Diversity Monitoring in Montana

2008-2010

Final Report

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Executive Summary

In Montana, very little information exists on the status and distribution of a diverse assemblage of vertebrates, including small mammals, amphibians, terrestrial reptiles and bats. The Montana Inventory & Monitoring Project (Diversity Monitoring) was initiated to: (1) simultaneously provide information on a diverse suite of faunal groups; (2) provide baseline information on species' distributions, site occupancy rates, and detection probabilities that can be used to inform current species conservation status ranking and management efforts; (3) evaluate methodologies and preliminary estimates of site occupancy and detection rates in order to refine survey protocols for future monitoring efforts; (4) establish a baseline of information that can eventually be used to assess changes in distribution and status over time related to changes in habitat and/or management efforts; (5) identify immediate or future research needs for individual species, species assemblages, or habitats; and (6) identify gaps in species' ranges across the state and potentially create maps identifying patterns in individual or collective occupancy rates of species across the state.

During the period 2008 - 2010, 3,863 individual surveys were conducted during 213 days at 3,048 unique locations within Montana. A majority of sampling occurred on private property (51%), with additional sampling occurring on US Forest Service property (16%), Bureau of Land Management property (13%), State land (12%) and other lands (9%).

During structured surveys, 5,806 species detections were recorded, and of those detections, 84 unique species were identified. In addition to structured survey observations, 5,912 species observations were recorded incidentally at 2,634 different locations. We detected 21 Species of Concern in Montana during structured surveys but failed to detect several others identified as Species of Greatest Conservation Need in the Comprehensive Fish and Wildlife Conservation Strategy (2005) including; Great basin pocket mouse, northern bog lemming, meadow jumping mouse, Couer d'Alene salamander, milksnake, smooth greensnake, and Western hog-nosed snake.

The number of detections and number of different species detected for each sample type varied considerably by geographic location. In general, the number of bat species detected was highest along the length of the Missouri River and lowest in the northern quarter of the State. The number of species detected at lentic sites was highest in east-central Montana. For small mammals, the number of species detected at survey sites was highest in eastern Montana and lowest in southwestern Montana. The greatest number of herp species detected at survey sites was found in south central and south east Montana, however, detections statewide were overall low.

Deer mouse had the highest estimate of occupancy for small mammal trap line surveys. For bat acoustic detector surveys, several species had detection-corrected occupancy estimates near 80% within their known range in Montana at the q-quad scale, including hoary bat, little brown myotis, pallid bat, and silver-haired bat, although a high degree of uncertainty surrounded the estimate for pallid bat. Fringed myotis and Townsend's big-eared bat had the lowest detection-corrected occupancy estimates within their known range in Montana

For lentic site surveys, estimated occupancy rates within the known range of species were highest for long-toed and tiger salamanders and Woodhouse's toad, although the estimates for long-toed salamander and Woodhouse's toad contained a high degree of uncertainty. American bullfrog, gophersnake and great plains toad had the lowest occupancy estimates within their known range. Occupancy estimates were not obtainable for five of the eleven species encountered during reptile area search surveys due to a lack of repeat detections.

We estimated detection probability at both a statewide extent and within the boundaries of the known range of the species within Montana and found that detection probabilities varied greatly between species and species guilds. As a group, reptiles were the least detectable. Estimates of detectability for bat acoustic detectors had little uncertainty when compared to other types of surveys.

Our results indicate that no species was perfectly detected at all survey locations. Because some species are more easily detected than others for a given survey methodology, including the parameter of detectability will improve the occupancy estimate when compared to a raw, or naive, estimate of occupancy.

The data collected through this work expanded the known range for the following seven species: dusky or montane shrew, pygmy shrew, fringed myotis, Eastern red bat, pallid bat, Southern red-backed vole, and montane vole.

Results of our occupancy and detection analyses suggest the single-season survey methodology presented herein can serve as an effective monitoring tool for most bats, small mammals, reptiles and amphibians. We found that the methods used were most appropriate for estimating occupancy of these animals when detection probabilities were greater than one percent. We estimated detection probabilities of less than one percent for several groups of mammals including most squirrels, weasels, skunks, and species including bushy-tailed woodrat, Ord's kangaroo rat, Preble's shrew, Merriam's shrew, Eastern red bat, Yuma myotis, and spotted bat. Many of the targeted reptile species had similar low detection rates. Generally speaking however, we believe the methodologies used provide an adequate framework for broad-spectrum detection of a majority of target species in Montana considering that we detected 40 of 58 small mammal species (excluding lagomorphs and mustelids), 15 of 16 bats, 13 of 22 reptiles and 12 of 19 amphibians during this project.

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Introduction

The Montana Inventory & Monitoring Project (Diversity Monitoring) was proposed in response to a recognized need for baseline information on a variety of non-game species (Montana Comprehensive Fish and Wildlife Conservation Strategy (CFWCS), Montana Fish, Wildlife & Parks 2005). This recognized need included the need to develop a long-term inventory and monitoring program that would:

(1) simultaneously provide information on a diverse suite of faunal groups,

(2) provide baseline information on species' distributions, site occupancy rates, and detection probabilities that can be used to inform current species conservation status ranking and management efforts,

(3) evaluate methodologies and preliminary estimates of site occupancy and detection rates in order to refine survey protocols for future monitoring efforts,

(4) establish a baseline of information that can eventually be used to assess changes in distribution and status over time related to changes in habitat and/or management efforts,

(5) identify immediate or future research needs for individual species, species assemblages, or habitats,

(6) identify gaps in species' ranges across the state and potentially create maps identifying patterns in individual or collective occupancy rates of species across the state.

Background

Maintaining a diverse assemblage of native species is important for maintaining the ecological relationships and ecological services on which all species depend. Benefits of maintaining biodiversity may include protecting food web dynamics, safeguarding against disease outbreaks, maintaining high quality range and forest land, and providing harvestable plants and animals (Allan and Flecker, 1993). Everett et al.(1994), Noss and Cooperrider (1994) suggest that monitoring biodiversity is an important element of ecosystem management and can be incorporated into an adaptive management approach for land management.

In Montana, very little information exists on the status and distribution of a diverse assemblage of vertebrates, including small mammals, amphibians, terrestrial reptiles and bats (Montana Fish, Wildlife & Parks, 2005). Completing baseline statewide assessments is essential to determining appropriate steps for conserving these species.

The goal of this project was to develop and refine survey, inventory, and monitoring protocols in order to better understand the distribution, status, and habitat requirements of species or groups of species identified as most in need of inventory within Montana (Montana Fish, Wildlife & Parks, 2005). It is our hope that development of effective and standardized methodologies will allow other state, federal, tribal, and private entities to follow our lead and gather compatible data. In addition, standardized protocols will set the stage for future work.

Methods

Planning for this three year project began in 2007 with plans to divide the state into three survey areas. The first area selected to be surveyed was the northeast section of the state. Surveys began in this area in 2008 (Figure 1). Six crew members were hired each year to work in teams of two. Table 1 summarizes the materials used for each survey type.

Sample Site Selection

We used a stratified randomized sampling design to select survey sites across public and private lands statewide in order to make inferences about occupancy and detection rates in various habitats within the known range of individual species. The sample site, or unit of study for this project, was defined as a quarter-quadrangle grid cell (q-quad) and there were 11,265 potential q-quads available for sampling across the state (Figure 1). Quads were divided into primary and oversample groups to give crews flexibility in eliminating quads with limited access, inappropriate habitat, or inadequate habitat for surveys. Individual q-quads varied slightly in size, but were generally 3 x 4.3 miles in size (Figure 2). Q-quads that were entirely contained in water or within Bureau of Indian Affairs or National Parks land were not included as potential sites to be sampled for this study. All q-quads that were sampled were surveyed on multiple occasions over a period of several days based on a strict schedule (Figure 3). Specific survey locations within each q-quad varied depending on the faunal group that was the focus of each survey type (see below) (Figure 4).

Small Mammal Trapline Surveys

Three potential survey sites were placed within each q-quad: one within a riparian cover type, and one within each of the two most dominant cover types. If the two most dominant habitat cover types were extensively modified by humans (e.g., hay field and cropland), only one of the modified habitats was surveyed. Survey locations were prioritized based on: (1) their accessibility, i.e, public land or private land where permission had been granted; and (2) the size of the cover type patch. Large patches were preferred for sampling to limit influence from adjacent habitat types.

Traplines were oriented in habitat cover type patches so that they were all within relatively uniform structure. Each 100-meter line was composed of 10 stations, each spaced 10-meters apart. Each station had 1 Victor mouse trap, 1 museum special, 1 pitfall trap, and 1 Sherman trap and station numbers 2 and 9 also had a rat trap (Figures 5 and 6). Traplines were allowed to weave or arc in order to remain within a single habitat cover type. Pitfall traps were dug into the ground and placed flush with soil so that animals were not alerted to their presence; when possible, pitfall traps were placed to take advantage of natural fences in the terrain like logs, rocks and drainages. Snap traps were baited with a peanut butter and sweet feed mix and Sherman traps were baited only with sweet feed mix to keep trigger devices clean. Snap and Sherman traps were placed in natural runways approximately 1-meter from the central pitfall trap rather than at exact right angles as indicated in the example diagram (Figure 5).

All traps were set in the evening and checked each morning as early as possible to minimize animal stress and mortality. Traps were sprung and left closed each morning in order to prevent incidental mortalities of non-target species. Surveyors wore latex gloves and HEPA masks when handling live and dead animals and checking traps. Hand sanitizers were used after handling traps. To handle live captures in Sherman traps, a bag was placed over the trap opening and the animal was shaken into the bag, sexed, weighed, measured, marked and released. Measured attributes included total length (nose to tail tip), tail length, hind foot length (include claws), ear length.

The following were kept as museum voucher specimens at each q-quad: (1) the first specimen of deer mouse, montane vole, and meadow vole; (2) all snap trap captures of other species regardless of number captured; (3) all shrews; (4) any animal for which species identity was uncertain; (5) one example of each species captured. When necessary, live animals were euthanized by placing a cotton-ball dabbed with a small amount of isoflurane into the opposite corner of the bag until 15 or more minutes after the animal had stopped breathing. Vouchered specimens were placed in an individual zip lock bag with a fully completed museum voucher tag. All specimens from each trap line were placed in a larger bag labeled with the trapline (site) name and number and q-quad name and number. After the three nights of trapping in a q-quad, all bags from each trap line were placed in a bag labeled with the q-quad name and number. Vouchered animals were placed on ice or in a refrigerator. All vouchered species were later sent to the University of Montana, Missoula to be prepared as museum voucher specimens by work study students. Species identification was verified by Paul Hendricks, Montana Natural Heritage Program Zoologist, and Dave Dyer, Curator of the Phil Wright Memorial Zoological Museum.

Variables recorded at each small mammal trap line included both categorical and quantitative descriptions of habitat and conditions during the survey (Appendix I - Small Mammal Trap Line Data Sheet). Digital photographs of each trap line were taken from a vantage point that allowed the trap line flags to be seen in the context of the surrounding habitat.

Bat Acoustic Detector Surveys

Each major habitat cover type within each q-quad was sampled using a Petterson D240x acoustic detector attached to I-river MP3 player/recorders (typically the iFP-899 model, but also the H320 Zoom model). Survey locations were prioritized by the following criteria: (1) representation of all major cover types; (2) readily accessible locations on public land or on private lands where permissions to survey were received; and (3) wetland and native terrestrial cover types; and (4) relatively large habitat patches where the detector could be placed inside the edge of the habitat patch by 100 meters or more. Detectors were spaced a minimum of 400-meters apart in order to ensure independence between surveys.

Variables recorded at each acoustic survey site included both categorical and quantitative descriptions of habitat, the origin and quality of the habitat, and potential threats to the habitat (Appendix I - Bat Acoustic Survey Data Sheet, including detector settings).

Acoustic detectors and recording devices were housed inside weatherproof containers that were mounted on conduit attached to a piece of rebar pounded into the ground as an anchor point (Figure 7). Detectors and recorders were turned on shortly before dusk to capture the first emerging bats of the evening and were collected each morning at various times after sunrise. Batteries in the detector and recorders sometimes died during the deployment period, especially on cold nights. However, we feel that the detector/recorder units consistently recorded for the first six hours after deployment. Detectors were collected each morning and .wav files were downloaded to a laptop computer and attributed with q-quad, location, basic habitat descriptions, and other survey information.

At the end of each field season, calls were analyzed using Sonobat 3.0™ (SonoBat, 2012), which has automatic species recognition capabilities using a hierarchy of discriminate function analyses on up to 72 different call characteristics (e.g. duration, upper slope, lower slope, maximum frequency). However, this software package does make regular errors in species identification. Thus, In order to verify the call identification results of this automated program, at least one call sequence per species per site was confirmed by hand by Susan Lenard, Montana Natural Heritage Program Zoologist.

Specific detector settings: The Petterson D240x detector settings were: normal, time expanded output, high gain, auto trigger, low trigger level, high frequency trigger source, and 1.7 seconds of real-time recording. The H320 Zoom recorder settings were: File Format = MPEG layer 3; Encoder bitrate = 160 kilobytes per second; Frequency = 44.1 kHz; Source = Line In; Channels = Mono; File Split Options = N/A; Prerecord time = 1s; Clear Recording Directory = N/A; Clipping light = N/A, Trigger settings = repeat, stop, 1s, -25db, 0s, -40db, 2 s, 1s; Automatic Gain Control = N/A; AGC Clip Time = N/A.

Lentic Site Surveys

All standing water bodies present within each quad or found incidentally while in the field were surveyed when they were accessible. If no standing water bodies were found on the topographic maps, accessible lands were surveyed for water by driving roads or hiking major trails to examine areas of low topographic relief or backwaters of streams that might provide lentic breeding habitat. If too many suitable water bodies were found within each quad, those likely to have more suitable habitat were prioritized for survey.

Each water body surveyed within a lentic site was considered an independent survey location. Surveys were considered independent by individual observer as well. Timed visual encounter and dip net surveys were conducted in all portions of the water bodies less than 50 cm in depth. If little emergent vegetation was present, then observers were asked to carefully examine shallow water environments for the presence of eggs, larvae, or post metamorphic animals. Areas with extensive shallows required systematic searches and dip netting while wading through the area on evenly spaced transects (Figure 8). In areas with dense emergent vegetation, observers intensely sampled the area with a dip net. At sites with steep shorelines, visual searches and dip netting were performed. If multiple waterbodies were surveyed within a 200 meter radius of an existing start point, those waterbodies were considered as part of the original survey. Digital photographs of each site were taken from a vantage point that allowed the entire site to be seen in the context of surrounding habitats.

Variables recorded at each lentic survey site included both categorical and quantitative descriptions of existing habitat, the origin and quality of the habitat, and potential threats to the habitat (Appendix I - Lentic Site Survey Data Sheet).

Voucher specimens of amphibians and reptiles were collected if the record filled a significant hole or extended the species' known range or if the identity of the species was uncertain, e.g., tadpoles found in eastern MT. For amphibian and reptile eggs, and newly hatched amphibians, individuals of the same species were placed together in a small jar containing 10% buffered formalin. Amphibian larvae that were collected as vouchers were first placed in a Tricaine (MS-222) solution (1 teaspoon per liter of H_2O) until they failed to respond to a mechanical stimulus. They were then placed in a 10% buffered formalin solution for storage.

Amphibian adults and juveniles collected as voucher specimens were euthanized by placing a small bead (3/4") of extra strength Orajel (20% Benzocaine active ingredient) on a finger and spreading it out over the thighs, abdomen, and top of the head of the individual(s) collected. The animal was then placed in a Ziploc bag in a darkened area (e.g., a box) for 10-15 minutes until the animal failed to respond to a mechanical stimulus. The brains of the animals were then injected with a 10% neutral buffered formalin solution in order to stop the animal's central nervous system. Animals were then placed in a fixing container containing a shallow layer of 10% formalin with formalin-soaked paper towels placed on top of them for >24 hours to fix the specimen(s) tissues. Body cavities of large individuals were injected with 10% buffered formalin using a syringe. After 24 or more hours, the fixed individual(s) were placed in a jar containing 10% buffered formalin. All specimens remained in 10% buffered formalin until the end of the field season. At the end of the field season specimens were removed and washed in a jar of water (preferably running water) for 48 hours. For long-term storage, individually tagged specimens were placed in a jar containing 70% ethanol.

Reptile Area Search Surveys

Survey sites were located by visually assessing each quad on 1:24,000 scale topographic maps for areas with noticeable topographic relief (Figure 9). Rock outcrops and cliff faces often constitute boundaries between substrate types that differ in erodibility and rock strata. These areas often provide underground chambers or collapsed areas that serve as cover or even hibernacula. Other factors considered in survey site selection included: (1) site accessibility, i.e., public land or private lands where permission was received; (2) size of the rock outcrop (the larger the size, the better); and (3) aspect of the survey location, with higher priority given to south facing sites than north facing sites. When time allowed, field crews attempted to survey four or more rock outcrops per quad.

Each rock outcrop or coulee rim surveyed was considered an independent survey location. Surveys were considered independent by individual observer as well. If a rock outcrop or coulee rim was large, then multiple survey locations were made using an approximate size of 400 x 100 meters, based on natural breaks such as a drainage or area with reduced amounts of cover objects. If rock outcrops or coulee rims were not present within a quad, then transects through a dominant cover type were substituted as survey locations.

Timed visual encounter surveys were conducted in all portions of the rock outcrop by slowly moving through the area. Rocks were visually examined at distances from 0 to 15 meters. Objects providing cover, such as logs or rock slabs were lifted. Potato rakes were used to probe rock crevices while listening and watching for animal movements.

Digital photographs of each site were taken from a vantage point that allowed the entire site to be seen in the context of surrounding habitats. Variables recorded on datasheets at each reptile survey site included categorical descriptions of existing habitat and conditions of the survey that could have influenced the probability of detecting the species (Appendix I - Reptile Data Sheet).

Voucher specimens of reptiles were only collected if the record filled a significant hole or extended the species' known range or if the identity of the species was uncertain. Protocol for preserving voucher specimens of reptiles followed that of the amphibian preservation protocol. Large snakes and turtles were not euthanized nor were they collected as voucher specimens unless found dead (e.g., road kill).

Incidental captures and observations

During surveys for other taxa crews recorded all non-target animals that could be identified to species. Number of individual and any notable behavior, such as courtship or nesting, was also recorded. (Appendix I - Incidental Data Sheet). Incidental animals encountered that could not be identified to species level were collected as voucher specimens for later identification purposes. No migratory birds were collected.

Millipedes, slugs, and snails were placed directly into vials containing 70% ethanol. No more than two animals of each species were placed in containers. After death (6-24 hours) any mucus exuded was gently brushed off and the animal was placed in 95% ethanol for 24-48 hours. Any remaining mucus was then brushed/washed off again and a dissecting pin was used to perforate the animal along its length so that ethanol would penetrate the body. Animals were then placed in 70% ethanol for long-term storage so they could be used as museum vouchers and as a source of tissue for genetic analyses.

