

Glacier National Park Bat Inventory and Monitoring Project



Summary Report
2011-2014
Lisa J. Bate

Executive Summary

We confirmed the presence of nine bat species in Glacier National Park (GNP): Little brown bat, Long-eared bat, Long-legged bat, California Myotis, Yuma Myotis, Big Brown Bat, Eastern Red Bat, Silver-haired Bat, and the Hoary Bat. As a result of these surveys, we added three new species to Glacier's mammal list: California, and Yuma Myotis, and the Eastern Red Bat. Our findings contributed to range expansions for each of these three new species. During 49 trapping sessions from 2011 through 2014, we trapped and processed bats at 41 different locations throughout GNP. We processed a total of 764 individuals and caught an average of 15.6 bats per night. This included nights when we did not catch any bats. Poor capture success appeared to be weather related. No bats showed signs of White-nose Syndrome (WNS). In addition to mist-netting surveys, we conducted night-time acoustic surveys at 85 different locations within 31 grid cells within GNP over the past four years. We recorded over 57,000 bat passes during warm-season months (May-September). Although we never captured an Eastern Red Bat in Glacier, we recorded 131 bat passes at 22 percent ($n = 19$) of our detector sites during our acoustic surveys. All were east of the divide. Our acoustic evidence was further supported by the capture of 13 Eastern Red Bats just north in Waterton Lakes National Park (WLNP). We confirmed all but the Hoary and Eastern Red Bats as breeding residents in GNP. We examined 25 structures in GNP for bat presence from 2011 through 2014; sixteen of these structures were confirmed as roost sites. We confirmed the presence of bats at five winter detector sites confirming that bats hibernate on the both the east and west sides of GNP. We also confirmed bat use in three caves, yet it is still unknown whether these structures are used as hibernacula. Recommendations are made for continuing inventory efforts to determine if additional species reside in GNP. We also outline long-term monitoring plans to learn more about the timing and travel corridors for migratory bats, and efforts to locate and monitor bat activity and roost sites of bats susceptible to WNS.

Cover Photos (Across rows, left to right, starting from upper left): Long-eared Bat (*Myotis evotis*), Silver-haired Bat (*Lasionycteris noctivagans*), California Myotis (*M. californicus*), Yuma Myotis (*M. yumanensis*), Little Brown Bat (*M. lucifugus*), Long-legged Bat with pup (*M. volans*), Eastern Red Bat (*Lasiurus borealis*), Big Brown Bat (*Eptesicus fuscus*), and the Hoary Bat (*Lasiurus cinereus*).

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Introduction

Compared to eastern North America, very little is known about bat populations in the west. In the east, bats hibernate in huge colonies often numbering in the tens of thousands (Tuttle 2003). In Montana, however, the largest known hibernaculum supports 1757 bats with a median number of only four observed in other known hibernacula (MNHP, B. Maxell, 2015. pers. comm). Bats are difficult species to study; they are nocturnal, their calls are ultrasonic making them inaudible to the human ear, and they roost during the day either alone or in small groups.

In Glacier National Park (GNP), our knowledge about bats was nearly nonexistent because no formal studies had ever been conducted prior to 2011. GNP's wildlife database contained records of only four bat species, one of which was a single road-killed individual. Of 11 potential species in Glacier, six are Montana species of concern (SOC), or potential SOC (MNHP 2014).

Bats are an integral component of our ecosystems. They feed on both forest and agriculture insects, pollinate plants, disseminate seeds, and are considered a keystone species in cave ecosystems (BCI 2012). Without bats, it is estimated that the agriculture industry in the United States could lose as much as \$53 billion a year due to crop loss and the need for pesticides (USFWS 2011). Bats provide food for hawks, owls, and other mammals. Bats make up 25 percent of mammalian species worldwide. Loss of bat populations would send rippling effects throughout many ecological communities with potentially serious impacts. Recent developments, however, have made it critical that we begin to learn about bats before we risk losing populations or entire species.

In 2006, a white powdery fungus was found growing on the noses of infected bats in a cave in New York. This fungus, *Pseudogymnoascus destructans* (Pd), causes white-nose syndrome (WNS). WNS infects bats during hibernation, upsetting a bat's homeostasis and causing it to arouse more frequently from hibernation. This process causes bats to deplete their fat stores before spring, resulting in death by starvation or freezing. Mortality rates in some areas are nearly 100 percent. Biologists are now concerned that WNS will spread to western states. WNS has now spread to 25 states and five provinces (Figure 1), killing an estimated 7 million bats.

Bats are the slowest reproducing mammals for their size with female bats typically giving birth to one young per year. This low reproductive rate makes bats highly susceptible to population declines when mortality rates are high, as they currently are for some species.

In 2011, an emergency petition was submitted to the US Fish and Wildlife Service to list the Little Brown Bat as federally endangered (Kunz and Reichard 2010) due to a rapid decline in their populations (Frick et al. 2010). This was once the most common bat in the eastern United States. In 2012 an emergency assessment subcommittee of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) concluded that along with the Little Brown Bat, both the Tri-colored Bat (*Perimyotis subflavus*) and Northern Myotis (*Myotis septentrionalis*) were assessed as endangered (EC 2014) due to the ongoing spread of WNS and bat mortalities associated with the disease.

The other threat to bat populations is indirectly tied to climate change. Wind energy is renewable and environmentally clean, helping to reduce greenhouse emissions, yet the design or location of a wind farm may prove deadly for migrating bats due to collisions with turbines or from lung implosions due to pockets of low pressure created in front of the turbines (Baerwald et al. 2009, BCI 2010). In southern Alberta wind farms have been generating energy there for years. Wind farms continue to be erected there and in north-central Montana. Evidence from Alberta suggests that bats may be migrating along the east side of the Rocky Mountains (Baerwald and Barclay 2009) and the Waterton-Glacier International Peace Park may be part of this route. Understanding how bats are using these parks will lead to a better understanding of their needs.

The main objectives of this study were to collect baseline data on bat diversity and distribution throughout GNP. Specifically we sought to: 1) assess bat species diversity and distribution throughout the park in a systematic and standardized way; 2) determine which habitat types supported each species; 3) identify roost sites; 4) determine whether bats hibernate in GNP; 5) determine whether bats use GNP as a migration corridor; 6) determine the overall health of bats in the area; and 7) invest in the necessary training and equipment that would allow park biologists to take over bat inventories and monitoring in GNP. Meeting these objectives, will inform decision making if WNS is found in GNP, and will further understanding of the potential impacts of wind energy development on our migratory bats.

Although this study was an international effort focused on bat inventories within Waterton-Glacier International Peace Park, this report only provides results and discussion on the GNP portion of the study. Results for the Waterton Lakes National Park (WLNP) portion of study are available in a separate report (Lausen 2012).

Study Area and Methods

We conducted our study in GNP, which is located in the northwestern corner of Montana. To the north, GNP is bordered on the east side of the continental divide by WLNP in Alberta. The continental divide bisects GNP into two regions, typically referred to as the east and west sides of the park, with elevations ranging from approximately 950 to 3200 m. Habitats are numerous and varied in successional stages: riparian areas, wetlands, grasslands, shrub fields, montane deciduous and coniferous forests, burned forests, sub-alpine and alpine environments, lakes, and rock and glacier environments.

To sample a wide range of habitats and to gain the best overall distribution for our bat surveys throughout the park, we adapted the Bat Grid protocol developed by biologists in the Pacific Northwest (Ormsbee 2007), which uses a 10² km grid cell as a sampling unit (Figure 2). Fifty-nine of these grids were contained wholly within GNP boundaries, but others contained as little as five percent of their land area within GNP.

Initially in 2011, we focused on trapping bats in grid cells that lay within 2 km of a road to maximize the number of nights we could trap. This was required because the survey equipment is bulky and heavy, making it necessary to use stock or boat support for trap sites further away from roads.

In 2012 and 2013, after observing that most of the trap sites close to roads were also close to human structures, we chose to expand the surveys to locations further from roads. Knowing that Little Brown Bats often select buildings for roost sites, we sought to increase the bat species diversity of our sample by moving away from roads and buildings.

We also targeted different habitats for surveys. For example, we surveyed for bats by Nyack Creek where one the largest stands of cottonwood forest exists in the park looking for migratory bats like the Eastern Red Bat which choose deciduous stands of trees for roost sites (Foresman 2012). We surveyed for bats in Poia, Zoo, and Algal Caves looking for evidence of use in these structures given concerns about WNS. We also surveyed near buildings and bridges, in both burned and unburned forest habitats, meadows, wetlands, near cliffs, and along, or over, creeks, rivers, and lakes to sample as many different habitats that potentially supported different species and numbers of bats.

We used both visual and acoustic survey techniques within each grid cell to sample for bats. We used mist netting as the primary visual sampling technique. We also visually inspected buildings, bridges, and caves for roosting bats or guano. We used acoustic sampling as our secondary sampling technique. Acoustic surveys allowed us to sample habitats that were not suitable for trapping such as open, burned forests or meadows. It also allowed us to detect bats that typically forage higher and are less likely to be caught in nets close to the ground.

Visual Surveys

At each trap site, we established from 1 to 10 nets within 0.8 km of each other. The number of nets established at each site varied depending on the habitat features at the site, the number of experienced handlers working that night, and the amount of time we had to setup nets upon arrival (Table 1). We used a variety of net widths (2 to 9 m) across trails and slow-moving water, arranged as a single- or double-net set stacked on poles. We used triple-high nets in more open areas. These nets joined three nets of equal width (4 to 18 m) and were tied together on a pulley system that extended up to 8 m high.

Within each grid cell we chose net sites with habitat features that appeared to have the highest probability of capturing bats. Typically, these were areas around small bodies of water in the forest, along lakes or rivers, and along trails or old roads where we could funnel bats into our nets (Table 1).

Nets were set up during late afternoon and early evening hours, but kept closed until bats began to emerge from their day roosts (emergence) to feed. This minimized the number of birds that were incidentally caught in the nets during daylight hours. Each captured bat was placed in its own cotton bag for at least one hour to digest food, allowing us to obtain its accurate weight. Bats were released immediately after processing.

For each captured bat we recorded: 1) bat number; 2) net number; 3) time and date of capture; 4) species (Ormsbee 2005); 5) sex; 6) reproductive status; 7) age; 8) tooth class (Christian 1956); 9) weight (g); 10) forearm length (mm); 11) presence or absence of a keel which is flap of skin on the tail by each foot (Ormsbee 2005); 12) whether a biopsy was taken; 13) whether an acoustic sample was taken; 14) and comments on overall health and condition. Most importantly, we assessed all bats for any possible signs of WNS.

For each female bat, we assessed its reproductive status: nulliparous, non-reproductive, not obviously pregnant, pregnant, lactating, or post-lactating. We also assessed male bats for their reproductive status: non-reproductive, early scrotal, scrotal, or very scrotal (Ormsbee 2007).

We determined age mainly by looking at whether or not the bones were fused in the wing. Adult's bones are fused and have a round shape; juveniles are unfused and appear as a cylinder (Ormsbee 2005).

We took biopsy samples (2 mm diameter) from wing tissue using sterile disposable biopsy punches and stored each in 95 percent ethanol. Mitochondrial DNA was sequenced to determine species/subspecies identifications in cases where this could not be determined in the field with confidence (e.g. *Myotis lucifugus* vs. *M. yumanensis*) and for baseline data.

We followed decontamination guidelines outlined by the U.S. Fish and Wildlife Service (USFWS 2014) to clean nets and any equipment that came in direct contact with a bat to prevent the possible spread of WNS. We used the Canadian disinfectant Quats (3 percent concentrate as recommended by USFWS) or place nets in water at 50° C to kill fungal spores that may have been present. To minimize the use of disinfectant chemicals coming into contact with a bat's skin, we changed gloves between handling individuals. Rather than disinfecting calipers each time a bat was processed, we placed each individual in a plastic sandwich bag and took measurements from outside the bag. Each bat was weighed in its bag and the bag was later disposed of, or washed, if it was cotton.

Structures

During daylight hours we conducted visual inspections of bridges and buildings in the vicinity of, or on the way to, our next trap site. We recorded where we saw bat droppings, but not bats, indicating the structure was being used as a night roost. We also documented sightings during the day indicating that the structure was being used as a day or maternity roost. Wherever possible, we gently removed a bat from its roost to identify it to species and to determine reproductive status.

Prior to trapping one night at the Saint Mary Dormitory, we visually estimated the number of bats roosting in a bat box on the side of the building. At emergence (the time at dusk when bats leave their day roost), we also counted the number of individuals leaving the bat box to calibrate our visual estimate.

In the winter of 2010-2011, with help from the Bigfork High School Cave Club (BHSCC), we deployed 9 HAXO-8 data loggers in three different caves to record temperature and relative humidity every 49 minutes for six months. . Hibernating bats require both stable temperatures and humidity in their hibernacula; therefore, if a cave exceeded the known limits for temperature and/or humidity, we assumed the structure was unlikely to be a hibernaculum.

