Colorado Division of Parks and Wildlife
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WILDLIFE RESEARCH REPORT

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ABSTRACT

Mountain pine and spruce beetle infestations have reached epidemic levels in Colorado, impacting approximately 6.6 million acres since the initial outbreak in 1996. Though bark beetles are native to Colorado and periodic infestations are considered a natural ecological process, the geographic scale of their impact and simultaneous infestation within multiple forest systems has never been observed. This historic outbreak is having significant impacts on composition and structure of forest stands that will propagate for decades into the future. The widespread and rapid mortality of forested systems in Colorado is likely to have a dramatic, but poorly understood effect on wildlife species that depend on these habitats. This project proposed here will use occupancy estimation to determine which wildlife species (both species of conservation cocern and game species) maintain a presence throughout the course of an outbreak, which species disappear once a stand is infected, and when or if extirpated species return as the stand recovers. Statewide sampling began during summer 2013 and half of the proposed 300 sites were surveyed for breeding bird and small mammal activity. Data entry is ongoing and no formal analyses have been completed to date.

WILDLIFE RESEARCH REPORT

SMALL MAMMAL AND BREEDING BIRD RESPONSE TO BARK BEETLE OUTBREAKS IN COLORADO

JACOB S. IVAN

PROJECT NARRATIVE OBJECTIVE

Assess the impact of mountain pine beetle (*Dendroctonus ponderosae*) and spruce beetle (*Dendroctonus rufipennis*) outbreaks on small mammal and breeding bird communities in Colorado.

SEGMENT OBJECTIVES

1. Complete peer-reviewed study plan and power analyses for bark beetle project.
2. Complete fieldwork for first of two years of sampling.

INTRODUCTION

Mountain pine beetle (*Dendroctonus ponderosae*) and spruce beetle (*Dendroctonus rufipennis*) infestations have reached epidemic levels in Colorado, impacting several million acres since the initial outbreak in 1996 (http://foresthealth.fs.usda.gov/portal/PestSummary/DamageSummary). Though bark beetles are native to Colorado and periodic infestations are considered a natural ecological process, the geographic scale of their impact and simultaneous infestation within multiple forest systems has never been observed (Western bark beetle strategy; http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5338089.pdf). This historic outbreak is having significant impacts on composition and structure of forest stands that will propagate for decades into the future.

The widespread and rapid mortality of forested systems in Colorado is likely to have a dramatic, but poorly understood effect on at least some wildlife species that depend on these habitats. However, most work examining the impacts of beetle infestation on wildlife originates from the Pacific Northwest (e.g., Martin et al. 2006, Norris and Martin 2008, Ritchie 2008, Drever et al. 2009, Kroll et al. 2012). Studies assessing beetle impacts in the Southern Rockies are scant (e.g., Stone 1995) and no project to date has focused on Colorado. Additionally most previous work has focused largely on the avian community. Here we propose a study to assess the impacts of beetle infestations on a suite of wildlife species inhabiting the subalpine zone in Colorado. We focus on 3 mammalian and 12 avian species of conservation concern (Table 1). Note, however, that the sampling methods proposed here will likely result in detections of many other species beyond those of conservation concern, including game species. We will attempt to make statewide inference to both lodgepole pine (*Pinus contortus*) and Engelmann spruce (*Picea engelmanni*)/subalpine fir (*Abies lasiocarpa*) systems, which are being infested primarily by mountain pine beetle and spruce beetle, respectively.

We expect wildlife response to the beetle epidemic to vary by species and forest system. For instance, in mature lodgepole pine stands, we expect red squirrels to be fairly ubiquitous in areas that have not been or have only recently been impacted, but as the infestation runs its course and cone-producing trees die, we expect occupancy to decline (Fig. 1). Conversely, in that same system, we expect occupancy of snowshoe hares to be near zero in stands that have little or no beetle impact, but occupancy should increase dramatically as the canopy is opened up and understory develops (Fig. 2).

