Remote Camera Survey for Red Foxes

At Crater Lake National Park 2012

Maria Immel, Principal Investigator

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Permanent Address:
maria.immel@gmail.com
P.O. Box 1161, Willow Creek, CA 95573

SUMMARY

Information on red fox (*Vulpes vulpes*) within Crater Lake National Park consists almost entirely of incidental observations. Infrared remote cameras were deployed at 42 sites baited with scent lures during August and September 2012 for 585 effective trap nights. Camera locations were at elevations above 6000 feet in the vicinity of historical sightings. Red foxes were detected on 11 occasions over 8 nights at 7 sites. Genetic analysis of nuclear DNA from one opportunistically collected fur sample was unsuccessful, preventing definitive determination of the subspecific identity of the sampled fox. However, analysis did identify the composite mitochondrial haplotype 'A19', the most common mitochondrial haplotype identified in historical specimens of the Sierrra Nevada red fox (*V. v. necator*; hereafter SNRF). This is consistent with prior genetic analysis that determined SNRF were present within the park historically. SNRF, with only two known populations consisting of possibly less than 50 individuals combined, is currently under review by the U.S. Fish and Wildlife Service for listing as federally threatened or endangered and has been listed as threatened since 1980 in California.

ACKNOWLEDGMENTS

A number of staff at Crater Lake National Park contributed to the success of this small study. Greg Holm implemented the 2011 pilot camera survey which inspired this survey with the detection of a red fox. Steve Mark and Mary Merryman located the park's historical records of foxes. Mac Brock contributed the inspiration to conduct this survey as an independent researcher. The guidance of Sean Mohren and Wendy Wayne transformed the permitting process into a manageable undertaking. Elena Thomas and Lesley McClintok supplied precise locations of recent fox sightings; Jaclyn Carpenter, Kaitlin Keenon, Jeff Murphy, Paul Schauer, Chris Wayne, and Kathryn Williams reported credible fox sightings over the summer. Crater Lake National Park provided the use of 16 Scout Guard remote cameras, including SD cards and 128 rechargeable batteries. Last but certainly not least, Dr. Ben Sacks, Director of the Canid Diversity and Conservation Lab at University of California at Davis, offered information and encouragement as well as genetic analysis through the Veterinary Genetics Laboratory at University of California at Davis.

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BACKGROUND

Red Foxes within Crater Lake National Park

Information on red fox (*Vulpes vulpes*) within Crater Lake National Park (hereafter CRLA) consists almost entirely of incidental observations. The earliest known observations of red fox in CRLA in 1896 were of adults with young near both Watchman Peak and Castle Crest (Merriam 1897). In 1933 the first known CRLA wildlife census reported observation of one red fox and estimated the population size at 10. The report also warned "very vigorous patrolling will be necessary in order to prevent eradication of the fox in this Park" although foxes were "formerly very common". Between 1940 and 1946 annual population estimates were increased from 25 to 40 with accompanying reports of multiple observations of "several families", "numerous individual adults", and decreased trapping activity along the park boundary. The last available report from 1953 classified red fox as "uncommon" with "very few observations".

Although annual population estimates apparently ceased, incidental sightings continued to be reported through 2012. The park museum contains 133 incidental sightings reported between 1954 and 1992. More recent records are maintained in the office of the terrestrial ecologist. There are also two recent documented sightings prior to 2012: a black phase red fox photographed off Munson Valley Road above park headquarters in May 2009 and a red phase fox captured with a remote camera roughly one kilometer north of Lao Rock in September 2011.

Outside of Crater Lake there were 4 verified detections of red foxes in the Oregon Cascades between 1991 and 2011: a detection in the winter of 1993-1994 on the Umpqua National Forest approximately one mile north of CRLA, detections in the winter of 1998 and winter of 2000-2001 on the Rogue River National Forest, and a 2011 detection on Mt. Hood. Intensive surveying in the area of the Mt. Hood detection produced repeated detections of at least two individuals and researchers are currently attempting to collect samples for genetic analysis. Newspaper coverage in 2012 of the detections at Mt. Hood and CRLA prompted the reporting of 3 additional documented detections: near Santiam Pass roughly 100 miles north of CRLA in 2008 and 2009 and near Sparks Lake roughly 75 miles north northeast of CRLA in 2012.

Taxonomy and Genetics

The taxonomic identity of red foxes currently at CRLA is uncertain. Historically CRLA red foxes were considered to be members of the Cascade red fox (hereafter CRF) lineage which Merriam (1900) elevated to species status as *Vulpes cascadensis*. The distribution range outlined for CRF at that time included the Cascades of Washington and Oregon and the northern Sierra Nevadas. Merriam also assigned species status to the High Sierra Nevada red fox *V. necator*, and continued the species status of the Rocky Mountain red fox *V. macrourus*. However, by the 1930s all three mountain lineages of red foxes were assigned subspecific status within the North American red fox species *V. fulvus* (Bailey 1936, Grinnell et al. 1937). The current scientific name for CRF, *Vulpes vulpes cascadensis*, was assigned when Churcher (1959) determined that North American red foxes did not warrant species level separation from the red fox of Eurasia. However, for some time researchers have hypothesized the Columbia River isolates the CRF of Washington from the mountain red foxes of Oregon, which are more likely most closely related to the Sierra Nevada Red Fox *V. v. necator* (hereafter SNRF; Aubry 1983).

Recent studies (see Perrine et al. 2007, Aubry et al. 2009, Sachs et al. 2010, Statham et al. 2012a) have clarified the origins of the eleven subspecies of red foxes currently recognized in

North America. During the last glacial period members of the Nearctic lineage that was already present in North America lived south of the glaciers. By approximately 40,000 years ago climatic conditions had divided this lineage into eastern and western portions. When glaciers subsequently retreated northward and upward the foxes followed, presumably moving with the climatic conditions they were adapted to. Descendants of the eastern portion of the Nearctic lineage now occupy Central and Eastern Canada. Populations of the western portion of the Nearctic lineage became isolated in the western mountains, diverging into the three currently recognized mountain fox subspecies (i.e. CRF, SNRF, and Rocky Mountain red fox *V. v. macrourus*). The recently recognized low-elevation Sacramento Valley red fox (*V. v. patwin*) also arose from the SNRF lineage. While the Nearctic lineage was isolated south of the glaciers a second lineage of red foxes occupied Beringia. Descendants of this Holarctic lineage now occupy Alaska and Western Canada. The Holartic and Neartic lineages diverged approximately 400,000 years ago.

During the course of these recent genetic studies researchers confirmed their hypothesis that the Columbia River separates red foxes of the Washington and Oregon Cascades. In fact, researchers determined the range of Sierra Nevada red fox should be expanded to include the Oregon Cascades because historic mountain foxes of the Oregon Cascades are much more closely related to historic and current SNRF than CRF (Sacks et al. 2010). Among the specimens analyzed in this determination was a fox collected from CRLA in 1939 after it was hit by a car. Mitochondrial and nuclear genetic analyses identify the CRLA specimen as a SNRF (see Table S1 in the Supplementary Material of Sacks et al. 2010 and the Appendix of Aubry et al. 2009). A detailed account of the collection and submission of this fox to the Museum of Vertebrate Zoology (accession number MVZ89553) at the University of California at Berkeley is given in Ranger Frost's 1940 Annual Wildlife Report (Frost's original report is available from the Park historian, and a digital copy of this report is available on the Park's "S drive").

The genetic identity of red foxes within CRLA and the Oregon Cascades is further complicated by the potential presence of nonnative individuals accidentally and intentionally released from fox farms. Importation of nonnative red foxes into Oregon for farmed fur production began in 1921 (Finlay 1941). In 1940 there were over 300 fox farms in the state (Finlay 1941), and with nearly 7,000 known pelts harvested in 1939 the 1940 Federal Census ranked Oregon 7th nationally in the production of silver fox pelts (DOI 1942). The genetic integrity of red fox populations is not just a concern in Oregon; recent range expansions across the United States include both native and introduced lineages (Statham et al. 2012a).

Sierra Nevada Red Fox

By the 1930s SNRF were reported to occur at low densities within their range, which was defined to include the Sierra Nevada and Trinity Mountains as well as the southern Cascades within California (Grinnell et al. 1937). SNRF were listed as 'threatened' in California in 1980 due to concern that the population size was continuing to decline despite a ban on trapping (Perrine et al. 2010). At present the only known remaining populations of SNRF are in Lassen Volcanic National Park and in the Sonora Pass area near Kings Canyon National Park (Perrine et al. 2010, Statham et al. 2012b). The two populations combined may consist of less than 50 individuals. In 2011 the Center for Biological Diversity filed a petition for federal listing of the SNRF. U.S. Fish and Wildlife Service returned a positive 90 day finding in January 2012 that the petition contained sufficient information to warrant a one-year status review which is ongoing at this time (USFWS 2012). Incidentally, CRF were classified as a candidate for listing in Washington in 2010 (WDFW 2011).

Information specific to the ecology of mountain red foxes in the Oregon Cascades is extremely limited. Bailey (1936) observed:

> "Usually these foxes are absent from the densely timbered or brushy areas west of the Cascades as well as from the arid sagebrush valleys east of the range. Open grassy parks and meadows afford their favorite hunting grounds, and the greatest abundance of mice and small rodents on which they largely subsist."

Bailey's account concurs with distribution records from "subalpine meadows near the Crest or in the dry, open forests on the eastern Cascade slope" (Aubry 1983). Similarly, six of seven radio-collared CRF in Washington occupied mountain hemlock forests with extensive subalpine meadows; one radio-collared CRF occupied open forest habitat of the Grand Fir vegetational zone (Aubry 1983).

The only substantial ecological research completed to date on SNRF is the dissertation conducted by Perrine (2005) in the vicinity of Lassen Peak in California. There five radio-collared SNRF during the summer selected high elevation barren habitats, used high elevation shrub and conifer habitats in proportion with their availability, and avoided all mid-elevation habitat types. Analysis of baited remote camera detections in the Lassen area indicated elevation was the single most important habitat variable for detecting red fox in summer, with a positive correlation between elevation and detection.

Perrine (2005) also investigated the relationships between SNRF and martens (*Martes americana)*, a competitor and occasional prey, and between SNRF and coyotes (*Canis latrans*), a competitor and predator. This analysis evaluated habitat use data derived from baited remote camera detections and dietary information from scat analysis. Camera detections of SNRF and marten were positively associated with each other throughout the year with analysis of detections at the scale of 1 mi^2 grid cells. However, at the scale of individual cameras this association was only significant in winter. Dietary and niche overlap between SNRF and coyotes was lower in summer and fall, although still considerable. Camera detections of SNRF and coyote were positively associated at the 1 mi^2 scale, but not at the scale of individual cameras.

OBJECTIVE

The intent of this survey was to document the presence of red fox within high elevation areas of CRLA using remote cameras in the vicinity of recent and historic sightings. Documented locations of red fox presence within CRLA would aid efforts to obtain samples for genetic analysis and assist the development of a more rigorous and detailed study, contributing to the park's ability to make wise decisions in pursuit of the National Park Service mission to preserve natural resources for the current and future generations.

METHODS

Site Selection

Cameras were deployed within CRLA in the vicinity of historic incidental observation locations above 6000 feet; given the history of fox farms within the Klamath Basin a minimum elevation was employed to increase the likelihood that any detections would be of native foxes. Areas with the greatest number of sightings, most recent sightings, and most precise information on locations were surveyed first. Most observation locations referenced a considerable distance or large geographic feature (e.g. Watchman Peak). Specific locations within these areas were

selected arbitrarily, but with consideration of topography, habitat, accessibility and mounting requirements of the camera. All sites were either forested, at the edge between forest and meadow, or in small stands of trees within meadows. Favored features included ridge lines, saddles, draws, forest edge, and the presence of a game trail. However, some sites were intentionally placed in areas of relatively dense forest. The dominant tree species at camera sites was mountain hemlock (*Tsuga mertensiana*), lodgepole pine (*Pinus contorta)*, or whitebark pine (*P. albicauls)*. Campgrounds and areas of high visitor use were avoided and all sites were at least 100m from roads and trails to minimize disturbance to both park visitors and cameras.