We deployed three data loggers in Zoo Cave and four in Poia Cave on November 7 and two data loggers in Algal Cave on November 12, 2010. Based on recommendations from Jason Corbett (Bat Conservation International, J. Corbett, pers. comm., 2010) we placed all data loggers approximately 1.8 m above the cave floor. In each cave a data logger was placed about 3 m from the cave entrance, and others were placed further inside the cave because different bat species select for different ambient temperatures. Maps of exact locations of where data loggers were deployed were created by students of the Bigfork High School Cave Club (GNP files).

During summer months we inspected Poia, Zoo, and Algal Caves to assess bat presence and/or use. We obtained backcountry permits and followed the disinfection protocols outlined by the USFWS (2014) before and after entering the caves.

As part of a National Park Service protocol, we also collected soil samples from one cave to be tested for the fungus *Pd*. Ten samples were collected from Poia Cave and sent to Kevin Castle, DVM, MS, Wildlife Veterinarian with the Washington Support Office (WASO-Biological Resource Management Division in Fort Collins, CO).

Acoustic Surveys

We recorded acoustic ultrasonic recordings using a combination of Anabat detectors (SD1, SD2, and AnabatII-ZCAIM; Titley, Australia) and SM2BAT detectors (192, 384 models; Wildlife Acoustic Technology, Tucson, AZ, USA). We placed Anabat detectors in weatherproof housings on wooden stands, and strapped SM2BAT units to snags, tree trunks, fences, or parts of buildings. We programmed detectors to start recording at dusk and continue until sunrise when the unit would turn off; this was considered one survey night. In most locations detectors only recorded for one survey night although we left some detectors out until battery power was exhausted, typically after seven nights.

We began deploying solar arrays with large 6- and 12-volt batteries to power SM2BAT detectors for extended periods starting in December 2011. Our objectives for this were three-fold: 1) to document the presence of hibernating bats; 2) learn about migration patterns of bats within GNP; and 3) document the arrival and departure of migrating bats.

We analyzed zero-crossing recordings from Anabat detectors using filters and manual examinations in AnalookW 3.8s. We analyzed the full-spectrum recordings from SM2BAT detectors using the automated Sonobat 3.1.4. NW Montane version (Szewczak 2013). If the call was inconclusive or questionable as to species, we visually inspected the call. Only calls that contained the discriminating echolocation characteristics of a given species (Szewczak and Weller 2006), were considered “definitive”; otherwise, they were considered either probable, unknown, or re-categorized to a different species or genus, or placed in the high, or low, frequency group of bats (Susan Lenard 2014).

We standardized all acoustic analyses by first converting echolocation calls from WAC to WAV files using WAC2WAV 3.2.5. (Wildlife Acoustics 2011). Before converting files we would check the split trigger, skip noise, and Sonobat boxes. In addition, we set Maximum duration = 86400, Minimum signal = 0.002, Minimum frequency = 16000, Minimum spacing (s) = 5, filter = SMX-US Comp, and Maximum frequency = 125000. In 2011 and 2012 the Minimum spacing of 8 seconds was used, but this file length often caused Sonobat to crash

due to memory limitations. Next all files were run through Sonobat Batch Scrubber 5.2.vi to remove noise files.

To determine the distribution of a particular bat species within GNP, we recorded each location where a bat was, or was not, caught. We used our acoustic data in the same way (detected or not) to further examine the distribution of bats throughout the park. To assess overall bat activity throughout the park, we summed the number of bat passes per night at each site. For sites where detectors were left longer than one day, we averaged the number of bat passes per night.

In 2011 and 2012, Canadian bat biologist, Cori Lausen (Birchdale Ecological, *bats Rus division*), was the principle investigator for the GNP Bat Inventory and Monitoring Project. Our ability to hire her to lead these surveys and train GNP staff in bat survey techniques was invaluable. She had been working with bats for 17 years prior to her work here. In 2013, as originally planned, the GNP bat project was taken over entirely by trained park staff, allowing us to continue with bat inventories within the park and initiate our long-term monitoring plans (Bate 2010).

Results

Visual Surveys

During 49 trap-night sessions, we trapped and processed bats at 41 different locations throughout GNP (Figure 3). Some trap sites we revisited in subsequent years, such as Belly River and Goat Haunt, either because of their high productivity in the first year or because we thought the site held high potential to catch additional bat species. We processed a total of 764 individuals, representing eight different bat species: Little Brown, Long-eared, Long-legged, California and Yuma Myotis along with Big Brown, Silver-haired, and Hoary bats (Table 2). We caught an average of 15.6 bats per night. This included nights when we did not catch any bats. Almost all nights with few, if any, bat captures appeared to be weather related.

The Little Brown Bat was the most commonly captured species (Table 2), comprising 68 percent of all captures (Figure 4). They also had the widest distribution of sampled bat species in the park with individuals caught at 78 percent of the trap sites (Figure 5a). The majority of the Little Brown Bats were adult (Table 3) females (Table 4). We observed all stages of reproductive status in the female sample; females that were pregnant, not obviously pregnant, or non-reproductive were the most common. We also documented females that were nulliparous, or females still lactating or post-lactating. The majority of the male Little Brown Bats we processed were non-reproductive (Table 5) with approximately 25 percent showing the beginning stages of testes enlargement (early scrotal) and only three considered scrotal. None of the males were in the 'very scrotal' stage.

The Hoary Bat was the second most abundant species captured with 82 individuals (11 percent) processed (Table 2). The majority of these were captured in 2012 at the Belly River-Two Mile and Goat Haunt trap sites. We captured Hoary Bats at 10 net sites (25 percent of the locations), primarily east of the continental divide (Figure 6a). More than half of the Hoary Bats we caught were juveniles (Table 3) and most were males (Table 5). Of the females, most were non-reproductive. By contrast, most males were in the early scrotal phase.

The Long-eared Bat was the third most abundant bat species captured (Table 2) with 66 individuals processed, comprising 9 percent of all the bats we captured (Figure 4). They were widely distributed throughout the park especially in areas with mature/old growth, mixed-conifer forests. We caught them at 39 percent of our net sites (Figure 7a). At a net site along Ole Creek in an old-growth forest stand, the Long-eared Bat was the only bat species we caught ($n = 9$). Nearly all the Long-eared Bats we caught were adults (Table 3); two-thirds were females (Table 4) and the remaining were males (Table 5). Similar to Little Brown females, we observed all reproductive classes for this species. All males were non-reproductive (Table 5).

We caught 30 (4 percent) Silver-haired Bats during our study (Table 2) (Figure 4). These bats were present at 76 percent of our net sites (Figure 8a) and had a broad distribution throughout the park. Silver-haired Bats are considered habitat generalists (Foresman 2012) and we observed a similar pattern finding them in a variety of habitats from open water, to forests and meadows. Most of the Silver-haired Bats we caught were adults (Table 3). We observed most reproductive classes in the female Silver-haired Bats (Table 4). Of the males, most were still non-reproductive (Table 5).

We also caught 30 (4 percent) California Myotis (Table 2) (Figure 4). Considered a bat of arid regions throughout most of its range, it typically inhabits desert areas near open water (Adams 2003). In contrast, we found it in very different habitat—areas with old-growth forest characteristics (Figure 9a), mainly in the North Fork region of the park west of the divide. Most of the California Myotis we caught were adult (Table 3) males (Table 5). Of the females captured, we documented multiple reproduction statuses (Table 4). Nearly all males still showed no signs of reproduction (Table 5).

We captured Long-legged Bats (Table 2) at 27 percent of our net sites, all of which were in the northern half of the park both east and west of the divide (Figure 10a). Considered common throughout much of its range in the Rocky Mountains from Alaska to Mexico, our records suggest it to be more uncommon with only 23 captured in the park. Again, most of the Long-legged Bats we captured were associated with mature/old-growth forests. Adults were more than four times as common as juvenile Long-legged Bats (Table 3) and females were nearly twice as common as males (Tables 4 and 5). Females were found in most reproductive statuses (Table 4). All males were in non-reproductive status (Table 5).

We only caught 3 (< 1 percent) Big Brown Bats in GNP during our mist-nettings sessions (Table 2); all were in the northern half of the park (Figure 11a). In addition to these three captures, however, we observed one roosting on the bridge crossing the North Fork of the Flathead River in Polebridge (Please see *Structure* section for details.), and one apparently overwintered in a building in West Glacier. This bat required rehabilitation, but was later successfully released. Based on our acoustic analyses, however, Big Brown Bats are likely more common in the park than our capture data shows (Please see *Acoustic Survey* section.). All Big Brown Bats we caught were adults (Table 3); two were early scrotal males (Table 5) and one was a pregnant female (Table 4).

The remaining bats we captured were either Little Brown or Yuma Myotis (Table 2). These two species overlap in their physical characteristics, making it difficult to differentiate between them in the field (Ormsbee 2005). Genetic and/or acoustic analyses are the best tools for differentiating between these two species. We submitted three biopsies to the Wildlife Genetics International Lab in Creston, BC from net sites on the west side of the park (Appendix 1). Based on genetic testing, we confirmed the presence of at least one Yuma Myotis in GNP that was caught along Lower McDonald Creek (Figure 12a). The other two samples submitted came back as Little Brown Bats. In 2014, three additional biopsy samples from east of the divide were submitted to the same genetics lab to determine if Yuma Myotis may also occupy eastern parts of GNP. As of this writing, we have not received the results.

During four years of surveys we did not find any bats with signs of WNS. We did, however, document numerous cases (n = 121) of bats with mites, bed bugs, fleas, internal parasites, minor injuries, or fur loss (GNP data files).

Other species that were accidentally captured and released uninjured included: Swainson's Thrush (*Catharus ustulatus*), Northern Waterthrush (*Parkesia noveboracensis*), Northern Saw-whet Owl (*Aegolius acadicus*), and Flying Squirrel (*Glaucomys sabrinus*). In 2012, we experienced two bat mortalities, both of which were Hoary Bats. Both carcasses were submitted to John Bryan, NPS wildlife veterinarian for necropsies. In 2013, the results indicated that one bat died from capture myopathy (stress) and the second likely died from emaciation. No other bats died in other years, but a Spotted Sandpiper (*Actitis macularius*) was accidentally killed in a triple-high net in 2013.

Structures

We examined 25 structures in GNP for bat presence from 2011 through 2014 (Table 6). We documented bat use at all bridges constructed of concrete if cracks and crevices existed, confirming that expansion joints provide excellent roost sites. The older Rose Creek and Saint Mary Bridges were also constructed of concrete and rock, but lacked expansion joints. Bats were not using either of these structures. Bridges constructed of wood and treated with creosote did not show any evidence of bat use, as creosote is toxic and bats tend to avoid structures treated with it (BEL, Lausen, pers. comm., 2011)

In 2014, the existing Rose Creek Bridge was replaced with a new concrete bridge whose design did not include expansion joints. To mitigate for this, two bat houses were built and attached to the underside of the new bridge. One house would accommodate larger bats like the Big Brown Bat and the other was designed for smaller bats like the Little Brown Bat. Both houses followed plans provided by Bat Conservation International (Tuttle et al. 2013).

We trapped at both the Camas and Lower McDonald Creek Bridges and confirmed them as roost sites (Table 1). The bridge on Highway 2 near the Walton Goat lick also functioned as a bat roost site and may possibly be a maternity roost; however, we did not trap at this bridge. We documented a Long-legged Bat maternity roost under the Lee Creek Bridge.

One of our trap sites was the bridge crossing the North Fork of the Flathead River in Polebridge. We processed many pregnant female Little Browns here, indicating that this is an important maternity roost site (Table 6). We also found a Big Brown Bat roosting singly during the day.

The Historic Many Glacier Hotel has been long known as a bat roost site (Bogan and Geluso 1999). In the past, visitors would refuse to stay in certain rooms or demand a refund due to the smell and noise created by bats roosting in the walls. The hotel likely functions as a day, night, and maternity roost. Due to its construction design—wooden lap siding on the outside that swells and shrinks with the elements creating lots of gaps, and its height—the hotel likely functions as a massive bat house. Ongoing efforts to exclude them from walls and the interior of the hotel continue today. In 2012, we observed hundreds of bats emerging from the southeast side of the building.

In 2012 we were contacted to help find a solution for bats flying in the Many Glacier Hotel's dining hall. Obviously, this was an ongoing problem; bats were also observed roosting in the dining hall in 1999 (Bogan and Geluso 1999). To help solve the problem, we recommended that all chimneys and vents be screened to prevent bats from entering the building. This was completed that fall after the bats had left the building. An acoustic detector deployed at the sight confirmed the presence of Little Brown Bats.

Most, if not all, historic buildings in the St. Mary's Hudson Bay District area have functioned as roost sites for bats. Several of the bat houses attached to the St. Mary dormitory are also occupied during the warm season months (Table 6). We did an emergence count and trapped at the one bat box site on the dorm in 2012 (Table 1), finding that this box served as a maternity roost. We estimated about 175 bats using bat boxes on the dormitories (Table 6). We did this by counting the number of bats we could see and then estimating how many rows of bats there were. Our estimates of bat numbers from one of the bat boxes were then compared to the actual number we counted emerging. Our estimates were +/- 7 bats from the actual count emerging.

