected western gray squirrel hair. Within the nest search area, we found one nest that looked like it was not actively used based on the nest having gaps between structural branches and it lacked newer green or red pine needles and instead had black decomposed needles. Our second nest survey was conducted in the Benson Creek watershed where hair-sampling tubes had collected western gray squirrel hair and squirrels were observed on three separate occasions. During this nest search we did not find any nests.

2011 Hair-sampling tube distribution results

In 2011, we recorded 629 observations at 101 hair tube sample locations (Figure 8). There were also 17 sites where multiple tube designs were placed to study squirrel behavior.

There were five population centers in the seventeen sample locations containing western gray squirrel hairs Two of these locations were new sightings, located more than 500 meters from a previously known site.

In addition there were 55 samples recorded as red squirrel hairs, 11 samples recorded as yellow-pine chipmunk hairs, and 80 samples recorded as unknown species' hairs. The results of the 2011 surveys are displayed in Figure 10, along with the combined results from 2010 and 2012.

2012 Hair-sampling tube distribution results

In 2012, volunteers observed western gray squirrel hairs in 10 sites out of 186 sample locations. Four of these sites were new. The other six sites were located in a cluster where gray squirrels had been discovered earlier (Figure 8).

2013 Hair-sampling tube distribution results

In 2013, a total of 110 hair tubes were placed by volunteers and staff. Out of these, 15 had positive western gray squirrel hair samples from 8 different locations. These locations confirmed previous results in the area, as well as filling in the area between previous year's positive samples (Figure 8).

2014 Hair-sampling tube distribution results

In 2014, 159 hair tubes were placed and checked a total of 420 times, with a total of 149 positive hair results (Figure 9). 72 of these results were either confirmed or suspected western gray squirrel (Figure 8). Most of the other hair results were confirmed or suspected red squirrel, the remaining were yellow-pine chipmunk, bushy-tailed packrat, unknown rodent, or, in one case, bear.

Volunteers and PBI staff placed these hair tubes in 159 locations ranging from the mid-Chewuch river to the burn areas of Black Canyon Creek. 56 of these locations resulted in either confirmed or suspected western gray squirrel hair. While none of these sights were sampled under the exact trees as previous year's samples, at least 17 of these positive or suspected samples were in the same areas and are assumed to be part of the same population as those established in previous years. These samples surveyed to confirm presence of this year as well as better establish the boundary of the populations. This was most obvious in the lower Chewuch population (Figure 10a and 10b) but also occurred in several areas around Black Canyon and Squaw Creek, where a much larger, well established population has been observed over a large area.

The three new areas, represented by a total of 31 positive western gray squirrel hair samples tube locations, had no previous western gray squirrel samples included the east side of the lower Chewuch River along Boulder Creek, the east side of East Chewuch Road, and the hills west of the established lower Chewuch population. The 2014 data also established a further range of the previously observed population both north and south. These are thought to be expansions of nearby known populations but could also be new populations from migrating squirrels which have traveled from more distant areas. In either case, squirrel distribution appears to be more extensive than previously established. This could be a result of squirrels being present in these

areas in previous years but not entering the hair tubes, or a result of wider and changing dispersal.

One suspected cause of dispersal may be the Carlton Complex Fire which burned an extensive area of established western gray squirrel territory (Figure 12). While the long-term effects the fire will have on the population is still unknown, we have done some preliminary work by putting up wildlife cameras and hair tubes in the burned areas and have 5 positive or suspected western gray squirrel hair tube results and 12 videos of these squirrels. The fire burned in a mosaic of severity throughout the burned area, resulting in different effects on wildlife. (A full report of the fire's impacts on wildlife is in progress.)

Wildlife cameras were more extensively utilized in 2014 than previous years. A total of 17 videos of western gray squirrels were recorded during this field season at three locations. All of these were in the burned area and feature squirrels hunting for food and running on the ground and up trees.

An up-to-date sighting database has also been created from previous year's sighting information, as far back as 2002. So far, 100 western gray squirrel sightings have been mapped, some of which represent multiple sightings in the same location. These sightings have established potential squirrel populations in several new areas, including a population near Mazama; further north than any hair tubes have found western gray squirrel samples. Sightings are reported from PBI staff, volunteers, community members and wildlife camera videos.

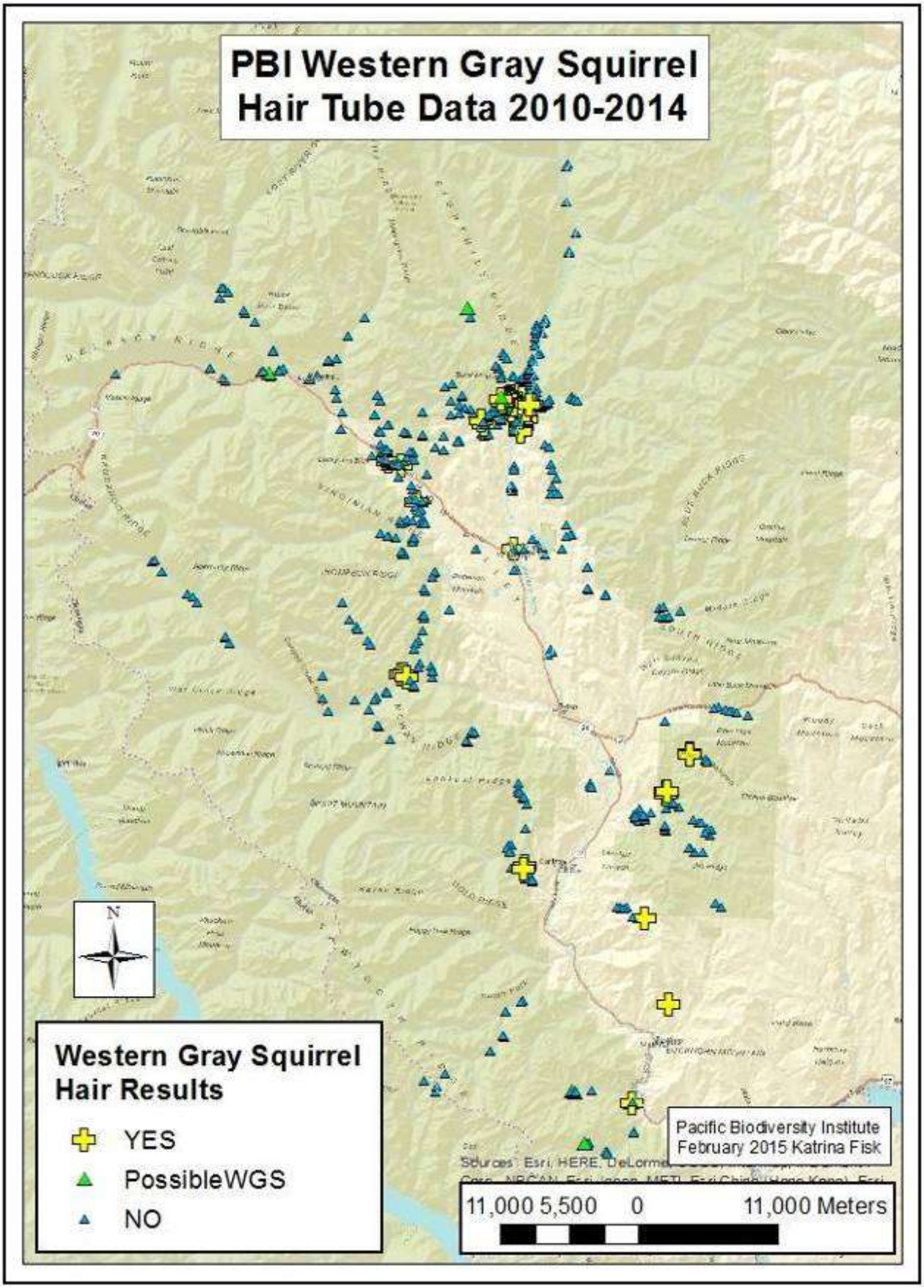


Figure 8. Pacific Biodiversity Institute volunteer hair-sampling tube locations placed from 2010 to 2014.

