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Monitoring Western Gray Squirrels for Landscape Management in Western Washington

Abstract

Western gray squirrels (*Sciurus griseus griseus* Ord) are rare in western Washington and population distribution information has proven difficult to gather. A variety of standard survey methods employed on the Fort Lewis Military Reservation in southern Puget Sound in 1998-99 yielded limited results, likely due to the squirrel's elusive behavior and low-density population. We tried a new survey approach in 2004 using hair-snare tubes, which proved successful in providing information on the distribution of habitat used by western gray squirrels and eastern gray squirrels, the latter previously unknown to be resident in the interior woodlands. The hair-snare tubes also contributed information on habitat use by western and eastern gray squirrels during management actions such as timber cutting and eastern gray squirrel trapping. Knowledge of squirrel distribution allowed managers to strategically allocate resources to improve habitat. Hair-snare tubes are relatively inexpensive to construct and easy to install, and have the potential to provide distribution information on squirrel populations that are widely distributed or occur at low densities, and difficult to detect visually. At the same time, interpretation of results obtained from hair-snare devices are constrained by unknowns regarding numbers of individuals depositing hair samples, and inter- and intra-specific behavioral interactions that influence hair deposition patterns. Despite the drawbacks, knowledge gained from hair-snares can serve as a basis for management planning and lead to the application of other direct study techniques, such as radio-telemetry, that are likely to yield more detailed information.

Introduction

Western gray squirrels (*Sciurus griseus griseus* Ord) have become increasingly rare in Washington, and were listed as 'threatened' by the Washington Department of Fish and Wildlife in 1993. A recovery plan prepared for the species in Washington (Linders and Stinson 2007) includes population monitoring as an important recovery task. Recovery, protection, and adaptive management of a threatened species requires monitoring to detect changes in distribution, abundance, habitat use, and response to management activities. Distribution information is critical to the identification of high priority areas for protection or implementation of management actions intended to enhance the habitat of a target species.

The last known population of western gray squirrels west of the Cascade Mountains in Washington is centered on the Fort Lewis Military Reservation at the southern edge of Puget Sound (Washington Department of Wildlife 1993) (Figure 1). Considerable distribution and natural history information was gained from this population in the early 1990s using visual survey and focal follow study techniques (Ryan and Carey 1995). By the late 1990s, however, squirrel numbers on Fort Lewis had apparently declined to a level where a variety of traditional survey techniques failed to provide more than a few observations (Bayrakçi et al. 2001). Alternative survey and monitoring approaches were sought.

Surveys based on repeat visits to sample sites to note presence or absence of sign (e.g., hair, feces, tracks, nests) offer good potential for long-term monitoring programs for rare and/or elusive species (McDonald 2004). Hair-snare devices have proven successful for detecting the presence of mammals, especially carnivores (Woods et al. 1999, McDaniel et al. 2000, Boulanger et al. 2002, Belant 2003, Clark et al. 2003, Weaver et al. 2005, Schmidt and Kowalczyk 2006, Depue and Ben-David 2007, Kendall and McKelvey 2008), and small mammals (Suckling 1978, Lindenmayer et al. 1999, Scotts and Craig 1988), including squirrels (Gurnell et al. 2001, John L. Koprowski, University of Arizona, personal communication). Hair-snares are a relatively simple, noninvasive and inexpensive tool for drawing mammals to a baited device to obtain dorsal guard hairs. Dorsal guard hairs can then be identified to species or