METHODS

This project will primarily use occupancy estimation to determine which wildlife species maintain a presence throughout the course of an outbreak, which species decline or disappear once a stand is infested, and when or if extirpated species return as the stand recovers. As such, multiple surveys will be conducted at each site, and for each survey, we will record whether the species of interest is detected or not detected. This "1,0" encounter data can then be used to estimate the probability of detecting a species given that it occurs at a site (p), as well as the proportion of sites (ψ) in the population that are occupied (MacKenzie et al. 2002, MacKenzie et al. 2006). For avian species, multiple "surveys" result from binning the detections of each species during a 5-minute point count into 1 minute intervals (thus 5 "surveys"). Additionally, sampling for avian species involves conducting surveys at 16 spatial replicates within each 1-km sample unit of interest (see *Sampling Avian Species* below). Thus, multiple survey information may come from space as well as time. For mammalian species, we will bin camera data into daily or weekly intervals to transform continuous camera sampling into the multiple survey framework of occupancy estimation. Note that because both the mammalian and avian species we will sample are mobile, the metric we are estimating is more appropriately termed "probability of use" rather than "probability of occupancy" (MacKenzie et al. 2006, p. 213). That is, we will attempt to estimate the proportion of sites being used by a particular species of interest and relate that to beetle infestation. Sampling will occur statewide with sample sites stratified by system (lodgepole pine or spruce/fir). For the purposes of this project, we will assume that each selected site is closed to changes in occupancy over the course of our sampling session. Thus, we assume that each cell is either used by a species of interest or not, and this status does not change over the course of the sampling period (end of May through early July for avian species; end of May through end of August for mammalian species). Additionally, we assume that if abundance of a species changes in response to beetles, that change will be reflected in occupancy estimates. In other words, species will not appreciably change their home range size as their abundance changes, a phenomenon that could make occupancy estimation blind to the wildlife response that is actually occurring (Efford and Dawson 2012).

Sampling Avian Species:

Avian sampling will follow the design described by Pavlacky et al. (2012) in which the each sample unit (1-km cell) is sub-sampled by 16 point count stations separated by 250m (Fig. 3). Each sample unit will be surveyed by a pair of technicians over the course of a single morning (half-hour before sunrise to 5 hours after sunrise) during the breeding season (late May to early July). Point counts will last for 5 minutes at each of the 16 stations, and technicians will record each species seen or heard during each minute of the count. They will also measure the distance to each individual using a laser range finder to facilitate truncation of detections for analysis and for use in density estimation via distance sampling. At the conclusion of each point count at each of the 16 stations, technicians will play short recordings of both dusky grouse (*Dendragapus obscures*) and northern goshawks (*Accipiter gentilis*) in an effort to elicit a response from those 2 species of interest.

All sampling will follow established protocols (Hanni et al. 2012). That is, access to each site will be verified ahead of time to avoid trespassing, exposure to unsafe conditions, and to ensure completion of the survey in the allotted time. At each station, in addition to recording birds seen and heard, technicians will record covariates potentially important in explaining variation in detection probability including cloud cover, wind speed, and temperature. They will also record the general habitat type, along with attributes of the canopy, shrub, and ground cover layers. See "Covariates" below for further details.

Sampling Mammalian Species:

Presence-absence data on small to medium-sized mammals species can be efficiently obtained over a broad scale using snow tracking, track plates, or remotely triggered cameras (Zielinski et al. 1995, Zielinski et al. 2013). Snow tracking is highly dependent on environmental conditions, raises safety and access issues, and cannot be dove-tailed efficiently with breeding bird sampling. Track plates work well, but require frequent visits to remove tracks and replace bait. Recent advances in remotely triggered cameras coupled with the availability of large, cheap memory allow for extended camera deployments with few, if any, visits between the initial deployment and retrieval (Kucera and Barrett 2011). For these reasons, we will use cameras as the primary mechanism for sampling the small to medium-sized mammals of interest.

To maximize efficiency, avian crews will deploy a single camera in the center of each 1-km sample unit as they are conducting point counts (Fig 3). Cameras will remain deployed for at least 8 weeks, then will be retrieved during mid to late summer after avian surveys have been completed. Deployments will be altered slightly from typical game animal set-ups to account for the smaller-bodied targets. That is, cameras will be positioned slightly lower (~70cm) and closer to a lured target tree (~3m). We will use only a small amount (<5 ml) of lure (whichever of the following performs best during ongoing pilot work: commercial apple scent, rabbit lure, squirrel lure, marten lure, or peanut butter) to draw individuals in the immediate vicinity to the target tree, and thus pull them in front of the camera. Note that while the camera will be deployed in the center of each $1km^2$ sample unit, we do not assume that the camera is sampling all small mammals in that unit. We will treat the camera itself (and its zone of sensitivity) as the sample unit for the mammalian portion of the project, as is customary for occupancy estimation using this method.