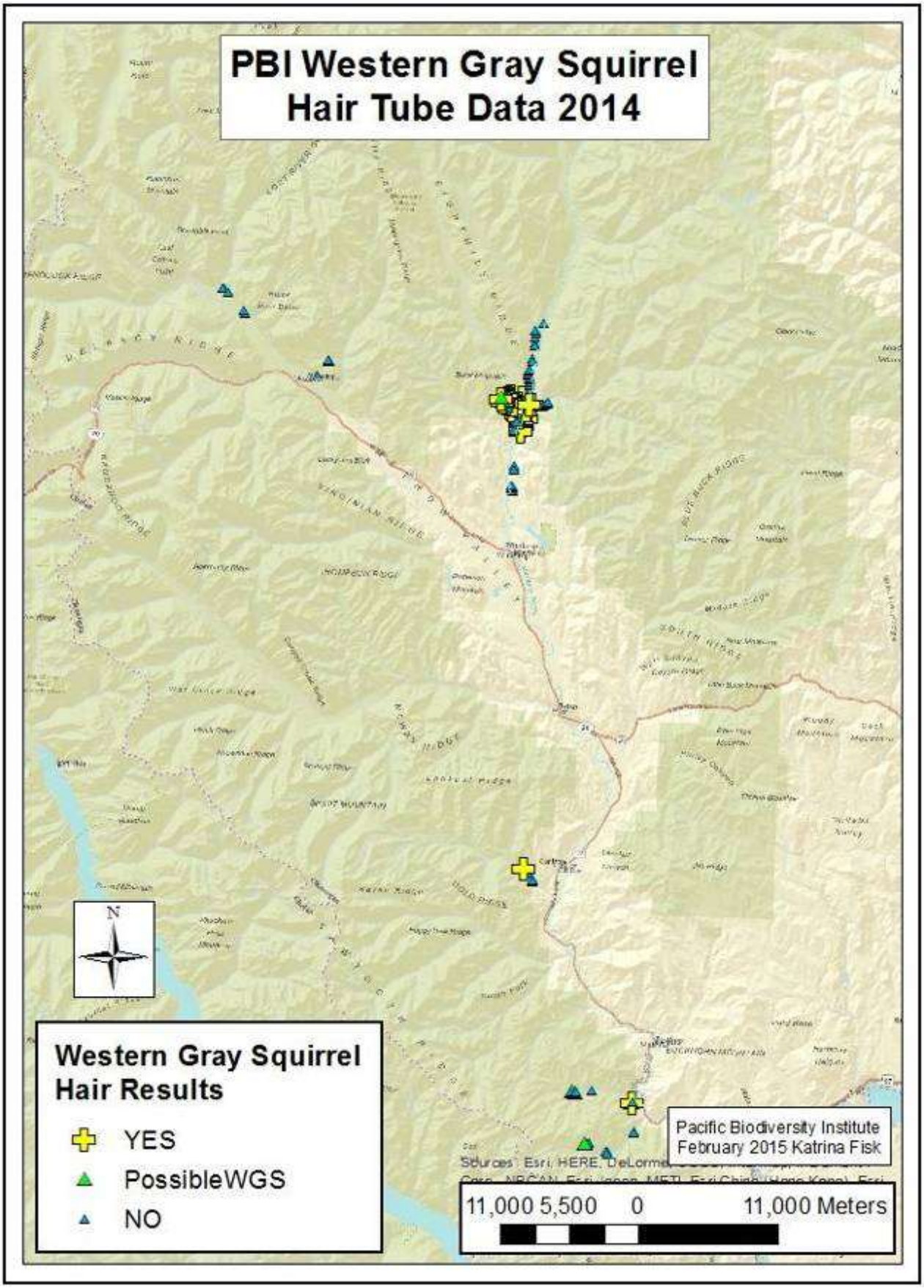


Figure 9. Pacific Biodiversity Institute volunteer hair-sampling tube locations from 2014.

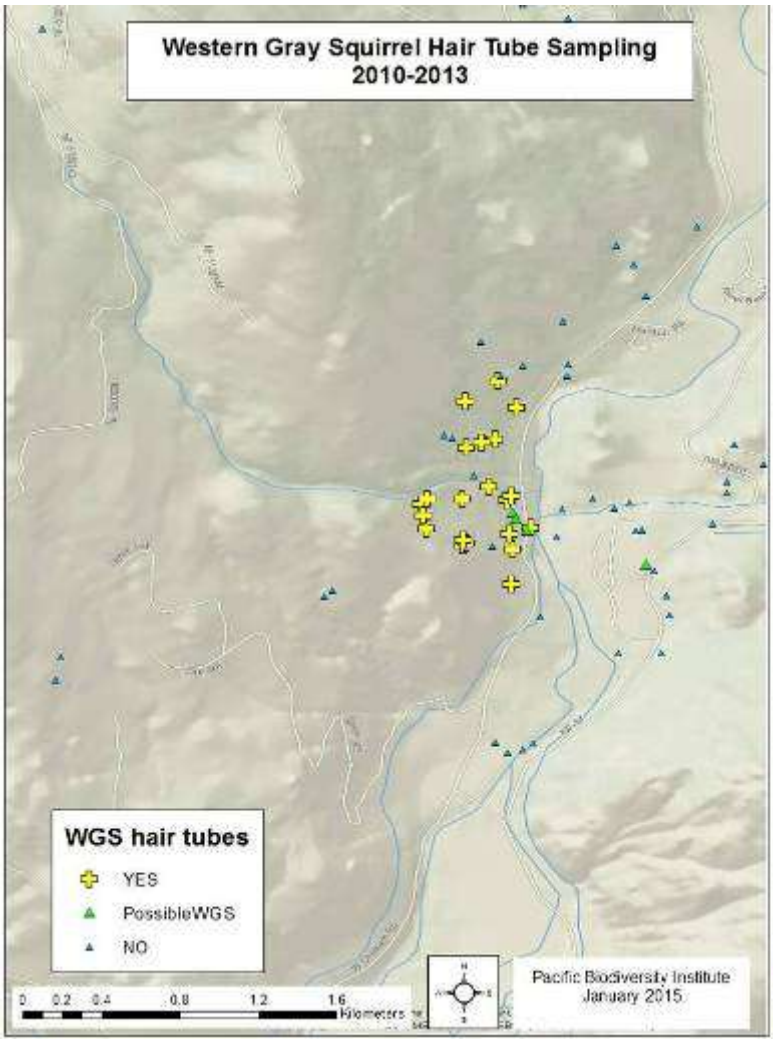


Figure 10a. Hair-sampling tubes with positive and suspected western gray squirrel results for years 2010-2013