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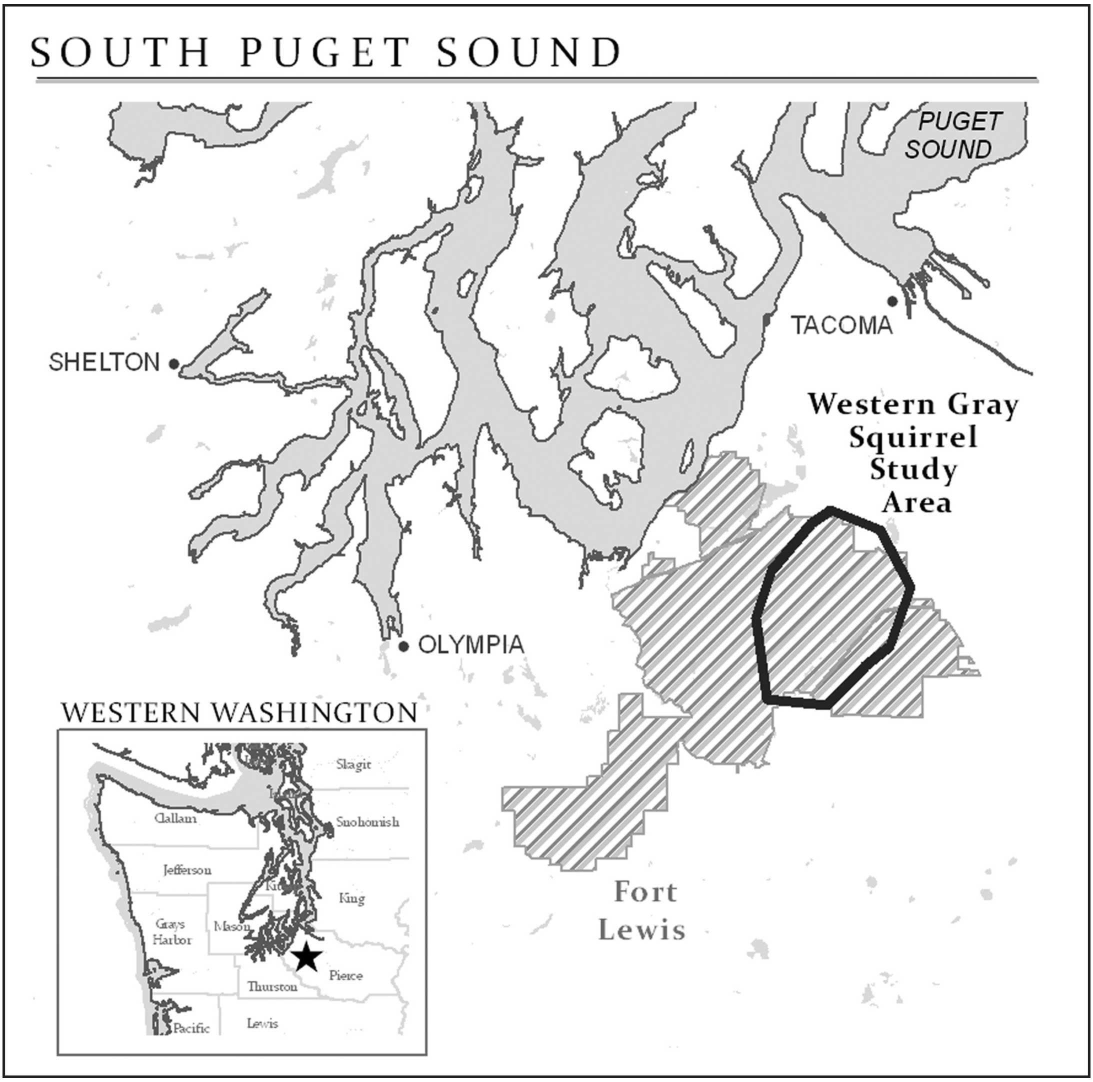

Figure 1. Map of western Washington showing the outline of the main western gray squirrel study area within the Fort Lewis Military Reservation (diagonal stripes), 2004–2007.

genera by microscopic examination of various morphologic features (Moore et al. 1997). Hair-snares can provide information on occupancy or habitat use patterns but do not normally yield abundance data for a population. Visual surveys can be an effective method of surveying squirrel populations, and if conducted systematically, may provide an index of relative abundance (Gurnell et al. 2001). Visual surveys were successful in detecting the presence of western gray squirrels on Fort Lewis in 1992-93 (Ryan and Carey 1995), but detected few (5) squirrels in 1998 and none in 1999 (Bayrakçi et al. 2001).

Our goal was to determine if hair-snare tubes could detect the presence of western and eastern gray squirrels (*Sciurus carolinensis*) on Fort Lewis, the former having recently proven difficult to detect, and the latter a species not known to be resident within the interior of Fort Lewis woodlands. As a corollary, we sought a means of discriminating among the hairs of sympatric tree squirrel species to allow identification of hair samples to species. To complement the presence – absence data from the hair snares, we added visual surveys directed in time and space to determine if we could obtain squirrel observations to generate an index of relative abundance in five high-use sites. We describe the hair-snare devices and characteristics for identifying the hairs of three sympatric tree squirrels in western Washington, along with results of our hair-snare and directed visual surveys to provide an update on the status of western gray squirrels on Fort Lewis.