Data Management

Each of the multiple, roving survey crews used standardized data sheets to record information and describe variables for each type of survey (Appendix I - Data Sheets). At the end of each day, crews used laptop computers to record data into a Microsoft Access database (Figure 10). At the end of the field season, each of the crew databases were checked for errors and missing information. Final data were then appended to a master database.

Once all data were compiled for all years, we used a series of queries in the database to populate detection and non-detection data and create encounter history files. These encounter history files were later used to estimate occupancy and detection probability for each species. Photographs taken of each survey location and representative photographs of each quad were downloaded onto laptops and labeled with quad name, location name, and date.

For each reptile search area, the area surveyed was delineated in GIS and estimates of total area surveyed were populated back into the database. We also used GIS to populate descriptive statistics for each survey location such as elevation, percent ReGAP habitat cover type within 100 meters of each survey location, and land ownership (public or private).

Data Analysis

We used single-season occupancy models to estimate the proportion of sites occupied (psi) and detection probability (p) for each species observed within each of the four different survey types. We used a single-season probability-based model (MacKenzie et al. 2002, 2005, 2006) that consisted of two kinds of parameters: psi represents the probability that a site is occupied by the target species, and p_j is the probability of detecting the species at an occupied site during the *j*th independent survey of a site. Maximum likelihood methods are used to estimate occupancy and detection probability. Within a given season, no changes in occupancy are assumed at each site (i.e., sites are either always occupied or unoccupied by the species), however, if changes in occupancy occur randomly then this assumption can be relaxed (MacKenzie et al. 2006). Additional assumptions that apply to single-season models include: (1) detections occur independently at sites; (2) occupancy and detection probabilities are similar across sites and time, except when differences can be modeled with covariates; and (3) the target species is identified correctly.

Occupancy probability can be modeled as a function of site-specific covariates that do not change during the season (e.g., habitat type), whereas detection probability can be modeled as a function of either site-specific or survey-specific covariates (e.g., weather conditions or observer). Occupancy and/or detection probability can be measured as a function of covariates using the logistic equation:

$$\theta_i = \frac{\exp(\mathbf{X}_i\boldsymbol{\beta})}{1 + \exp(\mathbf{X}_i\boldsymbol{\beta})}$$

, where θ_i represents the parameter of interest for site i, X_i is the row vector of covariate information for site i, and B is the column vector of coefficients to be estimated. A number or habitat covariates were collected for future analysis as resources or interest permit (Table 2). The quad was considered the sampling unit for occupancy and detection estimates at both a statewide scale and within the known existing range of a given species. For each quad, we summarized species detection and non-detection information on the day of survey. Non-detection may arise if either the target species does not occupy the site or the investigator does not detect the species at an occupied site. After occupancy and detection was estimated at a statewide scale, we then used the known range of a species as a constraint to refine and inform our non-detection data. For example, a species was only considered non-detected when it was not observed at a given site and it was possible to capture the species because the survey occurred in the existing known range of the species. If the quad being sampled was outside the known range of the species and it was not detected, the corresponding non-detection data was not included in the analysis. An ArcGIS geoprocess that merged species range maps (Montana Natural Heritage Program, 2012) and quarter-quads was used for this constraint process.

Detection data were stored in an MS Access database. A python script was used to access data tables and create encounter history files in a .txt format for each species in a given survey (Appendix II). Encounter history files for each species with detection and non-detection data were formatted such that a '1' was assigned to detections and a '0' was assigned to non-detections for each quad and day sampled for a given survey type. A python script was then used to import encounter history files into an analysis program that estimated occupancy and detection.

We used the R (R Development Core Team, 2012) package RMark (Laake and Rexstad, 2008) to construct single-season occupancy models for program MARK (White and Burnham, 1999). We chose program MARK because it can interface with Program R and allows for single-season occupancy models as well as covariate analysis. Estimates of occupancy and detection probability were made at two different scales, the quad level (a 3x4.3 miles grid) and location level (defined as a 100 meter buffer around a survey point). By estimating occupancy and detection rates at two different geographic extents or grid sizes we hoped to see changes in occupancy and detection estimates that might indicate differences in the home ranges of the species being surveyed.

We then refined our occupancy and detection probability estimates by limiting the occupancy and detection estimates to the known range of the species within the state (range-limited estimate). In essence, this estimate of detection and occupancy would indicate the likelihood of detecting a species in areas of the state that may contain suitable habitat in which a species of interest could occur. We later included location level and survey level covariates to explain differences in location-level occupancy and detection probability estimates using a competing-model based approach**.**

Results

Survey Summary

During the period 2008 - 2010, 3,863 individual surveys were conducted during 213 days at 3,048 unique locations within 282 individual quads within Montana (Table 3). The number of quads sampled represents 3% of available quads for the entire state. A majority of sampling occurred on private property (51%), with additional sampling occurring on US Forest Service property (16%), Bureau of Land Management property (13%), state land (12%) and other lands (9%).

During structured surveys, 5,806 species detections were recorded, and of those detections, 84 unique species were identified. Species were detected at most small mammal, bat acoustic, and lentic site surveys, however, reptile search survey detections were less productive (Table 4). For small mammal, lentic site, and reptile surveys, most detections were identifiable to a species although a few detections did not result in species identification either because there was not an accompanying or acceptable voucher specimen that could be used to verify the record or the specimen could simply not be identified to the species level. Many bat acoustic call sequences did not have definitive detection call sequences and therefore were identified as 'probable' species detections. Only definitively identified bat acoustic call sequences were included as acceptable observation records (Table 4). In addition to structured survey observations, 5,912 species observations were recorded incidentally at 2,634 different locations.

We detected 21 Species of Concern in Montana during structured surveys but failed to detect several others identified as Species of Greatest Conservation Need (CFCWS, 2005) including; Great basin pocket mouse, northern bog lemming, meadow jumping mouse, Couer d'Alene salamander, milksnake, smooth greensnake, and Western hog-nosed snake.

The number of detections and number of different species detected for each sample type varied considerably by geographic location (Figures 11a - 11d). In general, the number of bat species detected was highest along the length of the Missouri River and lowest in the northern quarter of the state. The number of species detected at lentic sites was highest in east-central Montana than in western Montana. For small mammals, the number of species detected at survey sites was highest in eastern Montana and lowest in southwestern Montana. The greatest number of herp species detected at survey sites were found in south-central and south-east Montana however detections statewide were overall low.

For small mammal trap line surveys, the total number of captures differed by trap type and species (Table 6). Museum Specials accounted for the most number of captures (N=619) and had the highest success rate per trap set (6.6% were successful), whereas track plates were the least productive with four captures and a detection rate of 1.4%. Due to the sampling design, the number of each trap type set varied considerably with many more pitfall, Sherman, and mouse traps used compared to rat traps, Tomahawk traps and track plates. Forest and woodland habitats accounted for the most number of small mammal and bat species captured (Table 5). The average amount of time spent surveying varied by survey type (Table 3). Because small mammal trap lines and bat acoustic detector surveys were overnight efforts, those surveys lasted for longer periods of time (851 and 750 minutes, respectively) when compared to lentic and reptile search surveys which were discrete events lasting an average of 34 and 45 minutes, respectively (Table 3).

Occupancy Estimates

We estimated occupancy at the q-quad level for each species captured at two different spatial extents, a statewide extent and within the boundaries of the known range of each species in Montana (Range-limited estimate) (Tables 7-8). We also estimated occupancy at the location level within the boundary of the known range of each species in Montana (Figures 12b – 17b). A lack of repeat detection data prevented the estimation of occupancy for species at the q-quad level including many squirrels, weasels, skunks, and other species including Bushy-tailed woodrat, Ord's Kangaroo Rat, Preble's shrew, Merriam's shrew, Eastern red bat, Yuma myotis, spotted bat, eastern racer, northern alligator lizard, spiny softshell turtle, and Rocky Mountain tailed-frog.

Occupancy estimates varied significantly by species and by survey type. For both statewide and range-limited estimates of occupancy (Tables 7-8) at the q-quad scale, deer mouse had the highest estimate of occupancy for small mammal trap line surveys. Detection-corrected occupancy estimates for deer mouse were 93.3% at the q-quad scale and 75.6% at the location level, meaning that deer mouse were likely present at approximately 75% of the locations surveyed. For bat acoustic detector surveys, several species had detection-corrected occupancy estimates near 80% within their known range in Montana at the q-quad scale, including hoary bat, little brown myotis, pallid bat, and silver-haired bat; although a high degree of uncertainty surrounded the estimate for pallid bat. Fringed myotis and Townsend's big-eared bat had the lowest detection-corrected occupancy estimates within their known range in Montana at the q-quad scale, at 13.1 and 2.2% respectively.

For lentic site surveys, estimated occupancy rates within the known range of species (Table 8) were highest for long-toed and tiger salamanders and woodhouse's toad, although the estimates for long-toed salamander and woodhouse's toad contained a high degree of uncertainty. American bullfrog, gophersnake and great plains toad had the lowest occupancy estimates within their known range. Detection-corrected occupancy estimates for reptile species encountered during reptile area search efforts indicate that greater short-horned lizard had the highest point estimate of occupancy within its known range, although the estimate contained a high degree of uncertainty. Occupancy estimates were not obtainable for five of the eleven species encountered during reptile area search surveys due to a lack of repeat detections.

Detection Estimates

We estimated detection probability at both a statewide extent and within the boundaries of the known range of the species within Montana (Tables 7-8) (Figures 12a – 17a). Estimates of detection probability for each species did not vary between statewide and within range extents.

We found that detection probabilities varied greatly between species and species guilds. For example, most shrews and voles had detection probabilities less than 0.6 and were difficult to detect, whereas deer mice, some ground squirrels and some bat species were more easily detectable. Deer mouse had the highest small mammal detection rates, at 88%, whereas mammal species such as long-tailed weasel, northern flying squirrel, Ord's kangaroo rat, striped skunk had detection rates less than 1%. As a group, reptiles were the least detectable, with estimates generally less than 0.2.

Estimates of detectability for bat acoustic detectors had little uncertainty when compared to other types of surveys. Hoary bats had the highest detection rate at 63%, whereas Yuma myotis and spotted bats had detection rates near 1%.

Range Extensions

The data collected through this work expanded the known range for the following seven species: Dusky or montane Shrew, Pygmy Shrew, Fringed Myotis, Eastern Red Bat, Pallid Bat, Southern Red-backed Vole, and montane Vole.

Discussion

Results of our occupancy and detection analyses suggest the single-season survey methodology presented herein can serve as an effective monitoring tool for most bats, small mammals, reptiles and amphibians. We found that the methods described were most appropriate for estimating occupancy of these animals when detection probabilities were greater than one percent. We estimated detection probabilities of less than one percent for several groups of mammals including most squirrels, weasels, skunks, and species including bushy-tailed woodrat, Ord's Kangaroo Rat, Preble's shrew, Merriam's shrew, Eastern red bat, Yuma myotis, and spotted bat. Many of the targeted reptile species had similar low detection rates.

Detection probabilities for these species were low because repeat detections rarely occurred at individual sampling locations. The lack of repeat detections for these species or groups of species suggests that alternative or additional sampling methods may be more appropriate for detecting presence. However, considering that we detected 40 of 58 small mammal species (excluding lagomorphs and mustelids), 15 of 16 bats, 13 of 22 reptiles and 12 of 19 amphibians during this project, the methodologies presented herein provide an adequate framework for broad-spectrum detection of a majority of target species in Montana.

Detection estimates for many of the bat species had a relatively low amount of uncertainty, possibly indicating that bat acoustic detectors and the recording/analyzing software used to analyze bat calls were more able to perfectly detect the presence of species than were human observers that attempted to detect other species during other types of surveys.

Estimates of occupancy from reptile area search survey were heavily influenced by the lack of repeat detections at locations by multiple observers. Because detection estimates were generally low for many species encountered during reptile area search efforts, detection-corrected occupancy estimates were either unobtainable or of poor quality for many reptile species encountered. Occupancy estimates were only available for six of the eleven species encountered on reptile area search efforts. Interestingly, estimates of occupancy that were not obtained for some reptile species during reptile area search surveys were possible with lentic survey data because repeat detections were made more frequently. The lack of detection during reptile surveys and positive repeat detections during lentic surveys suggests that some reptile species such as gophersnake and common gartersnake, and possibly others, are better suited to a more randomized sampling scheme that incorporates a broader range of habitats.

A major benefit of developing occupancy estimates for rare or elusive species is that a large spatial area can be searched at minimal expense, compared to other survey methods that attempt to estimate abundance. Accordingly, for species that are difficult to detect, an estimate of occupancy may be less expensive to obtain, and potentially more meaningful as a description of population status.

Our results indicate that no species was perfectly detected at all survey locations. Because some species are more easily detected than others for a given survey methodology, including the parameter of detectability will improve the occupancy estimate when compared to a raw, or naive, estimate of occupancy. Figures 18a-d show ratios of detection-corrected point estimates of occupancy to non-corrected estimates of occupancy for species captured in this study.

These comparisons suggest that for many species, detectability should be an important factor when estimating site occupancy. Although some species such as deer mouse were easily detectable when present within a q-quad, most species were less detectable. Animal behavior, vegetative cover, weather, and observer skill likely contributed to some differences in detection; however, the reduced detectability of some animals may be due to the use of inappropriate methods for capturing or detecting these species. For example, some of the larger species of small mammals may have been too large to be captured by the Sherman, rat, tomahawk, or pitfall traps used for this survey. Detection capability for each species, survey type, and trap type should therefore be a major consideration when estimating site occupancy. Table 7 therefore provides baseline estimates for which future sampling efforts could be compared against. Undoubtedly, some species such as the white-footed mouse simply cannot be detected with these types of general survey techniques. Species such as the smooth green snake were not detected at all with these efforts due to their behavior and habitat specificity.

Peliminary results (not shown in detail in this report) of competing model based framework for comparing covariates suggests that the presence of certain species and or species guilds may be influenced by a variety of habitat factors. In general, the most predictive covariate for small mammals was elevation, however, many of the competing models failed to out compete the null model. Bat models similarly appeared to be driven by elevation, although the occupancy of numerous species was sometimes best described by an interaction model that considered dominant habitat type and elevation. The models describing the occupancy estimate of lentic species seemed to vary somewhat by species, with some being best described by grazing variables, maximum water depth, or elevation. For species that were best described by maximum water depth, the optimal depth was typically a maximum water depth less than one foot. More analyses could be conducted with this data set and the large number of variables measured.

Although an effort was made to sample all habitats with equal proportion, native habitats were sampled more frequently than non-native habitats. Still, the results of both small mammal trap line surveys and bat acoustic detections surveys highlight the importance of forest and grassland habitats for bats and small mammals. Numbers of species and numbers of detections were highest where the dominant cover type was identified as forest and woodland habitats, with shrub land and grassland habitats a close second.

Potential Improvement to Methods

Changes to the Sampling Protocol

Reptile area search surveys should be randomized to avoid oversampling south facing slopes. This tended to skew results, hence occupancy estimates were only obtained for the subset of reptilian species with a seemingly higher fidelity to south facing hillsides. Expanding the search area to include more diverse types of habitat may have allowed us to detect other species, including species of concern, that utilize moist, shady, or other diverse types of habitats.

Changes to the Database

Although data entry and storage of information collected during the survey was adequate, several changes to the design of the existing database would improve efficiencies in analyzing data. Where possible, limiting free text data entry and forcing categorical designations to pick lists during the data entry process would standardize data fields and greatly reduce mistakes and the need for later error checking and quality control.

We used a Python code that transformed covariate data into a format that could be interpreted and analyzed by program RMark for the estimate of detection and occupancy. Covariate data fields used in text files for program RMark must be formatted such that no spaces exist. Because the database often contained lengthy text descriptions used for field entry and those fields often contained spaces, editing the categorical designations to conform to the format requirement for RMark was resource-intensive. Short notations or codes would have been preferable, as would have numeric designations, when possible.

Additional Improvements

Although this study focused exclusively on vertebrate species guilds for which little information in Montana had previously been collected, the random site sampling and occupancy estimation methods employed by this survey could be expanded to better monitor biodiversity and comprehensively monitor all animal and plant groups in an ecosystem. Wilson and others (1996) identified attributes of biodiversity that can be assessed at each level of ecological organization. At the landscape level, attributes that could be monitored include the identity, distribution, and proportions of each type of habitat, and the distribution of species within those habitats. Although this project did not collect information on non-native plants or climate variables, future modifications to the study design, through the addition of several covariates, could help in understanding potential effects of invasion and climate change. Jonzen et al. (2006) suggests 15 year intervals of data are needed to detect potential changes due to climate change.

Conclusions

The goal of this project to develop and refine survey, inventory, and monitoring protocols in order to better understand the distribution, status, and habitat requirements of species or groups of species identified as most in need of inventory within Montana (Montana Fish, Wildlife & Parks, 2005) was met for a large number of species in Montana. We detected 21 Species of Concern but failed to detect several others identified as Species of Greatest Conservation Need (CFCWS, 2005) including; Great basin pocket mouse, northern bog lemming, meadow jumping mouse, Couer d'Alene salamander, milksnake, smooth greensnake, and Western hog-nosed snake. However, we believe the methodologies used provide an adequate framework for broad-spectrum detection of a majority of target species in Montana considering that we detected 40 of 58 small mammal species (excluding lagomorphs and mustelids), 15 of 16 bats, 13 of 22 reptiles and 12 of 19 amphibians during this project. See tables indicating which species had the highest detectibility rates.

The fact that the known ranges of seven species was extended through this work is significant and important to future management, (range expansions identified for dusky or montane shrew, pygmy shrew, fringed myotis, Eastern red bat, pallid bat, Southern red-backed vole, and montane vole.)

Management Implications

This work has shown that this type of survey is indeed useful to address project objectives particularly for species that are habitat generalist or easily captured, i.e., species with high detectability rates. The species records collected doubled or in some cases tripled the number of records in the state database for nongame records. Positive findings from the results presented here include the range extensions detected for numerous species. This type of information along with the positive detections for various species have and will no doubt have positive influence on species listing decisions by the US Fish and Wildlife Service.

Significantly more complex analysis could be conducted to tie habitat variables to species detection. Habitat management recommendations cannot be made from the results presented in this report but could be made following further analysis of the data collected.

Acknowledgements

This project was conducted over a three year period and was financially supported through a State Wildlife Grant and a matching contribution from Montana Fish, Wildlife & Parks (FWP). Total cost of the three year study was over $750,000 dollars. Montana Natural Heritage Program (NHP) coordinated the logistics of the study in consultation with FWP staff. Numerous field technicians braved harsh weather, biting bugs and a demanding schedule to complete this project. Special thanks to Dan Bachen, Brent Cascaddan, Charles Crawford, Adrienne Cunningham, Ronan Donovan, Ayla Doubleday, Bob Haynes, Shannon Hilty, Kristi Kyle, Stephanie Marcello, Kevin Narum, Ellison Orcutt, Kayhan Ostovar, Christie Quarles, Kyle Richardson, Rebecca Skeldon, Chelsea Whenham, Nicole Wong, and Sarah Young. Biologists from FWP also contributed valuable time in the field to assist with logistics, methods, and surveys, including Allison Begley, Scott Denson, Kristi Dubois, Jay Newell, and Ryan Rauscher. Steve Carson, Andrew Jakes and Adam Messer contributed time in testing and developing pre-project survey methodologies. This project would not have been possible without assistance from species experts such as Susan Lenard of NHP, who served as the resident bat expert, identifying bat acoustic calls. Coburn Currier reviewed over 4,000 bird records collected incidentally during this project. Paul Hendricks and Dave Dyer identified voucher specimens collected during small mammal trapping efforts. David Stagliano assisted with identification of vouchered insects, mollusks, and fishes collected as incidentals. Kevin Podruzny of FWP provided valuable input on the results and interpretation of occupancy and detection estimation models. Lydia Bailey of FWP assisted with cartographic design of species maps. Finally, Jeff Herbert was instrumental in securing funding and supporting this project during its inception.