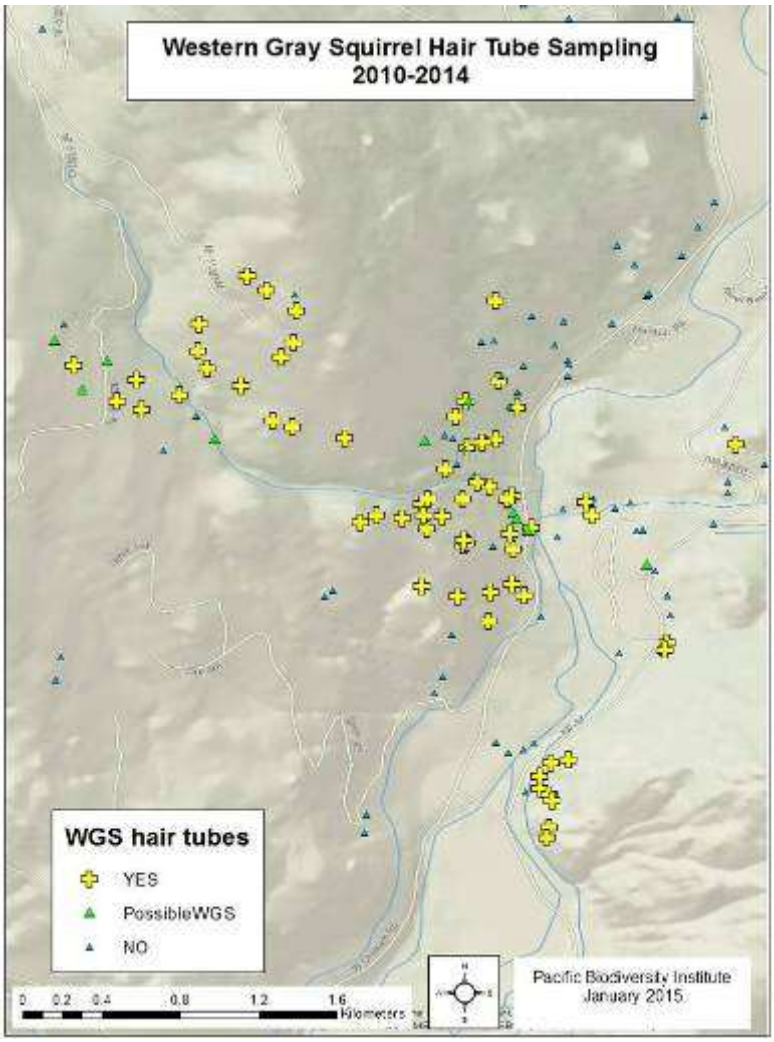


Figure 10b. Hair-sampling tubes with positive and suspected western gray squirrel results for years 2010-2014

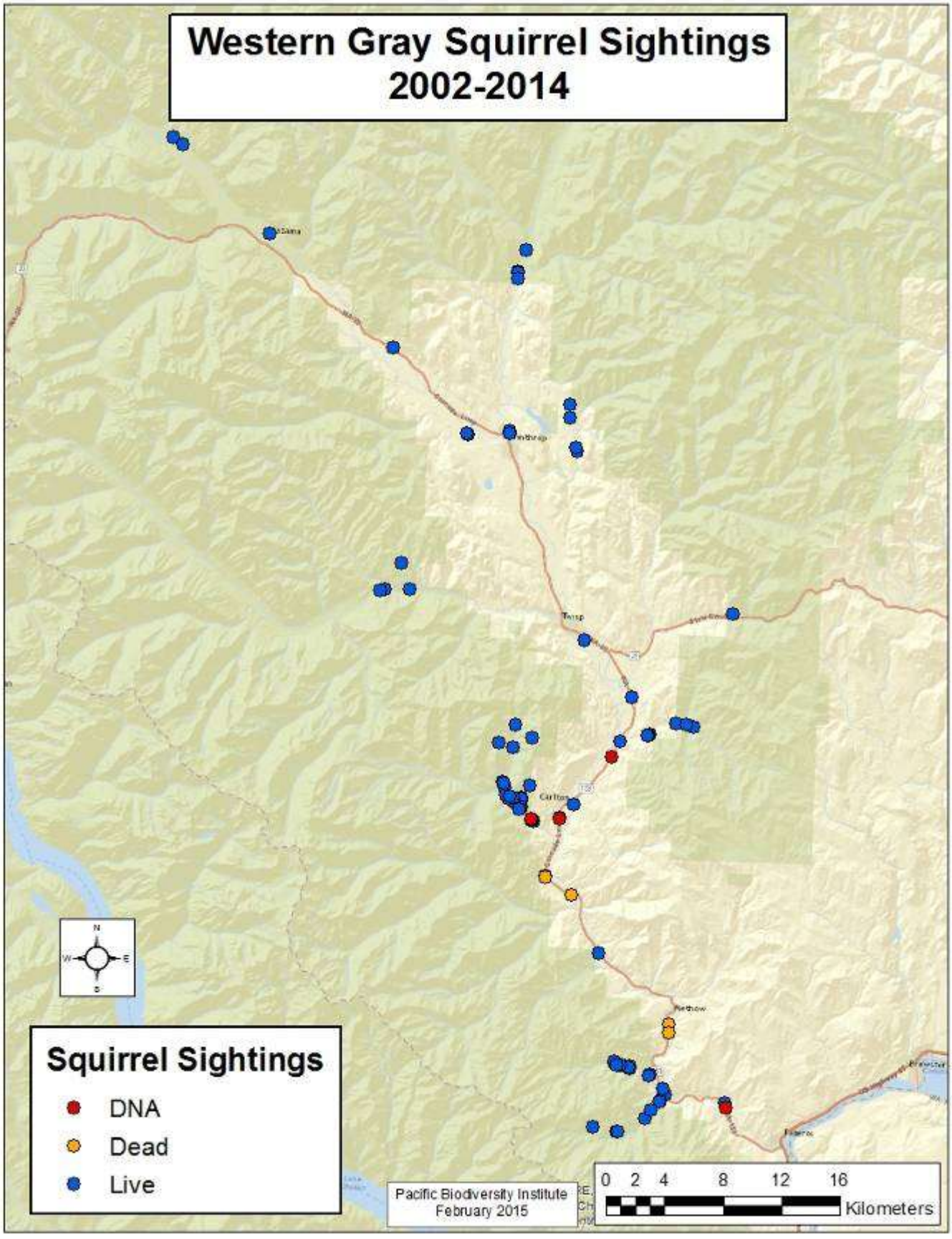


Figure 11. Sightings map from 2002-2014. Sightings include dead specimens, road-killed specimens which had a DNA sample taken from them, and living individuals observed.