Methods

Study Area

The Fort Lewis Military Reservation is a Department of Defense (U.S. Army) training installation in central western Washington near the southern end of Puget Sound (Figure 1). It contains 31,800 ha of relatively undeveloped lands comprised of forest, woodland, wetland, and grassland habitats used for training purposes. The 21,800 ha of forest vegetation is primarily coniferous and dominated by Douglas-fir (*Pseudotsuga menziesii*), but includes 1,093 ha of Oregon white oak (*Quercus garryana*) and oak-conifer woodlands, and 1,296 ha of hardwood forest (Fort Lewis 2006). Fort Lewis is distinguished as having the largest (700 ha) natural population of ponderosa pine (*Pinus ponderosa*) west of the Cascade Range in Washington (Foster 1997). In addition to the western gray squirrel, other squirrels present include the Douglas' squirrel (*Tamiasciurus douglasii*), northern flying squirrel (*Glaucomys sabrinus*), and the non-native eastern gray squirrel. The terrain is generally level with scattered depressions and rolling hills.

Current efforts addressing western gray squirrel conservation and research center on approximately 4,000 ha in the north-central portion of the military reservation (47°00-06'N, 122°26-34'W) where previous research yielded higher concentrations of western gray squirrel sightings compared to other areas on the reservation (Ryan and Carey 1995). This area is characterized by an interspersion of marshes, lakes, streams and associated riparian and upland vegetation communities. Oak associated communities are typically ecotonal between dry or moist prairie and conifer or other hardwood habitats (Thysell and Carey 2001).

Management activities to benefit western gray squirrels on Fort Lewis emphasize restoration of oak communities to approach presumed historical conditions prior to European settlement (Chappell et al. 2000, GBA 2002, MacDougall et al. 2003, Gedalof et al. 2006). Activities include mowing, herbicide treatments, and prescribed fire to reduce dense concentrations of understory shrubs, especially non-native Scot's broom (*Cytisus scoparius*) and Himalayan blackberry (*Rubus armeniacus*) in oak conifer stands. Timber removal operations and conifer girdling favor oaks and other hardwoods beneficial to squirrels. The creation of cavities for squirrels in forests with a diminished snag component, due to timber management activities, is expected to increase opportunities for maternal den sites, as female western gray squirrels raise young in tree cavities elsewhere in Washington (Linders et al. 2004). Longer-term efforts include planting concentrations of large shrub and tree species that provide squirrel foods adjacent to oak-conifer stands. Most recently, an eastern gray squirrel trap and removal trial was implemented to investigate the efficacy of this management tool for limiting the presence of the non-native squirrel in a priority conservation zone for the western gray squirrel.

Hair-Snare Tubes

Hair-snare tubes were a 38 cm length of black 7.6 cm diameter Acrylonitrile Butadiene Styrene (ABS) pipe with double-sided sticky mounting tape attached to a flat metal bar inside the roof of the tube on either end (Figure 2). Whole walnuts in the shell were used as bait. Most walnuts were loose, but one walnut was glued in the center of the tube to: a) provide a longer-lasting bait in the event of walnut removal by non-target species, and b) cause the squirrels to expend more effort

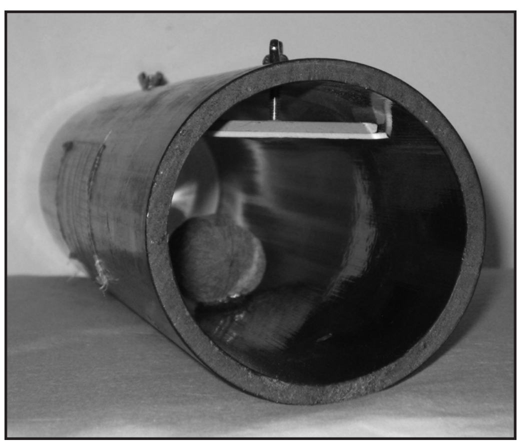

Figure 2. Close-up of hair-snare tube used for detecting the presence of gray squirrels on Fort Lewis, WA.