In 2012, we confirmed the Fish Creek Boat House as a Little Brown Bat maternity roost after pregnant females were caught emerging from the structure (Tables 1 and 6). In 2013, we also confirmed the south side of the Headquarters building in West Glacier as a maternity roost after a number of female Little Brown Bats and their pups kept appearing in the building. That September, up to 15 juvenile Little Brown Bats were found outside the Headquarters building below the location of the maternity roost. The bats were weak and appeared dehydrated. Many could not fly until they received water. The south side of this building is known for its capacity to hold heat. During our inspection of the interior of the building we found small openings on the second story where the bats were entering into the wall. A hole on the inside of the building was then covered to prevent bats from gaining access to the interior.

Results from the data logger deployment in caves were disappointing. Batteries in six of the nine data loggers failed, as they had previously been used for another research project and were not rechargeable. Based on the remaining battery life, however, we had expected them to last six months. We did, however, retrieve data from at least one data logger in each cave.

In Algal Cave, the relative humidity (RH) stayed constant at 100 percent and the temperature stayed constant at 5.8° C. In Poia Cave the RH stayed constant at 100 percent and the temperature varied little from 2.8° C. In Zoo Cave, however, both the RH and the temperature varied widely. The RH ranged from 19 percent to 100 percent and the temperatures ranged from -7.8° to 7.2° C.

Acoustic Surveys

In addition to mist-netting surveys, we conducted night-time acoustic surveys at 85 different locations within 31 grid cells within GNP over the past four years (Figure 3b). Most detectors sampled for one night, but a few sampled up to seven nights or longer depending on accessibility and battery life. We recorded over 57,000 bat passes (GNP data files) during warm-season months (May-September). Based on these recordings, we confirmed nine species in the park (Table 7). Along with the eight species caught in mist nests (Table 2), we also definitively recorded Eastern Red Bat passes on our detectors (Table 7).

Based on acoustic calls the Little Brown Bat was again the most commonly detected bat species in GNP (Table 3; Figure 4b). They were detected at 89 percent of our detector sites (Figure 5b). The calls of the Little Brown Bat are in the 40 kHz range and are differentiated from other *Myotis* species by the longer duration of their call, high-frequency range, and the slope of the lower part of their call (Appendix 2).

Hoary Bats were the second most commonly detected bat in our acoustic surveys (Table 2 and Figure 4b), however, the percentage of Hoary Bats detected by calls nearly tripled compared to the number captured. This was not unexpected because the Hoary Bat typically forages higher above the ground, so are more difficult to capture in nets. Indeed, most of the Hoary Bats we captured were caught in our triple-high nets. Also, the echolocation calls of the Hoary Bat are one of the easiest bat calls to recognize especially when they are long and flat and because of their low frequency (Appendix 2). Although Hoary Bats were only captured at 12 percent of our net sites (Figure 6a), they were detected acoustically at 81 percent of detector sites (Figure 6b) and were distributed throughout GNP.

Similar to the Hoary Bat, the percentage of Silver-haired Bats greatly increased based on acoustic surveys (Table 7), nearly quadrupling the percentage detected compared to capture numbers (Table 2) (Figures 4a and b). Silver-haired Bats calls can also be short and flat like the Hoary, but are diagnostic when they are ≥ 26 kHz (Appendix 2). This species was also widely distributed throughout GNP (Figure 8b).

The Long-eared Bat represented 6 percent of all bats recorded acoustically (Table 7 and Figure 4b). In contrast to our capture data that showed Long-eared Bats mainly in the northern half of the park, however, results from our acoustic calls showed this species to also be distributed throughout GNP (Figure 7b).

The detection of Big Brown Bats also increased based on acoustic call percentages compared to captures numbers (Figures 4a and b). Although they represented < 1 percent of bats captured at the net sites (Figure 11a), we recorded the presence of Big Brown Bats at nearly half the detector sites (Figure 11b). The definitive acoustic characteristic for this species can be challenging due to similarities with the Silver-haired Bats (Appendix 2); nevertheless, our results indicate that Big Brown Bats likely reside throughout GNP.

The bats classified as Yuma *Myotis* were detected acoustically at 15 percent of our detector sites (Figure 12b) and represented about 1 percent of all bats classified (Table 7 and Figure 4b). Acoustic surveys suggest that they may be distributed throughout the northern part of the park (Figure 12b).

Just as the Yuma *Myotis* may be confused with the Little Brown Bat in hand, it may also be confused with the California *Myotis* based upon their call (Appendix 2). Both are small bats with high frequency calls (50 kHz) that at times cannot be distinguished from one another. Hence, this duo of species was the sixth most abundant species group based on calls throughout the park (Table 7 and Figure 4b). The distribution of this

species group (Figure 13b) likely leads to more questions than answers, since the range of these bats was thought to end west of the continental divide in Montana (MNHP 2014, Foresman 2012). Adams (2003), however, shows the Yuma's range extending into central Montana. In our surveys we never knowingly caught a California Myotis east of the divide, but we did catch a number of bats that were either Yuma or Little Brown Myotis. As mentioned above, we submitted additional biopsy samples in 2014 from bats captured east of the divide that could potentially be Yuma Myotis. As of this writing, we have not received the results. The other possibility is that these two bat species were misclassified by SonoBat (Sweczak 2013) because their calls may be interpreted differently, depending on the surrounding environment (Redgwell et al 2009).

Although we never captured an Eastern Red Bat in GNP, we recorded 131 Eastern Red Bat passes at 22 percent of our detector sites during our acoustic surveys (Figure 14b). All were east of the divide. The definitive acoustic characteristic of the Eastern Red Bat was a call that lasts longer than 10 ms (Appendix 2) and many met this criterion. Our acoustic evidence was further supported by the capture of 13 Eastern Red Bats just 4 km north of one of our net sites in Waterton Lake National Park (Lausen 2012). This species typically forages at tree-top level (Foresman 2012) like the Hoary, making it difficult to capture.

The California Myotis was one of our smallest bats averaging around 5 g (GNP data files). It has high frequency (50 kHz) echolocation calls (Appendix 2) and typically forages near the edges of vegetation and over water (Foresman 2012). We detected them at 44 percent of our detector sites (Figure 9b), compared to being caught at 20 percent of our net sites (Figure 9a). Acoustic surveys suggest that the range of the California Myotis extends east of the continental divide.

Similar to our capture data (Figure 10a), it appears that Long-legged Myotis may only occupy the northern portion of the GNP (Figure 10b). We only confirmed 56 bat passes of this species over a four-year period. They were detected at 21 percent of our sites.

The average number of bat passes per night varied among sites ranging from 1 to over 5,000 (Figure 15). Much of the variation was likely a result of the weather. On nights when it rained or temperatures dropped quickly, both insect and bat activity would nearly or completely stop (GNP data files). By contrast on warm, calm nights, bats were far more likely to be active throughout the night especially when moths were flying. Localized insect hatches could have been responsible for some of the high numbers we observed.

As a result of our winter (October through March) acoustic monitoring efforts thus far, we detected bat activity at five different sites during six different sessions (Figure 16), suggesting that bats do hibernate in GNP. Bats were not detected during two sessions due to a complete equipment failure (no data were recorded) and to disposable batteries that only lasted a week.

Discussion

As a result of our bat inventories from 2011 through 2014, we confirmed the presence of nine bat species in GNP: Little brown bat, Long-eared bat, Long-legged bat, California Myotis, Yuma Myotis, Big Brown Bat, Eastern Red Bat, Silver-haired Bat, and the Hoary Bat. Prior to these surveys only six bat species were known to be present in GNP with one species, the Big Brown Bat, represented by a road kill specimen. We were able to add three new species to Glacier National Park's mammal list: California, and Yuma Myotis, and the Eastern Red Bat, and our findings expanded the known range for each of these three new species (MNHP 2015).

Little Brown Bat

Based on both our visual and acoustic surveys, the Little Brown Bat was the most commonly caught and acoustically detected bat in GNP. It is also considered the most common bat in Montana and perhaps the United States (Foresman 2012). We observed all reproductive stages for female Little Brown Bats, confirming them as a breeding resident in GNP (Table 4). This species is considered common in forested habitats and is

one of the main species to forage over open water (Adams 2003, BCI 2015), but will also forage in meadows, along open trails and roads, and by cliffs and human structures. Burned habitats that retain large (> 31 cm diameter-at-breast height [DBH]) snags and trees are especially important due to the high number of roost sites and insects found there (Schwab 2006). They eat a variety of aquatic and terrestrial insects including midges, mosquitoes, flies, beetles, and moths, consuming up to 1200 insects per hour during peak activity, including mosquitoes (BCI 2015).

Of all bat species found in GNP, the Little Brown Bat is the species most likely to roost in human structures. This can complicate proposed renovation projects in the park because they are also considered a species of concern both here in GNP and Montana due to concerns about WNS spreading westward (MNHP 2015). In 2011, an emergency petition was submitted to the US Fish and Wildlife Service to list the Little Brown Bat as federally endangered (Kunz and Reichard 2010) due to a rapid decline in their populations (Frick et al. 2010). In Canada, the Little Brown Bat was listed as Endangered in 2012 (Environment Canada 2014). In eastern North America, millions of Little Brown Bats have died from WNS and mortality rates approached 100 percent in some areas causing local extirpations (BCI 2015). Little Brown Bats are slow reproducers, raising only one pup per year and it is thought that it will take years to get population numbers of Little Brown Bats back to levels reported prior to the arrival of WNS.

We found Little Brown Bats roosting under bridges and in any part of a building that allowed them entry into a warm, dry, protected space to escape weather and predators (GNP data files). They roosted in attics, the open spaces behind siding or under roofing, chimneys, and inside walls. Little Brown Bats also roosted in a number of the bat houses put up on buildings throughout the park. Away from human structures, Little Brown Bats will roost in the cavities and crevices of larger trees and snags, caves, mines, talus rock piles, and cracks and crevices in cliff habitat, but these roost sites are much harder to locate without the use of radio telemetry (Schwab 2006).

Bat roost sites vary with the species, gender, time of day, reproductive status, and the habitat and weather. Single, non-reproducing Little Brown Bats can be found in any of the roost sites listed above during the warm season months (April through September). Day roosts, where a bat will sleep for the day, vary in temperature and location from night roosts although the reasons are unclear, but may have to do with energetics (Foresman 2012). A night roost is where a bat will come to periodically rest and digest during the night hours in between foraging bouts. A maternity roost is where pregnant and lactating females will roost while giving birth and raising their young, and in areas where the ambient air temperature stays much warmer than a day or night roost site (Foresman 2012). The warm temperatures likely increase the rate of development in the pups. Little Brown pups attain adult size within three weeks.

All maternity roost sites found in GNP were either under concrete bridges or in buildings (Table 6), similar to the south-facing side of the headquarters building where temperatures stayed warm or even hot by human standards throughout the day. We observed that the ambient air temperature under a bridge at night was about 5° C warmer than temperatures away from the bridge. Females can give birth anytime in the summer starting in June.

Roosts can also vary depending on the gender of the bat (Adams 2003). During the breeding season females are more likely to be found at lower elevations with males occupying sites at higher elevations (McGuire and Boyle 2013). This is thought to be a means of niche partitioning. Indeed, when we surveyed at higher elevation sites—such as Ole Lake and Two Medicine—the majority of the Little Brown Bats we caught were males (GNP data files).

Many buildings in GNP that are in need of renovation may be used by the Little Brown Bat as maternity roost sites, so we recommend that site checks are always made prior to the start of a renovation project. Exposing maternity roosts before pups have matured will likely result in pups dying because they are not able to fly to a more protected area. To mitigate this risk, a long-term focus of both our wildlife and integrated pest management programs has been to ensure that all bat houses in GNP are properly designed and located (BCI

2011). More recently we have partnered with a local Eagle Scout, as a way to obtain his badge, by building four bat houses and a bat mini-condo. These structures will be established in areas with documented bat roost sites nearby.

Hibernacula, the roost sites used in winter when food resources are depleted, are usually found in caves and mines where the temperature and RH remains level throughout winter. Bat species go into “torpor,” lowering their metabolism and allowing them to pass most of the winter sleeping and living off fat reserves they accumulated during the warm months.

In Montana, the Little Brown Bat is considered a year-round resident and is thought to hibernate in caves and mines (MNHP 2015), but the numbers detected in the winter are far less than those in summer, suggesting it may be partially migratory. There are 15 known caves and 5 mines in GNP (GNP data files) that potentially could support hibernating bats. We have evidence of bats overwintering at five of our sites in the park, but the quality of the echolocation calls did not allow us to definitively identify any of the bats to species although both high- and low- frequency bats were detected (GNP data files). WNS infects bats while they are hibernating so it is imperative that we determine whether this species hibernates in GNP and Montana.