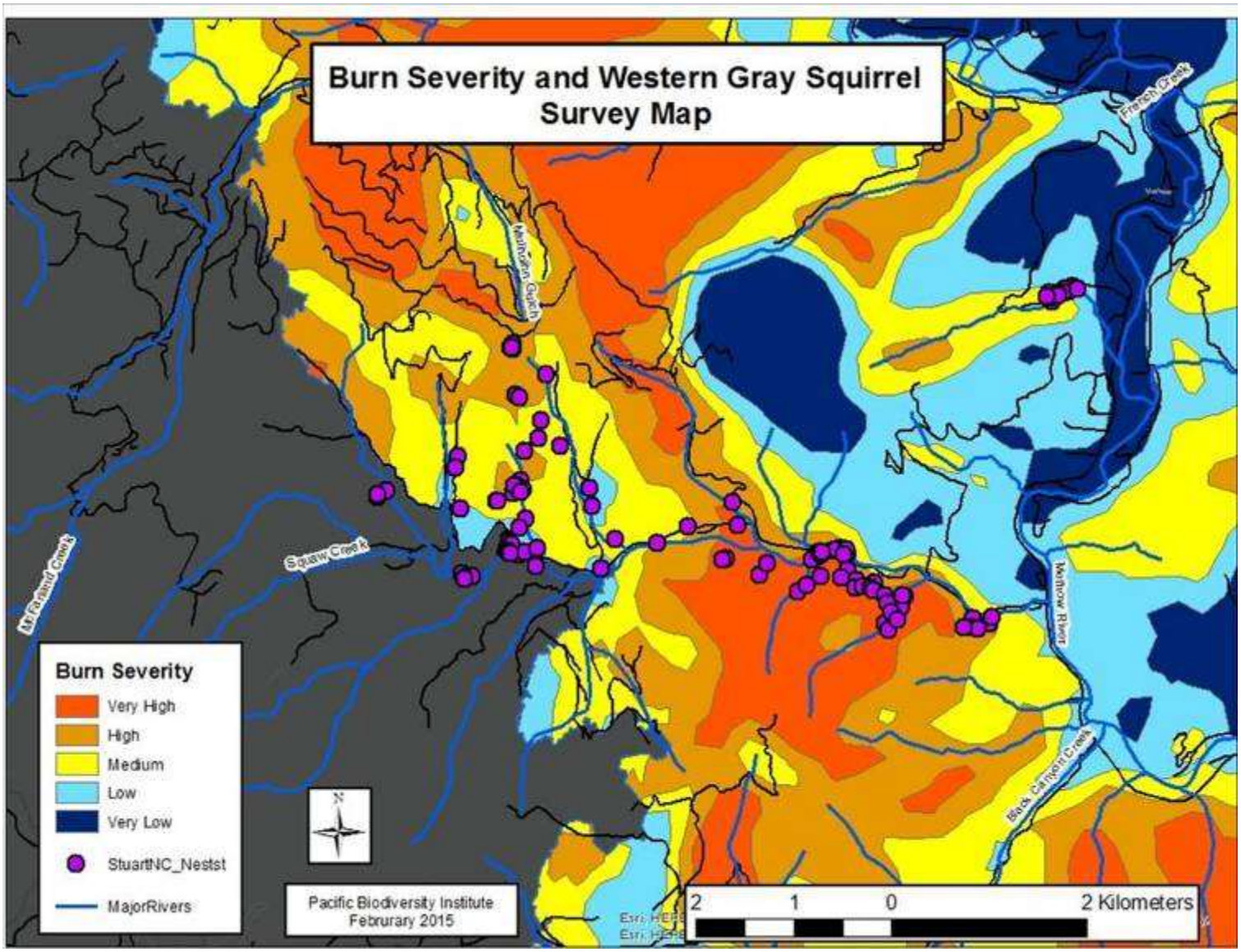


Figure 12. Burn Severity assessment of the Carlton Complex Fire (burn severity levels 1 (most severe) to 5 (least sever) with western gray squirrel nesting sites (purple dots) (Katie Stewart 2013, in progress.)

Discussion

Volunteer efforts

Since 2009, approximately 755 square kilometers have been surveyed using hair sampling tubes. We identified 15 new areas covering approximately 86 square kilometers in the upper Methow watershed where western gray squirrels were previously not documented. Our findings expand the knowledge base for the northern range of known western gray squirrel distribution in the North Cascades. Volunteers and staff were effective in deploying and checking hair-sampling tubes for western gray squirrel hair throughout the field season. They were confidently able to choose locations to place tubes in potential western gray squirrel habitats. Hair-sampling tubes baited with walnuts were effective in luring squirrels through the tubes, however we do not know to what extent they used the tubes based on their encounters. One tube placed by bird feeders on a volunteer's property allowed for visual observation of a western gray squirrel encountering the hair-sampling tube and immediately picking up one of the walnuts outside of the tube and running away with it. This activity was documented in photographs. Though it varied by year, majority of the tubes did not collect western gray squirrel hair. Additionally, some tubes which appeared to have signs of western gray squirrel chewing did not have collectable hair samples because the tape used to collect the samples has been chewed, lost, and, in the case of burned areas, covered in ash and no longer sticky. While hair tubes are not used to determine density estimates, based on the numbers of tubes with western gray squirrel hair, the species appears to be at a high density around the lower Chewuch River and could be expanding.

Hair-sampling tube techniques

Some interpretations cannot be made based on our hair-sampling tube distribution survey techniques. For example, since hair-sampling tubes were checked every three to four weeks, we were unable to differentiate whether multiple squirrels entered the tube, or only one without a wildlife camera at these locations, and the number of cameras available is limited. Similarly, we were unable to determine whether hair-sampling tubes in the same region that collected western gray squirrel hair were visited by the same individual or different squirrels. However, collected hair indicates that a squirrel was in the area, but we cannot conclude that this is part of their home range or whether they were dispersing through the area. In order to learn more about western gray squirrel home ranges in the upper Methow Valley, radio-telemetry data would be more effective. However, if a hair-sampling tube collects repeated samples of western gray squirrel hair over a several month period, this would provide evidence that the hair-sampling tube location may be part of an individual's home range that is used for a longer term. In contrast, if a hair-sampling tube only collects western gray squirrel hair once, but is never revisited over a long time period, we predict that the squirrel was dispersing through the area where the hair-sampling tube was placed. Hair collected for a period of time (e.g., two months) may indicate that the western gray squirrel has a seasonal residency in the area. Also, hair-sampling tubes located in areas that did not collect hair does not mean that squirrels are not present. We can only conclude that either they were not in the area, they were not familiar with the lure and therefore did not leave hair when they encountered a hair-sampling tube, or they did not encounter the tube even when in the area. In some cases, such as the burned area, squirrels appear to rip apart, scatter and make the sticky tape so dirty we are unable to collect hair from these samples. (Behavioral and location information suggests these are very likely western gray squirrels so these samples were labeled as "suspected" along with the less conclusive hair samples.)

Western gray squirrel nest surveys

Based on our experience with western gray squirrel nest searches, we found that in the upper Methow Valley, walking nest searches may not be the most efficient method for finding nests. The upper Methow Valley appears to have a lower density of squirrels than other areas where similar walking nest searches have been conducted (Hamer et al. 2005). The ponderosa pines, Douglas-fir trees, as well as abundant mistletoe growths all provide excellent cover to hide nests and therefore nests are likely to go unobserved by nest searchers. Additionally, the terrain is often steep in many areas of the upper Methow Valley. This slows down the walking pace, which prevents coverage of large areas searched for potential low densities of well-hidden nests. Other western gray squirrel researchers (pers comm. Katy Stuart, Sarah Gregory) find nests most effectively by using radio-telemetry to follow radio-collared squirrels.

Future work

This study helped identify areas that western gray squirrels occupy in the upper Methow Valley and outreached to private landowners in areas where western gray squirrels were documented. Our findings provide data to local agencies and organizations to help protect western gray squirrels and their habitat during land management activities. We at Pacific Biodiversity Institute can now further our research in these particular areas to better understand how to protect this state-threatened species.