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Figures

Figure 1. Study area for showing ecoregions and annual sampling frames and quarter-quarter sampling plots with primary and oversample plots.

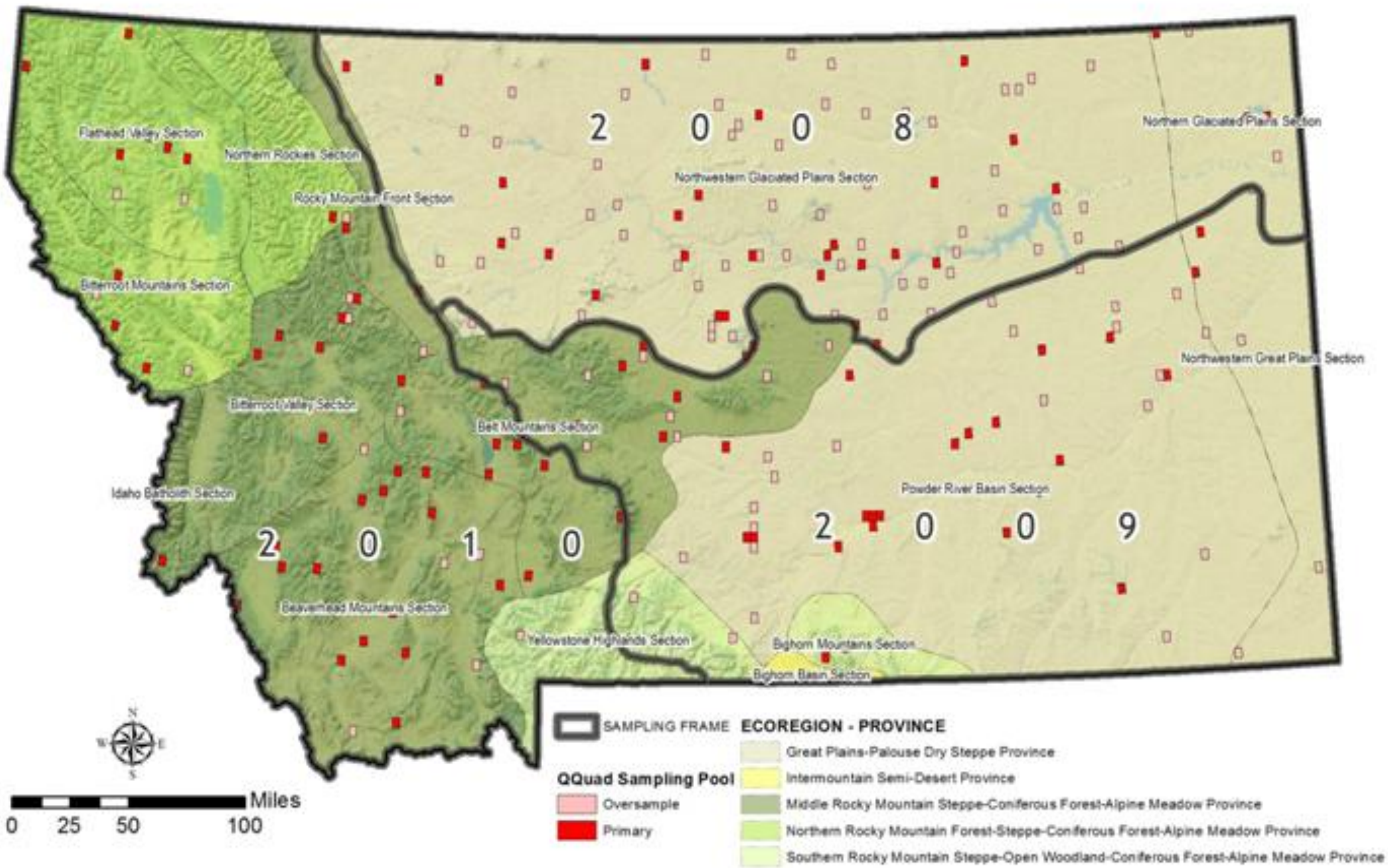


Figure 2. Example quarter-quarter map used for field sampling, showing land ownership patterns and various land cover types represented in a particular sample unit. Specific locations for trap placement or surveys were selected based on fauna group and habitat, e.g. one small mammal survey per quad had to be placed in a riparian area.

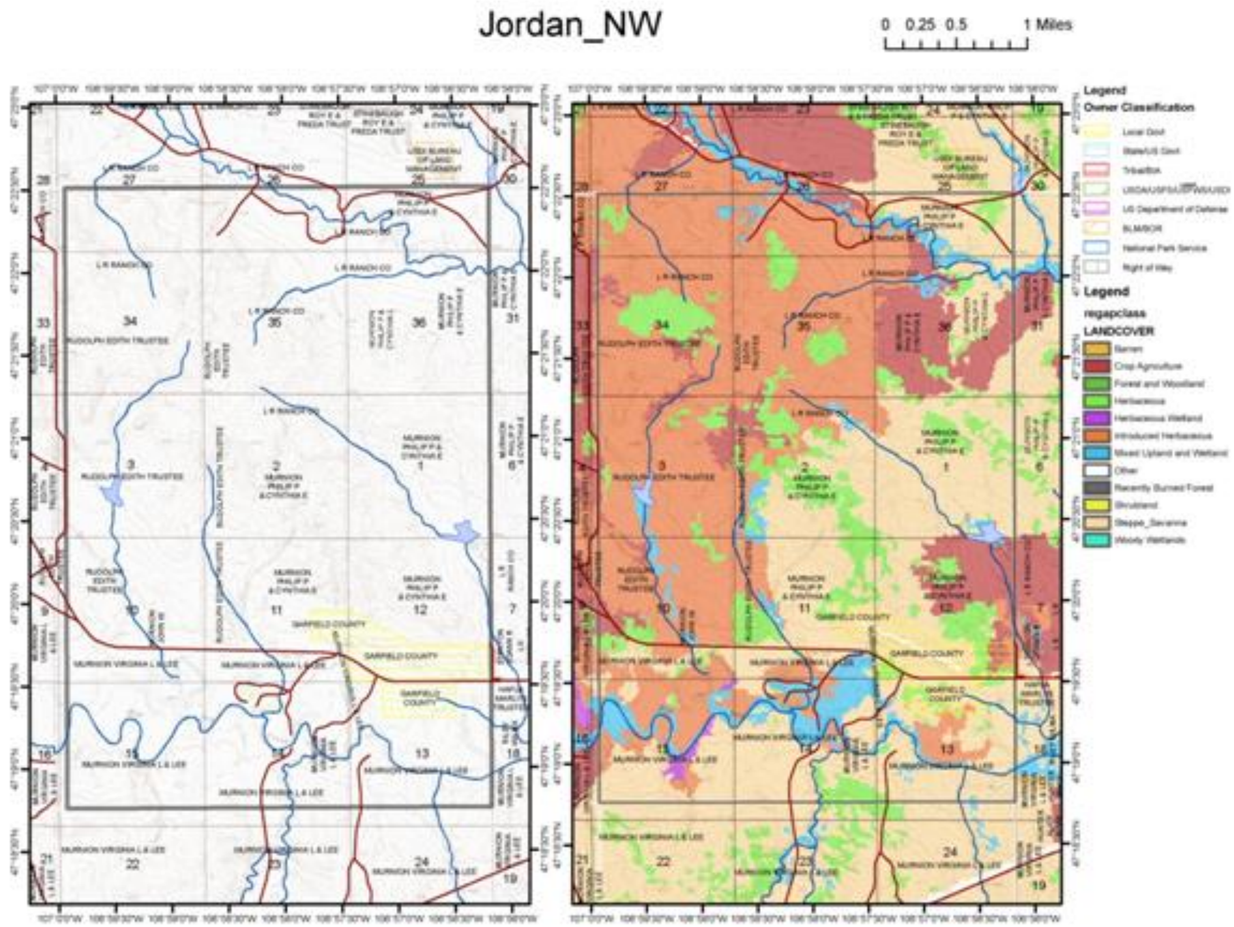


Figure 3. Example of sampling timeline for one quad.

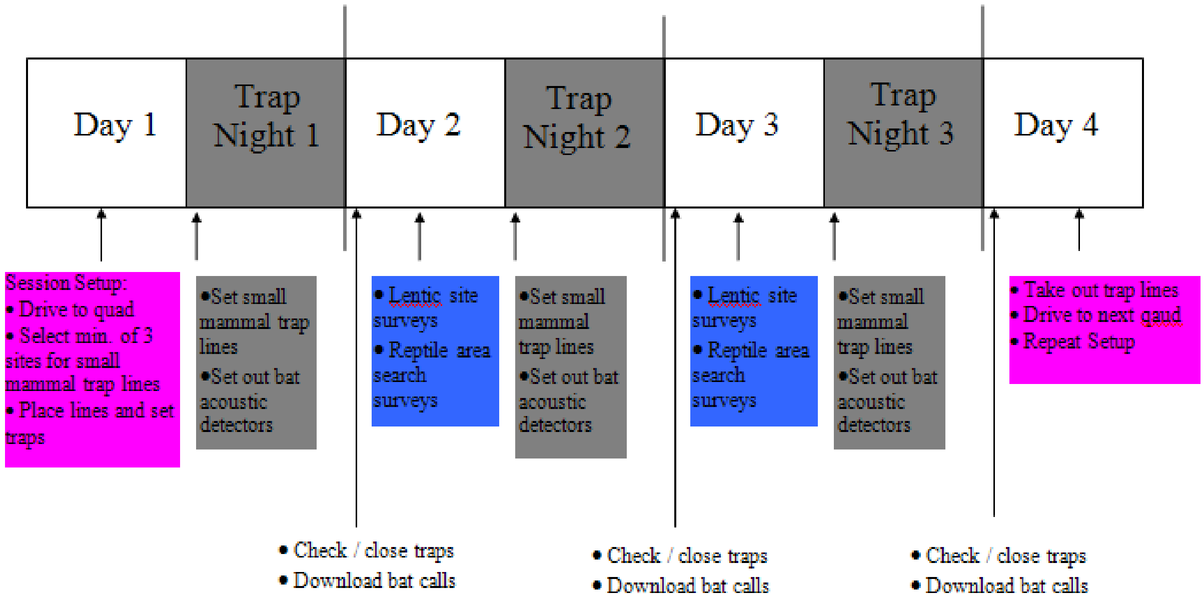


Figure 4. Sample quarter-quad showing example locations of bat acoustic, lentic, reptile, and small mammal trap line sites within a 3 x 4.3 mile quarter-quad.

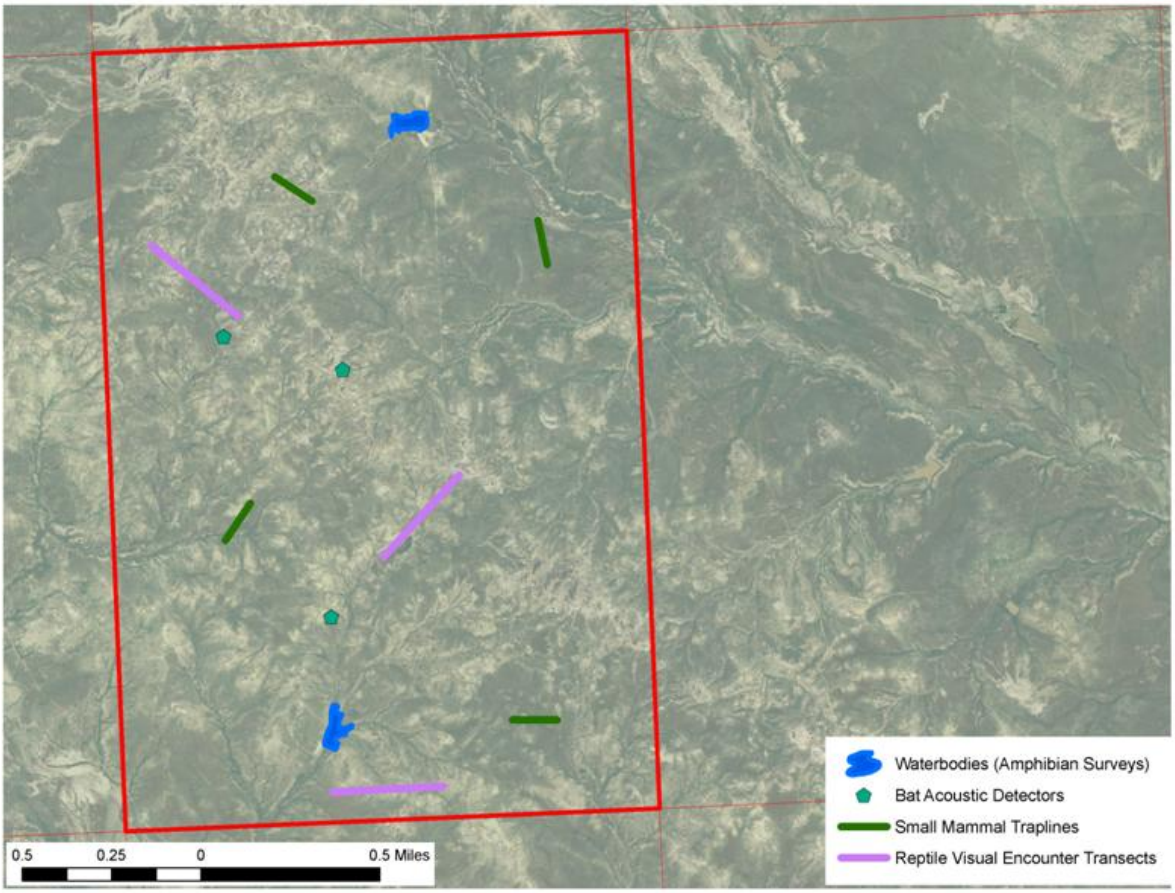


Figure 5. Diagram of small mammal trap line, demonstrating different sample types at each line.

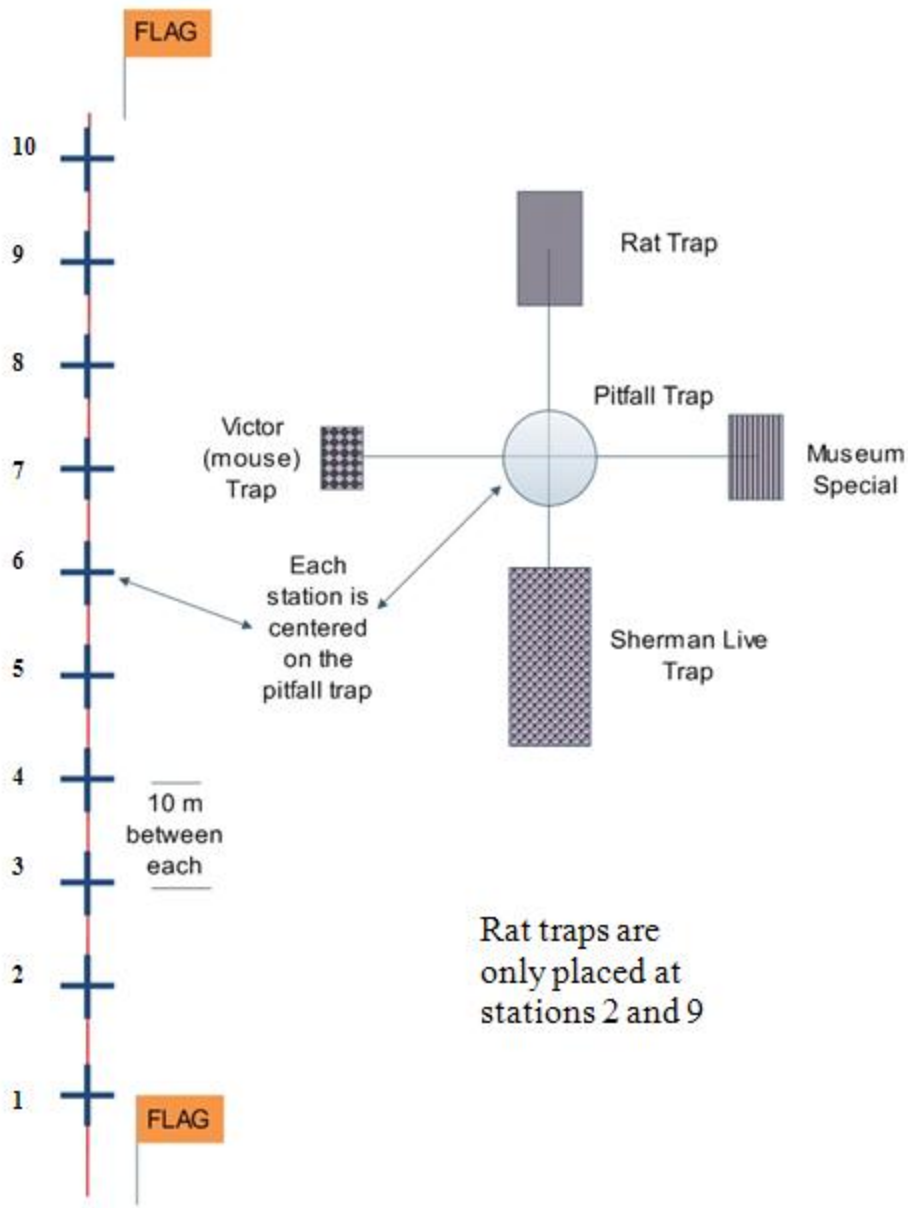


Figure 6. Photograph of a small mammal line trap site in eastern Montana showing the orientation of a pitfall trap and a sherman live trap.

Figure 7. Photograph of a bat acoustic detector sampling site, showing an iRiver H320 recording unit housed inside a protective enclosure that is mounted to a pipe.

Figure 8. Photograph of a lentic search site in eastern Montana with significant emergent vegetation that required netting and transect surveys.

Figure 9. Photograph of a reptile area search site with high topographic relief in eastern Montana.

Figure 10. Entity relationship diagram of the database tables used to store information collected during structured surveys of the Diversity Monitoring Project. Lookup tables with covariate attributes and options are not shown for the sake of brevity.