Annually, GNP welcomes over 2 million visitors, including some from states or provinces that are WNS positive. A single individual, wearing contaminated clothing or gear from a WNS-positive cave, could establish the disease in the west. In Europe, bats appear to be immune to the disease suggesting that it has existed there for an extended period of time allowing bats to build immunity to the disease, however, contaminated caving gear from Europe (Puechmaile et al. 2010) is thought to have transported it to the eastern United States, where there is no immunity to WNS.

Although bat use has been confirmed in three caves in GNP, based on presence of droppings, we have yet to determine if they function as roost sites or hibernacula as. To date, we have not observed a bat in these caves, but the interior of the caves is complex with many hidden areas where bats could potentially roost unseen. The Algal and Poia Caves had temperatures conducive (cool with little variation) for hibernacula and the RH readings also appeared conducive (high RH), but the results are questionable because data loggers can get saturated with water, giving false readings (MNHP, Maxell, 2013, personal communication).

Data from Zoo Cave were inconclusive because the only data logger with retrievable data was near the entrance where the temperature and RH varied greatly. We suspect that Zoo Cave is unlikely to support hibernating bats because we found persistent ice features inside it during summer, suggesting the interior of the cave drops well below freezing in the winter. Also, there is pack rat (*Neotoma cinerea*) guano nearly 2 m deep in some areas of the cave; bats typically do not like to occupy sites heavily infested with pack rats (BEL, C. Lausen, 2011. pers. comm.).

We considered using our long-term bat detectors with solar panels outside of these caves to determine if bats were hibernating within, but the equipment would not survive in avalanche country. Recently, we put in a proposal to purchase two data loggers. The requested customized data loggers would be placed inside the caves and are capable of monitoring for extended periods on lithium batteries. This would eliminate the need to deploy solar setups susceptible to avalanche loss and allow us to avoid the dangerous and logistically difficult situation of surveying for bats in GNP during winter. The grant would also allow us to submit guano samples for genetic testing to identify the species. Although we had collected guano from caves in 2011, the lab we submitted the samples to shut down and the samples were lost. New samples would be sent to a Wildlife Genetics Lab in Nelson, BC. Sites where hibernacula are found may require increased protections. Although none of the bats we processed showed signs of WNS, biologists believe it is only a matter of time until the disease moves out west (WBWG 2009).

In our first year of surveys when we focused surveys close to roads (< 2 km), we may have inadvertently been surveying primarily Little Brown Bat habitat. With roads come human structures and therefore roost sites. Indeed, when we began to survey areas further from roads and human structures, we found that our bat diversity increased (GNP data files).

Hoary Bat

The Hoary Bat, our second most commonly captured bat ($n = 82$), is our largest bat with a wing span of about 40 cm. They are migratory, but there is no information on where they migrate to in the fall (Foresman 2012). Hoary Bats are also listed as a Species of Concern in GNP and in MT (MNHP 2015) due to impacts from wind farms (Baerwald 2008). Migrating bats are known to collide with wind turbines or experience lung implosions from the low pressure created in front of the wind turbines. Research has shown that increasing a turbine's cut-in speed (speed at which turbines are triggered to turn on) can significantly reduce bat mortalities (Baerwald et al. 2009). Hoary Bats are not known to be susceptible to WNS (BCI 2015).

Based on our acoustic data, Hoary Bats appear to be wide-spread and common throughout GNP during the summer. Although we only caught 82 Hoary Bats in our trap sessions, we recorded nearly 4,000 Hoary Bat passes from July 9 through October 8 (all years combined) and at over 80 percent of our detector sites. Whether they arrive earlier than July is unknown because most of acoustic detectors were not deployed until July. Our future long-term monitoring objectives include year-round acoustic monitoring on both the east and west side of the park so that we can better answer questions about the migratory timing and paths of this species.

Our capture rate for Hoary Bats was very erratic across the years given how often we detected them in our acoustic surveys. Nearly all ($n = 79$) the Hoary Bats we captured were caught in 2012. It appeared that we had our nets set at just the right time and place to catch migrating Hoary Bats in August of 2012. In one night alone we processed 42 Hoary Bats caught along the Belly River (GNP data files). Two nights later we caught numerous Hoary Bats at Goat Haunt. In response to the night in the Belly, Cori Lausen stated that we may have found the "most substantial bat migration route currently known for Hoary Bats across North America" here in GNP (BEL, Lausen, pers. comm., 2012). Return visits to this same location in subsequent years, however, did not produce the same results. In 2013, we had wet overcast weather and bat activity was minimal, so it was understandable that we did not catch or even detect bats. However, in 2014 when the weather seemed conducive to bat activity, our capture results were still poor (GNP data files). Whether in 2012 we hit the migration time just perfectly, or we happened to be in the right place during a moth hatch, is unknown. We have installed a long-term solar-powered bat detector at the Belly River Ranger Station to help us understand if Hoary Bats migrate en masse along this same corridor every year around the same time, or if this was just an unusual event.

There is evidence to suggest that males and females migrate separately with males following a more western course and females tracking further east (Foresman 2012). Of the 82 Hoary Bats we caught, 71 (86 percent) were males (Table 5) and 11 (14 percent) were females, mostly non-reproductive and only one lactating, leaving it inconclusive as to whether Hoary Bats actually breed in GNP. Based on recommendations from bat biologist Cori Lausen, we plan on conducting June mist-netting trap sessions to see if we catch pregnant females (Lausen 2012). We are confident, however, as to the presence of Hoary Bats in GNP during the breeding season, as they are one of the easiest bats to definitively confirm through acoustic recordings (Ormsbee 2005; MNHP 2015); echolocation calls lasting up to 20 milliseconds and below 23 kHz are definitive for identifying Hoary Bats through their calls (Appendix 2).

Of the 79 Hoary Bats we processed in 2012, we found we could not differentiate between adult and juveniles based on whether or not the bones were fused in the wing (Ormsbee 2005). Instead, we relied on tooth class to differentiate between adults and juveniles (Christian 1956). This may be due to the fact that first-year male and female Hoary, Eastern Red, and Silver-haired Bats all are reproductively mature their first autumn (Cryan et al. 2012). These three species are the only known bats in temperate North America known to reach maturity so early. All three of these bats are considered migratory, while the *Myotis* are considered year-round residents.

We did not find roost sites for Hoary Bats in GNP, but without the use of telemetry, this would be very difficult. Hoary Bats roost alone in deciduous vegetation (Adams 2003, Foresman 2012) often wrapping their

uropatagium (membrane that extends between the thighs of a bat and includes the tail), which is furred, around them for added warmth. In Montana, Hoary Bats will also roost under the bark of old-growth ponderosa pine and Douglas-fir trees. Females with young will roost higher up than single males.

Although Hoary Bats will forage over water they tend to select openings in or adjacent to forests where they feed on beetles and moths (Foresman 2012, MNHP 2015). Hoary Bats can be distinguished from other flying bats because they fly fast and straight, rather than erratic and weaving like smaller bats.

Long-eared Bat

The Long-eared Bat, the third most abundant bat captured in GNP (Table 2), was observed in all reproductive stages, confirming that they too are a breeding resident in GNP (Table 4). Long-eared Bats are most commonly associated with old-growth forests near water (Foresman 2012) and our work confirmed this as well. Most captures were in unburned coniferous old-growth, but some were caught adjacent to burned areas where large snags and trees still remained. Researchers on Long-eared Bats in burned habitats in Montana recommend retaining large diameter trees, in high-density stands, to provide roosting habitat for this species (Schwab 2006). Insect abundance and diversity increase dramatically in burned forests, compared to unburned forests, making these habitats rich for numerous bat species. Long-eared Bats feed on moths, flies, and leaf hoppers (Foresman 2012) and are able to hover near vegetation and glean insects of the surface of plants due to their wing structure.

In addition to roosting behind the sloughing bark of trees and snags (Schwab 2006), Long-eared Bats roost in buildings, caves, mines, and rock outcroppings. There are few records of this species hibernating in Montana (MNHP 2015) and it is thought that they may migrate south for hibernation (Foresman 2012). Although our capture data shows this species mainly in the northern part of the park, our acoustic data recorded them throughout (Figures 7a and b). Their calls can be differentiated with nearly 100 kHz of bandwidth, nearly linear slope, and their characteristic frequency (Appendix 2). At one site along Ole Creek in the southern part of GNP, Long-eared Bats were the only species we caught (GNP data files) in old-growth mixed conifer forest with a very small and quiet stream running through it.

California Myotis

California Myotis comprised 4 percent of our bat captures. The confirmation of their presence enabled us to add the species to Glacier National Park's mammals list. The processing of these 30 bats documented both pregnant and lactating females (Table 4), indicating that they too are breeding resident in GNP.

The California Myotis are easily identified in hand, based on their size and keeled calcar (Ormsbee 2005). They also are much calmer when captured than the Little Brown Bat. California Myotis was the smallest bat we found in GNP and is one of the smallest in North America (Foresman 2012) with a wing span of about 22 cm and averaging 5.5 g (GNP data files). We found them in burned and unburned old-growth forests, mainly in the northwest part of the Park (Figure 9a).

Our study expanded the known range of this species further east than had been previously documented (MNHP 2015). There is some confusion, however, as to how far east this species really extends. Based on acoustic calls, it appears that the California Myotis resides throughout GNP (Figure 9b). The calls of this species overlap with that of Yuma Myotis (Appendix 2) as they both have a minimum frequency of 45-50 kHz so it remains possible that Yuma Myotis resides east of the divide. As mentioned above, we submitted biopsy samples from a bat east of the divide that we suspected was Yuma Myotis in 2014. As of this writing, we have not received those results. There is the possibility that these high-frequency calls were made when multiple bats were foraging in the same area (Lausen 2012), resulting in one bat making slightly higher calls than the other to focus in on their prey. These calls may also have been produced from Little Brown Bats while foraging in areas with high-vegetative clutter.

Silver-haired Bat

Silver-haired Bats also comprised four percent of our bat captures, but based on acoustic data, they are likely more abundant in GNP than capture data indicate. We detected nearly four times as many of them acoustically than we did through captures; however, their call can be confused with Big Brown Bat calls (Appendix 2). They are high flyers and known to be very mobile, covering great distances to forage (Adams 2002). We also confirmed this species as a breeding resident in GNP.

Silver-haired Bats tend to roost alone under bark, in cavities, bird nests, and buildings (Adams 2002) and outside of Montana they have been found hibernating in caves, mines, and buildings (Foresman 2012). They are a medium sized- bat, slow flyers, and feed on a variety of insects. We captured them in a variety of habitats including coniferous and riparian areas, and burned and unburned forests (GNP data files).

Silver-haired Bats were thought to be migratory (MNHP 2015), but recent data suggest that some may be year-round residents (Blejwas et al. 2014, BEL, 2013, C. Lausen; pers. comm., MNHP 2015). Silver-haired Bats are a potential SOC due to mortalities experienced during migration at wind farms (Baerwald et al. 2009). In addition, although this species has not been documented with WNS, it has tested positive for *Pd*, the fungus that causes WNS, in southeastern US (Bernard et al. 2015).

Long-legged Bat

Although we only captured 23 Long-legged Bats, we were also able to confirm them as a breeding resident in GNP because we located a maternity roost under the Lee Creek Bridge (Table 4). This is a docile species with a keeled calcar with fur extending on the ventral side of the wing to the elbow (Ormsbee 2005). Their calls may be confused with Little Brown Bats (Appendix 2).

Long-legged Bats forage in coniferous or deciduous forests and roost in buildings, the thick bark of trees, and caves. They forage on a variety of insects, are more tolerant of cold than other *Myotis* species (Foresman 2012), and are thought to be a year-round resident hibernating in caves and mines (MNHP 2015). We caught them in a variety of habitats, including deciduous and coniferous forests, burned and unburned forests, and around bridges (GNP data files). Foresman (2012) states that many of the Long-legged Bat captures in Montana were above 1,800 m. Our net and detector sites were below 1,800 m, perhaps explaining the low capture numbers for a bat considered common in western Montana.

Big Brown Bat

We only caught three Big Brown Bats over the course of four years (GNP data files), but did find one bat day roosting under a bridge and another that appeared to have spent the winter in a building in West Glacier. This bat was very dehydrated and weak and needed to be rehabilitated before it was released. Big Brown Bats are considered habitat generalists, often roosting in human structures such as buildings, bridges, and barns (Foresman 2012, Adams 2003), and are considered common in Montana (Foresman 2012). One reason we may have detected so few Big Brown Bats in GNP is because it is difficult to get a definitive call due to the overlap with the calls of Silver-haired Bats (Appendix 2). They tend to fly high making them one of the harder to catch bat species.

Yuma *Myotis*

We confirmed the presence of at least one Yuma *Myotis* in GNP through DNA testing, adding a second new species to Glacier National Park's mammal list. Biopsy samples from 3 of 7 captured individuals that could have been Yuma *Myotis* were submitted for testing; results indicated only one was positive.