Potential western gray squirrel habitats to be surveyed

PBI aims to continue the same work to understand their distribution in the Methow Valley since they may occupy currently unknown areas (Figure 11). Additionally, we were limited on the number of hair-sampling tubes available to put in the field and there are areas within the upper Methow Valley that may not have been adequately surveyed. To address this, we have initially identified additional regions for a future hair-sampling tube distribution study by using aerial photography on GIS to identify areas with large ponderosa pines and Douglas-fir trees.

Additionally, we plan on focusing on potential corridors to determine movement between areas known to have western gray squirrel occurrences. For example, Little Cub Creek and Beaver Creek would be good places to further sample in future years because it is identified by local biologists and GIS aerial photography as excellent western gray squirrel habitat with large ponderosa pine and Douglas-fir trees, though it has been lightly surveyed, more thorough sampling in this area could reveal more information.

Another main focus, especially for the 2015 field season, is going to be determining the extent of the impact the Carlton Complex fire had on the established, southern western gray squirrel population. This will be done by both re-sampling areas from 2014 (surveyed shortly after the fire) as well as expanding to other known populations surveyed by Katie Stewart and WDFW. Additionally, we will survey areas which have had new western gray squirrel sightings (such as those in the Carlton area) post-fire which had no western gray squirrel observations pre-fire.

Improvements in hair-sampling tube and other non-invasive sampling methods

A possible modification to the current hair tube design would be to add metal brushes to either side of the sticky tape. This may prevent squirrels from chewing off tape and could pick up additional hair samples.

A possible solution to the problem of insufficient hair samples in areas strongly suspected to have western gray squirrels is to use their chew marks to identify them. Western gray squirrels appear to be the only species which chews the ABS tubing and they leave distinct tooth marks. If we can classify the presence of these chew marks as at least possible, if not confirmed western gray squirrel presence, this may dramatically increase our positive samples. In order to ensure the marks came from a western gray squirrel at the site at which the tubes were deployed (as opposed to marks from previous years) we have cut off the chewed ends of the tubing.

An expansion on the previously used method of pairing motion detecting cameras with tubes could be to systematically place cameras with tubes in known western gray squirrel areas and observe how often squirrels visit the tubes. If identifiably different squirrels visit the same tube or if the same squirrel visits a tube multiple times, this could help us gather better population estimates or identify further method modifications needed for tubes (e.g. how often they are checked.)

Assessing habitats that western gray squirrels occupy

Pacific Biodiversity Institute wants to learn more about the habitat that western gray squirrels utilize. In areas where western gray squirrel hair was collected in hair-sampling tubes, sightings occurred, or nests were found, we initiated detailed habitat field surveys to accurately describe tree density and size, and plant community composition. In 2014, we included plant species lists and percentages, densitometer readings and additional data in the burned areas (see Appendix A1 and A2.) Eventually, we will compare our findings among regions in the upper Methow Valley and between regions previously surveyed in the lower Methow Valley, the South Cascades, and Puget Trough to determine whether there are regional specific habitat preferences.

During the 2010 - 2011 field seasons, we used GIS software to create habitat polygons around areas where western gray squirrels were present that appear to have similar forest structure (i.e., relatively uniform habitat conditions) based on aerial photographs. We also created polygons around habitats with relatively uniform conditions immediately adjacent to the polygon with dissimilar habitat conditions containing the positive western gray squirrel hair-sampling tube or nest. These surrounding habitat types might also be utilized by western gray squirrels. Within each polygon, we created a fixed grid in GIS which identified equidistantly spaced sampling points. The GPS coordinates for these sampling points were recorded and we centered our detailed habitat surveys at each of these sampling points. At each sampling point, we used a basal area factor of 20 to sample trees and snags and recorded the tree species, height, and diameter at breast height for each tree within the variable radius plot. We also recorded the number of trees in smaller size categories (0-1, 1-3, 3-5 inch diameter trunks) and decay classes of dead trees within an 8.5 m radius plot. Additionally, we assessed the habitat plant associations for each polygon by walking through the polygon and characterizing the dominant trees, shrubs, and herb species and noting an estimated forest canopy cover to one of six Daubenmire cover classes. The percent cover classes of each in addition to percent cover classes of nonorganic habitat such as gravel. The polygon was also characterized by land-use impacts such as grazing and erosion. The labor-intensive methodology of these habitat surveys only allowed time for assessing five polygons in the Benson Creek watershed where there were frequent western gray squirrel sightings and two nests (Figure 13). One polygon was also characterized in the Chewuch River watershed. Future work includes surveying additional polygons in the Chewuch River watershed and other areas where western gray squirrels were determined to occur.

During the 2011 - 2014 field seasons, we used previously gathered data as a base to identify possible new and expanded areas occupied by western gray squirrels. During the beginning of the 2014 field season, we focused mainly on assessing the extent of the lower Chewuch squirrel

population, both covering areas known to have western gray squirrels as well as expanding samples to the north, south, east and west of the known population.

One further aspect of analysis is to explore the possible correlation between western gray squirrels and red squirrels. Through camera footage, we know both western gray squirrels and red squirrels occupy the same area and will visit the same tubes. However, more than once red squirrels have been observed to enter the tube without leaving hair on the tape. This could mean our samples are skewed; recording fewer red squirrel hair samples than are actually present. Another question is the possibility that red squirrels are out-competing western gray squirrels for the walnuts around the tubes (or in some cases, even inside the tubes if the red squirrels manage to remove the inner walnut before a gray squirrel can find it.) Red squirrels are known to be more aggressive than western gray squirrels; this could mean exclusion both in habitat and in sampling.

Mapping both these potential correlations as well as other rodent species (yellow-pine chipmunk and bushy-tailed woodrat) in a rodent presence/absence could provide additional clues as to which areas rodents in general occupy or avoid. This will further our efforts in identifying the most likely habitat for western gray squirrels and rodents in general.