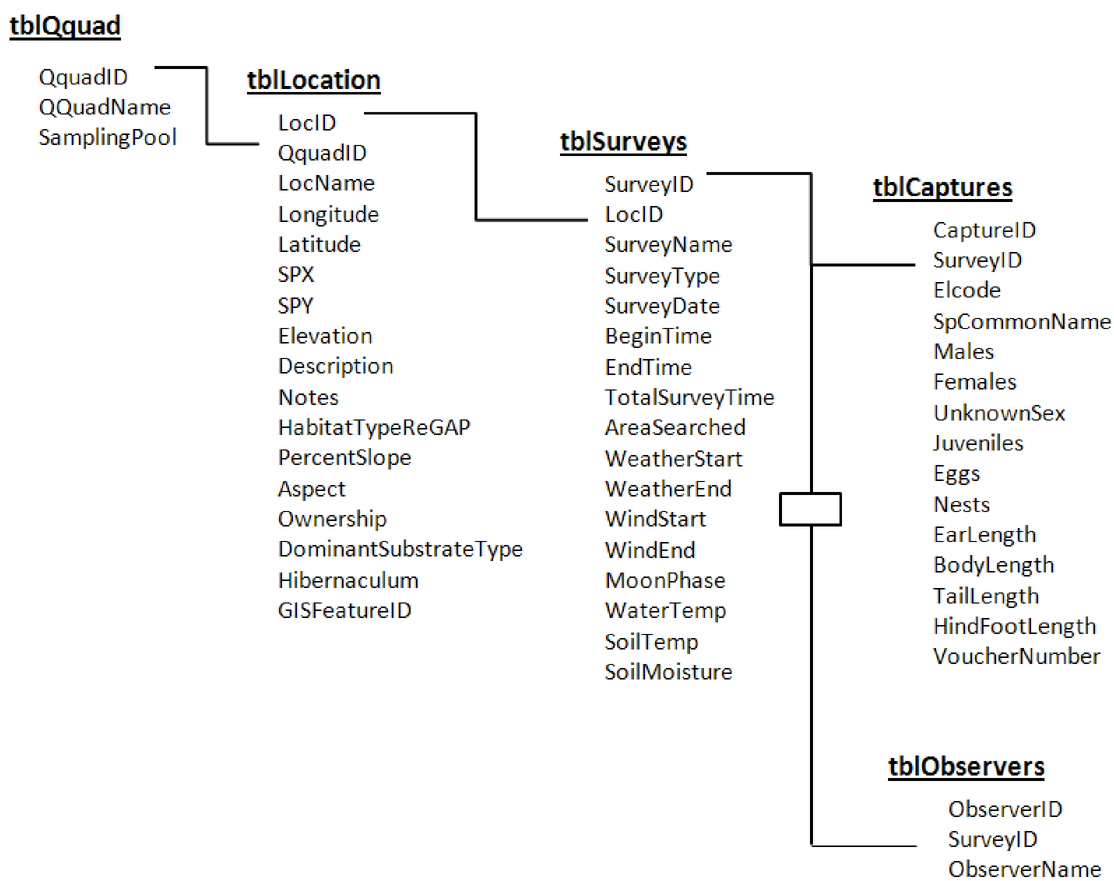


Figure 11a. Locations of small mammal trap line surveys, the number of unique species captured at each quad, and the total number of each species captured within a quad for the duration of the sampling period. Example: the large circle in southwest Montana with the number 23 inside it represents a survey where 23 individuals of 12-15 different species were detected. The number '3's in eastern Montana represent survey sites where 3 individuals of 1-2 species were detected.

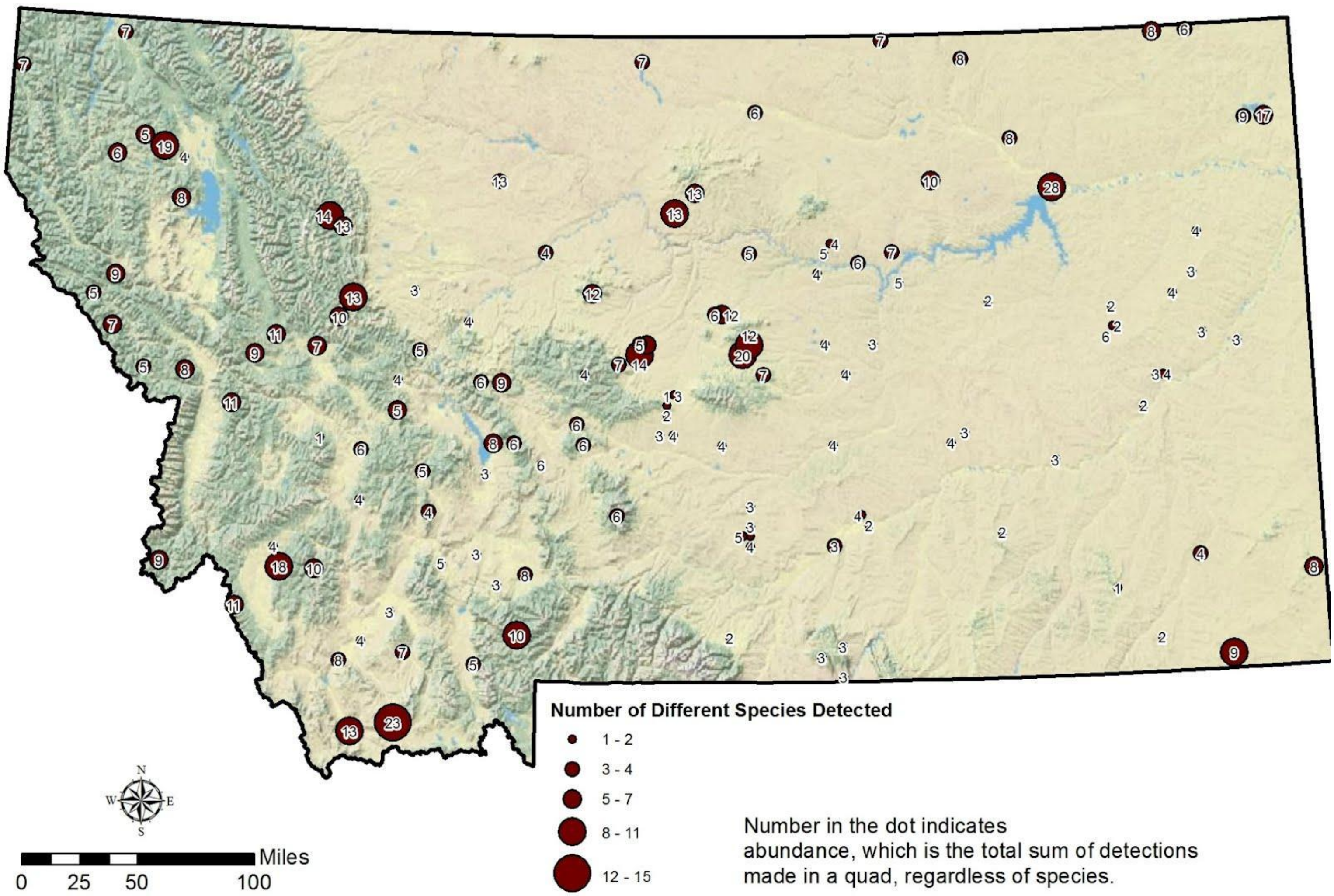


Figure 11b. Locations of bat acoustic surveys and the number of unique species detected at each quad and the total number of each species detected within a quad for the duration of the sampling period. Example: the large circle in northeast Montana with the number 7 inside it represents a survey where 7 individuals of 7-9 different species were detected.

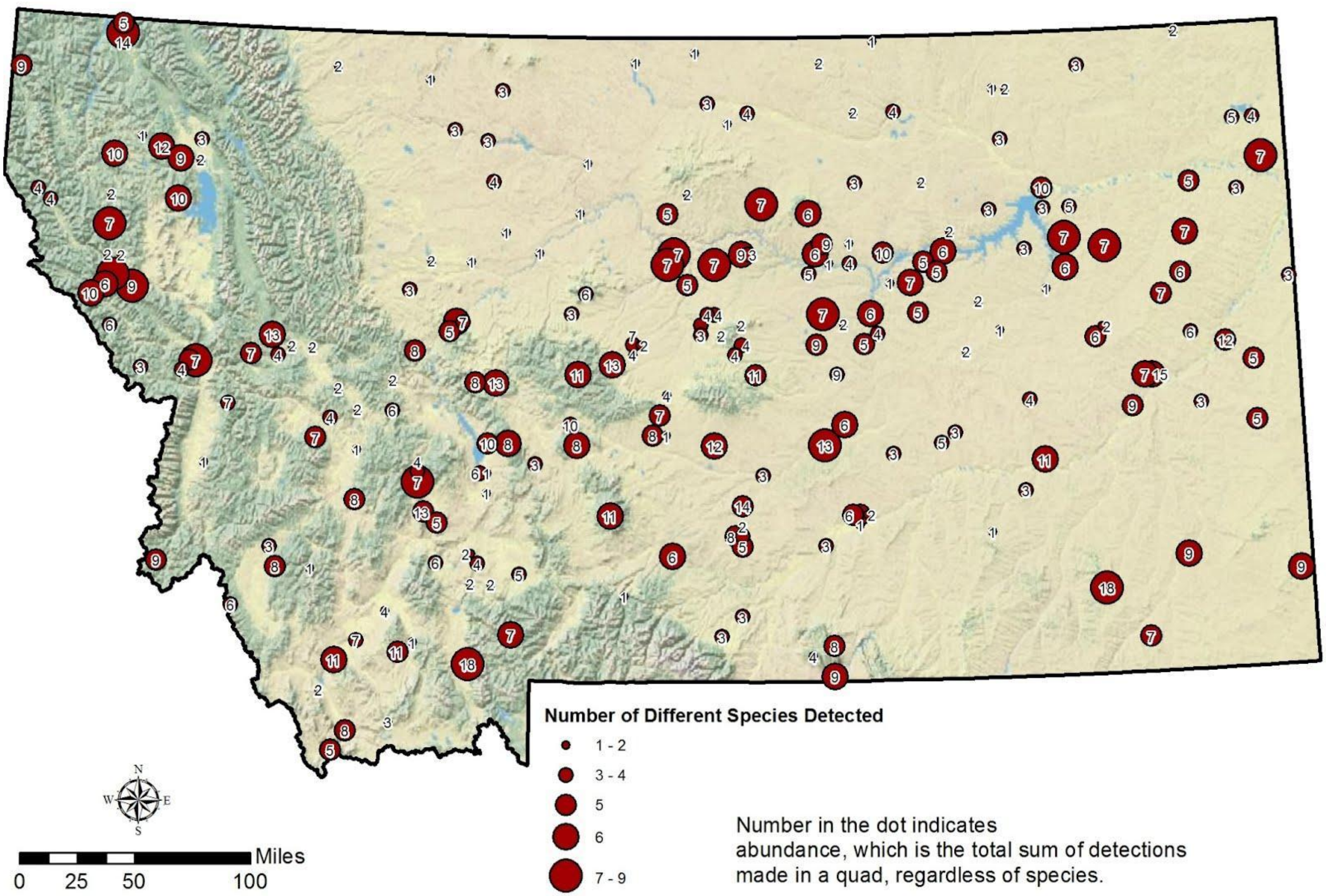


Figure 11c. Locations of lentic site surveys and the number of unique amphibian and reptile species detected at each quad and the total number of each species detected within a quad for the duration of the sampling period. Example: the large circle in northeast Montana with the number 8 inside it represents a survey where 8 individuals of 6-7 different species were detected.

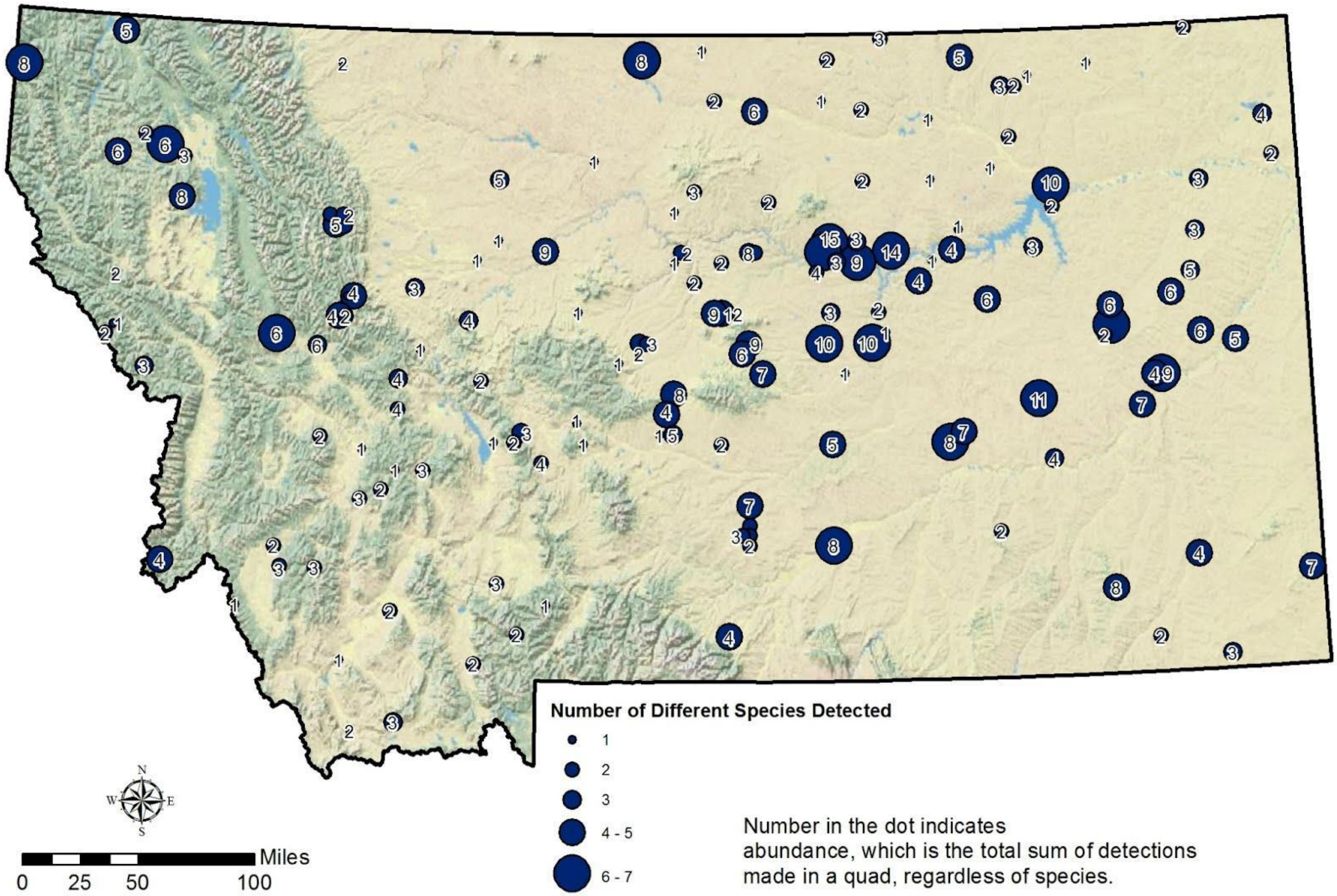
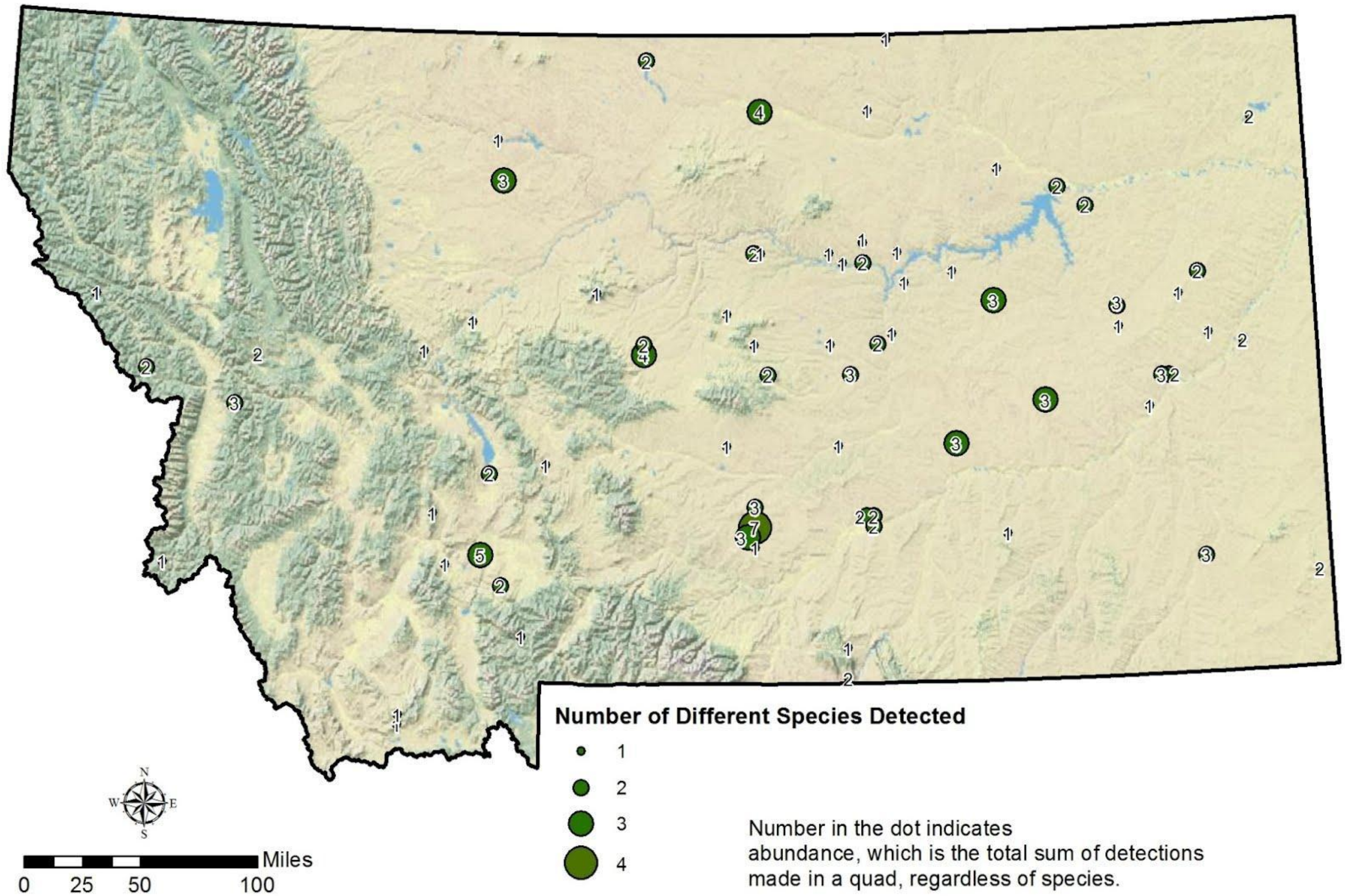
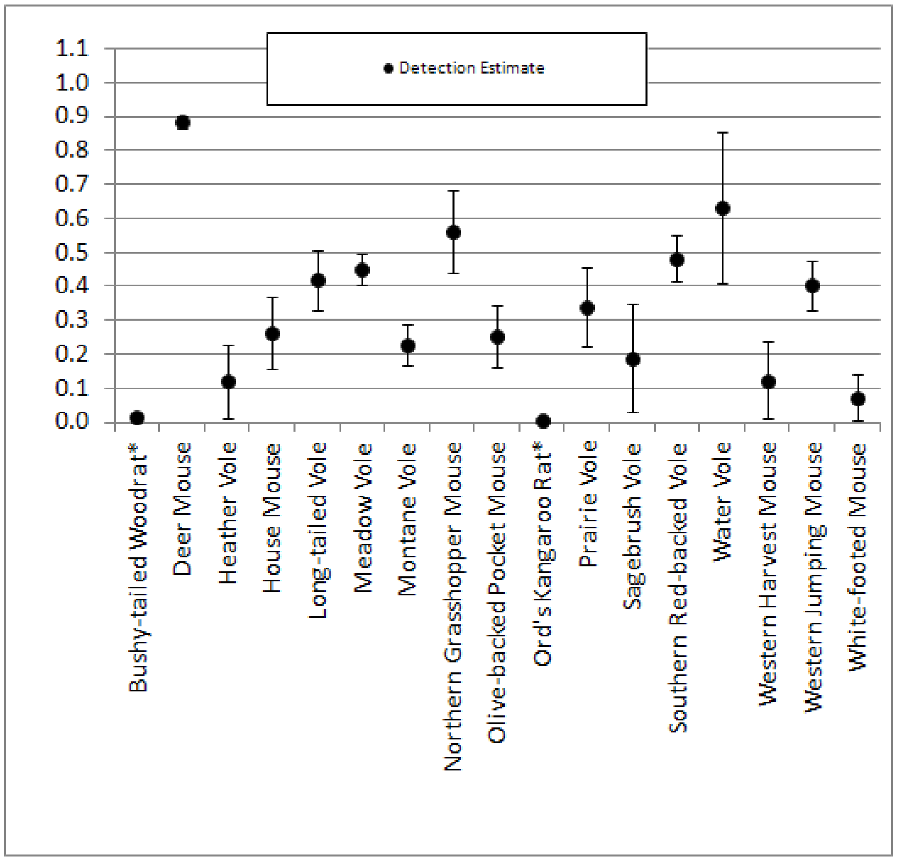


Figure 11d. Locations of reptile area search surveys and the number of unique species detected at each quad and the total number of each species detected within a quad for the duration of the sampling period. Example: the large circle in northcentral Montana with the number 4 inside it represents a survey where 4 individuals of 3 different species were detected.