Power Analyses:

In an effort to test remote cameras as a means for monitoring lynx (*Lynx canadensis*), 120 were deployed in the San Juan Mountains of southwest Colorado (exclusively spruce/fir forest) from Fall to early Summer, 2010–2011 (Ivan 2011). In addition to lynx photos, that effort yielded >4,000 photos of snowshoe hares (*Lepus americanus*), >1,000 photos of red squirrels (*Tamisciurus hudsonicus*), >400 photos of American marten (*Martes americana*) as well as several thousand photos of game species such as black bears (*Ursus americanus*), moose (*Alces alces*), elk (*Cervus canadensis*), and mule deer (*Odocoileus hemionus*). We used these pilot data to estimate probability of detection and occupancy (use) for these species. Binning the continuously collected data into weekly intervals resulted in detection probabilities of 0.11, 0.14, and 0.24 for marten, squirrels, and hares, respectively (ψ = 0.27, 0.33, and 0.47, respectively). Given that these sets were specific to lynx and that others have had better success sampling these species during summer (R. Truex, United States Forest Service, unpublished data; K. Blecha, Colorado State University, unpublished data), these estimates are likely conservative.

To determine sample size necessary to meet our objectives, we used these pilot estimates to conduct a power analysis. Using Program MARK (White and Burnham 1999), we simulated a scenario intended to mimic the expected response of snowshoe hares to pine beetle outbreaks in the lodgepole system. That is, for each simulation we specified a true model in which $p = 0.2$, and ψ for un-impacted stands was very low (0.1) but increased linearly to ~0.5 for stands that were impacted 15 years ago. We then fit to the data generated from this true model, an estimation model with the same structure as well as a second estimation model that did not include the linear relationship. We conducted 1000 simulations in this fashion for sample sizes of $N = 50, 75, 100, \ldots, 250$ sample units. We then computed the proportion of times out of 1000 simulations in which Akaike's Information Criterion (corrected for small sample size, AIC_c, Burnham and Anderson 2002) selected the estimation model that reflected truth. We interpreted this proportion as a measure of power, the probability of correctly identifying the underlying relationship given the sample size. This exercise indicated that we need to sample 125–175 units in order to attain enough power ($1-\beta = 0.80$) to reasonably expect to identify relationships of interest (Fig. 4). We assumed that these power estimates would be conservative for avian species as more information is available for estimating parameters of interest due to the 16 spatial subsamples within each primary unit.

Site Selection:

We obtained a 1-km grid covering western Colorado from the Rocky Mountain Bird Observatory (RMBO). From this we selected the population of sample units of interest based on the following criteria: Units had to occur largely on public land (i.e., we selected only those cells in which the ownership in the RMBO GIS layer was indicated as Forest Service, Bureau of Land Management, National Park Service, or State of Colorado), ≥75% of each unit had to occur above 8500' to ensure a reasonable chance of detecting hares and martens (Buttery and Gillam 1987, Armstrong et al. 2011), and ≥75% of each unit had to be covered with coniferous subalpine forest vegetation (i.e., spruce/fir, lodgepole pine, or mixed cover types as mapped using the Colorado Vegetation Classification Project dataset [CVCP, ndis.nrel.colostate.edu/coveg]). This resulted in a 15,113 sample units available for sampling.

Next, we overlaid the CVCP vegetation layer and tallied the percentage of each sampling unit covered by spruce/fir forests (CVCP values 61, 71, 81) or lodgepole forests (CVCP values 68, 77, 86). A unit was classified as spruce/fir if at least 2/3 of the vegetation cover within it was coded as spruce/fir; similarly, a unit was labeled as lodgepole pine if at least 2/3 of its land area was covered by that vegetation type. Units that could not be classified as one of these 2 vegetation types but for which the sum of the spruce/fir and lodgepole types exceeded 2/3, were classified as "mixed" forests. Because mixed forests generally occur adjacent to pure lodgepole pine stands, and because we do not have the resources to sample 3 stand types, we lumped these with lodgepole pine for the purposes of site selection. There were 7,035 units available for sampling in the spruce/fir stratum; 8,078 available in the lodgepole/mixed stratum