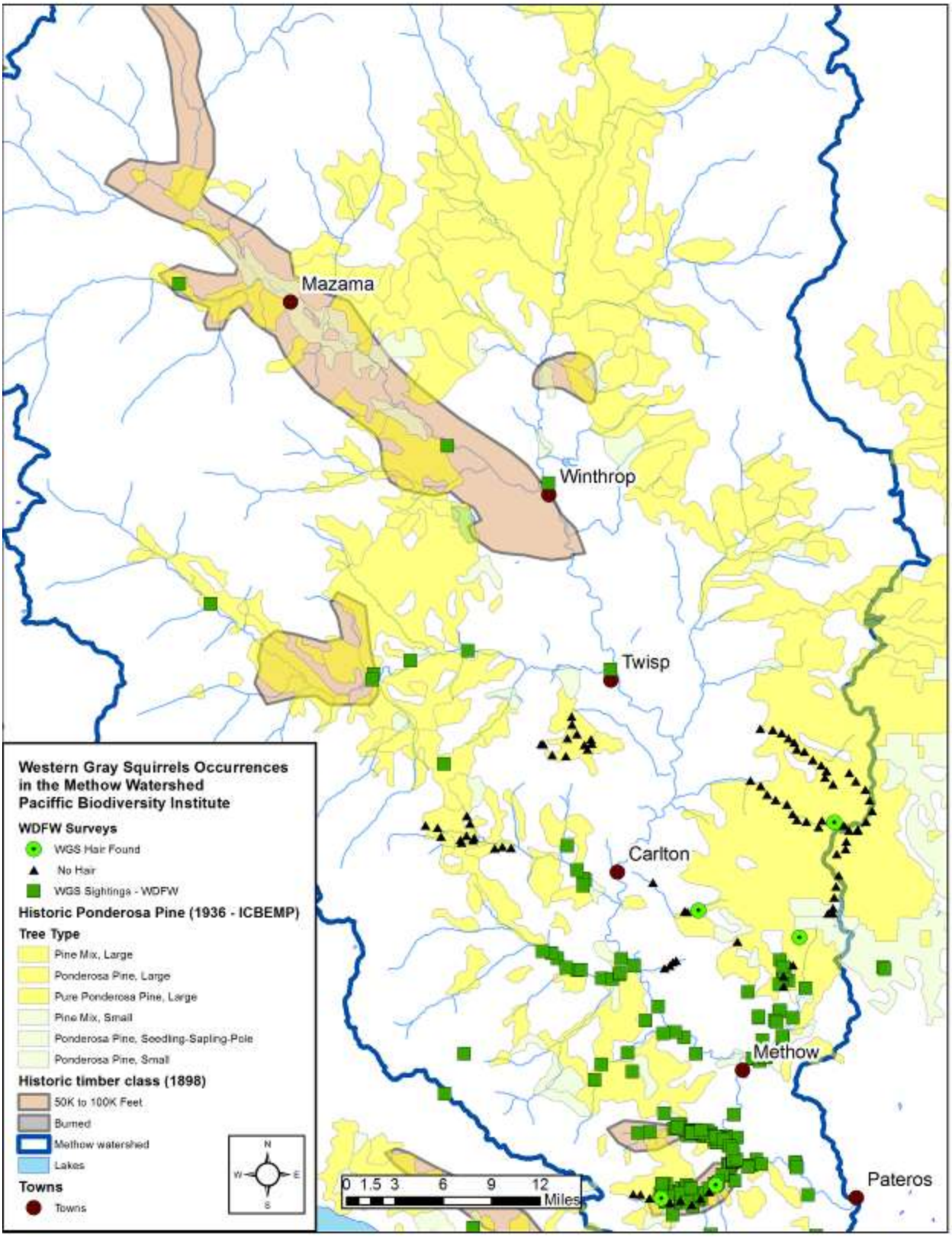


Figure 13. Study Area for western gray squirrel hair-sampling tube distribution survey overlaid on 1898 and 1936 maps of large timber and ponderosa pine habitats. Historical sightings and results of hair tube surveys conducted by WDFW are also shown. The 1898 map is from Gorman. 1936 map is from the Interior Columbia Basin Ecosystem Management Project (Bureau of Land Management and Forest Service).

Figure 14. Vegetation polygons (purple outline) and sampling points (yellow triangles) for detailed habitat field surveys in the Benson Creek watershed.

Connectivity between areas occupied by western gray squirrels

Our findings of where western gray squirrels are distributed in the upper Methow Valley have generated questions of corridor connectivity between occupied areas, dispersal between these locations. Future work may concentrate on existing connectivity as corridors for western gray squirrels in the Methow Valley. These connections are vital to recovery efforts which aim to help maintain healthy populations of western gray squirrels since young squirrels disperse when they are weaned from their mother, males travel substantial distances to find females that are in estrous one day out of the year, and squirrels travel to find food resources (Linders & Stinson 2007). Corridors between individual gray squirrel home ranges and between source population centers are vital to increase genetic variability within a breeding population since low genetic diversity is a threat to western gray squirrels in Washington State (Linders & Stinson 2007).

There may be potential movement corridors on larger (Figure 15) and smaller scales (Figure 16) between regions we have identified as occupied by western gray squirrels. Future studies can help determine whether individuals move along river riparian zones, or stay within ponderosa pine and/or Douglas-fir forests. An effort could be made to determine large landscape connections, such as whether and how western gray squirrels disperse between major watersheds as well. An example of dispersal was observed on June 17, 2000, when a western gray squirrel was observed at high elevations in open, whitebark pine forests along the Chelan-Sawtooth Crest (Morrison 2000, personal communication and WDFW Heritage sighting database).

Western gray squirrels have been recorded traveling several kilometers per day (Katie Stewart) and, based on the amount of road-killed squirrels, we know they are willing to cross roads. Movement caused by disturbances such as wildfires are another aspect of where squirrels might travel to or away from and their willingness to use or avoid burned areas as corridors. Preliminary observations from sightings suggests squirrels may be leaving burned areas in favor of near-by residential habitats where walnuts are present (e.g. Carlton. See Figure 10.)

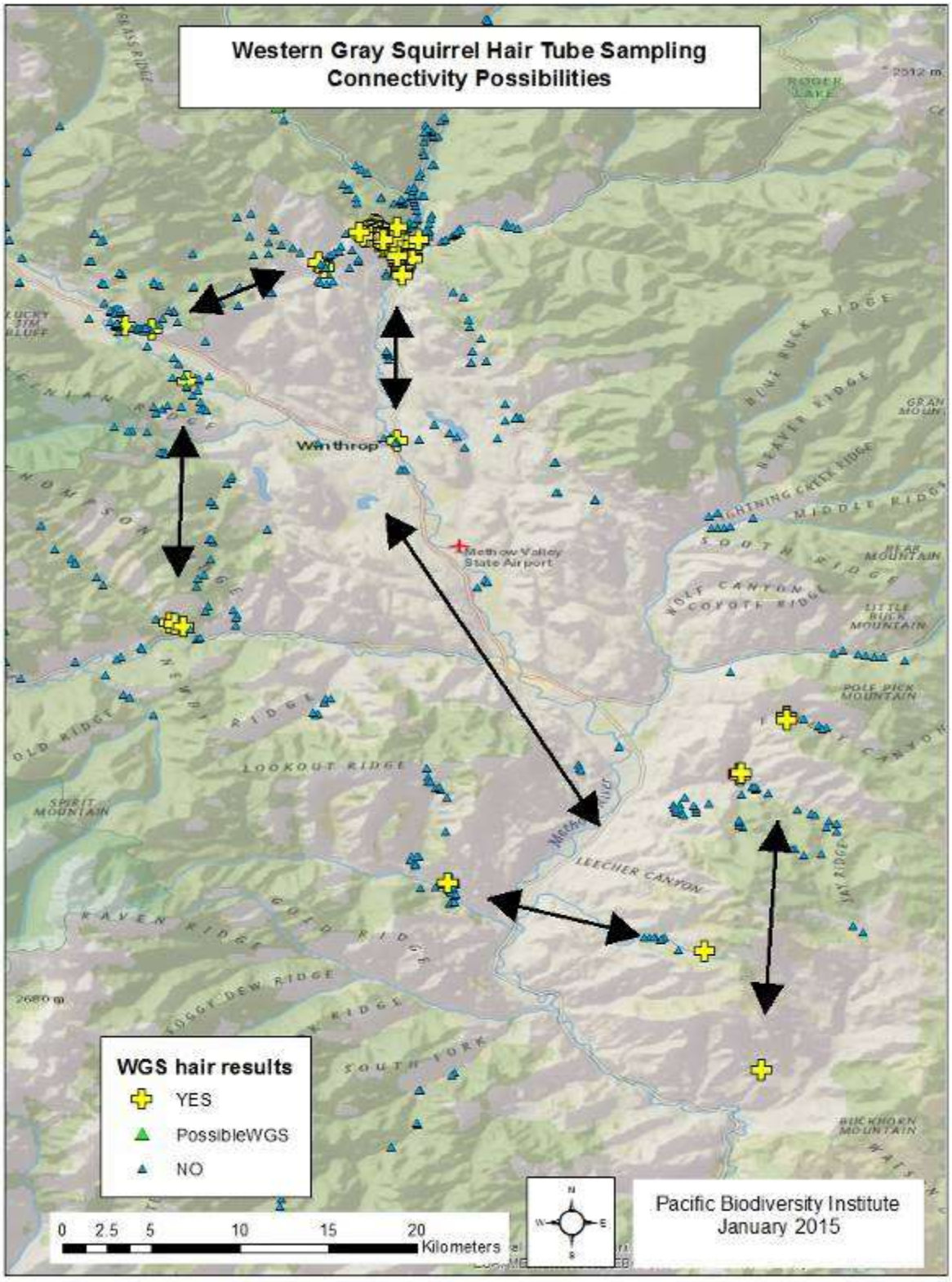


Figure 15. Potential corridors of connectivity (black arrows) between known western gray squirrel locations in the upper Methow Valley, between known populations in the lower Methow Valley, or even between the upper and lower populations.