Detection and occupancy eimates from small mammal capture efforts for Muridae, Heteromyidae and Dipodidae.
Figure 12a. Point estimates and 95% CI of detection (p) estimates. Asterisks represent species where too few repeat detections precluded an appropriate estimate of detection and/or occupancy. Generally speaking the higher the detection estimate the easier the species was to catch where it was present.

Figure 12b. Point estimates and 95% CI of occupancy (psi) estimates and percent of sampled quads where species was detected. Example: The naïve and corrected estimates of occupancy for deer mouse are the same while the corrected estimate of occupancy for heather vole is higher than the naïve or actual estimate of occupancy measured by the % of quads where the species was detected. The greatest difference between corrected and naïve or actual estimates of occupancy is seen for those species where species detectability was lowest. See Tables 7-8 for additional data.



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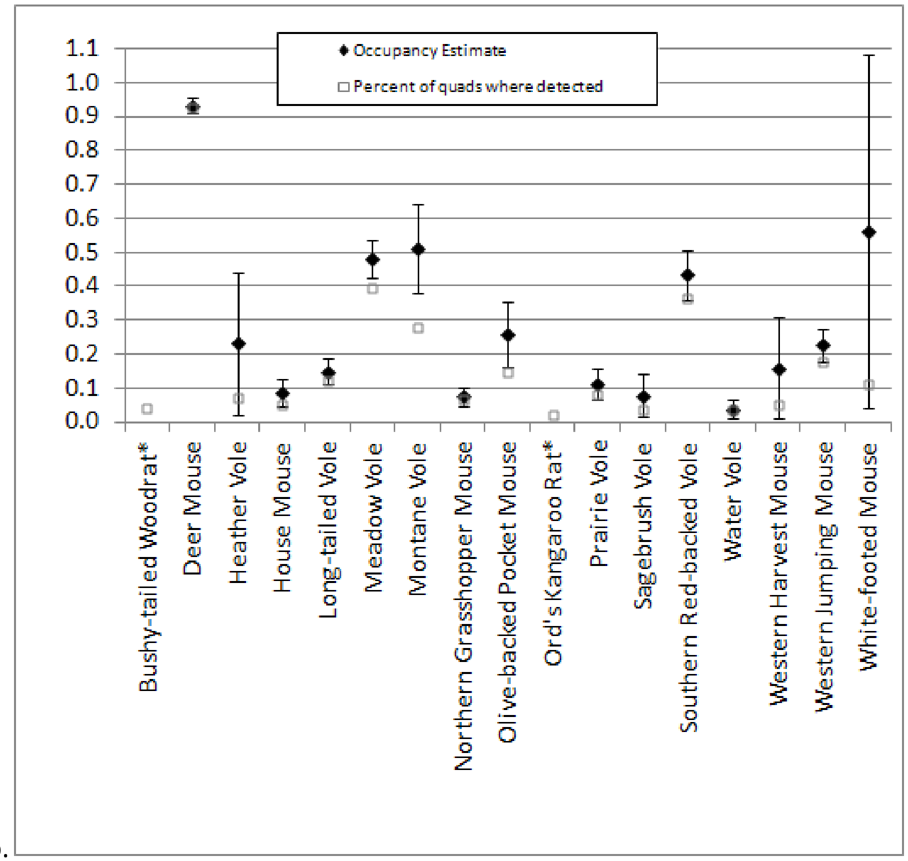
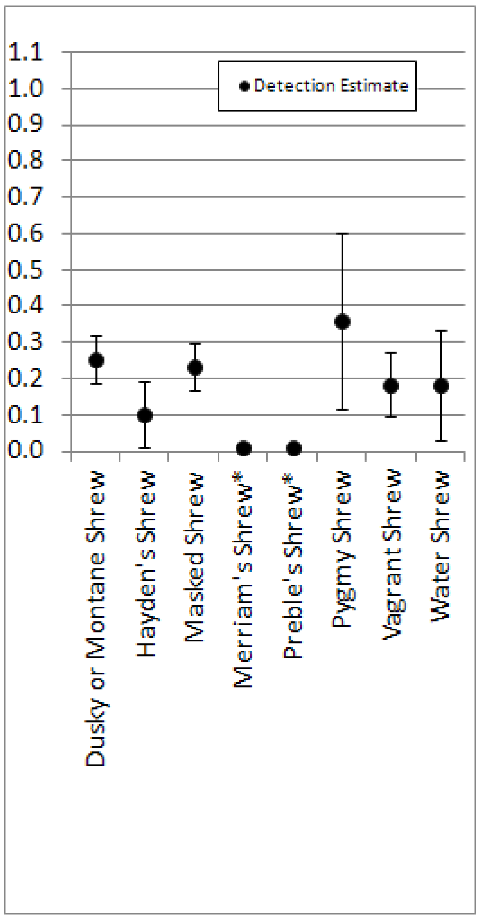


Detection and occupancy estimates from small mammal capture efforts for Soricidae.
Figure 13a. Point estimates and 95% CI of detection (p) estimates. Asterisks represent species where too few repeat detections precluded an appropriate estimate of detection and/or occupancy. Generally speaking the higher the detection estimate the easier the species was to catch where it was present.

Figure 13b. Point estimates and 95% CI of occupancy (psi) estimates and percent of quads where species was detected. Example: The naïve and corrected estimates of occupancy for pygmy shrew are nearly the same while the corrected estimate of occupancy for vagrant shrew is higher than the naïve or actual estimate of occupancy measured by the % of quads where the species was detected. The greatest difference between corrected and naïve or actual estimates of occupancy is seen for those species where species detectability was lowest. See Tables 7-8 for additional data.



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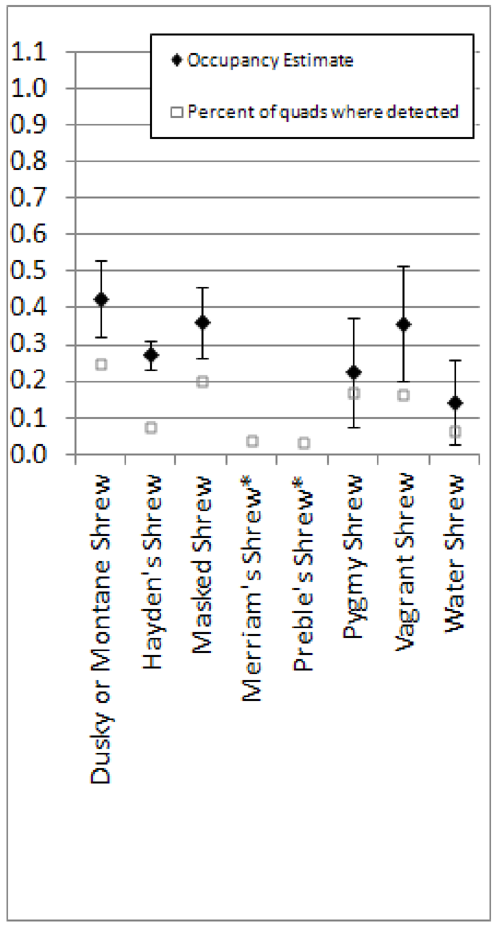
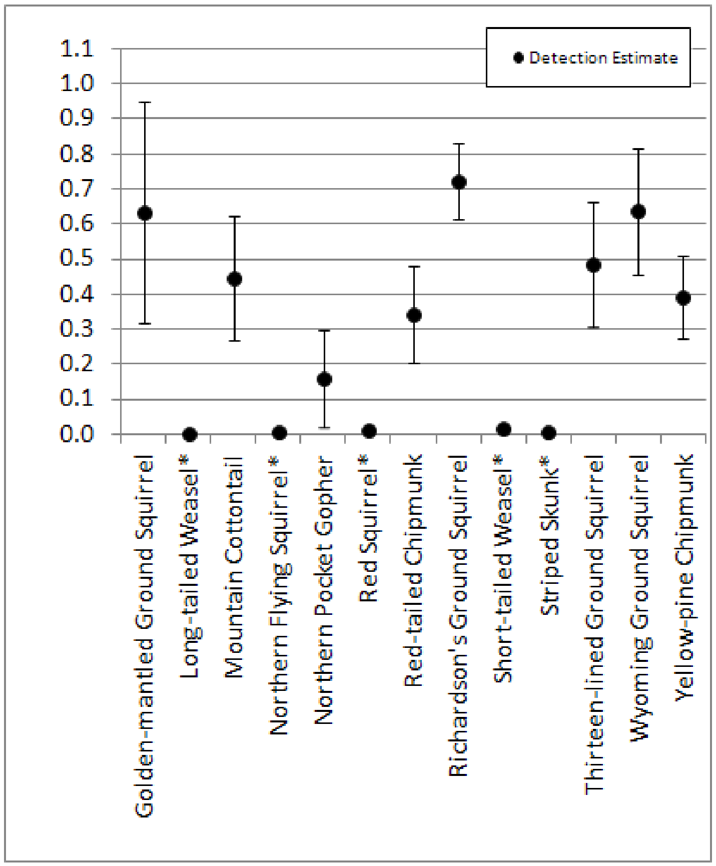


b.

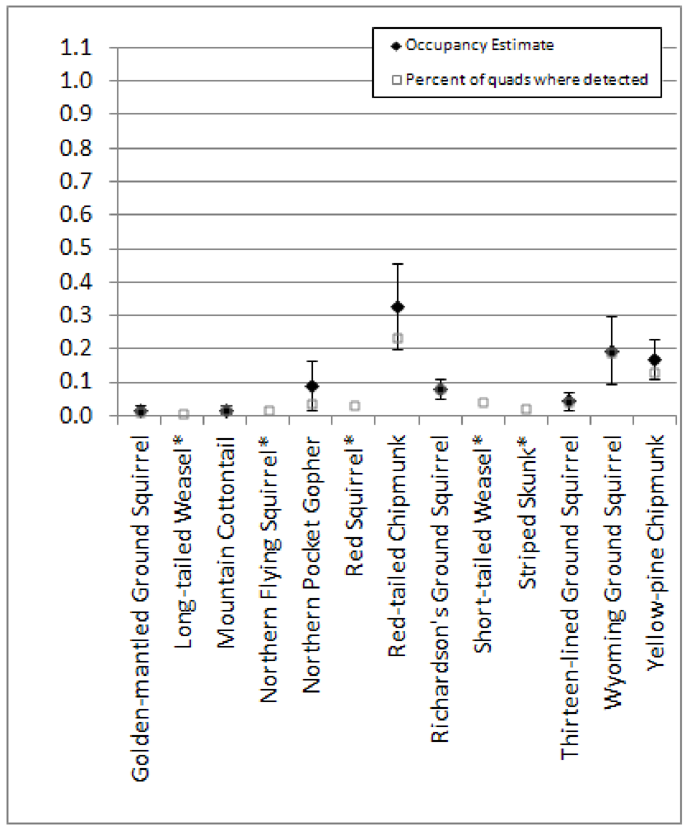
Detection and occupancy estimates from small mammal capture efforts for Sciuridae and Mustelidae.

Figure 14a. Point estimates and 95% CI of detection (p) estimates. Asterisks represent species where too few repeat detections precluded an appropriate estimate of detection and/or occupancy. Generally speaking the higher the detection estimate the easier the species was to catch where it was present.

Figure 14b. Point estimates and 95% CI of occupancy (psi) estimates and percent of quads where species was detected. Example: The naïve and corrected estimates of occupancy for Richardson's ground squirrel are the same while the corrected estimate of occupancy for red-tailed chipmunk is higher than the naïve or actual estimate of occupancy measured by the % of quads where the species was detected. The greatest difference between corrected and naïve or actual estimates of occupancy is seen for those species where species detectability was lowest. Striped skunks and long-tailed weasels were caught only in Tomahawk traps which were used during the 2008 field season only for field crew training purposes. Results for these species are not comparable to the other species caught in a diversity of traps. See Tables 7-8 for additional data.



a.



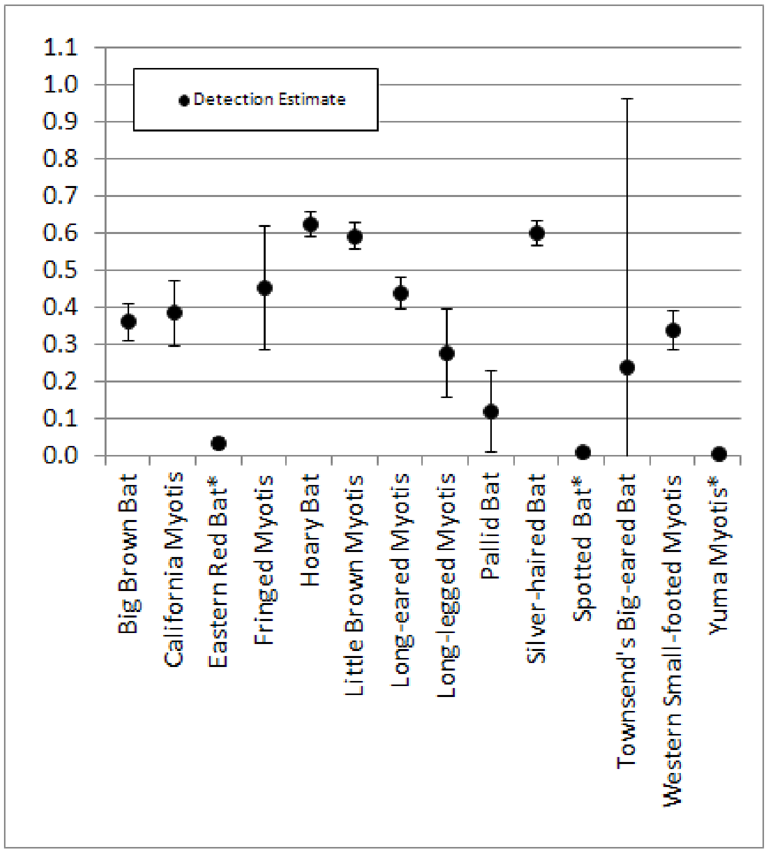
b.

Detection and occupancy estimates from bat survey efforts for all bat species detected.

Figure 15a. Point estimates and 95% CI of detection (p) estimates. Asterisks represent species where too few repeat detections precluded an appropriate estimate of detection and/or occupancy. Generally speaking the higher the detection estimate the easier the species was to catch where it was present.

Figure 15b. Point estimates and 95% CI of occupancy (psi) estimates and percent of quads where species was detected. Example: The naïve and corrected estimates of occupancy for Townsend's big-eared bat are the same while the corrected estimate of occupancy for pallid bat is much higher than the naïve or actual estimate of occupancy measured by the % of quads where the species was detected. The greatest difference between corrected and naïve or actual estimates of occupancy is seen for those species where species detectability was lowest. See Tables 7-8 for additional data.

a.