Cameras

ScoutGuard SG560 and Scout Guard SG560V digital trail cameras were deployed for 14 (n=34) or 15 (n=8) consecutive nights at 42 locations during August and September of 2012 (see Appendix I for details). One camera (Site 11) was disabled by an elk after 4 nights, reducing total effective trap nights for the survey to 585. Cameras were oriented north on trees or rocks ≤1m above ground level in locations where the camera would sense movement across a relatively open area and with a lower likelihood of false triggering from wind-blown vegetation. Cameras were set to take 5 megapixel images with the highest trigger sensitivity level. Initially cameras were set to take 1 photo per trigger with a 10 second delay between triggers. Camera settings were increased to 2 photos per trigger (Sites 23, 24, 26-42) with a 5 second delay between triggers (Sites 19-42) after the initial deployments did not exceed the capacity of the memory cards or rechargeable batteries.

At each site two scent wicks (Pro-Wick® by Wildlife Research Center®) treated with carnivore and canine specific commercial scent lures were temporarily affixed with zip ties to trees or rocks near the center of the camera's field of view. When possible the carnivore wick, scented with approximately 8ml of Caven's Gusto, was placed in an elevated location to facilitate scent dispersal, but most frequently it was placed at ground level. The canine specific wick, saturated with approximately 15ml Carman's Red Fox Pro Mix Scent and topped with approximately 2.5ml of Carman's Canine Call, was always placed at ground level.

Photo analysis

Summary statistics calculated for each site were: 1) number of species detected, 2) number of photographs triggered by each species, 3) number of visits by each species and 4) total number of animals detected for each species. To obtain these values photos were tagged with the identity and number of animals detected, as well as age (i.e. adult or young of the year) and gender when apparent. Photos closely spaced in time were considered in context when assigning tags. For instance, if a photo of a deer was recorded 10 seconds after an image with only a leg, then both photos were attributed to the deer. All sequential images at each site of the same species where less than 30 minutes elapsed between any two consecutive images were considered to represent a single visit (Kelly and Holub 2008). Within each visit the minimum number of individual animals that could account for the images was determined; these values were summed to calculate the total number of animals detected.

To be absolutely clear, 'number of animals detected' is *not* a count of the number of *unique* animals (that value could only be determined if all animals had individually identifying markings). Rather, 'number of visits' and 'number of animals detected' are presented as indicators of the *frequency and volume of activity* at sites, respectively. To illustrate, a camera visited once daily by the same fox and a site visited by a different fox each day would have

identical values for both ‘number of visits’ and ‘number of animals detected’ (see Appendix II for additional discussion).

RESULTS

Photos

Red foxes were detected at 7 camera sites with 20 photos across 11 visits (Figure 1**)**. Foxes visited Site 5 twice and Site 7 on four occasions. Average latency to first detection was 7 nights (range 2 – 13 nights). Coyotes were detected at 11 sites, including 2 sites also visited by foxes. Martens were photographed at 9 sites, none of which were also visited by foxes. Foxes were only photographed at night, in contrast to coyotes and martens which were detected during the day as well as at night. Detections of all three species appeared to be of solitary animals with the exception of two martens photographed together at Site 27. However, at least two individual foxes were documented within the park based on differences in coat color. Absence of fur in the tail region was apparent in several fox photos but not observed in either coyotes or martens.

Overall, cameras documented 312 visits by 15 mammal species, 7 bird species, and a bat and chipmunks which could not be identified to species level (Table 1; see Appendix II for site specific statistics and Appendix III for species detection maps). Animals were unidentifiable in 55 photos and the trigger for an additional 25 pictures could not be determined.

Genetics

Genetic analysis of the fur sample collected from Site 14 was conducted by the Veterinary Genetics Laboratory at University of California at Davis. The sample lacked a sufficient quantity of quality nuclear DNA for successful amplification, preventing definitive determination of the subspecific identity of the sampled fox. However, sequencing did identify the composite mitochondrial haplotype ‘A-19’ or more explicitly the cytochrome *b* haplotype ‘A’ and D loop haplotype ‘19’. This haplotype is the most common haplotype in the historical SNRF population and the basal haplotype of the mountain red fox lineage (Aubry 2009). Although the haplotype is not exclusive to SNRF it does exclude introduced foxes from the maternal lineage of the sampled fox. [Mitochondria are small organelles located in the cytoplasm of cells that contain their own DNA. Unlike nuclear DNA which is inherited from both parents, mitochondrial DNA (mtDNA) is inherited only from the mother; when a sperm and egg join the mitochondria of the sperm cell are not incorporated into the embryo. Cytochrome *b* is a specific gene within mitochondrial DNA (mtDNA); ‘A’ identifies one of the 13 variations of the gene identified from red foxes within the contiguous United States. The D loop is another portion of mtDNA that serves no function but accumulates genetic variation; ‘19’ identifies one of the 23 variations known to occur in red foxes within the contiguous United States (Statham et al. 2012a)]

DISCUSSION

At least two individual foxes were photographed in the park based on color phases. Note that the failure to detect foxes at sites should *not* be assumed to indicate the absence of foxes at those sites for a number of reasons; including deviations from standard protocols and several technical challenges encountered during this survey (see Appendix V for further discussion). The exploratory sampling design also does not readily enable inferences regarding the number of red foxes within the park, their distribution, or habitat associations. However, the results clearly indicate more intensive study is warranted and likely to be successful.

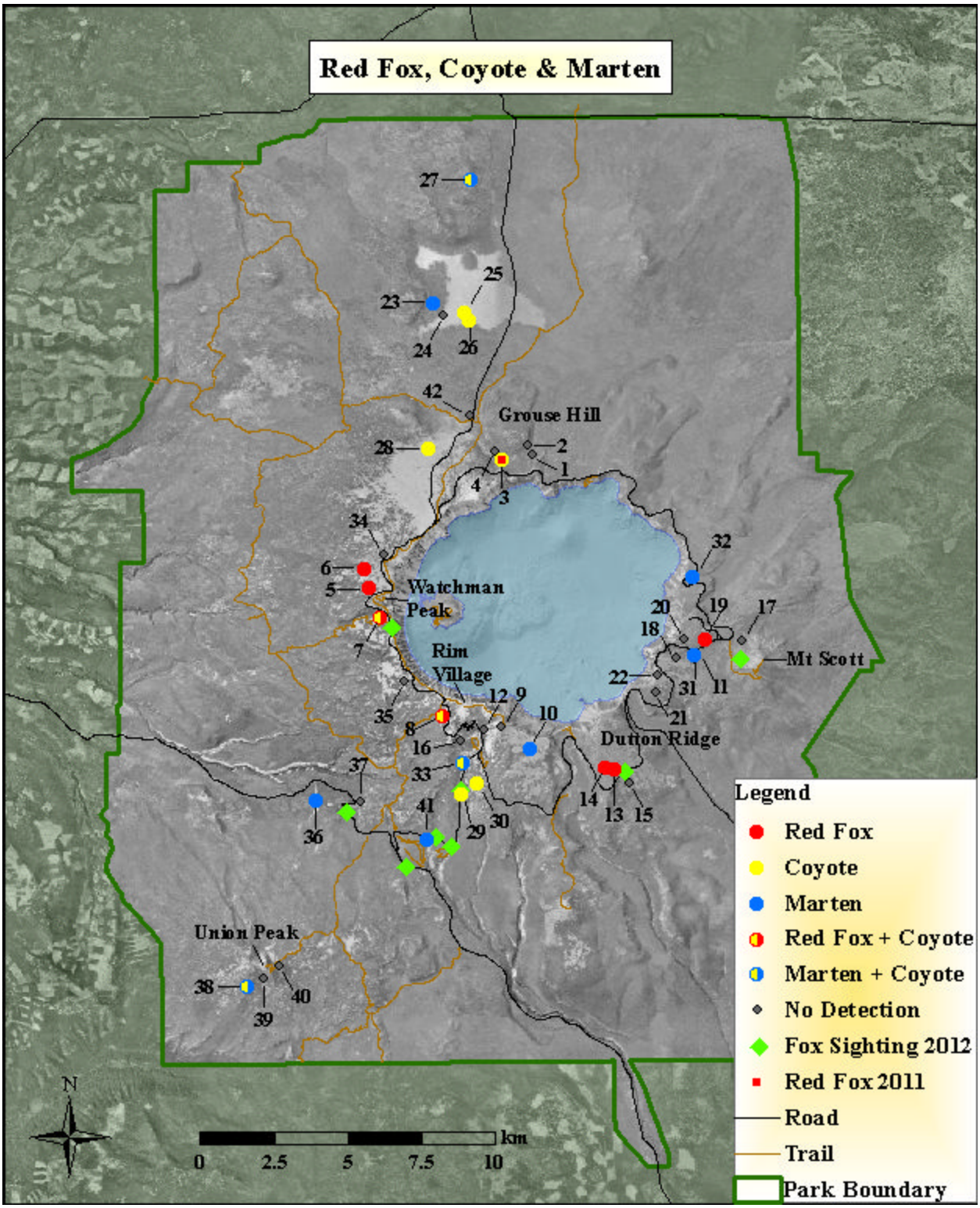


Figure 1. Locations of red fox, coyote and marten detections by remote cameras within Crater Lake National Park during August and September 2012. Numbers identifying the 42 remote camera sites reflect the sequence of camera deployment. Cameras operated at sites for 4-15 days (see Appendix 1). Locations of credible sightings of red foxes during 2012 and a single documented red fox detection from 2011 are also indicated.

Table 1. Species Summary. Summary by species of all identifiable animals photographed over the course of 585 effective trap nights across 42 remote camera sites within Crater Lake National Park between August 1 and September 26, 2012. 'Visit' and 'number of animals detected' are measures of the frequency and volume, respectively, of activity at sites; number of animals detected is not a count of unique individuals.

Species	# Sites	# Visits	# Animals Detected	# Photos
Deer (Mule & Columbian Black-tail)	35	157	202	770
Elk	17	42	85	241
Coyote	11	14	14	65
Marten	9	17	18	52
Black Bear	9	11	13	129
Douglas Squirrel	8	10	10	18
Red Fox	7	11	11	20
Person	6	6	8	13
Badger	3	3	3	8
Chipmunk*	3	3	3	5
Striped Skunk	2	3	3	12
Golden-mantled Ground Squirrel	1	13	13	32
Mountain Lion	1	2	2	26
Bobcat	1	1	1	12
Porcupine	1	1	1	4
Bat*	1	1	1	2
Spotted Skunk	1	1	1	2
Mammals	**42**	**296**	**389**	**1411**
Clark's Nutcracker	3	4	4	4
Steller's Jay	2	3	3	6
American Robin	2	2	2	5
Mountain Bluebird	1	4	5	8
Gray Jay	1	1	1	2
Sooty Grouse	1	1	1	2
Turkey Vulture	1	1	3	52
Birds	**10**	**16**	**19**	**79**
Animals	**42**	**312**	**408**	**1490**

*Species identification not possible for chipmunks and bat

A likely population of SNRF within CRLA is of significant conservation importance considering that the only known populations, both in California, may consist of less than 50 individuals combined. Current research at Mt. Hood and recent sightings of red foxes along the Cascades within Oregon offer encouragement that additional populations exist. However, few would be likely to experience the level of protection possible within national park boundaries. CRLA may be in the position to play an important role contributing to the conservation of the subspecies.