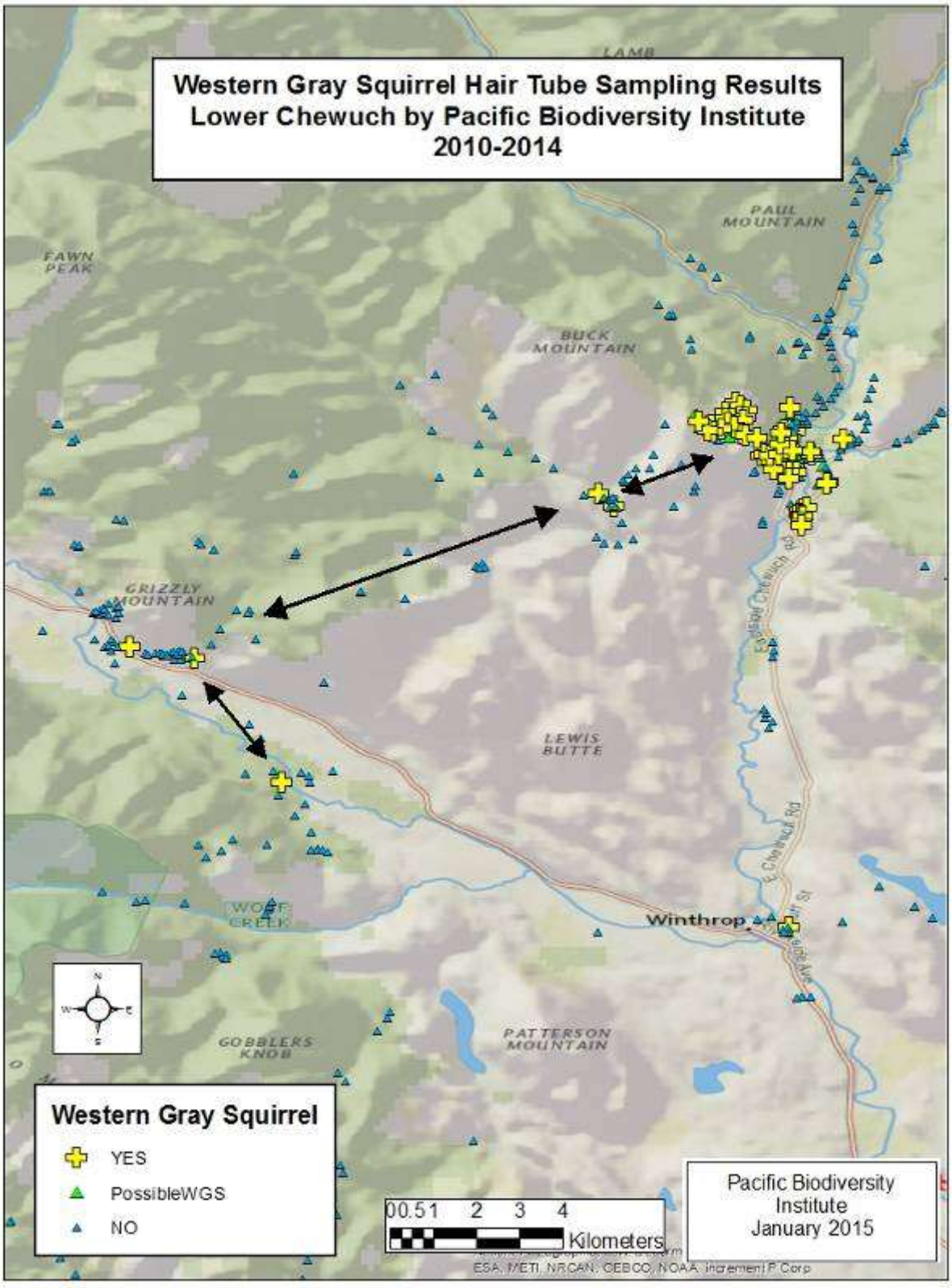


Figure 16. Potential corridor of connectivity (black arrows) between western gray squirrel locations in the Chewuch River watershed and the Cub Creek watershed.

Reducing road-killed western gray squirrels

We are interested in reducing the number of road-killed western gray squirrels in the Methow Valley. Volunteers were urged to record any road-kill western gray squirrel sightings on car trips. Some volunteers even agreed to pick up road-killed western gray squirrels they saw, which PBI obtained to send a DNA sample off for a genetic mapping project (Matthew Vander Haegen, pers. comm.) Recording road-kill locations and sighting date may help determine seasonal use of more established routes used by western gray squirrels. One possibility for reducing road-kill deaths is to identify areas where road-kill accidents are at a higher density and erect warning signs urging motorists to slow down since this is a road crossing area for the state threatened western gray squirrels. Common road crossing areas for western gray squirrels may put them at a high mortality risk and hinder recovery efforts.

Western gray squirrel conservation implications

Our study has helped identify 15 new western gray squirrel areas, which has expanded the knowledge base for the upper Methow Valley, a northern part of their distribution range. Over the years of this study, western gray squirrels have been observed in a wider range in the upper Methow than had previously been established. While further study is needed, assessment of the effects wildfire has on western gray squirrels is an important conservation aspect to consider, especially moving forward as the climate changes.

Cameras studying their behavior have been documented. Landowners and managers may make informed management practice decisions knowing they have western gray squirrels in the vicinity. Our study provided important information for agencies, private landowners, and local working groups for ongoing management activities such as timber harvest, prescribed burning, and livestock grazing that could potentially affect western gray squirrels and their habitats. The beginnings of analysis on natural disturbance events such as fires have also been provided. Our findings of western gray squirrel distributions will also help guide conservation prioritization of western gray squirrel habitats by local conservation agencies in Okanogan County.

Additionally, our community education component has allowed locals to be aware of their "backyard biodiversity". We have accomplished this through various talks, demonstrations, and educational videos posted on our website as well as YouTube. During our community education, we suggested potential ways to enhance western gray squirrel habitat. Suggested enhancements include promoting the growth of large trees which squirrels use for feeding and nesting, maintaining tree canopy connection so squirrels can travel between trees, and avoiding livestock overgrazing which leads to erosion and habitat degradation of squirrel foraging areas.