Figure 3. Hair-snare tube secured by deadfall and investigated by a western gray squirrel, Fort Lewis, WA, April, 2006.

in the tube to remove the secured bait, thereby increasing the likelihood of leaving multiple hairs affixed to the tape. Tubes were generally placed on the ground at the base of a large conifer with relatively sparse ground cover, and secured with natural materials such as deadfall, pliable sticks, or rocks (Figure 3). Oak-conifer and adjacent conifer stands were targeted based on characteristics of suitable habitat described by Ryan and Carey (1995). A minimum of 2 tubes were located 100 – 200 m apart within a stand and examined at intervals of 4 to 12 weeks to recover hairs on the sticky tape, which were then identified under a microscope. We installed and monitored 356 hair-snare tubes from February 2004 to December 2007. We conducted more frequent monitoring at intervals of three to six weeks in one oak-conifer stand to document habitat use by resident squirrels during two management actions. A timber cutting operation to remove oak-shading conifers and improve oak habitat was the first management action in December 2005. In March and April 2006, four eastern gray squirrels were trapped and removed from the stand as part of a larger trap and removal effort.

Hair Identification

We examined reference sets of dorsal guard hairs from western gray squirrels, eastern gray squirrels, and Douglas' squirrels with the aid of a 30X binocular dissecting scope to establish criteria for distinguishing among the hairs of the three largest Sciurid species occurring in the study area. A combination of characteristics, based largely on the color and size of alternating light and dark bands of individual hairs, was used to distinguish among species. The combination of intra-specific and inter-specific variability in some of these characteristics confounded the identification process. To address this, we developed a four point 'confidence rating' scheme, based on the presence of specific characteristics, to quantify the level of confidence in the accuracy of the species' identification for each hair sample (Table 1).

Directed Visual Surveys

We conducted weekly visual surveys directed in time and space to maximize squirrel observations at five sites where western gray squirrels had consistently been detected by hair-snare tubes (Figure 4). We targeted the time of day (07:30 a.m. – 12:00 p.m.) and season (26 August to 26 September) when the squirrels were most likely to be active based on previous research (Ryan and Carey 1995, Bayrakçi et al. 2001). All surveys were conducted under fair weather conditions (no high winds, rain, or unusual weather) by a single observer to maximize consistency of detection

TABLE 1. Characteristics of dorsal guard hairs of western gray squirrels, eastern gray squirrels, and Douglas' squirrels on Fort Lewis, WA. Each characteristic counted as one point on a four point confidence rating scheme for sample identifications.

Species	Characteristics for Identification Confidence Ratings
western gray squirrel	clear or white bands present complete absence of cream or yellow bands majority of black bands at tip relatively long (>1.25 mm) ≥ 10 hairs present
eastern gray squirrel	cream or yellow bands present distal yellow or clear or white band relatively long (>1.25 mm) and variable where clear or white distal band present, the black band at tip is relatively short (<1.25 mm) or absent ≥ 10 hairs present
Douglas' squirrel	yellow or orange bands present absence of clear or white bands distal yellow band short (≤0.75 mm) and consistent length among hairs of sample ≥ 3 hairs present

probabilities among sites. Following the protocol described in Ryan and Carey (1995), stands were surveyed by the observer walking slowly along the edge or through the interior of stands at 1 – 1.5 km / hr, pausing every 10 to 15 min in suitable habitat to search for squirrels using visual and auditory cues.

Results

We made 2,080 visits to 356 hair-snare tubes between February 2004 and December 2007 yielding: 857 samples with no hairs, 1,184 samples containing hairs from either a western or eastern gray squirrel or Douglas' squirrel, 13 samples containing hairs from two species, and 26 hair samples classified as unknown because they did not possess any characteristics of the three species being monitored. The latter 26 samples were removed from the analysis. The majority of hair samples for all three species were identified with high confidence ratings of 4 (85% of all species' samples) and 3 (9%), both scores serving as acceptable identifications for purposes of this survey (Table 2). Unacceptable scores of 2, and occasionally 1, were infrequent, and generally due to low numbers of hairs in the sample. The distribution of western and eastern gray squirrel hair samples identified with confidence ratings of 3 or 4 is illustrated in Figure 4. Douglas' squirrel locations were not included in Figure 4 because this species is generally not considered a management concern for western gray squirrels, and additional symbols on the map would diminish clarity of the gray squirrel locations. Five sites where western gray squirrel hair samples were consistently obtained are identified with circles on Figure 4.