Threats to SNRF are thoroughly discussed in the petition for their federal listing (CBD 2011) and in the Forest Service SNRF conservation assessment (Perrine et al. 2010). Potential concerns for red foxes within CRLA are listed briefly below:

1. *Lack of knowledge*: Lack of knowledge about all aspects of the ecology of red foxes in the area hampers the ability to make informed management decisions.
2. *Small population size*: Population size at CRLA is unknown but presumably small. Small populations face genetic threats such as genetic drift and inbreeding. Small populations are also much more vulnerable to extirpation (i.e. local extinction) if conditions cause death rates to rise (e.g. a disease outbreak) or reproductive rates to lower (e.g. a reduced prey base during a drought may not support reproductive demands).
3. *Vehicles*: Park records include several reports of red foxes being struck by cars as well as accounts of foxes being harassed by vehicles during winter conditions when the snow banks lining the roads make it difficult for foxes to get out of the road.
4. *Dogs* (*visitor and staff owned*): Even apparently healthy dogs are potential vectors for disease and parasites. Furthermore dogs can harass and even kill red foxes, as was documented in Lassen Volcanic National Park (Perrine 2005).
5. *Habituation to people*: Habituated foxes are at greater risk of exposure to human-associated hazards including vehicles and dogs. The presence of bear-proof trash cans and food lockers throughout CRLA limits opportunities for scavenging. However, the need to discourage visitors from feeding wildlife is ongoing. CRLA's historical records contain multiple accounts of feeding red foxes and several reports of begging foxes.
6. *Snowmobiles*: Over Snow Vehicle (OSV) use of the North Entrance Road during winter presents the potential for direct and indirect disturbance and could increase the ability of coyotes to penetrate farther into park despite winter conditions, causing increased potential for predation and competition.
7. *Non-native red foxes*: Non-native red foxes present a threat to the genetic integrity of native populations. Other concerns include the introduction of disease and increased competition for limited resources such as prey and denning sites. At this time it is not known if introduced foxes are present within CRLA. Even if they are not currently present, non-native foxes present an ongoing threat since introduced populations are expanding throughout the country. Non-native foxes could also be purposefully brought into the park, as occurred in Sequoia National Park when uninformed rehabilitators released foxes from southern California (Jurek 1992). However, multiple researchers have suggested that an unknown elevational barrier such as genetic adaptation or behavioral selection is preventing or limiting movements between all subspecies of mountain red fox populations and non-native populations in fairly close proximity at lower elevations (Aubry 1983, Aubry et al. 2009, Perrine 2005, Swanson et al. 2005, Sacks et al. 2010, Statham et al. 2012a).

8. *Rodenticides*: Because CRLA has an Integrated Pest Management Plan the potential for exposure to rodenticides within the park seems unlikely. However, recent research has revealed the extensive exposure of numerous carnivore species to rodenticides, including within national parks. Given the prevalence of rodents and the potential consequences of the actions of even one uninformed employee, annual education of park and concessions staff regarding acceptable IPM practices as well as signage in housing and even camping areas might be prudent.
9. *Fire suppression*: Fire suppression can lead to meadow encroachment, possibly reducing red fox foraging habitat and prey populations. Alternatively meadow conversion could simply alter the type of available prey. Uncertainty regarding the impacts of fire, fire suppression, and fuel reduction exemplify how effective management for foxes is hindered by the lack of knowledge of basic mountain red fox ecology.
10. *Climate change*: Why members of the mountain lineage of red foxes are apparently restricted to boreal and subalpine habitats is unknown. However, because of this association climate change could present a variety of threats, ranging from a reduction in suitable habitat to an increased amount of predation by and competition with coyotes which would likely become more common at CRLA with rising temperatures and reduced snowpack.

Additional conservation concerns outside of CRLA include trapping, habitat modification from logging and grazing, and rodenticide exposure around areas of human activity and in agricultural activity. These issues have the potential to impact foxes in CRLA if they expand their winter range beyond park boundaries and can impact foxes dispersing from or immigrating into the park.

PRODUCTS

Publications and Reports:
An initial Investigator's Annual Report summarizing field work was submitted on December 31, 2012. A final Investigator's Annual Report will be submitted in 2013. No additional field work is anticipated at this time. A "Casual Conversation" was presented to park staff on July 24, 2012.

Collections:
Not applicable. The sample of red fox fur collected opportunistically from Site 14 was consumed in the process of analysis.

Data and Other Materials:
Digital copies of all animal triggered photographs were stored on the CRLA "S drive" and provided to the CRLA Terrestrial Ecologist. Digital scans of the 1933-1953 Annual Wildlife Census reports and all incidental red fox sighting records stored in the CRLA museum were also placed on the "S drive". In addition, a summary GIS shapefile (*RedFoxCameraSurvey2012.shp*) and an Excel spreadsheet (*RedFoxCameraSurvey2012.xlsx)* containing an index of all stored photographs, counts of animals detected at each site, and site information were submitted with this report. The naming convention for photographs included the site number, date, time of file creation (note that file creation is slightly delayed from the time stamp on the photos), and a three digit serial number starting at one for each camera site (for example the first image in Appendix IV was named *FoxSite05_20120811_052627_013.JPG*).

LITERATURE CITED

Aubry, K.B. 1983. The Cascade red fox: distribution, morphology, zoogeography and ecology. Dissertation, University of Washington, Seattle.

Aubry, K.B., M.J. Statham, B.N. Sacks, J.D. Perrine, and S.M. Wisely. 2009. Phylogeography of the North American red fox: vicariance in Pleistocene forest refugia. *Molecular Ecology* 18:2668-2686.

Bailey, V. 1936. The mammals and life zones of Oregon. North American Fauna No. 55. Washington, D.C.: U.S. Department of Agriculture, Bureau of Biological Survey; 281-285.

Benson, J.F., J.D. Perrine, R.T. Golightly, and R.H. Barrett. Use of cover and response to cover type edges by female Sierra Nevada red foxes in winter. Western North American Naturalist 65: 127-130.

CBD [Center for Biological Diversity]. 2011. Petition to List the Sierra Nevada Red Fox (Vulpus vulpus necator) as Threatened or Endangered Under the Endangered Species Act. Available online:

Churcher, C.S. 1959. The specific status of the New World red fox. *Journal of Mammalogy* 40:13-520.

DOI [Department of the Interior, Information Service]. 1942. 2,655 Silver Fox Farms in U.S., Census Shows. Available online: www.fws.gov./news/historic/1942/19420113a. Accessed June 29, 2012.

Figura, P., and L. Knox. 2010. A lightweight, tree-mounted hair snare for mesocarnivores. Unpublished protocol. California Department of Fish and Game, Redding, CA.

Finlay, E. 1941. Fur Farming in Oregon. *Columbia Empire Furs* 1:16-17.

Grinnell, J., J. Dixon, and L. Linsdale. 1937. Fur-bearing mammals of California. Berkeley: University of California Press.

Jurek. 1992. Nonnative red foxes in California. Nongame Bird and Mammal Section Report, 92-04. California Department of Fish and Game.

Kelly, M. J., and E. L. Holub. 2008. Camera trapping of carnivores: trap success among camera types and across species, and habitat selection by species, on Salt Pond Mountain, Giles County, Virginia. 2008 *Northeastern Naturalist* 15:249–262.

Merriam, C.H. 1897. The Mammals of Mount Mazama, Oregon. *Mazama* 1:204-230.

Merriam, C.H. 1900. Preliminary revision of the North American red foxes. *Proceedings of the Washington Academy of Sciences* 2:661-676.

Perrine, J.D. 2005. Ecology of red fox (*Vulpes vulpes*) in the Lassen Peak Region of California, USA. Dissertation, University of California, Berkeley.

Perrine, J.D, J.P. Pollinger, B.N. Sacks, R.H. Barrett, and R.K. Wayne. 2007. Genetic evidence for the persistence of the critically endangered Sierra Nevada red fox in California. *Conservation Genetics* 8:1083-1095.

Perrine, J.D, L.A. Campbell, and G.A. Green. 2010. Sierra Nevada Red Fox (*Vulpes vulpes necator*): a conservation assessment. R5-FS-010. Pacific Southwest Research Station, USDA Forest Service, Vallejo, CA.

Sacks, B.N., M.J. Statham, J.D. Perrine, S.M. Wisely, and K.B. Aubry. 2010. North American montane red foxes: expansion, fragmentation, and the origin of the Sacramento Valley red fox. *Conservation Genetics* 11:1523-1539.

Sacks, B.N., M.J. Statham, and H.U. Wittmer. 2011. A restricted hybrid zone between native and introduced red fox (*Vulpes vulpes*) populations suggests reproductive barriers. *Molecular Ecology* 20:326-341.

Statham, M.J., B.N. Sacks, K.B. Aubry, J.D. Perrine, and S.M. Wisely. 2012a. The origin of recently established red fox populations in the contiguous United States: translocations or natural range expansions? *Journal of Mammalogy* 93:52-65.

Statham, M.J., A.C. Rich, S.K. Lisius, and B.N. Sacks. 2012b. Discovery of a Remnant Population of Sierra Nevada Red Fox (*VulpesVulpes Necator*). *Northwest Science* 86(2):122-132.

Swanson, B.J., R.T. Fuhrmann, and R.L. Crabtree. 2005. Elevational isolation of red foxes in the Greater Yellowstone ecosystem. *Conservation Genetics* 6:123-131.

USFWS [U.S. Fish and Wildlife Service]. 2012. Endangered and Threatened Wildlife and Plants; 90-Day Finding on a Petition to List Sierra Nevada Red Fox as Endangered or Threatened. Federal Register 77:45-52.

WDFW [Washington Department of Fish and Wildlife]. 2011. Threatened and Endangered Wildlife in Washington: 2011 Annual Report. Endangered Species Section, Wildlife Program. Washington Department of Fish and Wildlife, Olympia. 180pp. 150-151.

Zielinski, W.J., T.E. Kucera. 1995. American marten, fisher, lynx and wolverine: Survey methods for their detection. PSW-GTR-157. Pacific Southwest Research Station, USDA Forest Service, Albany, CA.

APPENDIX I. Camera Locations and Settings

Table 2. Site Summary. Survey site locations, camera settings, and photo counts for red fox remote camera survey conducted within Crater Lake National Park during August and September 2012. Pictures recorded during camera setup and take-down confirmed all cameras were functioning properly with the exception of Site 11 which was disrupted by an elk. More than 70% of the pictures attributed to wind (i.e. photos with obvious movement of either vegetation or shadows and the absence of animals) were generated by 5 cameras that each recorded > 1000 wind photos.