Our findings also confirmed and expanded the known range of this bat further east in Montana than previously thought (MNHP 2015). The exact range of this species has been unknown due to the difficulty distinguishing it from the Little Brown Bat. Three other biopsy samples from east of divide were submitted in 2014 for DNA analysis. As of this writing, we have not received the results.

The Yuma Myotis is a potential SOC in Montana mainly because so little is known about them and their range (MNHP 2015). They are easily confused with the Little Brown Bat based on physical characteristics, and their calls overlap with California Myotis (Appendix 2). Yuma Myotis feed on a variety of insects, but are most noted for foraging over open water (Foresman 2012). They roost in nearby buildings, bridges, cave and mines and are known to hibernate in caves and mines, but in Montana their hibernacula are undescribed (MNHP 2015).

Eastern Red Bat

We confirmed the presence of eight bat species in GNP through visual techniques (mist-netting); only the unexpected presence of Eastern Red Bat was confirmed through acoustic techniques. Our documentation of the presence of the Eastern Red Bat, corroborated with the capture of 13 Eastern Red Bats in Waterton Lakes National Park (Lausen 2012), allowed us to add a third new species to Glacier National Park's mammal list. Although their calls can overlap with Little Brown Bats, calls with duration > 10 ms are definitive for Eastern Red Bats (Appendix 2). The discovery of this bat in GNP greatly expanded the known westward extent of their range (MNHP 2015).

Prior to this study, it was thought that they only migrated through eastern Montana (Foresman 2012). While thrilling, the discovery of Eastern Red Bat in GNP made for a major delay in this study because the Montane version of Sonobat (Szweczak 2011) that we used in the analysis of the acoustic data did not include it; only the Plains version of SonoBat 3.1 covers all known bat species found in eastern Montana. It was two years before the software program was updated to include this additional species (Szweczak 2013). Had we run the acoustic analysis prior to this species being added to the program, it would have resulted in a number of misclassifications or omissions (BEL, 2013, C. Lausen; pers. comm.) and required us to reanalyze all data.

The Eastern Red Bat is considered a potential SOC in Montana (MNHP 2015). It is a migratory species and research has documented mortalities at wind farms (Baerwald 2008). Like the Silver-haired Bat, Eastern Red Bats have also tested positive for *Pd*, without having shown signs of WNS (Bernard et al. 2015).

Eastern Red Bats are a tree-roosting bat (Adams 2003, Foresman 2012), roosting in the leaves of deciduous trees. Like the Hoary Bat, they have a furred uropatagium that conserves heat while roosting in leaves. As their name suggests, their hair ranges from a red-to-orange color. They forage high above tree tops on moths, beetles, crickets and true bugs.

Other Bat Species

Preliminary acoustic data indicated that the Townsend's Big-eared Bat (*Corynorhinus townsendii*) and the Western Small-footed Myotis (*Myotis ciliolabrum*) may also reside in GNP, but their presence will not be definitive until further surveys are conducted. A third species, the Fringed Myotis (*Myotis thysanodes*), may occupy some of the Ponderosa pine stands on the west side of the park, but thorough surveys of these areas have yet to be completed. Access to these stands has been an issue every year due to high waters. Surveys from lands adjacent to GNP have confirmed these three species in northwest Montana (MNHP 2015).

Management Considerations

Long-term monitoring of GNP's bats will require both visual and acoustic techniques. A bat in hand allows us to positively identify the bat to species visually or by taking a biopsy. It also allows us to assess age, gender, reproductive status, and overall health. Bats infected with the beginning stages of WNS can now be identified with the use of ultraviolet light (Turner et al. 2014). Visual inspection of bridges and buildings will help identify additional roost sites throughout GNP. We also plan on initiating maternity roost-emergence counts for Little Brown Bats as a way to assess potential changes in bat populations (Fellers and Halstead 2015), given the current threat of WNS.

Long-term acoustic monitoring will allow us to survey areas not suitable for mist-netting, detect species more likely to evade capture because of their flight patterns, and help us to better understand the migration paths and timing of different bat species. Acoustic monitoring, however, is far from a perfect science. We have learned through our surveys that it is one thing to deploy a detector to record bat passes, yet an entirely different matter to deploy detectors to record high-quality echolocation calls. The wind moving through vegetation emits ultrasonic sounds, which either interfere with definitively identifying a bat to species, or creates numerous noise files that use up data storage space and battery power. Bat calls can be affected by a bat's gender and age, its proximity to other bats while foraging, and the surrounding physical and biological environment (Redgwell et al 2009). Microphones and batteries fail so we must continuously check equipment to assess its performance. Ultimately, all these factors affect whether or not a bat call can be analyzed to an individual species.

To augment our year-round acoustic monitoring program for the long-term, we have partnered with Waterton Lake's biologist, Barb Johnston to identify key locations in both parks to deploy our long-term detectors. Data from these detectors will help us better understand the bat species which hibernate, breed, and migrate through our parks.

Recommendations

White-nose Syndrome (WNS), a disease caused by the cold-loving fungus *Pd*, is currently found in 25 states and five provinces (BCI 2015). It has killed an estimated 7 million bats in eastern North America. The eastern edge of GNP is thought to be a corridor for migratory bats. Wind power development, expected to increase outside the Park, puts migratory bats at risk due to collisions and pressure changes associated with turbines. Therefore, it is critical that we have accurate, timely, and reliable baseline data on GNP bat populations before these threats are detected in, or near, GNP. To obtain these data we recommend that GNP:

1. Expand bat inventory surveys to include additional grid cells and habitats to determine what other additional species may reside in GNP.
2. Continue with visual inspections of buildings, barns, and bridges to identify additional bat roosts.
3. Conduct emergence counts of selected maternity roosts of Little Brown Bats on both the East and West side of GNP. This information will allow us to better assess potential impacts of WNS should it arrive.
4. Continue with winter acoustic monitoring to determine which species overwinter in GNP.
5. Continue long-term, year-round, acoustic monitoring to assess migration paths and timing of migratory bats.
6. Conduct mist-netting sessions in June to determine whether Hoary and Eastern Red Bats are resident breeders in GNP.
7. Install roost data loggers in caves to determine if they are being used as hibernacula.
8. Write best Management Practices Manual to provide guidelines to landowners and facility management personnel in GNP on how to protect roosting bats, especially females and their pups, during renovation and exclusion projects. An estimated 900 buildings exist in GNP, including those on private inholdings.
9. Continue to work with local youth groups to build and install bat houses to provide alternative roost sites for bats currently roosting in buildings.

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References Cited

- Adams, R. 2003. Bats of the Rocky Mountain West – Natural History, Ecology and Conservation. University of Colorado Press, Boulder. 288 pp.
- Baerwald, E.F. 2008. Variation in the Activity and Fatality of Migratory Bats at Wind Energy Facilities in Southern Alberta: Causes and Consequences. University of Calgary, MSc. Thesis. Calgary, AB.
- Baerwald, E. F., J. Edworthy, M. Holder, and R. M. R. Barclay. 2009. A large-scale mitigation experiment to reduce bat fatalities at wind energy facilities. *Journal of Wildlife Management* 73(7): 1077-1081.
- Bat Conservation International (BCI). 2010. Are Little Brown Bats Endangered? Retrieved from http://www.batcon.org/resources/media-education/news-room/newsletter-archive/bat_article/1386 (Feb 2015).
- Bat Conservation International (BCI). 2011. Bats in buildings; a guide to safe & human exclusions [PDF Handout]. Retrieved from http://www.batcon.org/pdfs/education/fof_ug.pdf [Dec. 2011]
- Bat Conservation International (BCI). 2015. White-nose syndrome resources. Retrieved from <http://www.batcon.org/resources/for-specific-issues/white-nose-syndrome> [Jan. 2015].
- Bate, L. 2010. Waterton-Glacier International Peace Park Bat Inventory and Monitoring Study Proposal. Unpublished document submitted to Glacier National Park Conservancy, GNP data files: 5 pp.
- BEL (Birchdale Ecological, Ltd). Cori Lausen, PhD. PO Box 606, Kaslo, B.C. Canada V0G 1M0.
- Bernard, R., Foster, J., Willcox, E., Parise, K. and G. McCracken. 2015. Molecular Detection of the Causative Agent of White-nose Syndrome on Rafinesque's Big-eared Bats (*Corynorhinus rafinesquii*) and Two Species of Migratory Bats in the Southeastern USA. *Journal of Wildlife Diseases* In-Press.
- Blejwas, K., Lausen, C. and D. Rhea-Fournier. 2014. Acoustic Monitoring Provides First Records of Hoary Bats (*Lasiurus cinereus*) and Delineates the Distribution of Silver-Haired Bats (*Lasionycteris noctivagans*) in Southeast Alaska. *Northwestern Naturalist*: Volume 95 (3): Pages 236-215.
- Bogan, M., and K. Geluso. 1999. Bat Roosts and Historic Structures on National Park Service Lands in the Rocky Mountain Region. Unpublished Report. US Geological Survey, Albuquerque, NM. 23 pp.
- Boyles, Justin G.; Cryan, Paul M.; McCracken, Gary F.; Kunz, Thomas H. 2011. Economic importance of bats in agriculture. *Amer. Assoc. of Advancement of Science*. Washington, .DC. Volume 332 (6025); 41-42.
- Christian, John. 1956. The Natural History of a Summer Aggregation of the Big Brown Bat, *Eptesicus fuscus fuscus*. *American Midland Naturalist*: Vol. 55, No. 1, pp. 66-95.
- Cryan PM, Jameson JW, Baerwald EF, Willis CKR, Barclay RMR, et al. (2012) Evidence of Late-Summer Mating Readiness and Early Sexual Maturation in Migratory Tree-Roosting Bats Found Dead at Wind Turbines. *PLoS ONE* 7(10): e47586. doi:10.1371/journal.pone.0047586

- Fellers, G., and B. Halstead. 2015. Twenty-Five Years of Monitoring a Townsend's Big-Eared Bat (*Corynorhinus townsendii*) Maternity Roost. *Northwestern Naturalist* 96(1):22-36.
- Foresman, K. R. 2012. *Mammals of Montana*. Missoula, Montana: Mountain Press Publishing Company. 429 pp.
- Gregory G. Turner, Carol Uphoff Meteyer, Hazel Barton, John F. Gumbs, DeeAnn M. Reeder, Barrie Overton, Hana Bandouchova, Tomáš Bartonička, Natália Martínková, Jiri Pikula, Jan Zukal, and David S. Blehert. 2014. Nonlethal Screening of Bat-wing Skin with the Use of Ultraviolet Fluorescence to Detect Lesions Indicative of White-nose Syndrome. *Journal of Wildlife Diseases*: July 2014, Vol. 50, No. 3, pp. 566-573.
- Environment Canada (EC). 2014. The Government of Canada added three species of bats to Schedule 1 of the Species at Risk Act (SARA). Retrieved from: <http://www.registrelep-sararegistry.gc.ca/default.asp?lang=En&n=073DC653-1>
- Frick, W.F., J.F. Pollock, A. Hicks, K. Langwig, D.S. Reynolds, G.G. Turner, C. Butchowski, T.H. Kunz. 2010. A once common bat faces rapid extinction in the northeastern United States from a fungal pathogen. *Science*, 329:679-682.
- Kunz, T., and J. Reichard. 2010. Status Review of the Little Brown Myotis (*Myotis lucifugus*) and determination that immediate Listing Under the Endangered Species Act is scientifically and Legally Warranted. Boston University's Center for Ecology and Conservation Biology. Boston, MA. 33 pp.
- Lausen, C. 2012. Waterton Lakes National Park Bat Survey. Birchdale Ecological Ltd. Kaslo, BC. 68 pp
- Ormsbee, P. 2005. Key to Idaho, Montana, and South Dakota Bats. Unpublished document: Willamette National Forest, Eugene, Oregon.
- Ormsbee, P. 2007. Bat Grid Draft Protocol. Unpublished document. Willamette National Forest, Springfield, OR. 13 pp.
- McGuire, L. and A. Boyle. 2013. Altitudinal migration in bats: evidence, patterns, and drivers. *Biological Reviews*: Vol. 88 (4). Pp. 767-786.
- Puechmaille SJ, Verdeyroux P, Fuller H, Ar Gouilh M, Bekaert M, Teeling EC. White-nose syndrome fungus (*Geomyces destructans*) in bat, France. *Emerg Infect Dis*. 2010 Feb.
- Redgwell, R, Szewczak, J., Jones, G., and S. Parsons. 2009. Classification of Echolocation Calls from 14 Species of Bat by Support Vector Machines and Ensembles of Neural Networks. *Algorithms* 2009, 2, pp. 907-924.
- Schwab, N. 2006. Roost-site selection and potential prey sources after wildland fire for two insectivorous bat species (*Myotis evotis* and *Myotis lucifugus*) in mid-elevation forests in western Montana. M.S. Thesis. University of Montana. 89 pp.