In an oak stand (Figure 4, Site A) monitored during two management actions, western gray squirrel hairs were consistently obtained from one to four hair tubes in the interior of the stand for 22 months prior to the timber cutting operation, while no eastern gray squirrel hairs were obtained during this time. Following the timber cutting, only eastern gray squirrels were detected in the stand for two months, while western gray squirrels were not. After the trap and removal of four eastern gray squirrels from the stand and adjacent environs, western gray squirrels were again detected in the stand, while eastern gray squirrel detections ceased.

We conducted two to three directed visual surveys in 2005 at each of the five sites consistently used by western gray squirrels, yielding a total of 11 observations of western gray squirrels and four observations of eastern gray squirrels during 14 hr of survey time. Western gray squirrel observations averaged 1 squirrel / 1.27 hr of survey time, with individual sites ranging from 0 squirrels / 3.22 hr to 1 squirrel / 0.44 hr (Table 3). Western gray squirrels were not observed at three of the sites targeted, despite collection of the species' hair samples in the hair-snares.

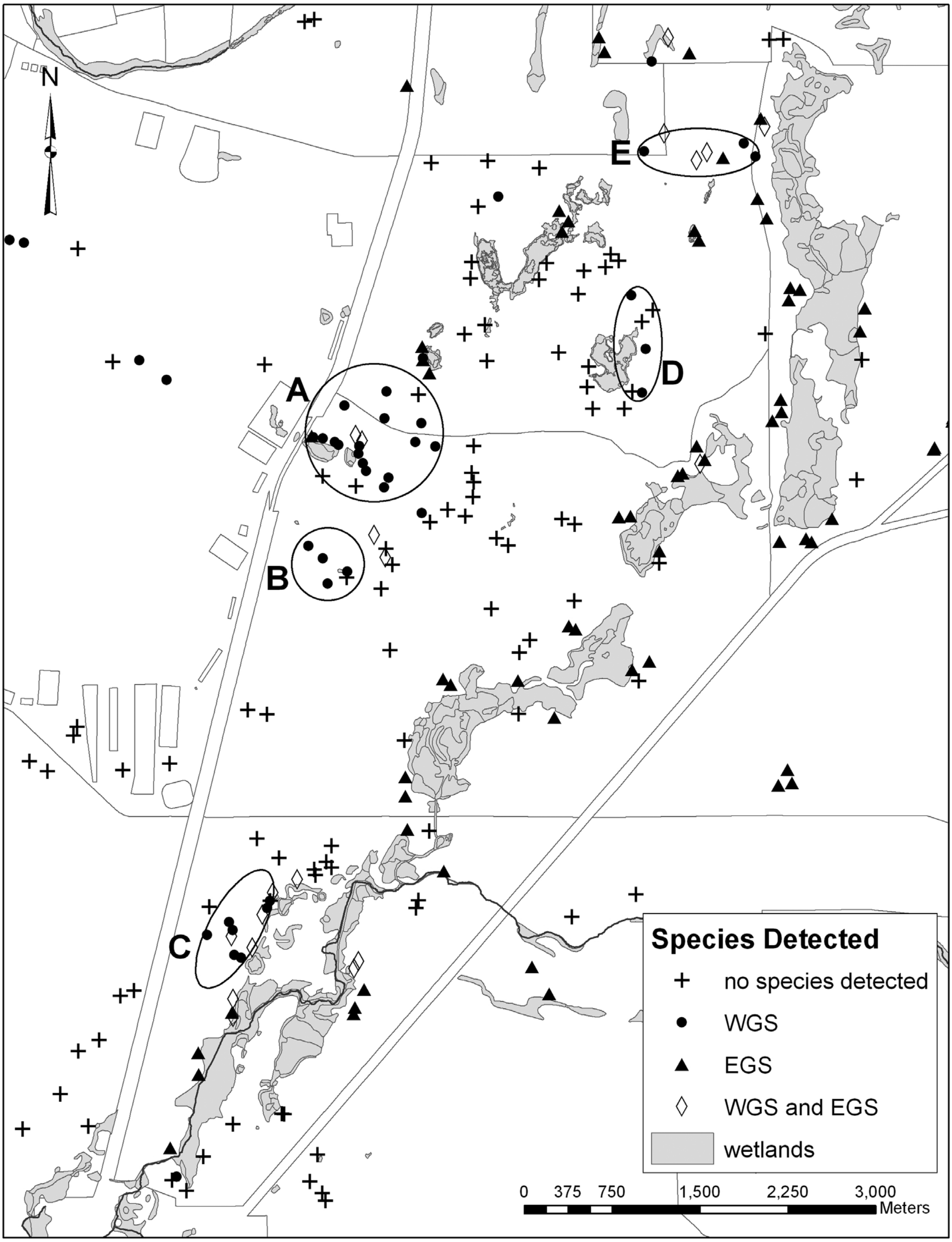

Figure 4. Map showing results of hair samples obtained for western (WGS) and eastern (EGS) gray squirrels using hair-snare tubes on Fort Lewis, WA, 2004 – 2007. Circles identify five sites where we consistently obtained western gray squirrel hair samples and conducted visual surveys in 2005.