Site	Location	UTM E*	UTM N*	Date Set	Date Collected	Trigger Delay (seconds)	Photos per Trigger	Effective Trap Nights	Total Photos	Setup & Take-down Photos	Wind Triggered Photos	Revised Total Photos	Red Fox Detected?
1	Grouse Hill	572494	4759628	8/1/12	8/15/12	10	1	14	105	5	39	61	No
2	Grouse Hill	572336	4759936	8/1/12	8/15/12	10	1	14	44	7	33	4	No
3	Grouse Hill	571498	4759503	8/1/12	8/15/12	10	1	14	79	1	49	29	No
4	Grouse Hill	571225	4759752	8/1/12	8/15/12	10	1	14	266	3	233	30	No
5	Watchman Peak	567005	4755148	8/2/12	8/16/12	10	1	14	2060	5	2003	52	**Yes**
6	Watchman Peak	566825	4755784	8/2/12	8/16/12	10	1	14	60	4	2	54	**Yes**
7	Watchman Peak	567386	4754153	8/2/12	8/16/12	10	1	14	109	2	58	49	**Yes**
8	Upper Corkscrews	569501	4750800	8/2/12	8/16/12	10	1	14	79	3	34	42	**Yes**
9	Garfield Peak	571436	4750412	8/4/12	8/19/12	10	1	15	853	11	834	8	No
10	Garfield Meadows	572438	4749682	8/4/12	8/19/12	10	1	15	57	3	40	14	No
11**	Mt Scott Meadows	578015	4752874	8/4/12	8/19/12	10	1	4	20	2	0	18	No
12	Munson Valley	570873	4750321	8/4/12	8/19/12	10	1	15	675	3	624	48	No
13	Dutton Ridge	575315	4749028	8/7/12	8/21/12	10	1	14	231	6	216	9	**Yes**
14***	Dutton Ridge	574990	4749038	8/7/12	8/21/12	10	1	14	51	3	27	21	**Yes**
15	Dutton Ridge	575765	4748506	8/7/12	8/21/12	10	1	14	52	3	9	40	No
16	Headquarters	570068	4749985	8/11/12	8/25/12	10	1	14	28	3	4	21	No
17	Mt Scott	579574	4753349	8/17/12	8/31/12	10	1	14	44	2	14	28	No
18	Mt Scott Meadows	577383	4752755	8/17/12	8/31/12	10	1	14	14	3	7	4	No
19	Cloudcap	578375	4753393	8/19/12	9/3/12	5	1	15	410	3	405	2	**Yes**
20	Cloudcap	577651	4753419	8/19/12	9/3/12	5	1	15	20	3	2	15	No
21	Reflection Point	576687	4751574	8/19/12	9/3/12	5	1	15	689	4	668	17	No

Site	Location	UTM E*	UTM N*	Date Set	Date Collected	Trigger Delay (seconds)	Photos per Trigger	Effective Trap Nights	Total Photos	Setup & Take-down Photos	Wind Triggered Photos	Revised Total Photos	Red Fox Detected?
22	Reflection Point	576762	4752188	8/19/12	9/3/12	5	1	15	51	3	15	33	No
23	Pumice Desert	569184	4764777	8/24/12	9/7/12	5	2	14	294	12	224	58	No
24	Pumice Desert	569493	4764379	8/24/12	9/7/12	5	2	14	154	6	142	6	No
25	Pumice Desert	570232	4764433	8/24/12	9/7/12	5	1	14	21	2	14	5	No
26	Pumice Desert	570362	4764188	8/24/12	9/7/12	5	2	14	108	4	98	6	No
27	Gaywas Saddle	570466	4768963	8/25/12	9/8/12	5	2	14	168	10	62	96	No
28	North Junction	568986	4759844	8/25/12	9/8/12	5	2	14	1543	10	1523	10	No
29	Munson Valley	570103	4748183	8/25/12	9/8/12	5	2	14	174	6	82	86	No
30	Sewage Lagoons	570648	4748524	8/25/12	9/8/12	5	2	14	61	6	18	37	No
31	Mt Scott Meadows	578011	4752715	9/3/12	9/17/12	5	2	14	3364	6	3332	26	No
32	Skell Head	577938	4755527	9/3/12	9/17/12	5	2	14	82	8	20	54	No
33	Sleepy Hollow	570162	4749193	9/4/12	9/18/12	5	2	14	48	4	12	32	No
34	Hillman	567463	4756272	9/8/12	9/22/12	5	2	14	2146	6	2124	16	No
35	Discovery Point	568175	4751948	9/8/12	9/22/12	5	2	14	90	4	16	70	No
36	Whitehorse Saddle	565186	4747973	9/8/12	9/22/12	5	2	14	110	8	48	54	No
37	Whitehorse Curve	566695	4747913	9/8/12	9/22/12	5	2	14	194	6	98	90	No
38	Union Peak SW	562852	4741634	9/9/12	9/23/12	5	2	14	4800	10	4643	147	No
39	Union Peak S	563397	4741900	9/9/12	9/23/12	5	2	14	88	8	44	36	No
40	Union Peak SE	563947	4742325	9/9/12	9/23/12	5	2	14	59	7	26	26	No
41	Goodbye Bridge	568956	4746634	9/11/12	9/25/12	5	2	14	160	14	94	52	No
42	N. Entrance Rd	570364	4760959	9/12/12	9/26/12	5	2	14	74	6	4	64	No
					Totals			**585**	**19,735**	**225**	**17,940**	**1,570**	

* UTM coordinates are in NAD83 Zone 10T North

** Elk knocked camera off tree on 8/9/12 at 02:49

*** Red fox fur sample collected from scent wick where fox rubbed against wick

APPENDIX II. Species Detections by Site

Species detection statistics (i.e. number of photos, visits, and animals detected) by survey sites within Crater Lake National Park are provided below for carnivores (Table 3), other mammals (Table 4), and birds (Table 5). Sites were surveyed with remote cameras for 4-15 consecutive nights (see Table 2**)** during August and September 2012.

A simple comparison of photo counts between sites is hindered by the different camera settings used during the survey. 'Visit' and 'number of animals detected' are measures of the frequency and volume, respectively, of activity at sites. All sequential images at each site of the same species where less than 30 minutes elapsed between any two consecutive images were considered to represent a single 'visit', recognizing that animals may linger in the vicinity of the camera without being within the camera's field of view. Within each visit the minimum number of individual animals that could account for the images was determined; these values were summed to calculate the total 'number of animals detected'. 'Number of animals detected' is *not* a count of the number of *unique* animals (that value could only be determined if all animals had individually identifying markings). The following example is provided for illustration of these definitions. A doe was photographed, followed 30 seconds later by 2 fawns. The next day a doe and fawn were captured in one image and a single fawn was photographed 30 seconds later. In total 2 deer visits were documented, with 3 and 2 animals detected respectively, and the total number of animals detected was 5.

Although remote cameras are used to study animals what they directly monitor is the particular location where they are deployed. Animal detections are influenced by the rate at which animals move through an area, which in turn varies with factors including the species, activity (e.g. feeding vs. fleeing), age, and health of animals as well as weather, terrain, and cover. The use of scent lures and/or edible bait also influences how long animals linger, how often they return, and how far they will travel to visit the site. In this exploratory survey a 30 minute interval was arbitrarily used to define the maximum elapsed time between photos that would be considered within a single visit. Using a 15 or 60 minute interval altered the total number of visits from 312 to 317 and 299 respectively, with deer and elk accounting for most of the variability (Table 6). The appropriate time interval used to define a 'visit' will vary with the research objective, species of interest, and methodology. Kelly and Holub (2008) used a 30 minute interval for carnivore surveys, but with entirely unbaited cameras (i.e. neither edible bait nor scent lures were used). In contrast Perrine (2005) used an 8 hour interval for cameras baited with meat and scent lures for SNRF surveys. Perrine also reported a high rate of return to cameras (the number of nights per site that foxes were detected). Presumably a fox attempting to feed would linger longer at the site and perhaps be more likely to return. However, in this survey six of the eleven red fox visits were detected with a single camera triggering (Table 7). The average time between the first and last photos of the five visits with multiple camera triggers was only 1.1 minutes (range 0.4 – 2.1 minutes). Even with a visit defined by a 60 minute interval average duration was just 12.0 minutes (range 0.4 – 56.5 minutes, n=4).

Table 3. Carnivore Detections by Site. Only sites with detections are listed.

	Number of PHOTOS / VISITS / ANIMALS DETECTED											
Site	**Black Bear**	**Bobcat**	**Mtn. Lion**	**Red Fox**	**Coyote**	**Badger**	**Marten**	**Spotted Skunk**	**Striped Skunk**	**Total Photos**	**Total Visits**	**Total Animals Detected**
1	6/1/1	-	-	-	-	-	-	-	-	**6**	**1**	**1**
3	-	-	-	-	1/1/1	-	-	-	-	**1**	**1**	**1**
5	-	-	-	**3/2/2**	-	-	-	-	-	**3**	**2**	**2**
6	-	-	-	**1/1/1**	-	-	-	-	-	**1**	**1**	**1**
7	-	-	-	**8/4/4**	1/1/1	-	-	-	-	**9**	**5**	**5**
8	-	-	-	**1/1/1**	1/1/1	-	-	-	-	**2**	**2**	**2**
9	2/1/1	-	-	-	-	-	-	-	-	**2**	**1**	**1**
10	-	-	-	-	-	-	1/1/1	-	-	**1**	**1**	**1**
11	-	-	-	-	-	-	1/1/1	-	-	**1**	**1**	**1**
13	-	-	-	**2/1/1**	-	-	-	-	-	**2**	**1**	**1**
14	-	-	-	**4/1/1**	-	-	-	-	-	**4**	**1**	**1**
17	-	-	-	-	-	1/1/1	-	-	-	**1**	**1**	**1**
19	-	-	-	**1/1/1**	-	-	-	-	-	**1**	**1**	**1**
20	-	-	-	-	-	1/1/1	-	-	-	**1**	**1**	**1**
21	5/1/1	-	-	-	-	-	-	-	-	**5**	**1**	**1**
23	-	12/1/1	-	-	-	6/1/1	2/1/1	-	-	**20**	**3**	**3**
25	-	-	-	-	4/1/1	-	-	-	-	**4**	**1**	**1**
26	-	-	-	-	6/1/1	-	-	-	-	**6**	**1**	**1**
27	30/2/2	-	-	-	24/3/3	-	20/5/6	-	-	**74**	**10**	**11**
28	-	-	-	-	2/1/1	-	-	-	-	**2**	**1**	**1**
29	-	-	-	-	16/1/1	-	-	-	-	**16**	**1**	**1**
30	-	-	26/2/2	-	2/1/1	-	-	-	-	**28**	**3**	**3**
31	2/1/1	-	-	-	-	-	-	-	-	**2**	**1**	**1**
32	16/1/1	-	-	-	-	-	6/2/2	-	8/2/2	**30**	**5**	**5**
33	-	-	-	-	2/1/1	-	2/1/1	-	-	**4**	**2**	**2**
36	12/1/1	-	-	-	-	-	2/1/1	-	-	**14**	**2**	**2**

Site	Number of PHOTOS / VISITS / ANIMALS DETECTED									Total Photos	Total Visits	Total Animals Detected
	Black Bear	Bobcat	Mtn. Lion	Red Fox	Coyote	Badger	Marten	Spotted Skunk	Striped Skunk			
37	24/2/2	-	-	-	-	-	-	-	-	**24**	**2**	**2**
38	32/1/3	-	-	-	6/2/2	-	4/2/2	-	-	**42**	**5**	**7**
39	-	-	-	-	-	-	-	-	4/1/1	**4**	**1**	**1**
41	-	-	-	-	-	-	14/3/3	2/1/1	-	**16**	**4**	**4**
Sum	**129/11/13**	**12/1/1**	**26/2/2**	**20/11/11**	**65/14/14**	**8/3/3**	**52/17/18**	**2/1/1**	**12/3/3**	**326**	**63**	**66**

Table 4. Other Mammal Detections by Site. Only sites with detections are listed.