- Szewczak, J. M., and T. J. Weller. 2006. Echolocation Call Characteristics of Oregon Bats. Unpublished training document. Humboldt State Univ. and USFS Redwood Sciences Lab. Arcata, California. 4 pp.
- Szewczak, J. M. 2011. Sonobat 3.1: Echolocation call characteristics of western US bats. Humboldt State University Bat Lab. Retrieved from [http://www. Sonobat.com](http://www.Sonobat.com)
- Szewczak, J. M. 2013. Sonobat 3.2: Echolocation call characteristics of western US bats. Humboldt State University Bat Lab. Retrieved from http://www. Sonobat.com/SonoBat_2.1_and_3.2.html
- Tuttle, M. Estimating Population Sizes of Estimating Population Sizes of Hibernating Bats in Caves and Mines. 2003. *in* O'Shea, T.J. and Bogan, M.A., eds., 2003, Monitoring trends in bat populations of the United States and territories: problems and prospects: U.S. Geological Survey, Biological Resources Discipline, Information and Technology Report, USGS/BRD/ITR--2003--0003, 274 p.
- Tuttle, M., Kiser, M, and S. Kiser. 2013. The Bat House Builder's Handbook. Bat Conservation International. Austin, TX. 36 pp.
- US Fish and Wildlife Service (USFWS). 2014. White-nose Syndrome-Decontamination. Retrieved from <https://www.whitenosesyndrome.org/topics/decontamination>

Figures

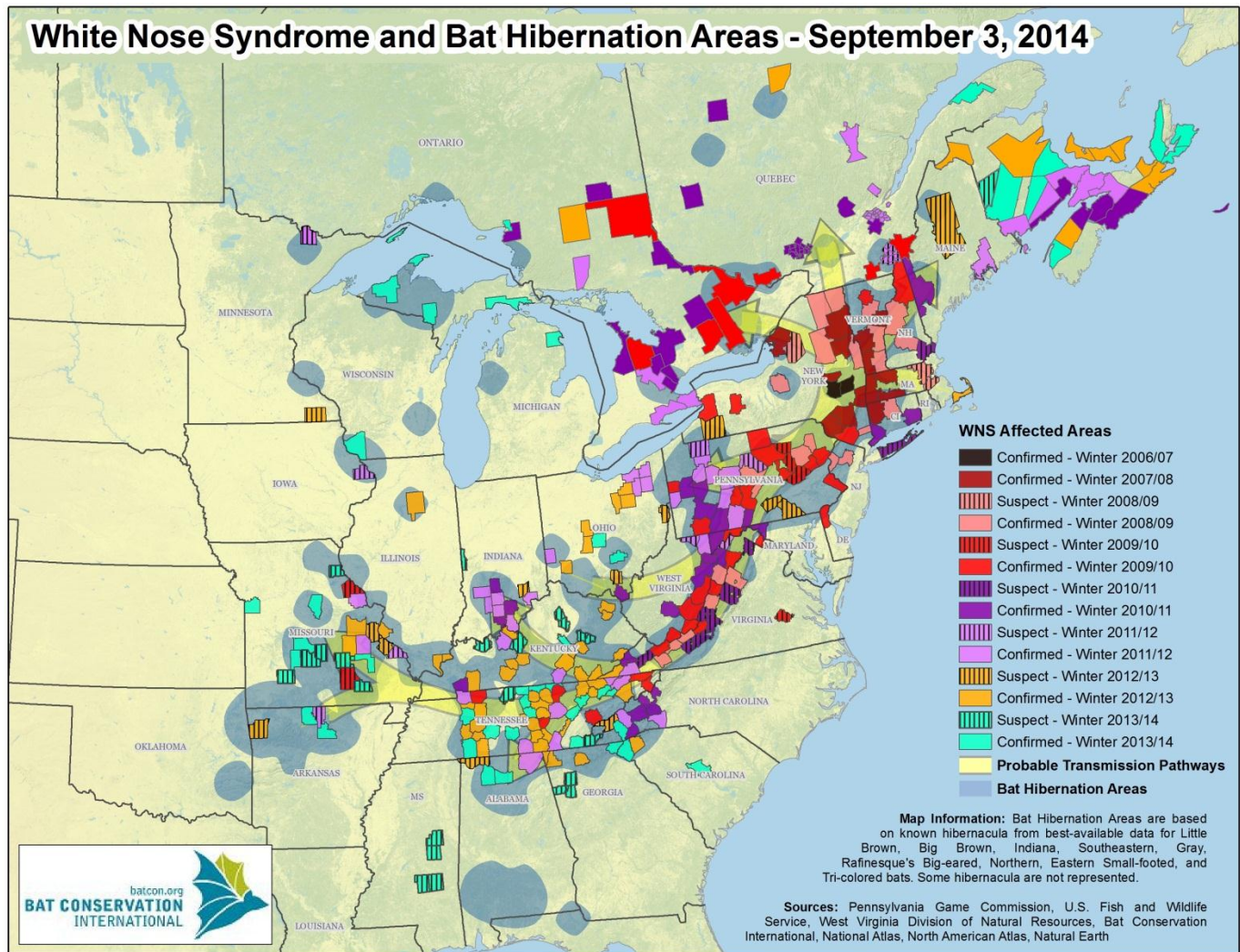


Figure 1. Known bat hibernacula and areas infected with WNS in eastern North America as of September 2014.

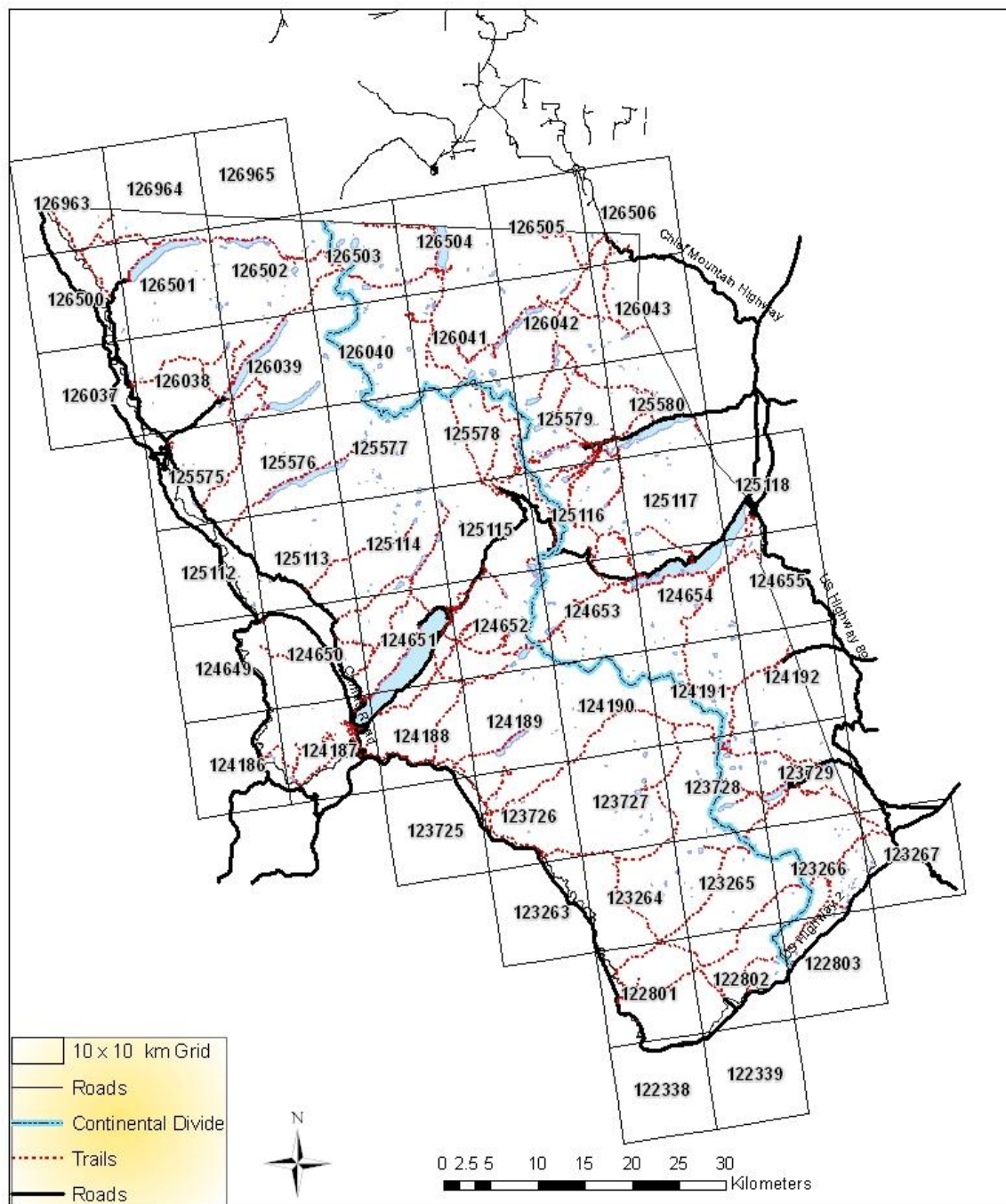


Figure 2. Glacier National Park and 10 x 10 km grid overlay showing sampling units for 2011 Bat Inventory and Monitoring Project.

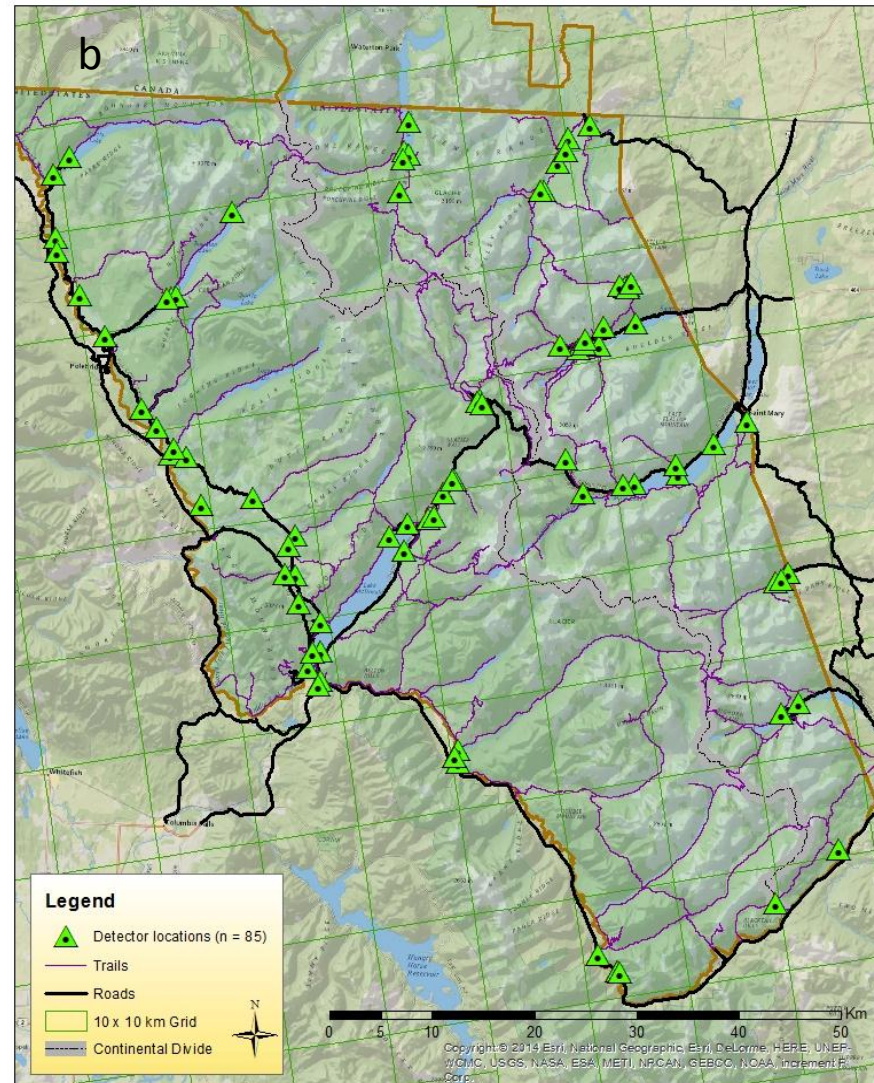
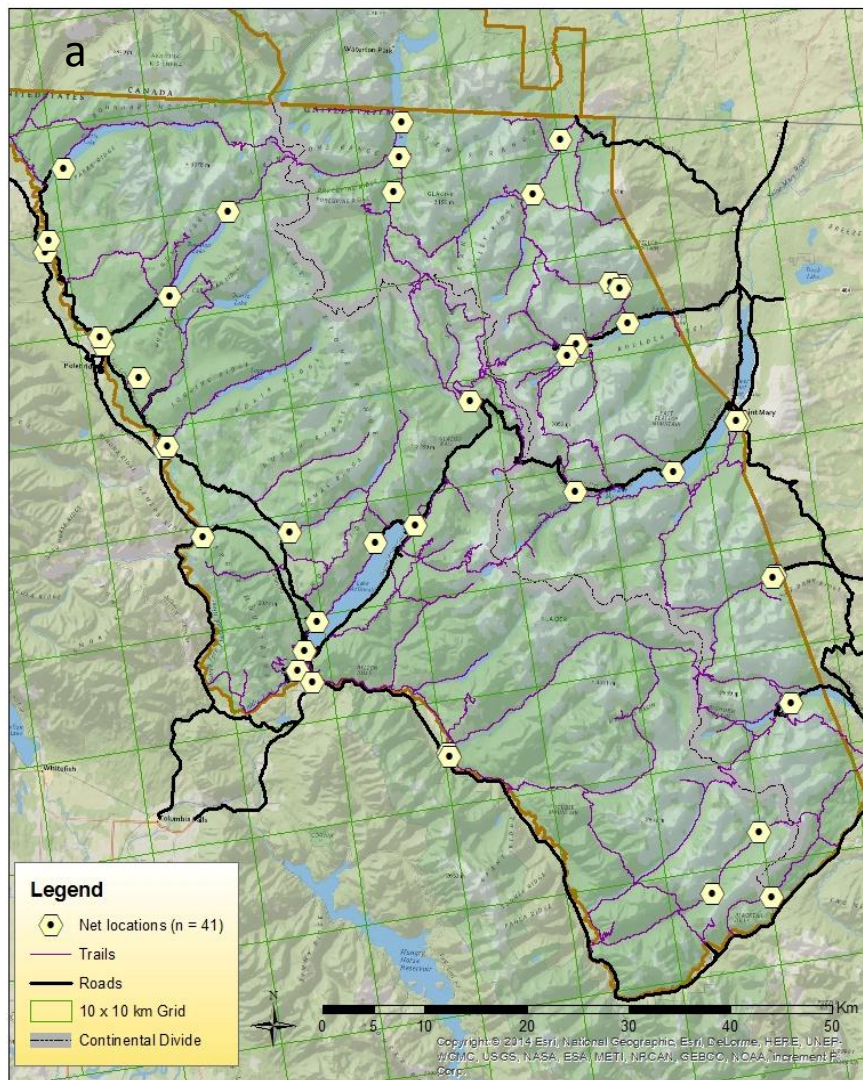