We selected a sample of 150 1-km^2 units from each of the 2 strata (spruce/fir, lodgepole/mixed) using the Reversed Randomized Quadrant-Recursive Raster (RRQRR) algorithm (Fig. 5, Theobald et al. 2007). This algorithm draws a random sample from the population of potential sample units, thus ensuring that the inference drawn from the sample applies back to the population. However, it also guarantees spatial balance such that selected sample units cover the full extent of the occurrence of the population in space. Importantly, the algorithm also assigns a sampling order to every unit available so that if and when units need to be discarded due to issues with access, safety, etc., new units (e.g., units 151, 152, 153, etc.) can be added on the fly to replace discarded ones without compromising the integrity of the sample.

To identify the types of relationships described in Section D above, the sample units should ideally be spread across the range of the primary covariate, "time since initial infestation." To check that this was roughly the case, we created a histogram binned by year of initial infestation. In general, the spatially balanced sample from the lodgepole/mixed stratum resulted in roughly equal representation of the available year classes. However, because the spruce beetle epidemic has not advanced to the extent of the pine beetle outbreak, stands that had not yet been infested were over-represented in our initial spatially balanced sampled from that stratum (i.e., 60% of the units selected had not yet been impacted). To even out our sampling (reduce the amount of sampling in the un-impacted category and spread the effort to other categories), we re-ran the RRQRR algorithm, this time specifying an inclusion probability of 0.2 for unimpacted units, 1.0 for all others. This resulted in a sample that was still balanced over space, but also more balanced with respect to time since initial infestation.

Covariates:

There are numerous variables that may influence both p and ψ. Some of these are of genuine interest (e.g., how occupancy estimates vary with time since initial infestation) while others are simply nuisance variables that create noise in the modeling process (e.g., daily differences in wind speed or differences between observers). Either way, variables that have a significant impact on either parameter should be measured and included in the analysis to afford the best opportunity for discovering how species react to beetle infestations. We provide a list of potential covariates of interest (Table 2) and indicate which will be collected during sampling, after sampling, and from remotely sensed information.

Data Analysis:

Data from the avian surveys will be uploaded daily and housed on a server maintained by RMBO. The RMBO database is designed to handle the type and quantity of data collected for this project and will facilitate queries necessary to prepare data for analyses. We will employ the hierarchical occupancy model described by Pavlacky et al. (2012) to analyze avian data. This model properly treats the 16 subsamples and will allow us to make inference about occupancy at the 1-km scale of interest as well as at subsampling scale (16 points). At a minimum, we will fit for each species, or guild of species, models that specify a constant, linear, quadratic, or 3rd order polynomial relationship between occupancy and time since initial infestation. We will make inference regarding which of these hypotheses best describes the response of a given species to beetle infestation using AIC_c. As described above, there is likely to be a large number of covariates that can potentially influence estimates of occupancy and/or detection probability, and an even larger number of potential combinations of these covariates. Given this reality, we will likely employ some sort of ad hoc method for limiting the size of the model set (Lebreton et al. 1992, Doherty et al. 2012). Because we will record the radial distance from the point count station to detected individuals, it may be possible to estimate density using distance sampling for at least some species (Buckland et al. 2001).

For mammalian species, all photos and associated data will be stored in a custom database previously designed by CPW for camera work. For each species and habitat type, we will fit models reflecting the same relationships between occupancy and time since initial infestation described above. However, these models will be fit using the tradition single-season occupancy formulation as described by MacKenzie et al. (2002, 2006) and implemented in Program MARK (White and Burnham 1999). As with modeling of avian response to beetle outbtreak, we will consider several covariates likely to influence detection and/or occupancy, and will use an ad hoc method to limit the number of possible models to fit.

RESULTS

As planned, we sampled 150 sites (N = 75 in each stratum) from May 28 to July 17, 2013. We were unable to secure permission to sample in wilderness using remote cameras. Therefore we excluded 74 sites selected in the original spatially balanced sample and replaced them with other sites outside of wilderness. Additionally, 7 sites from the original sample were discarded due to private property; 4 were discarded as they were deemed too difficult to access and/or sample; 4 were discarded due to wildfire activity. We hope to obtain permission to sample wilderness sites for the 2013–14 sampling season. In that case we will sample wilderness sites selected initially in addition to those sites slated for sampling in 2013–14.