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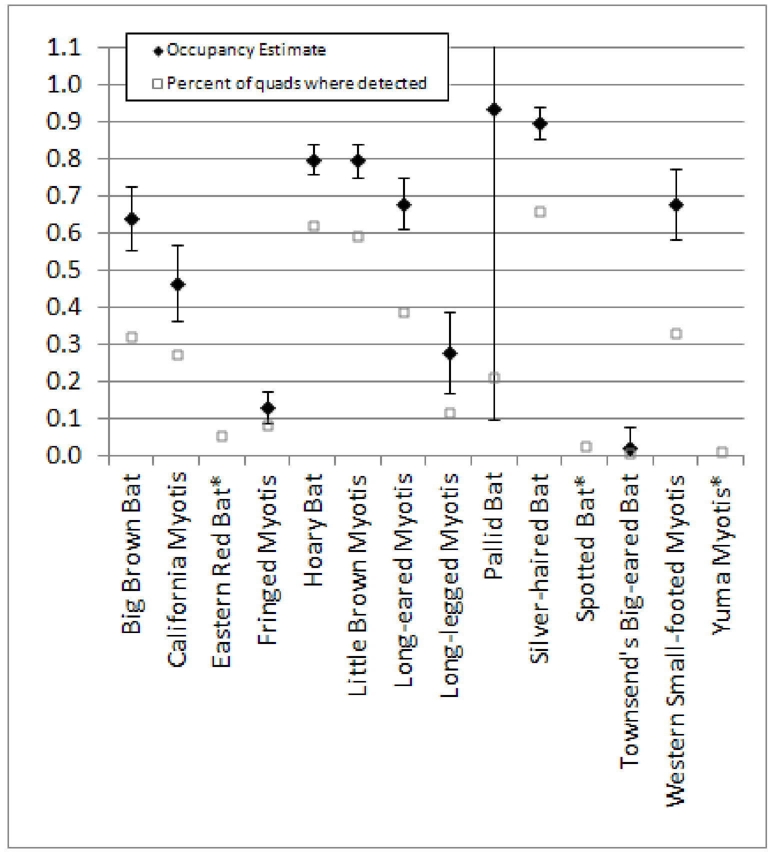
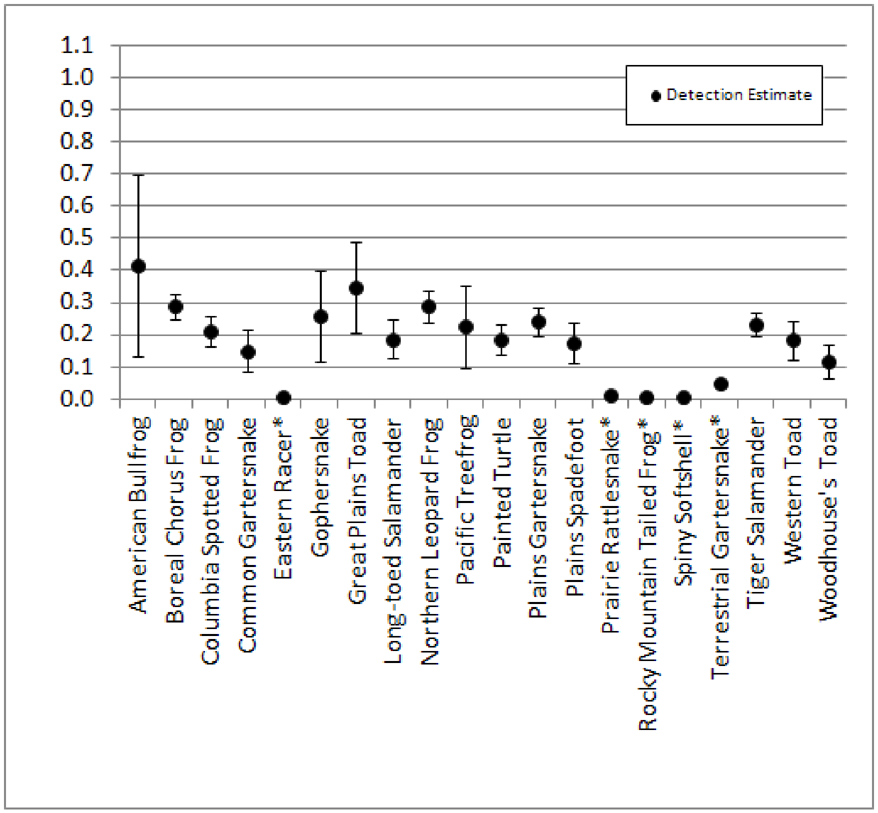


Detection and occupancy estimates from lentic site survey efforts for all amphibians and water-associated reptile species.
Figure 16a. Point estimates and 95% CI of detection (p) estimates. Asterisks represent species where too few repeat detections precluded an appropriate estimate of detection and/or occupancy. Generally speaking the higher the detection estimate the easier the species was to catch where it was present.

Figure 16b. Point estimates and 95% CI of occupancy (psi) estimates and percent of quads where species was detected. Example: The naïve and corrected estimates of occupancy for gopher snake are the same while the corrected estimate of occupancy for the long-toed salamander is much higher than the naïve or actual estimate of occupancy measured by the % of quads where the species was detected. The greatest difference between corrected and naïve or actual estimates of occupancy is seen for those species where species detectability was lowest. See Tables 7-8 for additional data.

a.


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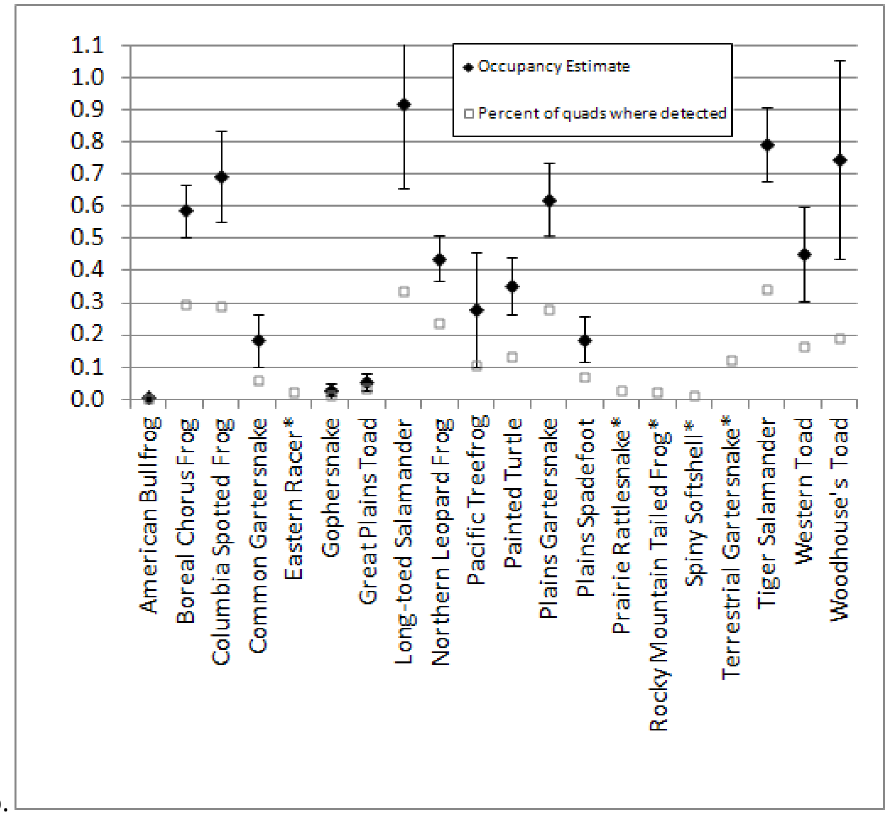
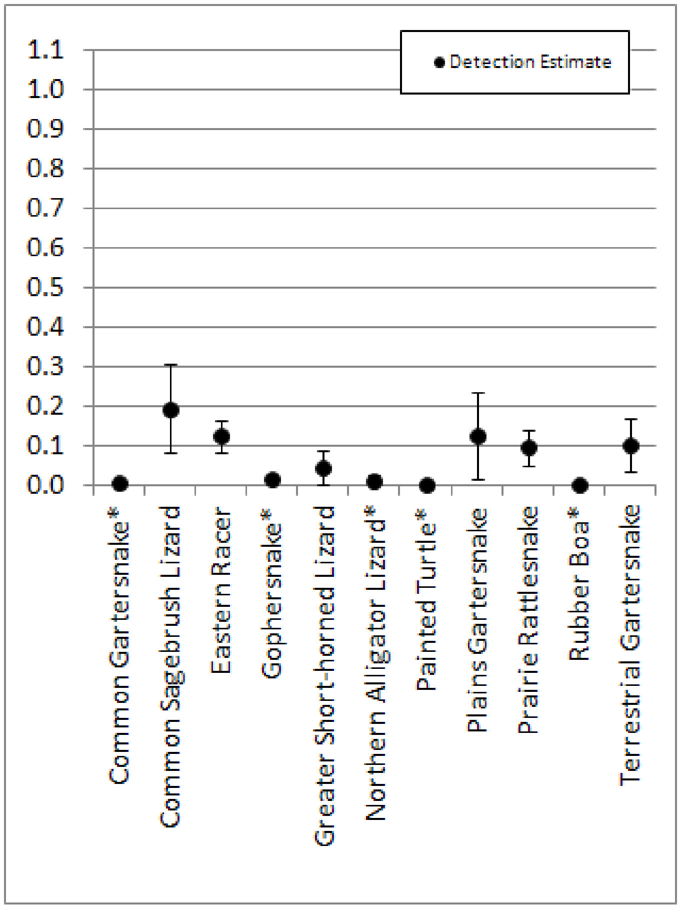


Detection and occupancy estimates from reptile area searches for all reptiles detected.
Figure 17a. Point estimates and 95% CI of detection (p) estimates. Asterisks represent species where too few repeat detections precluded an appropriate estimate of detection and/or occupancy. Generally speaking the higher the detection estimate the easier the species was to catch where it was present.

Figure 17b. Point estimates and 95% CI of occupancy (psi) estimates and percent of quads where species was detected. Example: The naïve and corrected estimates of occupancy for common sagebrush lizard were relatively close compared to the large difference between the naïve and corrected estimate of occupancy for the greater short-horned lizard. The greatest difference between corrected and naïve or actual estimates of occupancy is seen for those species where species detectability was lowest. See Tables 7-8 for additional data.

a.



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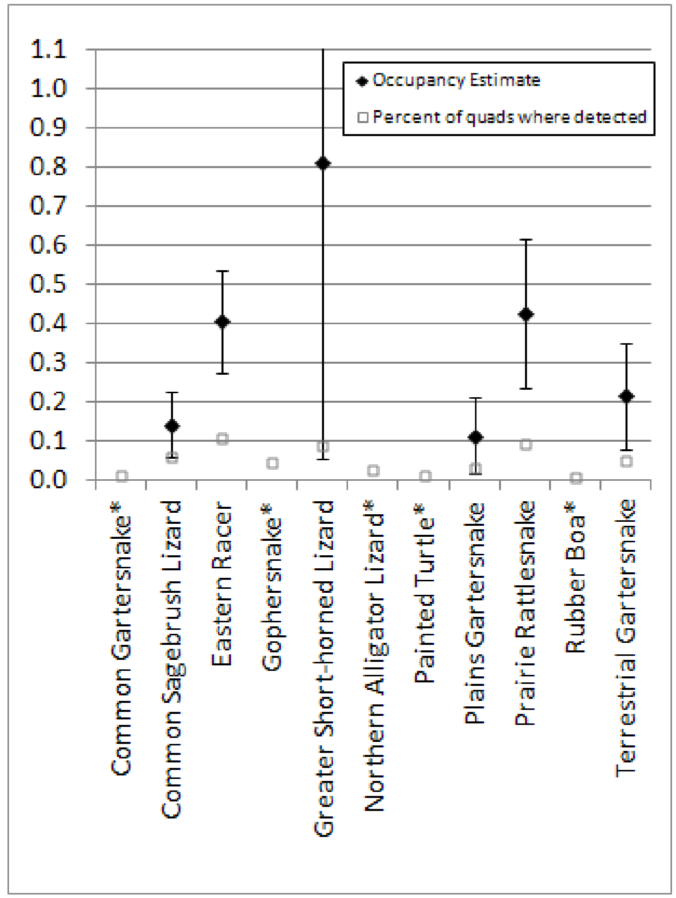


Figure 18a. Ratio of the percent of quads where a detection occurred (naïve detection) to the corrected occupancy estimate for each species captured during small mammal surveys. A ratio of one indicates that the percent of quads where a detection occurred and the occupancy estimate is identical. A ratio less than one indicates that the occupancy estimate is higher than the percent of quads where a detection actually occurred. Mountain cottontails were caught infrequently but within the same quad skewing results to a higher ratio than reality. Survey methods were not really appropriate for many of the species with a ratio of <1.0 making these low ratios expected for the weasels, bushy-tailed woodrat, striped skunk and squirrels.

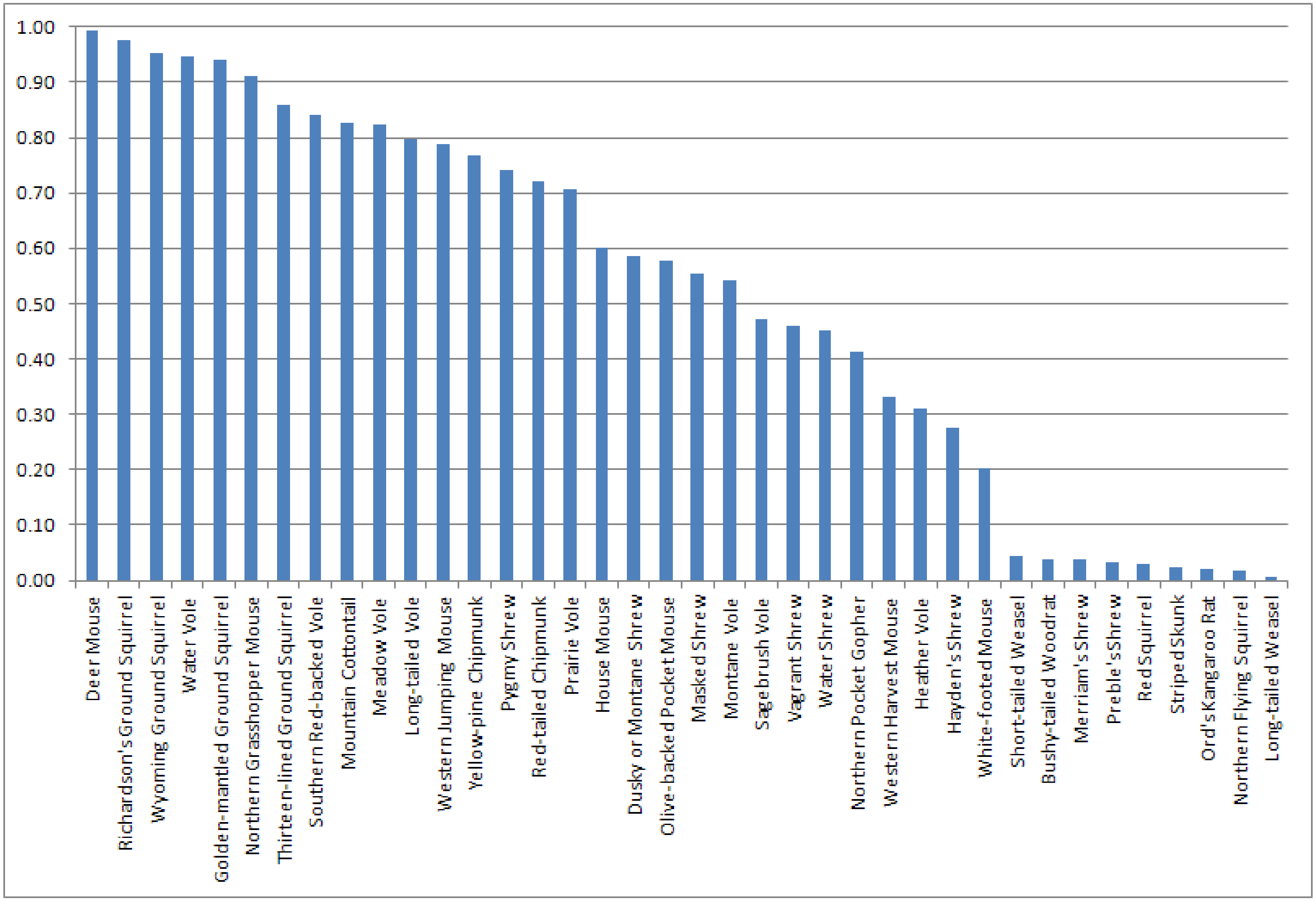


Figure 18b. Ratio of the percent of quads where a detection occurred (naïve detection) to the corrected occupancy estimate for each species captured during bat surveys. A ratio of one indicates that the percent of quads where a detection occurred and the occupancy estimate is identical. A ratio less than one indicates that the occupancy estimate is higher than the percent of quads where a detection actually occurred.

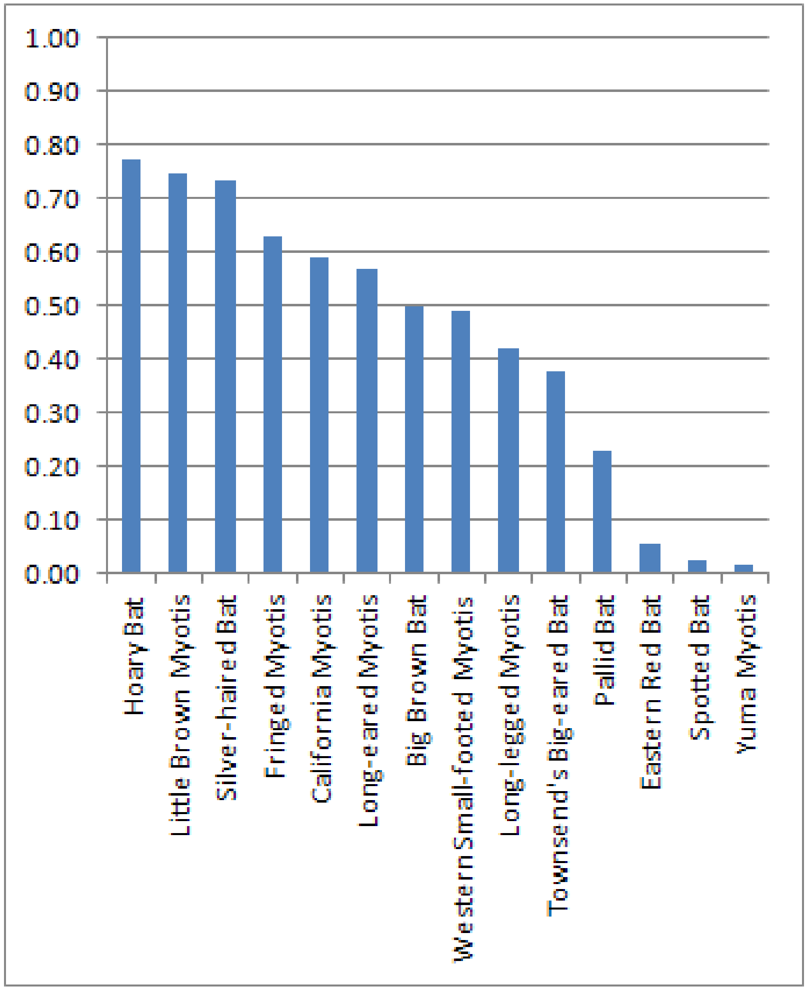
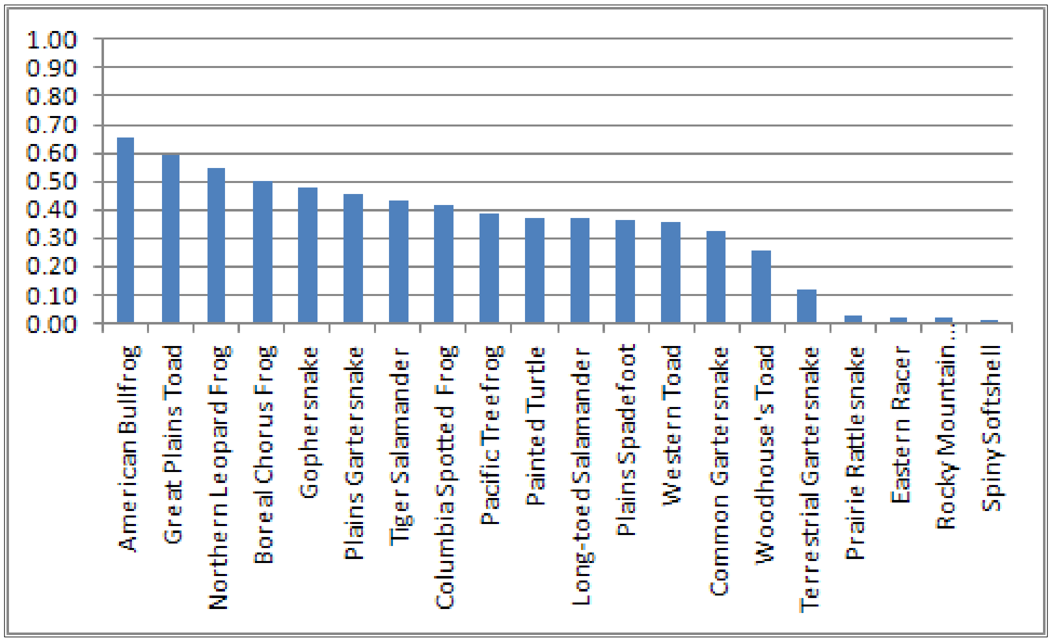


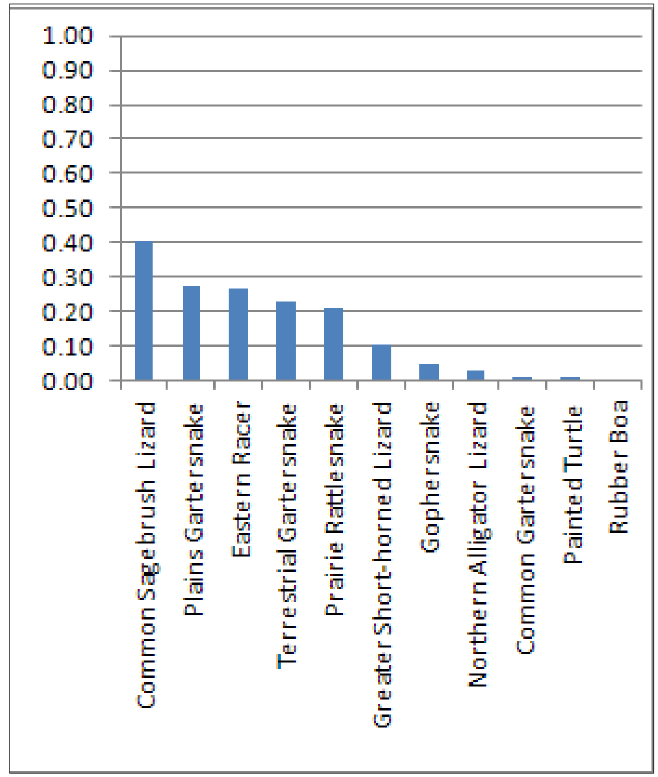
Figure 18c. Ratio of the percent of quads where a detection occurred (naïve detection) to the corrected occupancy estimate for each species captured during lentic surveys. A ratio of one indicates that the percent of quads where a detection occurred and the occupancy estimate is identical. A ratio less than one indicates that the occupancy estimate is higher than the percent of quads where a detection actually occurred.