Figure 3. Locations of mist-netting (a) and acoustic detector (b) sites established throughout GNP during spring, summer, and fall months for Bat Inventory and Monitoring Project: 2011-2014.

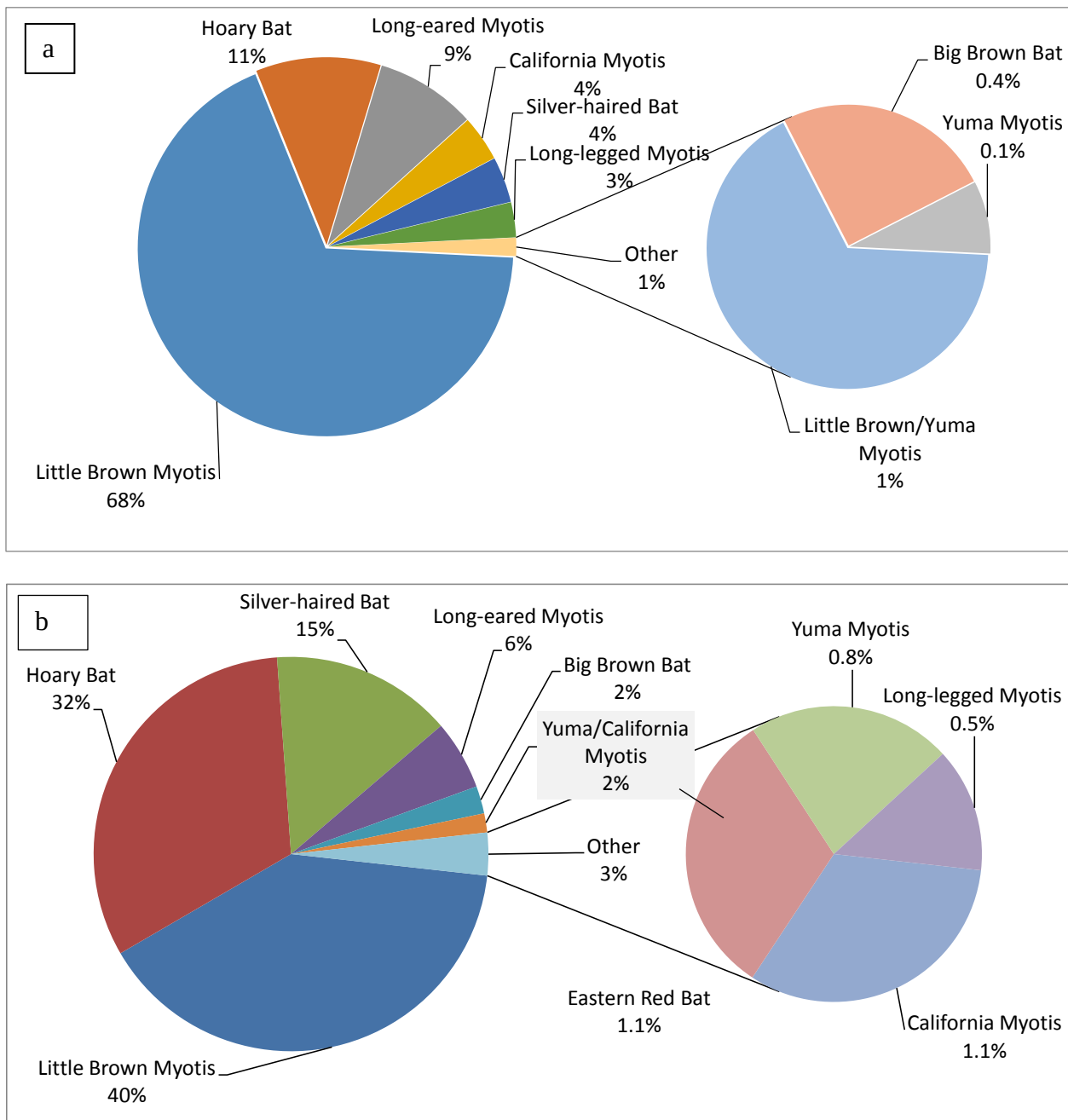


Figure 4. Percentage of each bat species captured and processed in GNP from 2011 to 2014 (a) and percentage of each bat species detected during acoustic surveys in GNP from 2011 to 2014 (b) during warm season months (May through September). Data only include calls that could be identified to species.

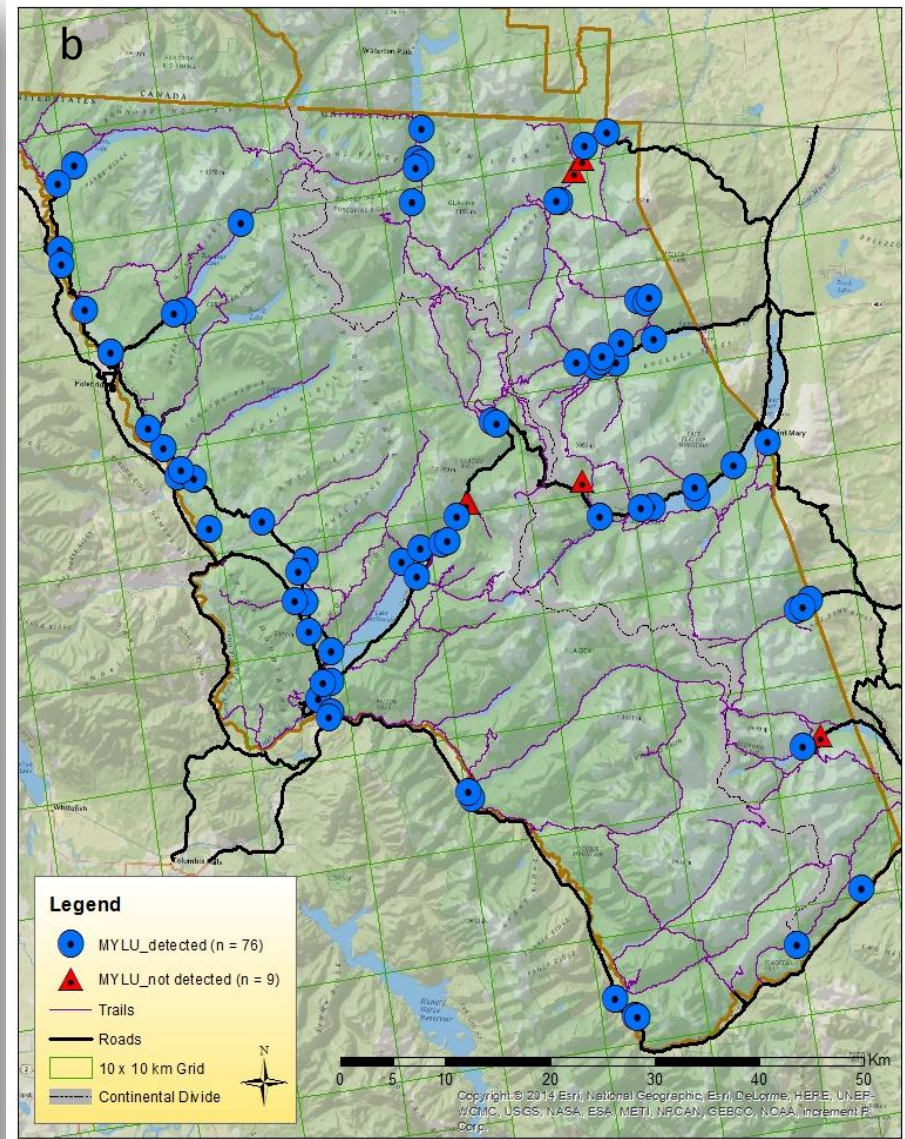
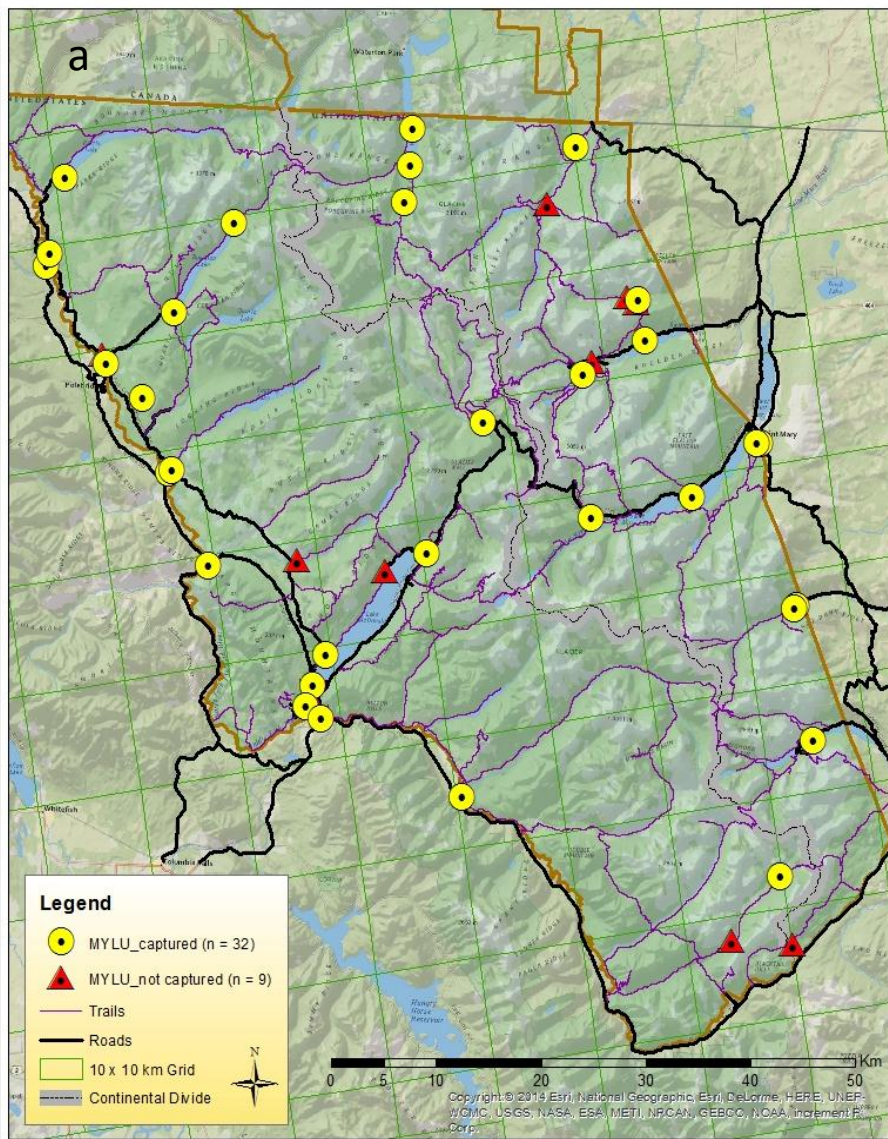


Figure 5. Locations where Little Brown Bats (MYLU) were, and were not, captured (a) or detected acoustically (b) during bat inventories in GNP from 2011-2014.