At this time, all data from the avian sampling portion of the project has been entered into the RMBO database, but no analyses have been performed. Fifty-six of the 150 remote cameras have been retrieved, yielding over 61,000 photos. Two of these cameras were destroyed by the West Fork Fire, which started near Wolf Creek Pass in the middle of June. No photos could be salvaged from those 2 devices. Two more cameras suffered severe, internal water damage. These cameras operated for at least part of the sampling period and we retrieved photos taken during their active period. Camera retrieval is ongoing and is expected to be complete by September 30. Photos have not yet been archived, but a cursory look at the sample indicates that all 3 mammalian species of interest were detected. Additionally, we obtained photos of elk, deer, moose, black bears, ground squirrels (   ), chipmunks (*Neotamias* sp.), and several species of birds.

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Table 1. Species of conservation concern targeted for sampling within the proposed project. All species are listed as Tier 1 or Tier 2 under the Colorado Wildlife Action Plan (CWAP) and/or as sensitive species by the United States Forest Service Region 2 (USFS R2) and/or as vulnerable at the Sub-national scale by NatureServ. Note that snowshoe hares and red squirrels are not listed specifically by any of these entities (thus the gray symbols), but together they comprise nearly 100% of the diet of Canada lynx, a state and federally listed species.

Species	CWAP	USFS R2	NatureServ
Mammals			
snowshoe hare	x		
red squirrel	x		
American marten		x	
Birds			
American Three-toed Woodpecker	x	x	x
Broad-tailed Hummingbird	x		
Cassin's Finch	x		
Cordilleran Flycatcher	x		
Dusky Flycatcher	x		
Dusky Grouse	x		
Evening Grosbeak	x		
Northern Goshawk	x	x	x
Olive-sided Flycatcher	x	x	x
Red Crossbill	x		
Red-naped Sapsucker	x		
Williamson's Sapsucker	x		

Table 2. Potential covariates that may influence detection probability (p) or occupancy (ψ) or both.

p	ψ
observer[a]	habitat type[a]
wind[a]	time since initial infestation[c]
cloud cover[a]	maximum severity of infestation[c]
temperature[a]	topographic wetness index[d]
habitat type[a]	canopy cover/height/species composition/live-dead[a]
canopy cover[a]	shrub cover/height/species composition[a]
shrub cover[a]	ground cover/type[a]
slope[b]	distance to edge of infestation wave[d]
	basal area[b]
	trees/acre[b]
	saplings/acre[b]
	coarse wood[b]
	horizontal cover[b]

[a]Recorded at each of the 16 point count stations during avian surveys; habitat covariates measured via ocular estimate.

[b]Detailed common stand exam measurements taken at camera location upon retrieval of camera