TABLE 2. Results of hair samples obtained between February 2004 through December 2007, by confidence rating, on Fort Lewis, Washington.

	western gray squirrel				eastern gray squirrel				Douglas' squirrel			
confidence rating	4	3	2	1	4	3	2	1	4	3	2	1
number of samples	326	22	8	2	598	59	31	3	109	32	18	2
% of species' samples	91%	6%	2%	1%	87%	9%	4%	<1%	68%	20%	11%	1%
species' total	358				691				161			

TABLE 3. Comparison of visual survey results for western gray squirrels conducted on Fort Lewis, WA from 1992 until present.

Dates of Visual Surveys	Results of Visual Surveys
1992-1993 (Ryan and Carey 1995)	1 squirrel / 8.8 hr
1998 (Bayrakci et al. 2001)	1 squirrel / 107 hr
1999 (Bayrakci et al. 2001)	0 squirrels / 155 hr
2005 (this study)	1 squirrel / 1.3 hr (total from five sites)
	• Site A – 1 squirrel / 1.4 hr
	• Site B – 1 squirrel / 0.4 hr
	• Site C, D, E – 0 squirrel / 3.2 hr, 1.2 hr, 1.9 hr, respectively

Discussion

Survey data confirm that hair-snare tubes were capable of obtaining squirrel hair samples that could be identified with a high level of confidence. Thus, hair-snares proved useful in indicating the presence of western gray squirrels on Fort Lewis where they had previously been difficult to detect by a variety of more traditional survey methods (Bayrakçi et al. 2001). Baited hair-snare tubes used in this survey may have been more successful in detecting squirrels compared to conventional traps because success required only that the wary squirrel insert its head and shoulders into the hair-snare tube (Figure 3), and not the entire body as with conventional traps. The hair-snare tubes also revealed the presence of a low level population of eastern gray squirrels in interior woodlands on Fort Lewis, where this species had not previously been reported as resident. Despite the relatively large diameter of the hair-snares (7.6 cm), they also proved capable of obtaining hair samples from the smaller Douglas' squirrels. Douglas' squirrel samples tended to have fewer numbers of hairs compared to the gray squirrel samples, which contributed to the overall lower confidence rating scores for this species.

The current western gray squirrel distribution on Fort Lewis, based on our hair-snare results, is greater than that reported for 1998-99 (Bayrakçi et al. 2001), but contains fewer locales than the distribution generated by visual surveys within the same area in 1992-93 (Ryan and Carey 1995). The recent increases in western gray squirrel distribution revealed through hair-snare sampling, compared to the 1998-99 survey efforts, could be attributed to: a) increased detection of the low level population with the aid of an alternative detection technique, the hair-snare tubes, and / or b) an increase in population numbers following the decline reported in 1998-99. There are no data to support or refute either possibility, and we assume both factors contribute to our current observations.

Data obtained from hair-snare surveys can contribute to understanding impacts of management actions on gray squirrels. Our results reveal that dynamics of western and eastern gray squirrel hair-snare visitation, and potentially site use, may have been altered by the timber cutting and eastern gray squirrel trap and removal management actions. Hair-snare results cannot, however, provide a comprehensive summary of all squirrel activity in a given locale (see below). The potential usefulness of hair-snares in reflecting actual responses to habitat changes needs further exploration due to a variety of unknown influences on hair-snare visitation by squirrels.