Figure 18d. Ratio of the percent of quads where a detection occurred (naïve detection) to the corrected occupancy estimate for each species captured during reptile surveys. A ratio of one indicates that the percent of quads where a detection occurred and the occupancy estimate is identical. A ratio less than one indicates that the occupancy estimate is higher than the percent of quads where a detection actually occurred.

c.



d.



Tables

Table 1. List of materials used for each survey type.

General Purpose Gear	Small Mammal Trap Line Surveys	Bat Acoustic Detector Surveys	Lentic Site Surveys	Reptile Area Search Surveys
Digital Cameras	Sherman Traps	iRiver H320 digital recorders	Aquarium nets	Long snake rakes
Garmin 60 CSX GPS Units	Museum Special Traps	Aluminum bat poles	Macroinvertebrate nets	Retractable snake rakes
Identification kits and Field Guides	5-gallon buckets for Pitfall Traps	PVC housing	Trichane	Snake grabber
File folders for storing quad data sheets	Victor brand Rat Traps	H320 wall chargers w/o adaptors	Formalin	Snake hook
Laptop computers	Large Tomahawk traps	H320 car chargers	Kill jars and cottonballs	Turtle Traps
Data sheets and All-weather paper	Isoflouran, kill jars, and cottonballs	H320 dock		Formalin
Clipboards, legal pads, pencils, pens	Flagging	Post pounder		Kill jars and cottonballs
Miscellaneous hand tools	Sweet feed	Headphones		Head lamps and flashlights
External Hard Drive for data storage	Irwin Chalk	Patch cords		
First Aid Kits	Ziploc/small plastic bags	Batteries - 9v and AA		
Safety masks and rubber gloves	Weed sprayers	Waterproof bat boxes		
BLM topo maps and Laminated quad maps				
Mitutoya 1-150mm electronic calipers				
Binoculars				
70 Watt Vector Pocket Power Inverter				
Digital scales				
Magnifying glasses				
Rulers / tape measures				

Table 2. Data types collected for each fauna sampling procedure. Italics indicates that data was obtained via ad-hoc GIS analysis, whereas bold indicates data was collected in the field for all fauna groups. Variable types are indicated by a letter code, representing Q = quantitative, C = categorical, Y/N = yes or no type variable.

	LENTIC SURVEYS		**MAMMAL TRAP LINES**		**BAT ACOUSTIC SURVEYS**		**REPTILE AREA SEARCH**
C	*Ecoregion*	*C*	*Ecoregion*	*C*	*Ecoregion*	*C*	*Ecoregion*
C	*Ownership*	*C*	*Ownership*	*C*	*Ownership*	*C*	*Ownership*
Q	*Elevation*	*Q*	*Elevation*	*Q*	*Elevation*	*Q*	*Elevation*
C	*ReGap Habitat Class*	*C*	*ReGap Habitat*	*C*	*ReGap Habitat*	*C*	*ReGap Habitat Class*
Q	TotalSurveyTime	Q	TotalSurveyTime	Q	TotalSurveyTime	Q	TotalSurveyTime
C	Observer	C	Observer	C	Observer	C	Observer
Y / N	SiteDry	Q	Trap Effort	C	Moon Phase	C	Percent Slope
C	LenticHabitatType	C	WeatherStart	C	WeatherStart	C	Dom Substrate
C	SiteOrigin	C	WeatherEnd	C	WeatherEnd	Y/N	PotentialHibernaculum
C	WaterColor	Q	TempStart	Q	TempStart	Q	AreaSearched
Q	WaterpH	Q	TempEnd	Q	TempEnd	C	PercentageLocationSurvey
C	WaterTurbidity			C	WindStart	C	SoilMoisture
C	WaterConnectedness			C	WindEnd	Q	SoilTemp
C	WaterPermanenence					C	WeatherStart
Q	MaxWaterDepth					C	WeatherEnd
Q	SiteLength					Q	TempStart
Q	SiteWidth					Q	TempEnd
C	% site <50cm deep					C	WindStart
Q	EmergentVegAreaMetersSquared					C	WindEnd
C	PercentSiteWithEmergentVeg					C	Aspect
C	PercentSiteWithLarvalActivity						
Q	RankSedges						
Q	RankGrasses						
Q	RankRushes						
Q	RankWaterLily						
Q	RankShrubs						
Q	RankOther		**LENTIC SURVEYS** (continued)				
C	PrimaryShallowsSubstrate	Y/N	FishSpawningHabitatPresent				
C	NorthShorelineCharacteristicsShallows	Q	InletWidth				
C	NorthShorelineCharacteristicsEmergen	Q	InletDepth				
Q	DistanceToForestEdgeMeters	C	InletSubstrate				
C	GrazingImpact	Q	OutletWidth				
Y/N	WaterDammedDiverted	Q	OutletDepth				
Y/N	TimberHarvestInArea	C	OutletSubstrate				
Y/N	MiningActivity	Q	Inclination				

Table 3. Summary of the types of surveys and the effort expended for each survey type during the period 2008 - 2010.

Survey Type	Total Number of Days Surveyed	Total Number of Unique Surveys	Total Number of Locations Surveyed	Total Number of Q-Quads surveyed	Average Survey Time (Minutes) with Standard Deviation	Average Area Searched (Square Meters) with Standard Deviation
Small Mammal Trap Line Surveys	161	1,182	423	137	851 +/- 115	NA
Bat Acoustic Surveys	181	1,465	1,418	271	751 +/- 161	NA
Lentic Site Surveys	133	712	706	180	34 +/- 31	3,937 +/- 93,925
Reptile Area Search Surveys	146	504	501	168	45 +/- 46	21,419 +/- 85,170
Total	213	3,863	3,048	282		

Table 4. Summary of the number of identifiable and unidentifiable observations made for each type of survey during the period 2008 - 2010. Only bat calls with definitive call sequences were included as identifiable captures. Bat acoustic surveys containing probable call sequences with no corresponding definitive call sequence were counted as unidentifiable detections.

Survey Type	Total Number of Identifiable Detections	Total Number of Surveys With Identifiable Detections	Percent of Surveys With Identifiable Detections	Total Number of Unidentifiable Detections	Total Number of Unique Species Detected
Small Mammal Trap Line Surveys	2,470	832	0.70	24	39
Bat Acoustic Detector Surveys	1,769	783	0.53	628	15
Lentic Site Surveys	1,372	436	0.61	27	20
Reptile Area Search Surveys	195	129	0.26	24	11
All Structured Surveys	5,806	2,180	0.56	703	84
Incidental Observations	5,912	2,634	NA	133	301
Total	11,718	4,814	NA	836	341

Table 5. Summary of sampling efforts and detections made by dominant type during small mammal trap line surveys and bat acoustic detection surveys, 2008 - 2010.

Dominant Habitat Type	# Small mammal locations surveyed	# Small mammal species detected	# Individual small mammals detected	# Bat detector locations surveyed	# Bat species detected	# Individual bats detected
Forest and woodland	121	30	359	397	12	503
Polar and high montane	9	8	21	15	4	8
Semi desert	81	21	205	242	13	310
Shrubland and grassland	107	22	288	349	13	452
Sparse rock vegetation	22	10	52	66	7	98
Transitional Vegetation	12	12	43	42	7	31
Water	3	2	8	39	9	65
Woody Wetland	1	6	3	6	1	1
Developed	8	5	26	59	10	73
Agriculture	36	16	121	150	8	155
Introduced vegetation	18	11	53	59	7	66

Table 6. Summary of trapping effort and detections made by trap type during small mammal trap line surveys, 2008 - 2010.

Trap Type	Total number of traps set	Total number of captures	Successful trap sets
Mouse Trap	10,249	444	4.3 %
Museum Special	9,417	619	6.6 %
Rat Trap	2,104	39	1.9 %
Pitfall	11,416	275	2.4 %
Sherman	10,473	428	4.1 %
Tomahawk (2008 only)	491	17	3.5 %
Track plate (2008 only)	282	4	1.4 %

Table 7. Statewide summary of survey and q-quad detections, detection estimates (p), occupancy estimates (psi) for all species captured during structured surveys for bats, lentic species, reptiles, and small mammals. Species with an asterisk represent those where the number of repeat detections using that survey method was too low for an appropriate estimate of occupancy.

Survey type	Species	# Survey detections	%Surveys where detected	# Quad detections	% Quads where detected	p	psi	p se	p lcl	p ucl	psi se	psi lcl	psi ucl
Bat Acoustic	Big Brown Bat	113	0.08	87	0.32	0.36	0.64	0.05	0.27	0.46	0.09	0.46	0.79
Bat Acoustic	California Myotis	36	0.02	28	0.13	0.35	0.22	0.09	0.23	0.53	0.06	0.13	0.35
Bat Acoustic	Eastern Red Bat	6	0.00	6	0.02	0.01	1.00	0.01	0.01	0.03	0.01	0.00	1.00
Bat Acoustic	Fringed Myotis	20	0.01	19	0.07	0.43	0.12	0.17	0.16	0.75	0.04	0.06	0.23
Bat Acoustic	Hoary Bat	235	0.16	168	0.62	0.63	0.80	0.03	0.56	0.69	0.04	0.71	0.87
Bat Acoustic	Little Brown Myotis	224	0.15	161	0.59	0.60	0.80	0.04	0.52	0.66	0.05	0.69	0.87
Bat Acoustic	Long-eared Myotis	148	0.10	105	0.39	0.44	0.68	0.04	0.36	0.53	0.07	0.53	0.80
Bat Acoustic	Long-legged Myotis	34	0.02	32	0.12	0.28	0.28	0.12	0.11	0.56	0.11	0.12	0.53
Bat Acoustic	Pallid Bat	7	0.00	6	0.02	0.12	0.12	0.11	0.02	0.50	0.11	0.02	0.52
Bat Acoustic	Silver-haired Bat	258	0.18	179	0.66	0.60	0.90	0.03	0.54	0.66	0.04	0.78	0.96
Bat Acoustic	Spotted Bat *	2	0.00	2	0.01	0.01	1.00	0.01	0.00	0.02	0.00	1.00	1.00
Bat Acoustic	Townsend's Big-eared Bat	2	0.00	2	0.01	0.20	0.02	0.76	0.00	1.00	0.08	0.00	0.96
Bat Acoustic	Western Small-footed Myotis	109	0.07	90	0.33	0.34	0.68	0.05	0.25	0.45	0.10	0.47	0.83
Bat Acoustic	Yuma Myotis *	2	0.01	2	0.01	0.01	1.00	0.00	0.00	0.02	0.28	0.00	1.00
Lentic Surveys	American Bullfrog	2	0.00	1	0.01	0.41	0.01	0.28	0.07	0.88	0.01	0.00	0.04

Survey type	Species	# Survey detections	%Surveys where detected	# Quad detections	% Quads where detected	p	psi	p se	p lcl	p ucl	psi se	psi lcl	psi ucl
Lentic Surveys	Boreal Chorus Frog	96	0.13	62	0.34	0.29	0.43	0.04	0.22	0.37	0.06	0.32	0.55
Lentic Surveys	Columbia Spotted Frog	53	0.07	40	0.22	0.21	0.35	0.05	0.13	0.31	0.08	0.22	0.52
Lentic Surveys	Common Gartersnake	17	0.02	13	0.07	0.15	0.15	0.06	0.06	0.32	0.07	0.06	0.33
Lentic Surveys	Eastern Racer *	6	0.01	6	0.03	0.01	1.00	0.00	0.00	0.00	0.00	0.00	1.00
Lentic Surveys	Gophersnake	6	0.01	4	0.02	0.26	0.03	0.14	0.07	0.60	0.02	0.01	0.10
Lentic Surveys	Great Plains Toad	8	0.01	5	0.03	0.35	0.03	0.14	0.14	0.65	0.02	0.01	0.08
Lentic Surveys	Long-toed Salamander	28	0.04	22	0.12	0.19	0.21	0.06	0.09	0.33	0.07	0.11	0.39
Lentic Surveys	Northern Leopard Frog	67	0.09	50	0.28	0.29	0.34	0.05	0.20	0.39	0.06	0.24	0.46
Lentic Surveys	Pacific Treefrog	6	0.01	4	0.02	0.23	0.03	0.13	0.06	0.57	0.02	0.01	0.11
Lentic Surveys	Painted Turtle	45	0.06	34	0.05	0.18	0.32	0.05	0.11	0.29	0.08	0.19	0.51
Lentic Surveys	Plains Gartersnake	62	0.09	45	0.06	0.24	0.35	0.05	0.17	0.35	0.07	0.23	0.49
Lentic Surveys	Plains Spadefoot	20	0.03	14	0.08	0.18	0.14	0.06	0.08	0.33	0.05	0.06	0.28
Lentic Surveys	Prairie Rattlesnake *	7	0.00	7	0.01	0.01	1.00	0.00	0.00	0.02	0.00	0.00	1.00
Lentic Surveys	Rocky Mountain Tailed Frog *	1	0.00	1	0.01	0.01	1.00	0.01	0.00	0.01	0.07	0.00	1.00
Lentic Surveys	Spiny Softshell Turtle *	1	0.00	1	0.01	0.00	1.00	0.00	0.01	0.03	0.07	0.00	1.00

Survey type	Species	# Survey detections	%Surveys where detected	# Quad detections	% Quads where detected	p	psi	p se	p lcl	p ucl	psi se	psi lcl	psi ucl
Lentic Surveys	Terrestrial Gartersnake	27	0.04	27	0.15	0.05	1.00	0.01	0.03	0.07	0.00	0.00	1.00
Lentic Surveys	Tiger Salamander	92	0.13	65	0.36	0.23	0.53	0.04	0.17	0.31	0.08	0.37	0.68
Lentic Surveys	Western Toad	26	0.04	19	0.11	0.18	0.19	0.06	0.09	0.32	0.06	0.09	0.34
Lentic Surveys	Woodhouse's Toad	29	0.04	25	0.14	0.12	0.35	0.05	0.05	0.26	0.15	0.13	0.65
Reptile Area Search	Common Gartersnake	3	0.01	3	0.01	0.01	1.00	0.00	0.00	0.01	0.01	1.00	1.00
Reptile Area Search	Common Sagebrush Lizard	9	0.02	7	0.04	0.19	0.07	0.11	0.05	0.49	0.04	0.02	0.19
Reptile Area Search	Eastern Racer	37	0.07	29	0.06	0.13	0.39	0.04	0.07	0.23	0.13	0.19	0.64
Reptile Area Search	Gophersnake	13	0.03	13	0.03	0.02	1.00	0.01	0.01	0.03	0.00	1.00	1.00
Reptile Area Search	Greater Short-horned Lizard	16	0.03	15	0.09	0.04	0.50	0.04	0.01	0.25	0.47	0.03	0.98
Reptile Area Search	Northern Alligator Lizard *	1	0.00	1	0.01	0.01	1.00	0.01	0.00	0.01	0.07	1.00	1.00
Reptile Area Search	Painted Turtle *	3	0.01	3	0.02	0.00	1.00	0.00	0.00	0.01	0.01	0.00	1.00
Reptile Area Search	Plains Gartersnake	6	0.01	5	0.03	0.13	0.11	0.11	0.02	0.51	0.10	0.02	0.47
Reptile Area Search	Prairie Rattlesnake	28	0.06	24	0.14	0.13	0.07	0.11	0.02	0.51	0.06	0.01	0.30
Reptile Area Search	Rubber Boa *	1	0.00	1	0.01	0.00	1.00	0.00	0.00	0.01	0.03	0.00	1.00