[c]Obtained from USFS Aerial Detection Survey Data, 1996-2012

[d]Computed using GIS

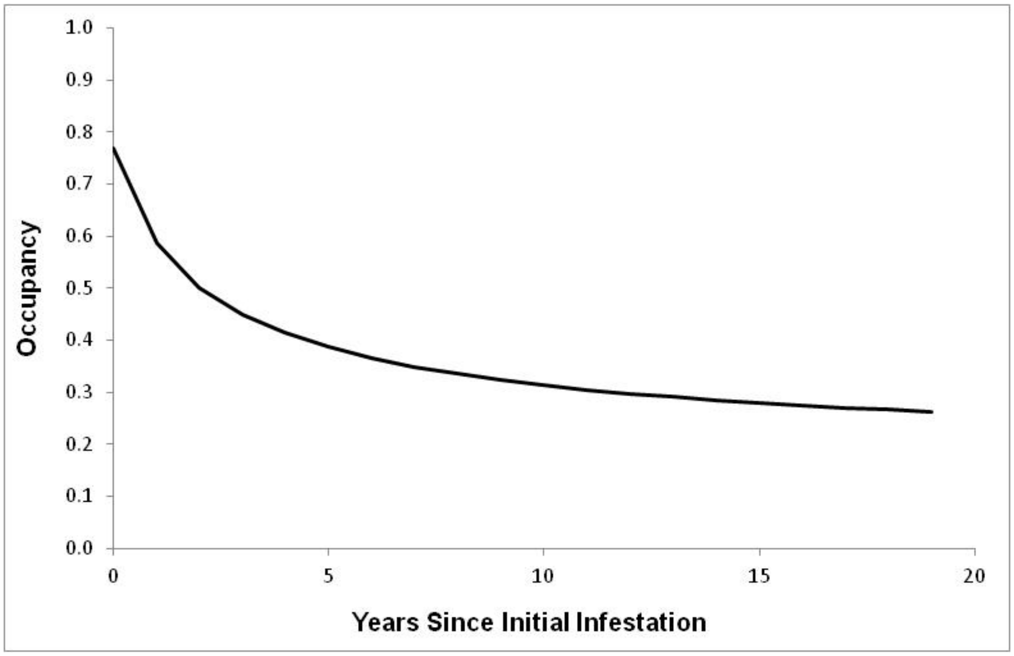

Figure 1. Hypothesized relationship between red squirrels time since initial infestation by mountain pine beetles. Occupancy should be high for mature lodgepole stands that have not yet been impacted by beetles, but should drop over time as cone production declines.

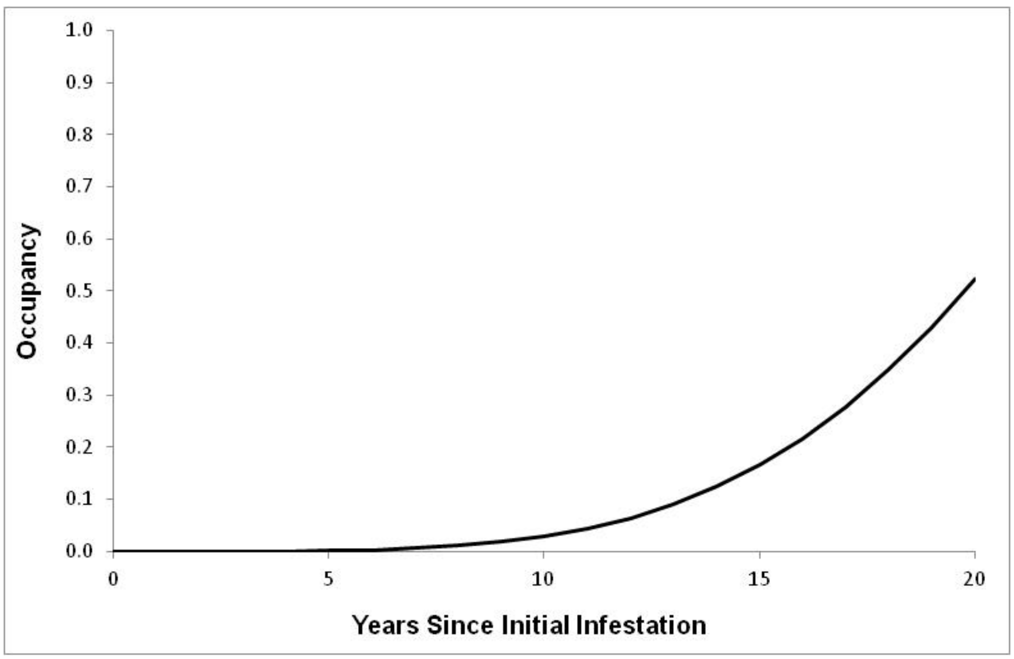

Figure 2. Hypothesized relationship between snowshoe hares and time since initial infestation by mountain pine beetle. Occupancy should be near zero for mature lodgepole stands that have not yet been impacted by beetles, but should increase over time as the understory develops.