Site	Number of PHOTOS / VISITS / ANIMALS DETECTED								Total Photos	Total Visits	Total Animals Detected
	Deer* (Columbian Black-tail & Mule)	Elk	Porcupine	Chipmunk	Douglas Squirrel	Golden-mantled Ground Squirrel	Person	Bat			
1	5/2/2	43/3/16	-	-	-	-	-	-	**48**	**5**	**18**
2	4/3/3	-	-	-	-	-	-	-	**4**	**3**	**3**
3	-	27/7/12	-	-	-	-	1/1/2	-	**28**	**8**	**14**
4	17/4/8	11/5/7	-	-	-	-	2/1/2	-	**30**	**10**	**17**
5	11/2/3	3/1/1	-	-	-	-	-	-	**14**	**3**	**4**
6	36/9/10	10/3/3	-	-	-	-	-	-	**46**	**12**	**13**
7	40/12/17	-	-	-	-	-	-	-	**40**	**12**	**17**
8	40/13/15	-	-	-	-	-	-	-	**40**	**13**	**15**
9	4/2/3	-	-	-	-	-	-	-	**4**	**2**	**3**
10	1/1/1	11/1/16	-	-	-	-	-	-	**12**	**2**	**17**
11	10/1/1	5/1/1	-	-	-	-	-	-	**15**	**2**	**2**
12	48/8/9	-	-	-	-	-	-	-	**48**	**8**	**9**
13	6/2/3	-	-	-	-	-	-	-	**6**	**2**	**3**
14	5/2/2	4/1/2	-	-	2/2/2	-	3/1/1	-	**14**	**6**	**7**

	Number of PHOTOS / VISITS / ANIMALS DETECTED										
Site	**Deer* (Columbian Black-tail & Mule)**	**Elk**	**Porcupine**	**Chipmunk**	**Douglas Squirrel**	**Golden-mantled Ground Squirrel**	**Person**	**Bat**	**Total Photos**	**Total Visits**	**Total Animals Detected**
15	5/1/1	35/4/7	-	-	-	-	-	-	**40**	**5**	**8**
16	15/6/6	-	-	-	-	-	1/1/1	-	**16**	**7**	**7**
17	23/8/12	-	-	-	-	-	-	-	**23**	**8**	**12**
18	4/3/3	-	-	-	-	-	-	-	**4**	**3**	**3**
20	14/4/5	-	-	-	-	-	-	-	**14**	**4**	**5**
21	12/4/4	-	-	-	-	-	-	-	**12**	**4**	**4**
22	29/5/10	-	-	-	-	-	4/1/1	-	**33**	**6**	**11**
23	32/1/3	2/1/1	-	-	2/1/1	-	-	-	**36**	**3**	**5**
24	-	6/1/3	-	-	-	-	-	-	**6**	**1**	**3**
27	-	20/3/4	-	-	2/1/1	-	-	-	**22**	**4**	**5**
29	44/11/15	24/4/4	-	-	2/1/1	-	-	-	**70**	**16**	**20**
30	4/1/1	2/1/1	-	1/1/1	2/1/1	-	-	-	**9**	**4**	**4**
31	4/1/1	12/2/2	-	2/1/1	-	-	-	-	**18**	**4**	**4**
32	20/2/3	-	-	2/1/1	2/1/1	-	-	-	**24**	**4**	**5**
33	24/5/6	-	-	-	-	-	-	-	**24**	**5**	**6**
34	16/2/3	-	-	-	-	-	-	-	**16**	**2**	**3**
35	18/5/6	-	-	-	-	-	-	-	**18**	**5**	**6**
36	28/3/3	12/1/1	-	-	-	-	-	-	**40**	**4**	**4**
37	30/3/4	-	-	-	4/2/2	32/13/13	-	-	**66**	**18**	**19**
38	95/16/20	-	-	-	-	-	-	2/1/1	**97**	**17**	**21**
39	30/5/8	-	-	-	-	-	-	-	**30**	**5**	**8**
40	12/3/3	14/3/4	-	-	-	-	-	-	**26**	**6**	**7**
41	20/2/2	-	4/1/1	-	2/1/1	-	2/1/1	-	**28**	**5**	**5**
42	64/5/6	-	-	-	-	-	-	-	**64**	**5**	**6**
Sum	**770/157/202**	**241/42/85**	**4/1/1**	**5/3/3**	**18/10/10**	**32/13/13**	**13/6/8**	**2/1/1**	**1085**	**233**	**323**

* 'Deer' includes detections of both Columbian Black-tailed deer (*Odocoileus hemionus columbianus)* and Mule Deer (*O. h. hemionus*).

Table 5. Bird Detections by Site. Only sites with detections are listed.

	Number of PHOTOS / VISITS / ANIMALS DETECTED									
Site	**Clark's Nutcracker**	**Gray Jay**	**Grouse, Sooty**	**Mountain Bluebird**	**Robin, American**	**Steller's Jay**	**Turkey Vulture**	**Total Photos**	**Total Visits**	**Total Animals Detected**
10	-	-	-	-	1/1/1	-	-	**1**	**1**	**1**
13	1/1/1	-	-	-	-	-	-	**1**	**1**	**1**
14	2/2/2	-	-	-	-	-	-	**2**	**2**	**2**
19	1/1/1	-	-	-	-	-	-	**1**	**1**	**1**
28	-	-	-	8/4/5	-	-	-	**8**	**4**	**5**
31	-	-	-	-	4/1/1	-	-	**4**	**1**	**1**
33	-	-	-	-	-	2/1/1	-	**2**	**1**	**1**
35	-	-	-	-	-	-	52/1/3	**52**	**1**	**3**
39	-	-	2/1/1	-	-	-	-	**2**	**1**	**1**
41	-	2/1/1	-	-	-	4/2/2	-	**6**	**3**	**3**
Sum	**4/4/4**	**2/1/1**	**2/1/1**	**8/4/5**	**5/2/2**	**6/3/3**	**52/1/3**	**79**	**16**	**19**

Table 6. Influence of Maximum Lag in Visit Definition upon Number of Visits and Detections. Only species with differences between time intervals are listed.

			Number of Visits						Number of Animals Detected					
Species	**Number of Sites**	**Number of Photos**	**15 Minute Lag**		**30 Minute Lag**	**60 Minute Lag**			**15 Minute Lag**		**30 Minute Lag**	**60 Minute Lag**		
Deer (Black-tailed & Mule)	35	770	158	(+1)	157	151	(-6)		203	(+1)	202	196	(-6)	
Elk	17	241	44	(+2)	42	37	(-5)		87	(+2)	85	79	(-6)	
Golden-mantled Ground Squirrel	1	32	14	(+1)	13	12	(-1)		14	(+1)	13	12	(-1)	
Marten	9	52	18	(+1)	17	17	---		19	(+1)	18	18	---	
Red Fox	**7**	**20**	**11**	**---**	**11**	**10**	**(-1)**		**11**	**---**	**11**	**10**	**(-1)**	
Total			**245**	**(+5)**	**240**	**227**	**(-13)**		**334**	**(+5)**	**329**	**315**	**(-14)**	

Table 7. Duration of Mammal Visits With Multiple Triggers.

Species	Total Visits	Proportion of Total Visits with Multiple Triggers	Duration of Multiple Trigger Visits (minutes)					
			30 Minute Lag		15 Minute Lag		60 Minute Lag	
			Average (range)		Average (range)		Average (range)	
Black Bear	11	82%	2.8	(1.3 - 5.6)	ND*		ND	
Bobcat	1	100%	2.9	(2.9 - 2.9)	ND		ND	
Mountain Lion	2	100%	2.2	(2.1 - 2.3)	ND		ND	
Red Fox	**11**	**45%**	**1.1**	**(0.4 - 2.1)**	**ND**		**12.0**	**(0.4 - 56.5)**
Coyote	14	50%	2.3	(0.3 - 5.2)	ND		ND	
Badger	3	33%	5.2	(5.2 - 5.2)	ND		ND	
Marten	17	24%	6.0	(0.2 - 21.3)	0.8	(0.2 - 2.1)	ND	
Spotted Skunk	1	0%	-		ND		ND	
Striped Skunk	3	67%	0.9	(0.5 - 1.3)	ND		ND	
Deer	157	69%	2.6	(0.2 - 24.4)	2.4	(0.2 - 24.4)	5.2	(0.2 - 55.1)
Elk	42	76%	5.3	(0.4 - 24.3)	3.9	(0.4 - 24.3)	13.3	(0.4 - 132.0)
Porcupine	1	100%	0.4	(0.4 - 0.4)	ND		ND	
Chipmunk	3	0%	-		ND		ND	
Golden-mantled Ground Squirrel	14	21%	11.9	(2.4 - 27.3)	4.2	(2.4 - 6.1)	16.8	(2.4 - 31.5)
Person	6	50%	8.6	(0.6 - 13.0)	ND		ND	
Bat	1	0%	-		ND		ND	

*ND = no difference from 30 minute values

APPENDIX III. Species Detection Maps

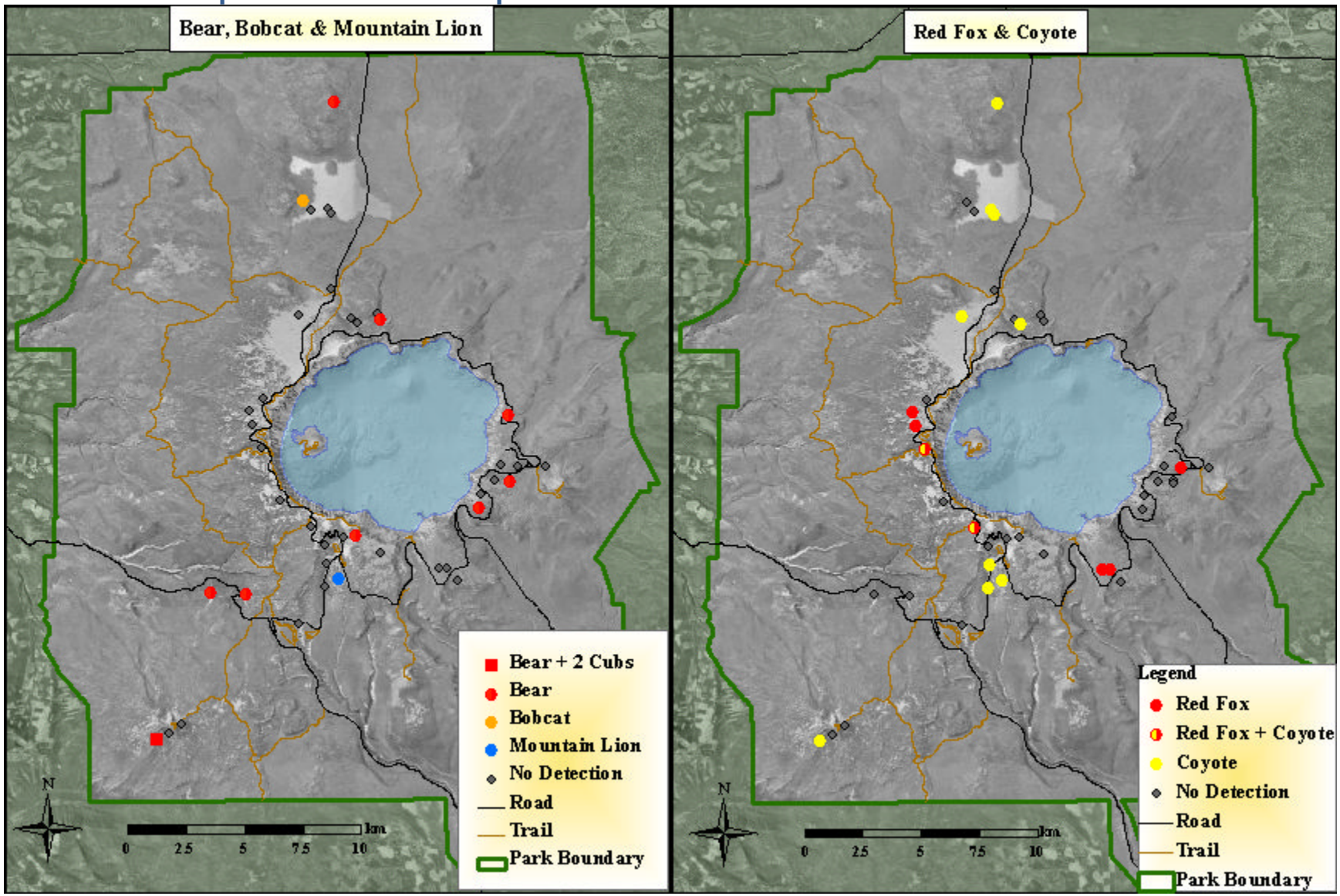


Figure 2. Ursid, felid, and caind detection locations. All detections were of single animals with the exception of an adult bear with two cubs near Union Peak.