Survey type	Species	# Survey detections	%Surveys where detected	# Quad detections	% Quads where detected	p	psi	p se	p lcl	p ucl	psi se	psi lcl	psi ucl
Reptile Area Search	Terrestrial Gartersnake	13	0.03	11	0.02	0.10	0.17	0.07	0.03	0.32	0.11	0.04	0.48
Small Mammal	Bushy-tailed Woodrat *	5	0.00	5	0.04	0.01	1.00	0.01	0.01	0.03	0.00	0.00	1.00
Small Mammal	Deer Mouse	343	0.29	124	0.91	0.88	0.93	0.02	0.85	0.91	0.02	0.87	0.97
Small Mammal	Dusky or Montane Shrew	36	0.03	27	0.20	0.24	0.36	0.06	0.14	0.39	0.09	0.20	0.55
Small Mammal	Golden-mantled Ground Squirrel	2	0.00	1	0.01	0.63	0.01	0.32	0.11	0.96	0.01	0.00	0.06
Small Mammal	Hayden's Shrew	7	0.01	6	0.04	0.10	0.16	0.09	0.02	0.45	0.15	0.02	0.62
Small Mammal	Heather Vole	6	0.01	5	.04	0.12	0.11	0.11	0.02	0.52	0.10	0.02	0.48
Small Mammal	House Mouse	11	0.01	7	0.05	0.26	0.09	0.11	0.11	0.51	0.04	0.03	0.21
Small Mammal	Least Chipmunk	6	0.01	4	0.03	0.29	0.0 6	0.16	0.08	0.64	0.03	0.02	0.1 7
Small Mammal	Long-tailed Vole	25	0.02	15	0.11	0.42	0.14	0.09	0.26	0.60	0.04	0.08	0.23
Small Mammal	Long-tailed Weasel *	1	0.00	1	0.01	0.00	1.00	0.00	0.00	0.02	0.00	1.00	1.00
Small Mammal	Masked Shrew	35	0.03	27	0.20	0.23	0.36	0.07	0.13	0.39	0.10	0.20	0.56
Small Mammal	Meadow Vole	92	0.08	53	0.39	0.45	0.48	0.05	0.36	0.54	0.06	0.37	0.59
Small Mammal	Merriam's Shrew *	3	0.00	3	0.02	0.01	1.00	0.01	0.00	0.04	0.00	0.00	1.00
Small Mammal	Montane Vole	38	0.03	29	0.21	0.23	0.40	0.06	0.13	0.37	0.10	0.22	0.61
Small Mammal	Mountain Cottontail	2	0.00	2	0.02	0.45	0.02	0.18	0.16	0.77	0.01	0.00	0.07

Survey type	Species	# Survey detections	%Surveys where detected	# Quad detections	% Quads where detected	p	psi	p se	p lcl	p ucl	psi se	psi lcl	psi ucl
Small Mammal	Northern Flying Squirrel *	1	0.00	1	0.01	0.01	1.00	0.01	0.00	0.02	0.00	1.00	1.00
Small Mammal	Northern Grasshopper Mouse	14	0.01	7	0.05	0.56	0.07	0.12	0.33	0.77	0.02	0.03	0.12
Small Mammal	Northern Pocket Gopher	6	0.01	5	0.04	0.16	0.09	0.14	0.02	0.59	0.07	0.02	0.37
Small Mammal	Olive-backed Pocket Mouse	16	0.01	11	0.08	0.25	0.14	0.09	0.12	0.47	0.06	0.06	0.28
Small Mammal	Ord's Kangaroo Rat *	1	0.00	1	0.01	0.01	1.00	0.01	0.00	0.02	0.06	0.00	1.00
Small Mammal	Prairie Vole	12	0.01	7	0.05	0.34	0.07	0.11	0.16	0.58	0.03	0.03	0.16
Small Mammal	Preble's Shrew	4	0.00	4	0.03	0.01	1.00	0.01	0.00	0.03	0.00	0.00	1.00
Small Mammal	Pygmy Shrew	4	0.00	3	0.03	0.28	0.04	0.21	0.05	0.76	0.03	0.01	0.15
Small Mammal	Red Squirrel *	3	0.00	3	0.02	0.01	1.00	0.01	0.00	0.03	0.00	0.00	1.00
Small Mammal	Red-tailed Chipmunk	11	0.01	8	0.06	0.29	0.09	0.13	0.11	0.57	0.04	0.04	0.21
Small Mammal	Richardson's Ground Squirrel	14	0.01	6	0.01	0.72	0.05	0.11	0.47	0.88	0.02	0.02	0.10
Small Mammal	Sagebrush Vole	5	0.00	4	0.03	0.19	0.06	0.16	0.03	0.64	0.05	0.01	0.28
Small Mammal	Short-tailed Weasel	3	0.00	3	0.02	0.01	1.00	0.01	0.00	0.02	0.01	1.00	1.00
Small Mammal	Southern Red-backed Vole	47	0.04	27	0.20	0.48	0.24	0.07	0.35	0.61	0.04	0.16	0.33
Small Mammal	Striped Skunk *	3	0.00	3	0.02	0.01	1.00	0.00	0.00	0.02	0.01	0.00	1.00

Survey type	Species	# Survey detections	%Surveys where detected	# Quad detections	% Quads where detected	p	psi	p se	p lcl	p ucl	psi se	psi lcl	psi ucl
Small Mammal	Thirteen-lined Ground Squirrel	6	0.01	3	0.02	0.48	0.03	0.18	0.19	0.79	0.02	0.01	0.08
Small Mammal	Vagrant Shrew	20	0.02	17	0.12	0.16	0.30	0.08	0.06	0.38	0.14	0.11	0.61
Small Mammal	Water Shrew	6	0.01	5	0.02	0.16	0.09	0.14	0.03	0.59	0.08	0.02	0.37
Small Mammal	Water Vole	4	0.00	2	0.02	0.63	0.02	0.22	0.21	0.92	0.01	0.00	0.06
Small Mammal	Western Harvest Mouse	5	0.02	4	0.03	0.12	0.09	0.11	0.02	0.52	0.08	0.01	0.42
Small Mammal	Western Jumping Mouse	36	0.09	22	0.16	0.40	0.21	0.07	0.27	0.55	0.05	0.13	0.31
Small Mammal	White-footed Mouse	10	0.04	9	0.07	0.07	0.33	0.07	0.01	0.36	0.30	0.03	0.88
Small Mammal	Wyoming Ground Squirrel	6	0.12	3	0.02	0.63	0.02	0.18	0.28	0.89	0.01	0.01	0.07
Small Mammal	Yellow-pine Chipmunk	14	0.07	9	0.07	0.40	0.09	0.12	0.20	0.64	0.03	0.04	0.17

Table 8. Range-limited summary of survey and quad detections, detection estimates (p), occupancy estimates (psi) for all species captured during structured surveys for bats, lentic species, reptiles, and small mammals. Species with an asterisk represent those where the number of repeat detections using that survey method was too low for an appropriate estimate of occupancy.

Survey Type	Species	# Survey detections	%Surveys where detected	# Quads where detected	% Quads where detected	p	psi	p se	p lcl	p ucl	psi se	psi lcl	psi ucl
Bat Acoustic	Big Brown Bat	113	0.24	87	0.32	0.36	0.64	0.05	0.27	0.46	0.09	0.46	0.79
Bat Acoustic	California Myotis	36	0.17	28	0.27	0.39	0.47	0.09	0.23	0.57	0.10	0.28	0.66
Bat Acoustic	Eastern Red Bat	6	0.04	6	0.05	0.04	1.00	0.01	0.02	0.08	0.00	0.00	1.00
Bat Acoustic	Fringed Myotis	20	0.05	19	0.08	0.46	0.13	0.17	0.18	0.76	0.04	0.07	0.24
Bat Acoustic	Hoary Bat	235	0.49	168	0.62	0.63	0.80	0.03	0.56	0.69	0.04	0.71	0.87
Bat Acoustic	Little Brown Myotis	224	0.47	161	0.59	0.60	0.80	0.04	0.52	0.66	0.05	0.69	0.87
Bat Acoustic	Long-eared Myotis	148	0.31	105	0.39	0.44	0.68	0.04	0.36	0.53	0.07	0.53	0.80
Bat Acoustic	Long-legged Myotis	34	0.07	32	0.12	0.28	0.28	0.12	0.11	0.56	0.11	0.12	0.53
Bat Acoustic	Pallid Bat	7	0.11	6	0.21	0.12	0.93	0.11	0.02	0.51	0.83	0.00	1.00
Bat Acoustic	Silver-haired Bat	258	0.54	179	0.66	0.60	0.90	0.03	0.54	0.66	0.04	0.78	0.96
Bat Acoustic	Spotted Bat *	2	0.01	2	0.03	0.01	1.00	0.01	0.00	0.04	0.00	1.00	1.00
Bat Acoustic	Townsend's Big-eared Bat	2	0.00	2	0.01	0.24	0.02	0.72	0.00	1.00	0.06	0.00	0.94
Bat Acoustic	Western Small-footed Myotis	109	0.23	90	0.33	0.34	0.68	0.05	0.25	0.45	0.10	0.47	0.83
Bat Acoustic	Yuma Myotis *	2	0.01	2	0.01	0.01	1.00	0.00	0.00	0.03	0.03	0.00	1.00
Lentic Surveys	American Bullfrog	2	0.00	1	0.00	0.41	0.01	0.28	0.07	0.88	0.01	0.00	0.04
Lentic Surveys	Boreal Chorus Frog	96	0.18	62	0.29	0.29	0.59	0.04	0.22	0.37	0.08	0.43	0.73
Lentic Surveys	Columbia Spotted Frog	53	0.15	40	0.29	0.21	0.69	0.05	0.13	0.32	0.14	0.38	0.89
Lentic Surveys	Common Gartersnake	17	0.03	13	0.06	0.15	0.18	0.06	0.06	0.32	0.08	0.07	0.40
Lentic Surveys	Eastern Racer *	6	0.01	6	0.02	0.01	1.00	0.00	0.00	0.02	0.00	0.00	1.00
Lentic Surveys	Gophersnake	6	0.01	4	0.01	0.26	0.03	0.14	0.07	0.60	0.02	0.01	0.10
Lentic Surveys	Great Plains Toad	8	0.02	5	0.03	0.35	0.05	0.14	0.13	0.65	0.03	0.02	0.14
Lentic Surveys	Long-toed Salamander	28	0.17	22	0.34	0.19	0.92	0.06	0.09	0.33	0.26	0.01	1.00

Survey Type	Species	# Survey detections	%Surveys where detected	# Quads where detected	% Quads where detected	p	psi	p se	p lcl	p ucl	psi se	psi lcl	psi ucl
Lentic Surveys	Northern Leopard Frog	67	0.12	50	0.24	0.29	0.44	0.05	0.20	0.40	0.07	0.31	0.58
Lentic Surveys	Pacific Treefrog	6	0.07	4	0.11	0.22	0.28	0.13	0.06	0.56	0.18	0.06	0.69
Lentic Surveys	Painted Turtle	45	0.07	34	0.13	0.18	0.35	0.05	0.11	0.29	0.09	0.20	0.54
Lentic Surveys	Plains Gartersnake	62	0.15	45	0.28	0.24	0.62	0.05	0.16	0.34	0.11	0.39	0.81
Lentic Surveys	Plains Spadefoot	20	0.04	14	0.07	0.18	0.19	0.06	0.08	0.33	0.07	0.08	0.36
Lentic Surveys	Prairie Rattlesnake *	7	0.01	7	0.03	0.01	1.00	0.00	0.00	0.02	0.00	1.00	1.00
Lentic Surveys	Rocky Mountain Tailed Frog *	1	0.01	1	0.02	0.01	1.00	0.01	0.00	0.05	0.00	1.00	1.00
Lentic Surveys	Spiny Softshell Turtle *	1	0.00	1	0.01	0.00	1.00	0.00	0.00	0.03	0.00	1.00	1.00
Lentic Surveys	Terrestrial Gartersnake	27	0.05	27	0.12	0.05	1.00	0.01	0.03	0.07	0.00	0.00	1.00
Lentic Surveys	Tiger Salamander	92	0.19	65	0.34	0.23	0.79	0.04	0.17	0.31	0.12	0.49	0.92
Lentic Surveys	Western Toad	26	0.09	19	0.16	0.18	0.45	0.06	0.09	0.32	0.15	0.21	0.72
Lentic Surveys	Woodhouse's Toad	29	0.09	25	0.19	0.12	0.75	0.05	0.05	0.26	0.31	0.11	0.99
Reptile Area Search	Common Gartersnake	3	0.01	3	0.01	0.01	1.00	0.00	0.00	0.02	0.01	0.00	1.00
Reptile Area Search	Common Sagebrush Lizard	9	0.03	7	0.06	0.19	0.14	0.11	0.06	0.49	0.08	0.04	0.38
Reptile Area Search	Eastern Racer	37	0.05	29	0.11	0.13	0.41	0.04	0.07	0.23	0.13	0.19	0.67
Reptile Area Search	Gophersnake	13	0.02	13	0.05	0.02	1.00	0.01	0.01	0.03	0.00	1.00	1.00
Reptile Area Search	Greater Short-horned Lizard	16	0.04	15	0.09	0.04	0.81	0.04	0.01	0.25	0.76	0.00	1.00
Reptile Area Search	Northern Alligator Lizard *	1	0.01	1	0.03	0.01	1.00	0.01	0.00	0.08	0.00	1.00	1.00
Reptile Area Search	Painted Turtle *	3	0.00	3	0.01	0.00	1.00	0.00	0.00	0.01	0.01	0.00	1.00
Reptile Area Search	Plains Gartersnake	6	0.01	5	0.03	0.13	0.11	0.11	0.02	0.51	0.10	0.02	0.47
Reptile Area Search	Prairie Rattlesnake	28	0.04	24	0.09	0.10	0.43	0.04	0.04	0.22	0.19	0.14	0.77

Survey Type	Species	# Survey detections	%Surveys where detected	# Quads where detected	% Quads where detected	p	psi	p se	p lcl	p ucl	psi se	psi lcl	psi ucl
Reptile Area Search	Rubber Boa *	1	0.00	1	0.01	0.00	1.00	0.00	0.00	0.02	0.03	0.00	1.00
Reptile Area Search	Terrestrial Gartersnake	13	0.02	11	0.05	0.10	0.21	0.07	0.03	0.32	0.14	0.05	0.57
Small Mammal	Bushy-tailed Woodrat *	5	0.01	5	0.04	0.01	1.00	0.01	0.01	0.03	0.00	0.00	1.00
Small Mammal	Deer Mouse	343	0.83	124	0.93	0.88	0.93	0.02	0.85	0.91	0.02	0.87	0.97
Small Mammal	Dusky or Montane Shrew	36	0.11	27	0.25	0.25	0.43	0.07	0.14	0.40	0.11	0.24	0.64
Small Mammal	Golden-mantled Ground Squirrel	2	0.01	1	0.01	0.63	0.01	0.32	0.11	0.96	0.02	0.00	0.10
Small Mammal	Hayden's Shrew	7	0.03	6	0.08	0.10	0.27	0.09	0.01	0.45	0.04	0.03	0.81
Small Mammal	Heather Vole	6	0.03	5	0.07	0.12	0.23	0.11	0.02	0.51	0.21	0.03	0.75
Small Mammal	House Mouse	11	0.03	7	0.05	0.26	0.09	0.11	0.11	0.51	0.04	0.03	0.21
Small Mammal	Long-tailed Vole	25	0.06	15	0.12	0.42	0.15	0.09	0.26	0.59	0.04	0.09	0.24
Small Mammal	Long-tailed Weasel *	1	0.00	1	0.01	0.00	1.00	0.00	0.00	0.02	0.00	1.00	1.00
Small Mammal	Masked Shrew	35	0.08	27	0.20	0.23	0.36	0.07	0.13	0.39	0.10	0.20	0.56
Small Mammal	Meadow Vole	92	0.22	53	0.40	0.45	0.48	0.05	0.36	0.54	0.06	0.37	0.59
Small Mammal	Merriam's Shrew *	3	0.01	3	0.04	0.01	1.00	0.01	0.00	0.04	0.00	0.00	1.00
Small Mammal	Montane Vole	38	0.12	29	0.28	0.23	0.51	0.06	0.13	0.37	0.13	0.27	0.74
Small Mammal	Mountain Cottontail	2	0.00	2	0.01	0.45	0.02	0.18	0.16	0.77	0.01	0.00	0.07
Small Mammal	Northern Flying Squirrel *	1	0.01	1	0.02	0.01	1.00	0.01	0.00	0.04	0.00	1.00	1.00
Small Mammal	Northern Grasshopper Mouse	14	0.04	7	0.07	0.56	0.07	0.12	0.33	0.77	0.03	0.04	0.15
Small Mammal	Northern Pocket Gopher	6	0.01	5	0.04	0.16	0.09	0.14	0.02	0.59	0.07	0.02	0.37
Small Mammal	Olive-backed Pocket Mouse	16	0.07	11	0.15	0.25	0.26	0.09	0.12	0.47	0.10	0.11	0.49
Small Mammal	Ord's Kangaroo Rat *	1	0.01	1	0.02	0.01	1.00	0.01	0.00	0.04	0.00	1.00	1.00
Small Mammal	Prairie Vole	12	0.04	7	0.08	0.34	0.11	0.11	0.16	0.58	0.05	0.05	0.24

Survey Type	Species	# Survey detections	%Surveys where detected	# Quads where detected	% Quads where detected	p	psi	p se	p lcl	p ucl	psi se	psi lcl	psi ucl
Small Mammal	Preble's Shrew	4	0.01	4	0.03	0.01	1.00	0.01	0.00	0.03	0.00	0.00	1.00
Small Mammal	Pygmy Shrew	4	0.07	3	0.17	0.36	0.22	0.24	0.07	0.82	0.15	0.05	0.61
Small Mammal	Red Squirrel *	3	0.01	3	0.03	0.01	1.00	0.01	0.00	0.03	0.00	0.00	1.00
Small Mammal	Red-tailed Chipmunk	11	0.11	8	0.24	0.34	0.33	0.14	0.14	0.63	0.13	0.13	0.60
Small Mammal	Richardson's Ground Squirrel	14	0.06	6	0.08	0.72	0.08	0.11	0.47	0.88	0.03	0.04	0.17
Small Mammal	Sagebrush Vole	5	0.01	4	0.04	0.19	0.08	0.16	0.03	0.64	0.06	0.01	0.32
Small Mammal	Short-tailed Weasel	3	0.01	3	0.04	0.01	1.00	0.01	0.00	0.04	0.00	1.00	1.00
Small Mammal	Southern Red-backed Vole	47	0.21	27	0.36	0.48	0.43	0.07	0.35	0.61	0.07	0.30	0.58
Small Mammal	Striped Skunk *	3	0.01	3	0.02	0.01	1.00	0.00	0.00	0.02	0.01	0.00	1.00
Small Mammal	Thirteen-lined Ground Squirrel	6	0.03	3	0.04	0.48	0.05	0.18	0.19	0.79	0.03	0.01	0.14
Small Mammal	Vagrant Shrew	20	0.06	17	0.17	0.18	0.36	0.09	0.07	0.41	0.16	0.13	0.68
Small Mammal	Water Shrew	6	0.03	5	0.06	0.18	0.14	0.15	0.03	0.63	0.12	0.03	0.51
Small Mammal	Water Vole	4	0.02	2	0.04	0.63	0.04	0.22	0.21	0.92	0.03	0.01	0.14
Small Mammal	Western Harvest Mouse	5	0.02	4	0.05	0.12	0.16	0.11	0.02	0.52	0.15	0.02	0.62
Small Mammal	Western Jumping Mouse	36	0.09	22	0.18	0.40	0.23	0.07	0.27	0.55	0.05	0.14	0.33
Small Mammal	White-footed Mouse	10	0.04	9	0.11	0.07	0.56	0.07	0.01	0.36	0.52	0.02	0.99
Small Mammal	Wyoming Ground Squirrel	6	0.12	3	0.19	0.64	0.20	0.18	0.28	0.89	0.10	0.06	0.47
Small Mammal	Yellow-pine Chipmunk	14	0.07	9	0.13	0.39	0.17	0.12	0.19	0.63	0.06	0.08	0.32