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Appendix A1 - Western Gray Squirrel Hair-sampling tube Survey Datasheet (2014 version)

Western Gray Squirrel Hair Tube Survey Datasheet 2014 (front)

Location ID: _____ **Watershed:** _____ **Tube Number:** _____
Observers: _____ **Date Deployed (mm/dd/yyyy):**_____
GPS Waypoint ID(s) (note if offset): _____ **GPS Name:** _____
GPS Accuracy: _____ **GPS Lat:** _____ **GPS Long:** _____ **GPS elev**: _____
Flagging color & location: _____ **Landowner consent obtained?** Y N Public
Dominant Overstory: Ponderosa Douglas_Fir Cottonwood Other _____
Dominant Understory: Grass/Forbs Shrubs Bare-Ground Shrub/Young-Conifers Pine Needles
Photo Numbers:_____**Notes:**_____
_____
_____

Date Checked: _____ **New Tube No. if changed**: _____ **# Walnuts missing**: _____
Tube: Present Rolled Missing **Hair Collected:** Y N **Tube**: Rebaited (same location) Removed
Notes:
_____
_____

Date Checked: _____ **New Tube No. if changed**: _____ **# Walnuts missing**: _____
Tube: Present Rolled Missing **Hair Collected:** Y N **Tube**: Rebaited (same location) Removed
Notes:
_____
_____

Date Checked: _____ **New Tube No. if changed**: _____ **# Walnuts missing**: _____
Tube: Present Rolled Missing **Hair Collected:** Y N **Tube**: Rebaited (same location) Removed
Notes:
_____
_____

Western Gray Squirrel Hair Tube Survey Datasheet 2014 (back)

Location ID: _____ Tube Tree DBH: _____ ____in.

Tree % cover: _____ spp. _____

Shrub % cover: _____ spp. _____

Herb % cover: _____ spp. _____

Grass % cover: _____ spp. _____

Densiometer Non-occupied points: _____ _____ _____ _____

Animals/notes:

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Appendix A2 - Western Gray Squirrel Hair-sampling tube Survey Datasheet for Burned Areas (2014 version)

Western Gray Squirrel Hair Tube Survey Datasheet 2014 (front)

Location ID: _____ **Watershed:** _____ **Tube Number:** _____
Observers: _____ **Date Deployed (mm/dd/yyyy):**_____
GPS Waypoint ID(s) (note if offset): _____ **GPS Name:** _____
GPS Accuracy: _____ **GPS Lat:** _____ **GPS Long:** _____ **GPS elev**: _____
Flagging color & location: _____ **Landowner consent obtained?** Y N Public
Dominant Overstory: Ponderosa Douglas_Fir Cottonwood Other _____
Dominant Understory: Grass/Forbs Shrubs Bare-Ground Shrub/Young-Conifers Pine Needles
Photo Numbers:_____**Notes:**_____
_____
_____

Date Checked: _____ **New Tube No. if changed**: _____ **# Walnuts missing**: _____
Tube: Present Rolled Missing **Hair Collected:** Y N **Tube**: Rebaited (same location) Removed
Notes:
_____
_____

Date Checked: _____ **New Tube No. if changed**: _____ **# Walnuts missing**: _____
Tube: Present Rolled Missing **Hair Collected:** Y N **Tube**: Rebaited (same location) Removed
Notes:
_____
_____

Date Checked: _____ **New Tube No. if changed**: _____ **# Walnuts missing**: _____
Tube: Present Rolled Missing **Hair Collected:** Y N **Tube**: Rebaited (same location) Removed
Notes:
_____
_____

Western Gray Squirrel Hair Tube Survey Datasheet 2014 (back)

Location ID: _____ Tube Tree DBH: _____ ____in.
Tree % cover: _____ spp. _____
Shrub % cover: _____ spp. _____
Herb % cover: _____ spp. _____
Grass % cover: _____ spp. _____
Densiometer Non-occupied points: _____ _____ _____ _____
Animals/notes:

Tree Canopy Cover:
spp 1: _____ ____% spp 2: _____ ____% spp 3: _____ ____% spp 4: _____ ____%
Ground Cover:
Living vegetation: ____% Needle cover %: _____ Bare ground %: _____ Charcoal %: _____
Tree Bole: Char height: _____ Scorch height: _____
Tree Condition Color: Black: _____% Brown: _____% Green: _____% Very Green: _____

Appendix B - Discussion of Western Gray Squirrel Hair Tube Design

This year, a Pacific Biodiversity Institute volunteer who has western gray squirrels around his house observed a squirrel going for a walnut in a tube and getting stuck in the tube. It eventually got out of the tube, but apparently it required some time and effort. Last year, he photographed a western gray squirrel adjacent to one of the tubes (Figures 1 and 2). From these photos, it is apparent that the squirrel is quite large in comparison to the three-inch diameter tube opening, particularly if you consider the constriction caused by the metal plate and sticky tape.

Figures 1 and 2: Photographs of a western gray squirrel adjacent to hair tube on Olson property.

During Pacific Biodiversity Institute's monitoring of sampling tubes for western gray squirrels, we occasionally find a tube that has been nibbled on the ends or rolled away from where it was set. Last week (2011 July 20) we visited a site on the Chewuch River and found a tube that had approx 4 inches chewed off of one end and 1 inch chewed off the other and had been rolled approx 30 feet (Figure 3 and 4). The angle of the extensive bite marks on the tube ends indicate chewing occurring from outside of the tube and looked to be caused by squirrel teeth. Western gray squirrel hairs were present on the sticky tape on both sides of the tube, but the interior walnut was still glued to the interior of the tube, indicating that the squirrel was probably trying to get the nut but eventually relented.

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Figures 3 and 4: Photographs of damage to hair tube 314, location LOCH102

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About 1 inch was chewed off both ends to a nearby tube and the walnut was taken (Figures 5 and 6). Again, the angle of the bite marks to the tube ends indicates the chewing occurred from outside of the tube. Western gray squirrel hair was present on both sticky pads. Both the exterior and interior walnut was removed from the tube. In addition, the tube had been significantly moved from its original position.

A third tube in the vicinity was completely missing. The cause was unknown, except that it was not in an area where people were likely to visit. This last tube was on a steep slope, where it could have rolled, but we did not find it despite an intensive search of a 100-feet radius of the original tube location.

Figures 5 and 6: Photographs of damage to hair tube 281, LOCH 101

Appendix Discussion

These various pieces of evidence lead us to wonder if the 3" diameter and 18" long ABS tubes that we are using are too small and/or too long for some of the larger western gray squirrels that are found in this area to successfully reach the interior walnut.

We are concerned that the design of the 3-inch tubes may not be optimal for non-invasive sampling of western gray squirrels that sometimes are larger than the 3-inch opening. While the squirrels probably leave hair stuck to the sticky tape in their effort to get to the interior walnut, they may occasionally get stuck in the tubes. They also seem to have a habit of chewing up a lot of ABS material in their efforts to get to the interior walnut. That could be somewhat harmful to the health of the squirrel as ABS is not known to be an essential nutrient or completely inert.

We are interested in getting more information that might inform us about whether the sampling tube design could be optimized, both for the comfort and safety of the squirrel and for sampling effectiveness. We are interested in knowing what other researchers may know about tube design, materials, diameter and length. We also wonder if the western gray squirrels that we are encountering in the upper Methow Valley might be slightly larger than the squirrels in western Washington, where the hair-sampling technique was first employed. It could be that a slightly large tube diameter might be appropriate here.

To help answer these questions, we are engaged in a small comparison trial of several alternative tube diameters and lengths. We are interested in learning if any others have conducted similar trials.