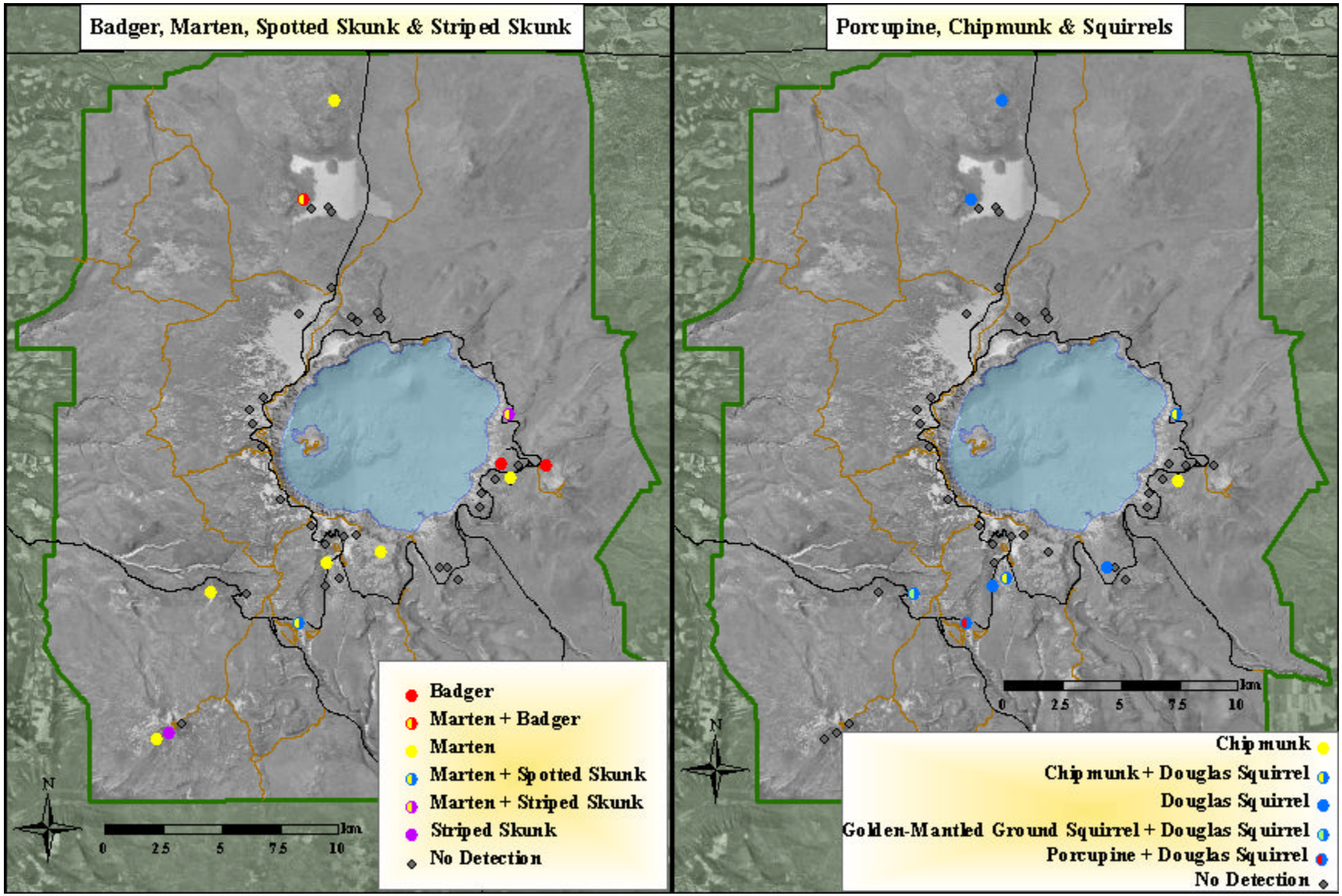


Figure 3. Mustelid and rodent detection locations. All mustelid detections appeared to be of solitary animals with the exception of two martens photographed simultaneously at the northernmost site.

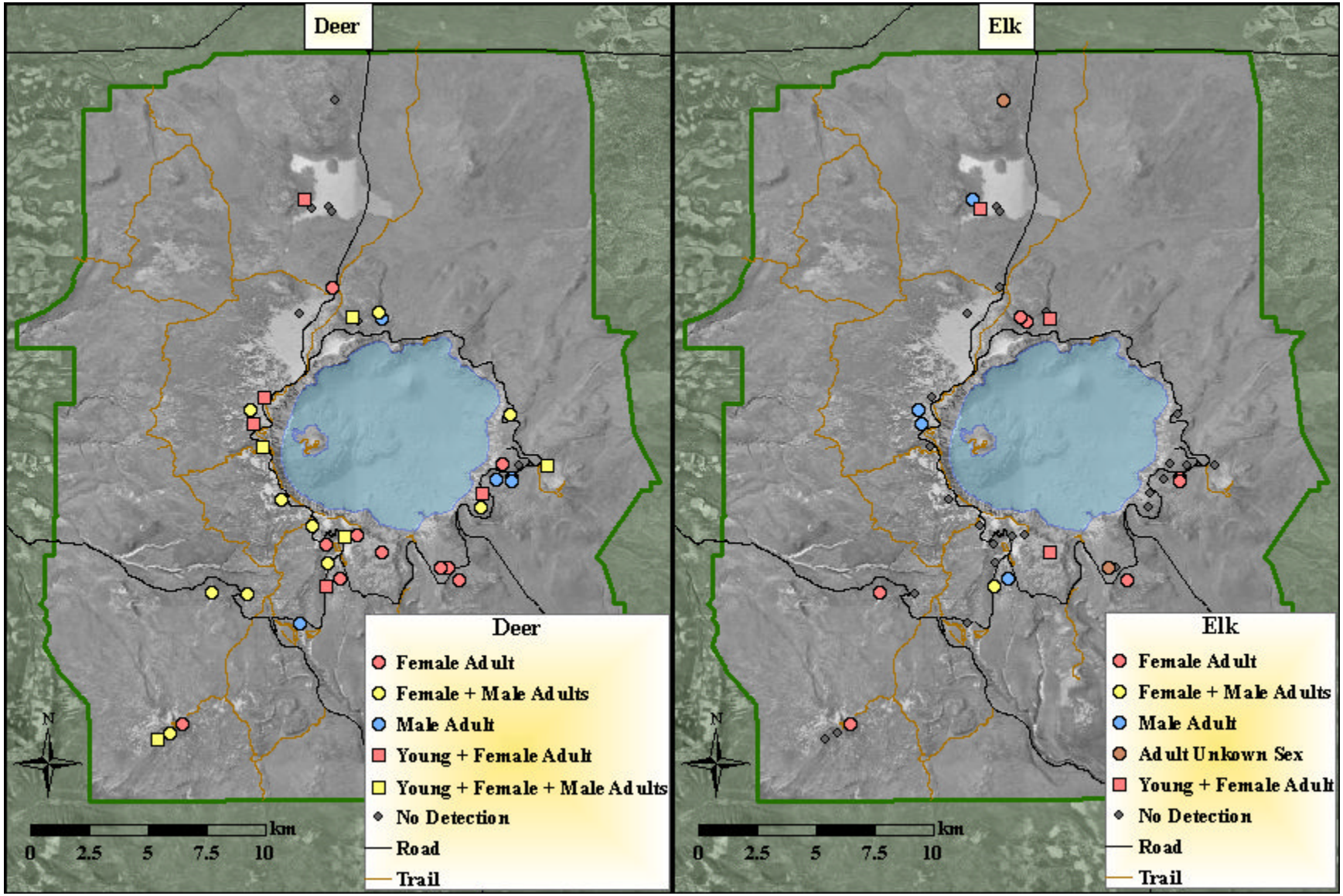


Figure 4. Ungulate detection locations. 'Deer' includes detections of both Columbian Black-tailed deer (*Odocoileus hemionus columbianus)* and Mule Deer (*O. h. hemionus*). 'Young' refers to young of the year; photos of only subadults or where the age was unclear were not assigned an age tag.

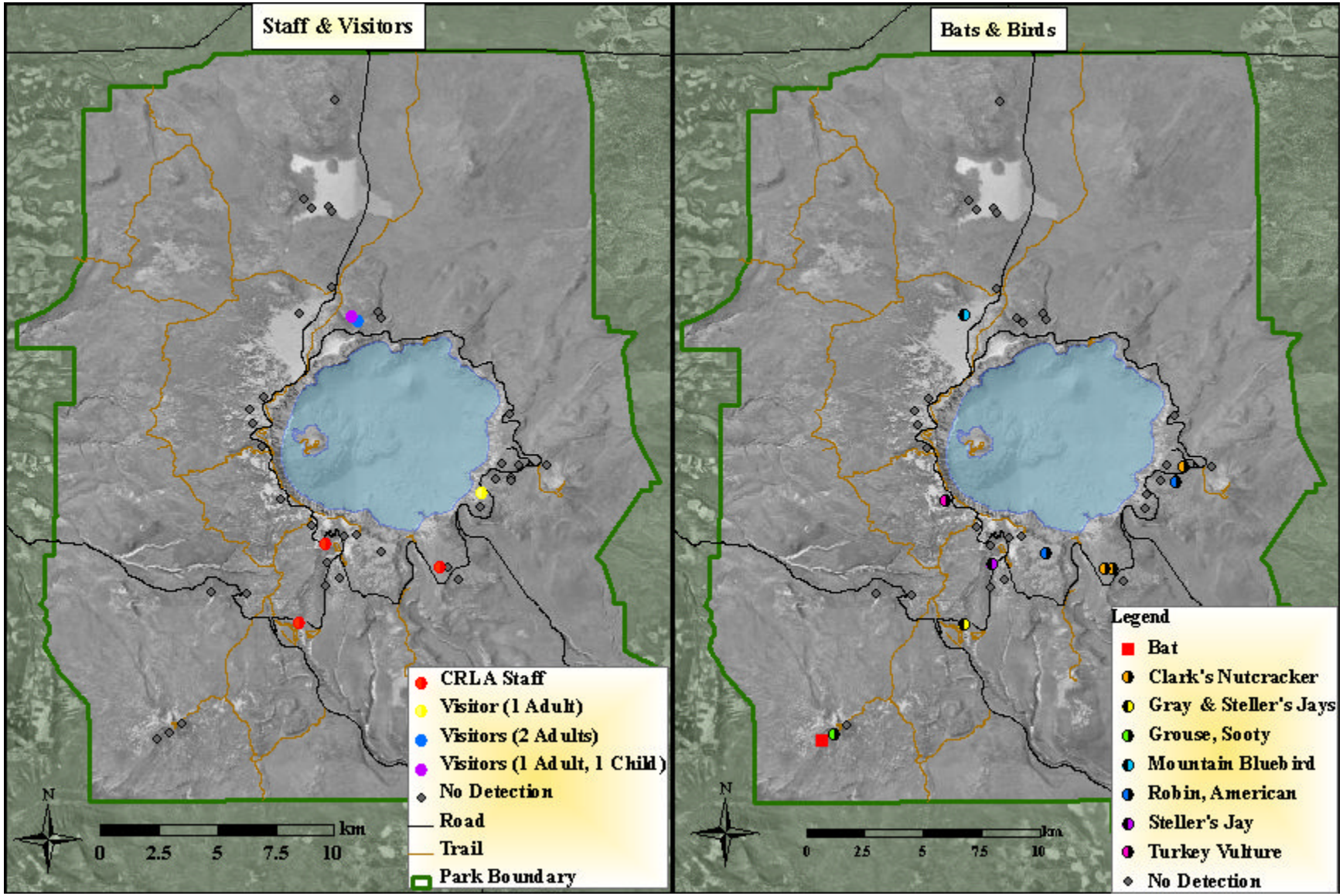


Figure 5. People, bat, and bird detection locations. There was no indication that visitors or staff were aware of the cameras. The bat and mountain bluebird detections occurred at sites with high numbers of photos attributed to wind triggering. These detections may have been coincidental with wind triggering. On the other hand, some photos attributed to wind may have been triggered by birds or bats which moved out of the camera's field of view before the photographs were taken.

APPENDIX IV. Red Fox Photos by Site

Site and image number are listed below photos; consecutive photos within a visit are listed with a hyphenated range. Image contrast and brightness were modified to improve visibility as needed.