As with most sign data, caution is warranted in interpreting presence-absence data (MacKenzie 2005) derived from hair-snares. Whereas the presence of a species can be confirmed by collection of hair in the snare tube, the absence of hair could result from the species being absent, or if present, avoiding use of the hair-snare device. False negative data are expected to occur where the probability of detection is < 1 for members of a population (MacKenzie et al. 2002). Factors that may decrease detection probabilities include behavior, especially wariness, which precludes visiting a hair-snare tube. Territorial behaviors, such as scent-marking by eastern gray squirrels (Taylor 1977, Koprowski 1994) could cause avoidance of hair-snare tubes by western gray squirrels. Additionally, if bait removal by non-target species consistently occurs before the target species investigates the tube, as could happen with non-target individuals habituated to the bait reward, target species' hair samples would not likely be deposited even though that species was present. Under these circumstances, the target species would falsely be considered absent from the hair-snare site. This may have been the case for western gray squirrels if there was an influx of eastern gray squirrels in the oak-conifer stand during the timber cutting activity. Directed visual surveys, focal follows, or camera traps could be employed as further investigative measures at sites where false negatives are suspected.

Hair-snare survey data are also limited in contributing to estimates of population abundance. In the absence of DNA analysis (Foran et al. 1997, Waits and Paetkau 2005) to provide individual identifications or abundance data, the information gained through hair tube sampling is limited to inferences derived from general presence - absence data. The addition of a second survey tool, directed visual surveys, has the potential to partially solve this problem by adding an index of relative abundance among sites or time periods, if the surveys are conducted systematically. The directed visual surveys we conducted in 2005 were successful in obtaining observations to calculate an index of relative abundance at two of the five habitats surveyed. The amount of survey effort at the other three sites was insufficient for visual detections, perhaps due to low numbers of squirrels or intermittent site use. In the case of extremely low habitat use by the target species, survey effort should be increased to provide sufficient opportunities to observe the species and ideally calculate detection probabilities leading to estimates of relative abundance (Conn et al. 2004), or abundance (Buckland et al. 2001), financial resources allowing. The potential for a survey to provide relative abundance information depends not only on the number of observations, but the survey's ability to meet the assumption that detection probabilities were consistent among sites or time periods (Conn et al. 2004). Data gathered in this study were insufficient to test the assumption of consistency of detection probabilities among sites. The surveys were designed *a priori*, however, to minimize variation in detection probabilities among sites by using a single observer, rotating the order of sites visited, restricting the search period by time of day and season, and focusing only on sites where squirrels were consistently detected by hair-snare tubes.

Despite a lack of observations at three of the sites, our total directed visual survey effort yielded relatively high observation rates compared with past survey results on Fort Lewis (Table 3). This disparity is most likely a function of the different survey objectives and designs. Previous surveys were conducted in a widespread searching manner to document the distribution of squirrels over a large area, whereas we targeted habitat regularly used by western gray squirrels to maximize the number of sightings to provide an index of relative abundance. Thus, directed visual surveys, coupled with hair-snare surveys, have the potential to gain observation data that could be useful for calculating relative abundance, or some measure of site use, in habitats frequented by wary squirrels.

Management Implications

As an initial phase when planning management actions for a low-level population over a large landscape area, hair-snares may offer a relatively inexpensive option for identifying habitats used by the target species. Our hair-snare tubes for squirrels cost about $3.50 in materials purchased from a local hardware store and welding shop, and were easy to install using natural materials on site. Once proficient, hair identification required one to two minutes per sample. Survey goals would determine sampling intensity and thus labor costs. Volunteers were incorporated in all phases of our survey, from hair-snare construction to sample collection and identification, making the snares ideal for use in citizen science programs. Whereas we deployed hair-snares in an unsystematic arrangement, targeting habitat characteristics derived from previous research (Ryan and Carey 1995) to maximize detections of western gray squirrels over a large area, more systematic arrays of hair-snares such as grid arrangements or transects could be employed where no prior data are available, or to gather information on a species' ecology such as characteristics of habitat use.

The distribution information derived from hair-snares also proved useful for the development of a second phase of research conducted by the Washington Department of Fish and Wildlife that incorporates radio-telemetry for both species of gray squirrel, and is providing more detailed information. Where funds allow, and if hair samples provide suitable genetic material, hair-snares may also offer a noninvasive approach to gather material for DNA analysis to generate abundance estimates (Foran et al. 1997, Boulanger et al. 2002, Waits and Paetkau 2005, Depue and Ben-David 2007). In summary, where squirrel or other mammal populations are difficult to detect using traditional study techniques, especially over a large geographical area, hair-snare monitoring may prove useful as a first phase technique to allow strategic implementation of beneficial management actions, directing visual or other survey techniques to occupied habitat, and planning for the application of other research tools designed to provide more detailed data to aid species' management.

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