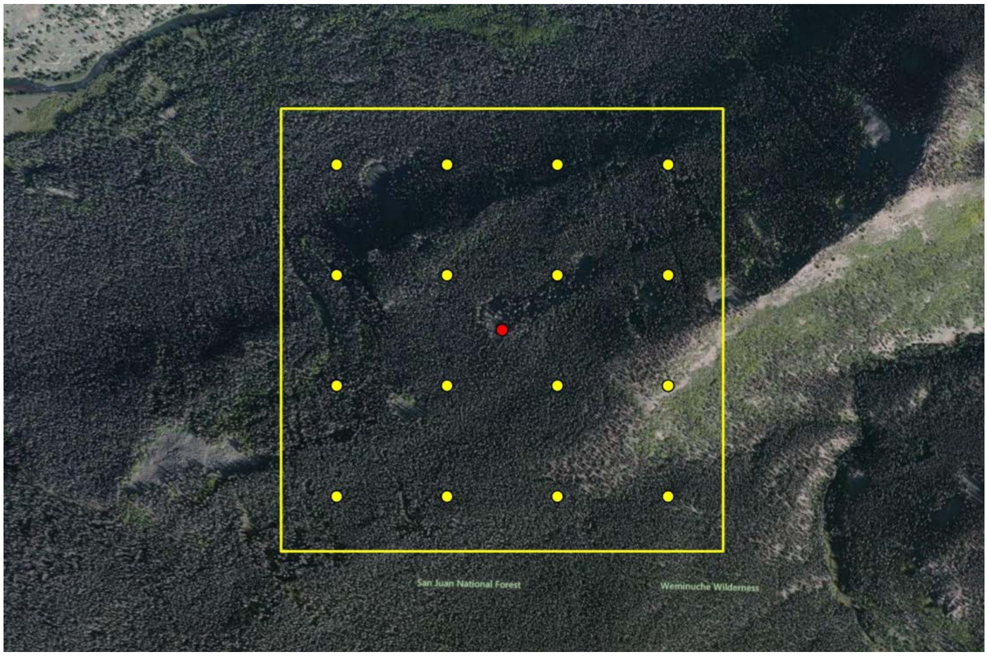

Figure 3. Example 1 km^2 sample unit with 16 equally spaced (250m) point count locations (yellow circles) inside and a remote camera deployed in the center of the unit (red circle).

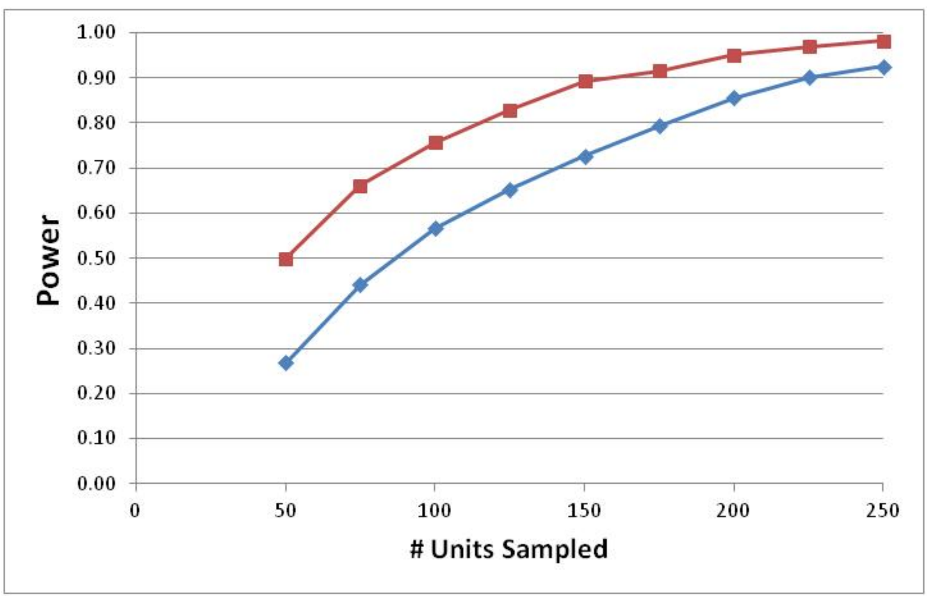

Figure 4. Power for detecting a linear relationship between occupancy and “time since initial infestation” for various sample sizes (number of 1-km units sampled). Curves are based on estimates of *p* obtained from pilot work. For all simulations ψ was specified to be 0.1 for un-impacted stands and increased linearly to 0.5 for stands impacted 15 years prior. Curves represent the proportion of 1000 simulations in which AIC_c correctly identified the model with the “time since initial infestation” covariate as the better model (red squares) or the better model by at least 2 AIC_c units (blue diamonds) compared to a constant model without the effect.