Site 5 Images 13-14

Image15

Site 6 Image 41

Site 7 Image 15 Images 16-19

Image 37

Site 7 (cont.) Images 48-49

Site 8 Image 32

Site 13 Images 8-9

Site 14 Images 1-4

Site 19 Image 1

APPENDIX V. Observations on Protocol and Future Considerations

The intent of the following section is to 1) highlight important differences between standard protocols and one used here, 2) describe several technical challenges encountered in this survey, some of which were a consequence of deviation from the standard protocol, and 3) to provide a list of questions and observations which might be of use to future researchers or prompt further inquiry. These comments have been placed in the final appendix to prevent distraction from the take home messages of the discussion section: that red foxes are present within CRLA, CRLA may be able to serve an important role in conserving SNRF, and there are a number of potential threats which SNRF face within and beyond CRLA.

Protocol Differences and Technical Challenges

This survey differed from standard mesocarnivore survey protocols (Zielinski and Kucera 1995, Perrine 2005) in several aspects which may have influenced fox detections. In order to survey a greater number of sites most cameras were deployed for only 14 nights, only one night longer than the observed upper range of latency to first detection and half the duration of standard surveys. Edible bait was not used to minimize the invasiveness of this pilot survey within a national park. In addition, scent lures were applied to wicks, and wicks were not refreshed with additional scent once installed at a site. Furthermore, 2 carnivore and 4 canine wicks were removed during the survey, presumably reducing the effectiveness of the impacted sites (coyotes were the only species observed when wick removal was captured by the camera).

Wind activity also almost certainly decreased the availability of cameras to document animal activity for extended lengths of time at 8 sites which collectively recorded nearly 90% of the 17,940 survey photos attributed to wind (.i.e. photos indicating movement of vegetation or shadows in the absence of an animal). Cameras heavily triggered by wind during the day, including Site 5 where a red fox was detected, remained available for nighttime detections. More problematic were sites with substantial wind triggering at night. Although local wind patterns likely explain most wind triggering, it is also possible that at least some photos were triggered by birds or bats moving fast enough to avoid detection.

Like wind, camera settings also appeared to limit camera availability. There appears to be a significant tradeoff between taking more images per trigger and more frequent images, particularly at night. The length of time that passed between sequential photos where an animal appeared to linger in front of the camera prompted an examination of the "observed" trigger delay versus the camera setting (Figure 6). Note that the manufacturer's website (HCO Outdoor Products Scout Guard FAQ http://www.hcooutdoors.com/faq.php?cID=3#12) states that "Interval Time" refers only to the period when the camera is in "sleep" mode to conserve battery life. However, cameras are also unavailable during the processing time required to transform each photograph into a JPEG and record it to the SD card. Note that processing time is longer for 5 megapixel images than for 3 megapixel images. Contrary to the information on the manufactures website, image processing appears to be longer under nighttime conditions. This information is particularly relevant for red foxes as they are generally most active at night, move quickly, and often do not appear to linger around scent lures. A fox that triggers a camera before entering the field of view may leave the area before the camera is available to capture another photo. Presumably this would be less of a concern with baited cameras because foxes attempting to obtain the food would linger in front of the camera longer.

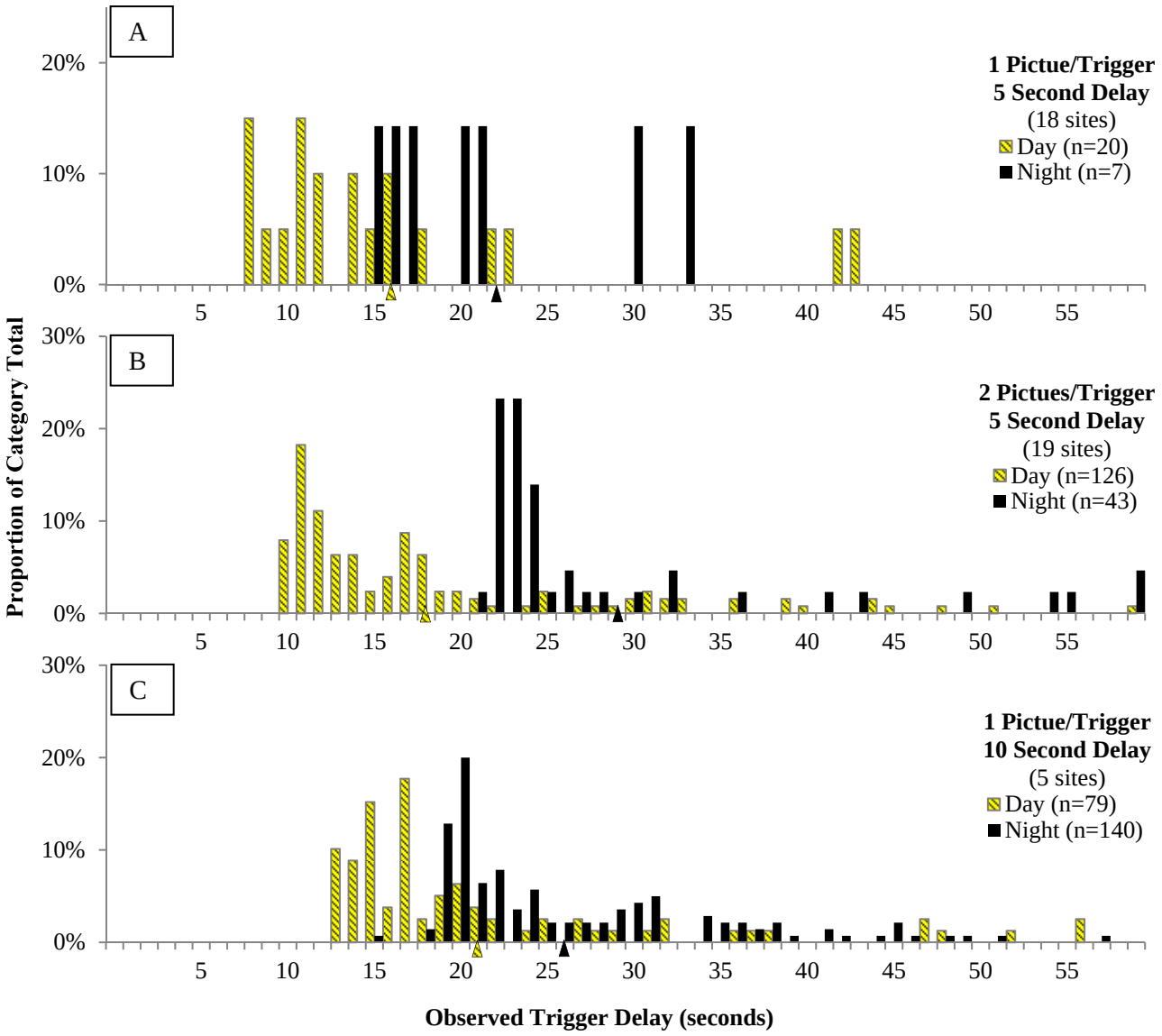
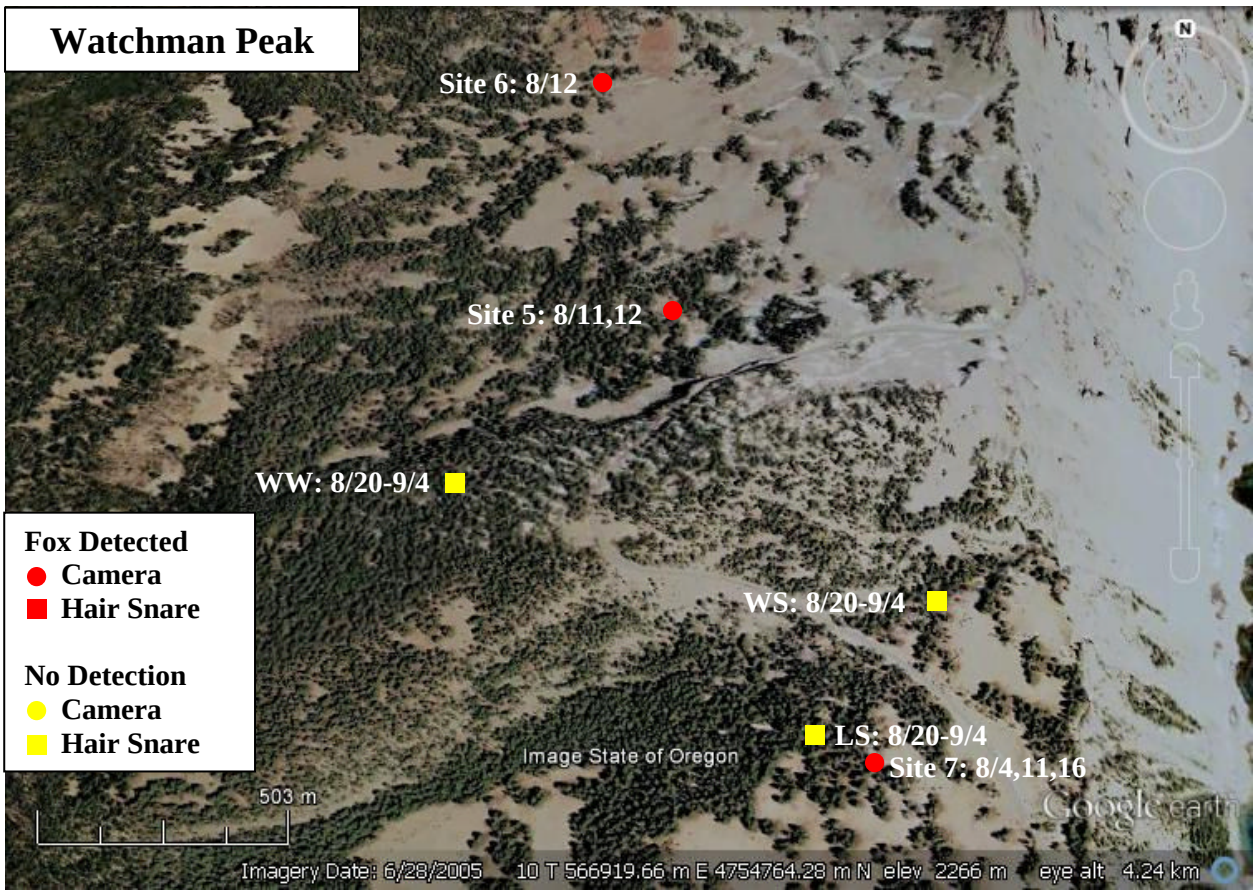
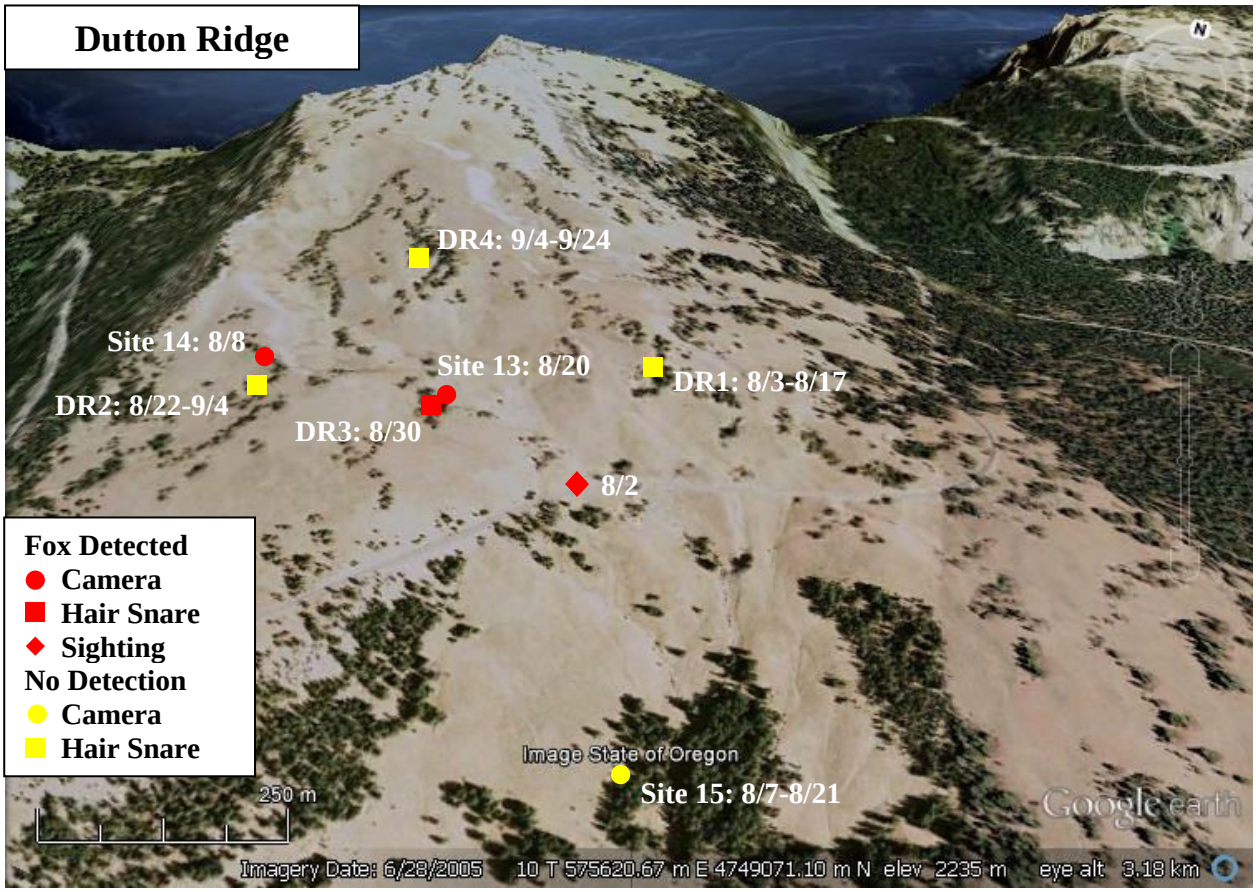


Figure 6. **Impact of Camera Settings on Observed Trigger Delay.** Distribution of observed trigger delay intervals of less than 60 seconds for cameras set to take one or two five-megapixel pictures with interval delay settings of 5 or 10 seconds. Triangles along the x-axis indicate the average interval for each category. Across all camera settings observed trigger delay interval is greater at night. Photos taken between 0500-0800 and 1800-2100 PDT were excluded from consideration to avoid twilight conditions where cameras were transitioning between color (day) and night (black and white) images. Although some sample sizes are small and animal activity varied between camera sites there is sufficient evidence to suggest trends for consideration.

Figure 7. Is red fox detectability influenced by camera set up? (page 32) After red foxes were detected during the camera survey park staff deployed cameras and hair snares in an effort to obtain fur for genetic analysis. Although these cameras and hair snares were set in the general area of recent detections only one fox visit to a hair snare was documented. Circles identify numbered camera survey sites, squares identify lettered hair snares. Red fox detection date(s) are listed, or where no detections occurred the survey period is provided. Despite repeated red fox camera detections around Watchman Peak no visits were detected by cameras at hair snare sets. On Dutton Ridge a red fox was photographed at 2 camera sites and 1 hair snare set.


Watchman Peak
Site 6: 8/12
Site 5: 8/11,12
WW: 8/20-9/4
WS: 8/20-9/4
LS: 8/20-9/4
Site 7: 8/4,11,16
Fox Detected
Camera
Hair Snare
No Detection
Camera
Hair Snare
Image State of Oregon
503 m
Imagery Date: 6/28/2005 10 T 566919.66 m E 4754764.28 m N elev 2266 m eye alt 4.24 km


Dutton Ridge
DR4: 9/4-9/24
Site 14: 8/8
DR2: 8/22-9/4
Site 13: 8/20
DR1: 8/3-8/17
DR3: 8/30
8/2
Site 15: 8/7-8/21
Fox Detected
Camera
Hair Snare
Sighting
No Detection
Camera
Hair Snare
Image State of Oregon
250 m
Imagery Date: 6/28/2005 10 T 575620.67 m E 4749071.10 m N elev 2235 m eye alt 3.18 km

Question: Were follow-up cameras with hair snares ineffective?

Immediately after camera retrieval images were reviewed for fox detections which were reported to CRLA's Terrestrial Ecologist. Two wildlife technicians (including the author) deployed remote cameras and hair snares in the vicinity of fox detections. Hair snares were constructed following the protocol of Figura and Knox (2010). Snares were baited with meat from road-killed deer and either tuna or sardines (deer meat was surplus from an unrelated project and had been collected with permission from Oregon Department of Fish and Wildlife). Gusto was used at all snares; Canine Call and Red Fox Pro Mix were used at later hair snares including the one snare site where a single fox was documented (unfortunately the fox visit occurred after a bear removed all bait from the site; no fox fur sample was obtained).

Camera surveys around Watchman Peak detected at least 2 individual foxes across 4 separate nights (Figure 8), including detections at Site 7 on 3 nights. However, none of the hair snares detected foxes, including the Lightning Springs snare (LS) which was only 130 meters from Site 7. On Dutton Ridge survey sites and hair snares were deployed after a credible sighting report on August 2. A red fox was subsequently photographed at Site 14 and Site 13 (separated by 325 meters) on August 8th and 20th, respectively. The sole red fox visit to a snare was on August 30th at snare DR3. DR3 was installed only 20 meters from Site 13 when the survey period for the site had been completed. Snare DR4, 75 meters from Site 14 was not visited. The challenge to detect foxes in areas where they had recently and repeatedly been detected raises a number of questions:

1. How far will a fox deviate from an intended travel route to investigate a scent lure and/or bait?
2. Are scent lures only attractive when they are novel?
3. Is Gusto significantly less effective for attracting red foxes? Zielinski and Kucera (2005) recommend a skunk based scent (e.g. Gusto) for mustelid surveys, but also mention a variety of other scent lure options.
4. Does the use of red fox urine and or a matrix lure (i.e. a lure containing scent from a female in heat; Red Fox Pro Mix is a commercial blend of red fox urine and matrix lure) enhance or hinder red fox detections? Does this vary between genders? Note that Perrine (2005) generally alternated between Gusto and Canine Call on a weekly basis and also used red fox urine. However, there is also concern among researchers that use of urine could reduce detections because it is used for communication, for example when marking a territory.
5. Does deer carrion repel red foxes during the summer when other food sources are plentiful? Perhaps if larger predators are attracted to the bait red foxes might actively avoid the area.
6. Are red foxes visiting the area but eluding detection?
7. Are the placement requirements of a hair snare set hindering detection? Red fox detections in the surveying effort occurred primarily in open areas (e.g. where cameras were mounted on a tree facing into a clearing). However, the need for two trees in proximity, one for mounting the camera and one for mounting the hair snare, required those sets to be in less open areas.
8. Hair snares were inspected regularly by technicians to ensure bait had not been removed by bears and to retrieve any hair samples obtained. Did human activity deter fox visitation?

9. Hair snares were always deployed after camera surveying (with the exception of snare DR1 at Dutton Ridge which was set after a credible sighting report prior to camera surveying). Is there a seasonal influence such as timing of dispersal?
10. Is the difference in detections merely a coincidence?

Observations for Future Consideration

Cameras:

- Consider leaving cameras in place for the standard survey duration of 28 days.
- Site selection for cameras may be very critical to successful surveying, as discussed above. Anecdotally foxes appeared to be detected at open locations during this survey period. A very simple post-hoc analysis appeared to confirm this impression. A score of 1 was assigned to sites arbitrarily considered to be open based on knowledge of the sites and after reviewing site photos. A score of 2 was assigned to closed sights while intermediate sights were assigned a score of 1.5. The average score across all sites where red foxes were detected was 1.1 (n=7); in contrast the average score for martens was 1.8 (n=9) and for all sites 1.4 (n=42). This concurs with the historical observations of Bailey (1936). However, during winter research indicates SNRF occupied mature closed canopy forests and avoid open areas (Benson et al. 2005, Perrine 2005).
- Use a view finder to ensure that cameras are aimed sufficiently low to detect animals that pass nearby but do not approach the lure or bait. Have field crews experiment with cameras prior to surveying efforts to develop an understanding of effective camera positioning (including elevated locations angled sharply downward), the field of view of the camera, how far cameras detect motion under daytime and nighttime conditions, and how vegetation can trigger cameras.
- The high sensitivity setting on the camera is advised to enable detection of fairly small animals at greater distance from the cameras. However, cameras are sometimes triggered while the animal is outside the field of view. One solution is to set the camera to take 2 or 3 pictures every time it is triggered. However, these photos are taken rapidly (≤1 second) and the camera is then unavailable until all of the images are processed. Therefore setting cameras to take a single photo but with a very short interval time might be a more effective approach. This is likely of greatest concern for cameras only using a scent lure as red foxes usually did not appear to linger long at the lure. Only 5 of 11 fox visits involved >1 camera triggering, of these the average documented duration was 1.1 minutes (range 0.4 – 2.1 minutes). In contrast the single fox visit to a hair snare spanned 11.7 minutes and triggered the camera 9 times, although the fox was not captured in the camera's field of view for 5 triggering during the middle of the visit. Incidentally, a bear had removed the meat from the hair snare the previous night. Presumably if meat had been present the fox visit would have lasted even longer.
- Continue to monitor the individual cameras for units that may be triggered exceptionally easily or malfunctioning (i.e. taking unusually high or low numbers of pictures).

Lures:

- Anecdotally canids and felids appeared to be photographed more often and for greater duration in the vicinity of the canine lures (i.e. Carman's Red Fox Pro Mix with Carman's Canine Call) but bears, mustelids, and ungulates appeared to be the more interested in the

carnivore scent lure (i.e. Caven's Gusto). The use of both types of lures may increase the range of species detected.

- Replenish lures. Perrine (2005) reapplied lures weekly, generally alternating between lures weekly.
- Use of scent wicks is not recommended.

Bait:

- Consider chicken rather than deer meat (Perrine 2005). Bait is likely to be most effective during winter when food is limited.

Winter surveying:

- Winter surveying presents safety and access concerns. However, red foxes may use larger areas in winter when food is scarcest. Determining the full range of foxes throughout the year is important for effective protection. SNRF in the Sonora Pass area have been detected at high elevations during both summer and winter (Statham et al. 2012b). However, both Grinnell (1937) and Perrine (2005) reported SNRF moving to lower elevations in winter. CRF did not change elevation in winter but they did expand their range (Aubry 1983). At CRLA incidental sighting reports indicate that at least some red foxes remain in the higher elevations of the park through the winter.

Roads and trails:

- Consider placement of cameras just off of roadways. Perrine (2005) determined that SNRF near Lassen often traveled on roads. They also spent time in campgrounds and parking lots. Although begging and scavenging was observed, Perrine also noted that some foxes spent more time in these areas when the park was closed and visitors were absent. At CRLA each time this author visited over the winter of 2012-2013 fox tracks were observed in the immediate vicinity of the Rim Village and traversing the road and lake rim alternately between Rim Village and Watchman Peak. On one occasion tracks from a pair of foxes were observed. Tracks were also observed at the Mazama campground. Surveying in the vicinity of roads might be not only easier but effective. However, clearly the chance of disturbance to both cameras and park visitors would increase significantly and purchase of camera locks would be required. Cameras placed along roads would likely need to be visited by staff more frequently: during the summer car traffic could deplete batteries and memory card space while during the winter snow clearing activities might bury cameras although higher camera placement should lessen that concern. Furthermore, caution would be necessary to ensure that red foxes were not being draw into dangerous conditions on active roads.