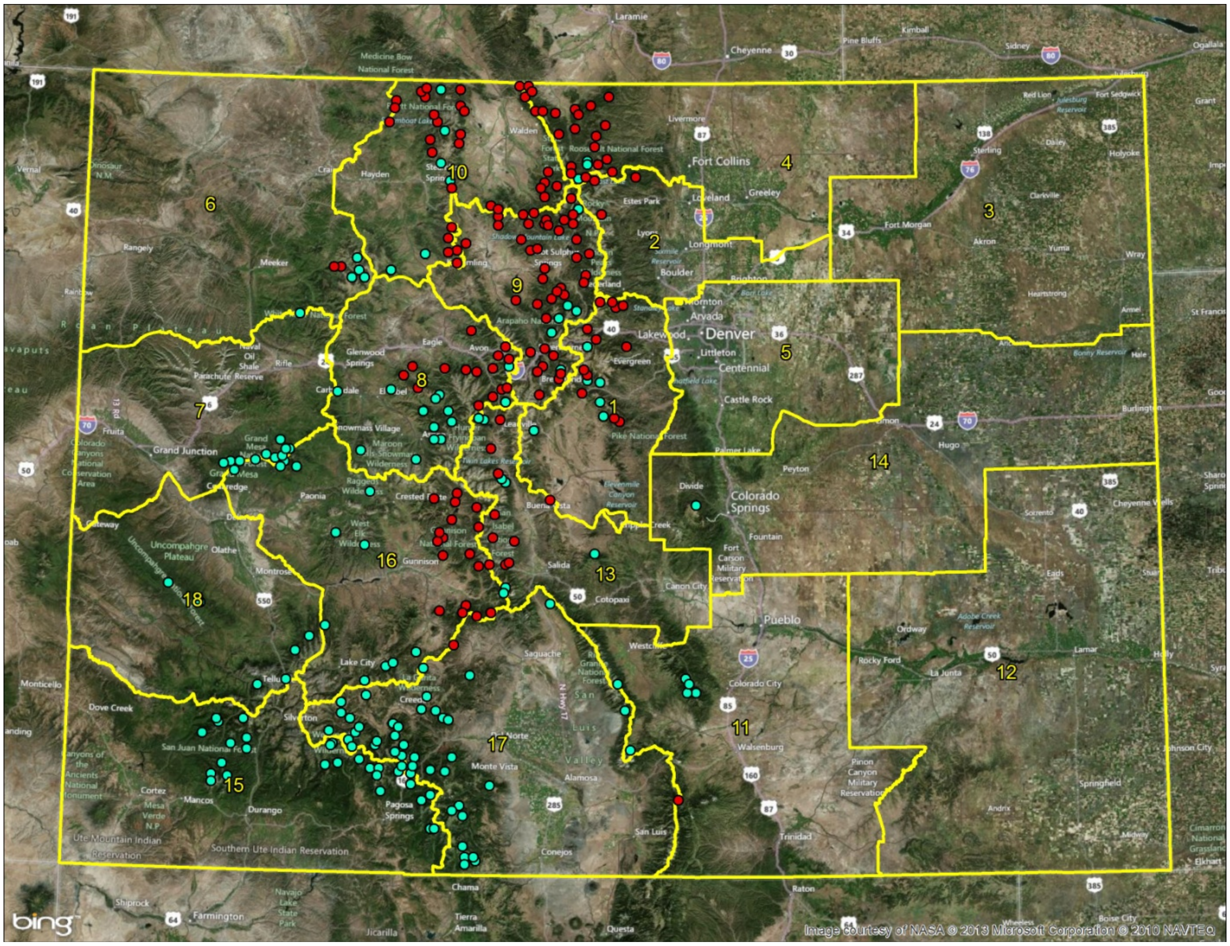

Figure 5. Initial selection of sample sites overlaid on Colorado Parks and Wildlife Area boundaries (yellow polygons). Red markers indicate the initial 150 sites selected for sampling the lodgepole pine/mixed system. Teal markers indicate the initial 150 sites selected for sampling the spruce/fir system. Selection was random and spatially balanced. Note that these sites are only the initial selection. Some will be discarded and replaced due to safety, access, and other issues during the course of sampling.