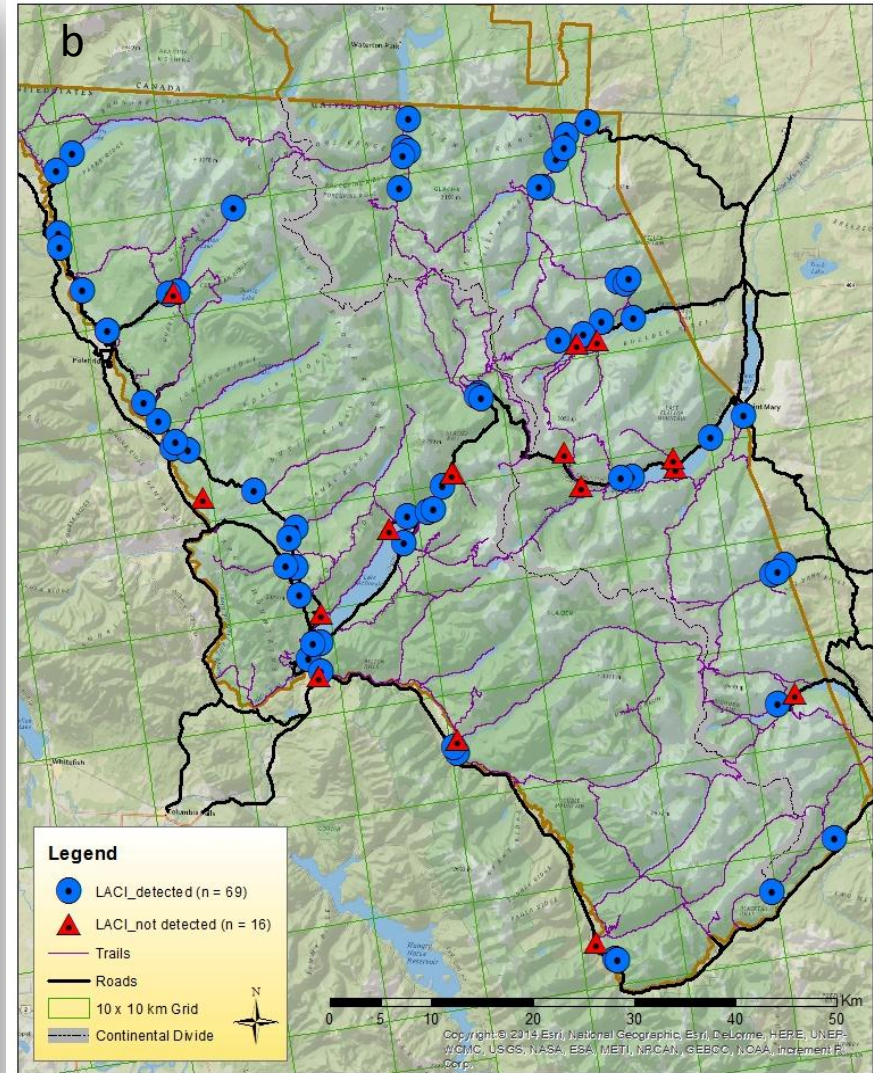
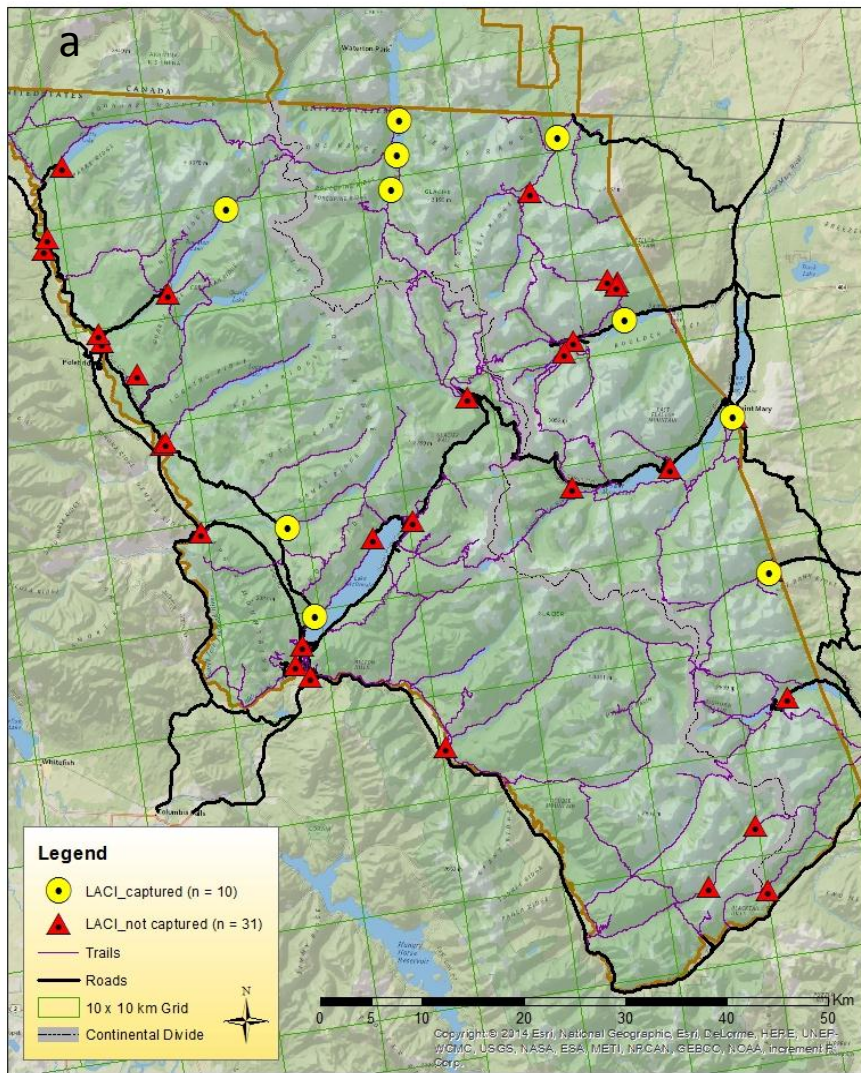


Figure 6. Locations where Hoary Bats (LACI) were, and were not, captured (a) or detected acoustically (b) during bat inventories in GNP from 2011-2014.

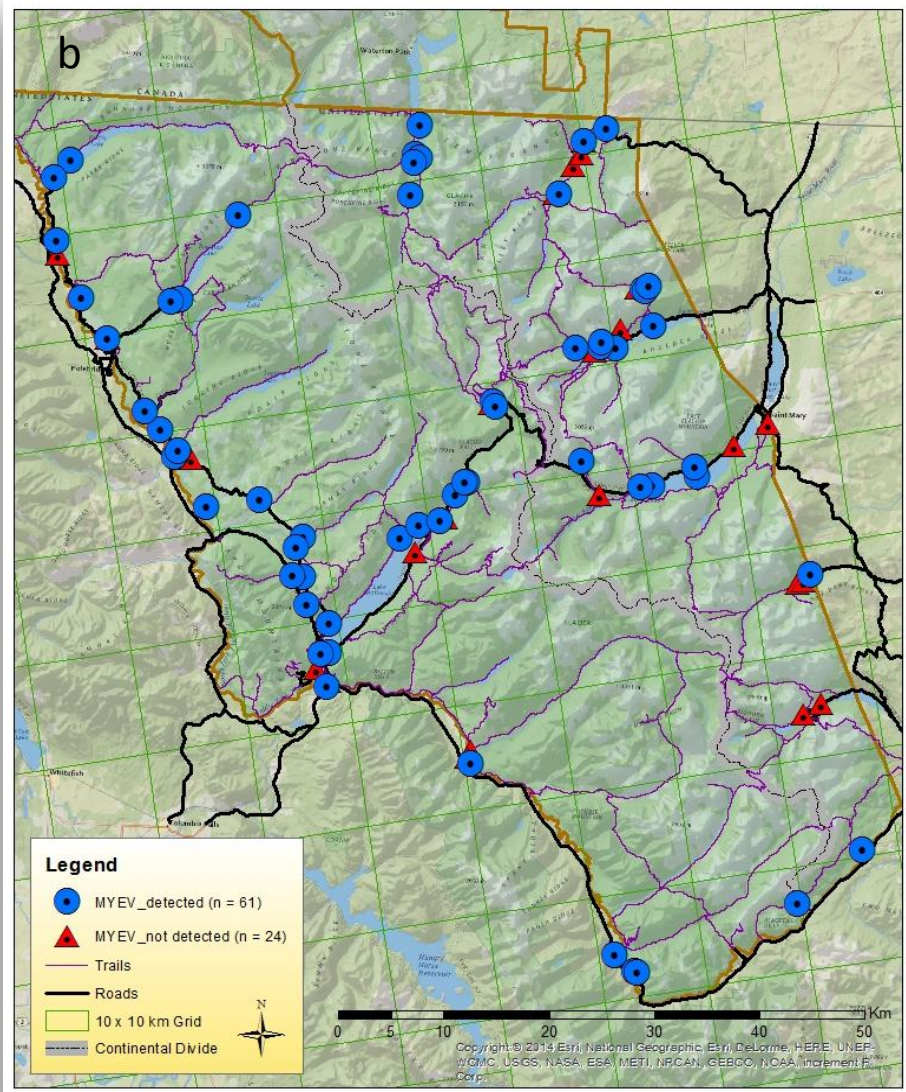
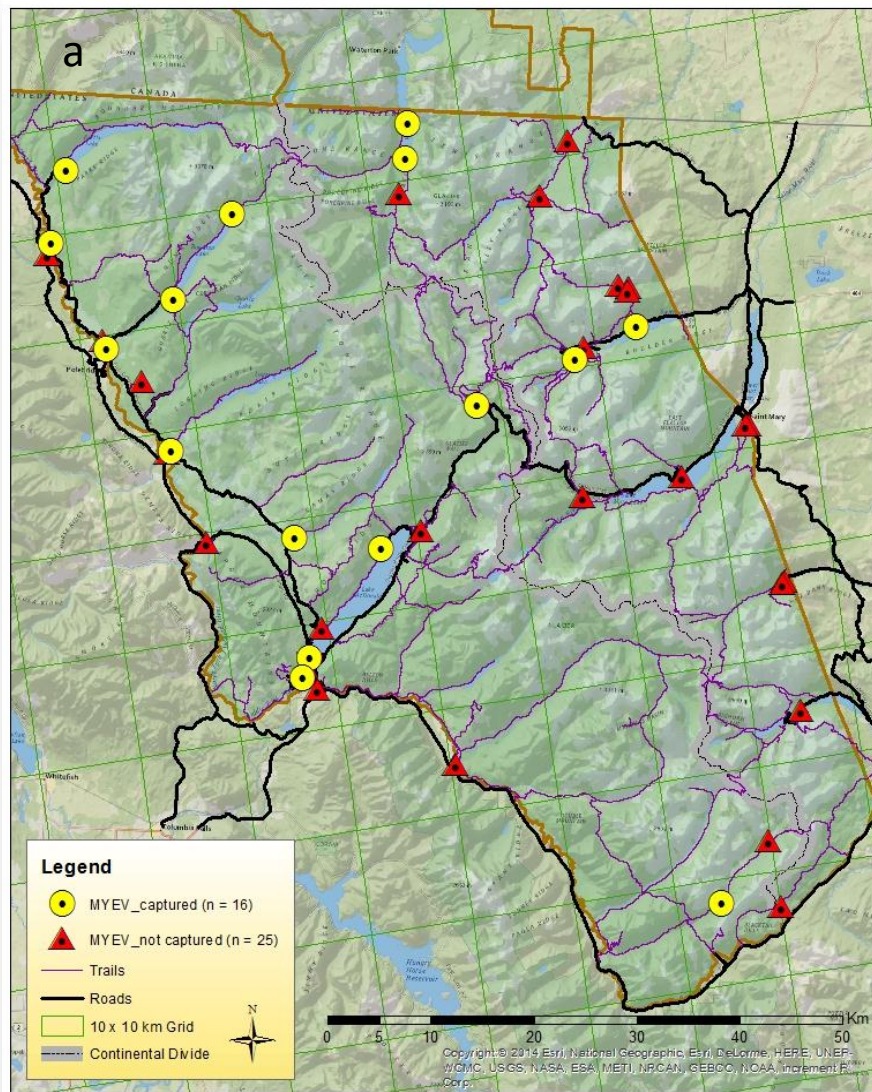


Figure 7. Locations where Long-eared Myotis (MYEV) were, and were not, captured (a) or detected acoustically (b) during bat inventories in GNP from 2011-2014.

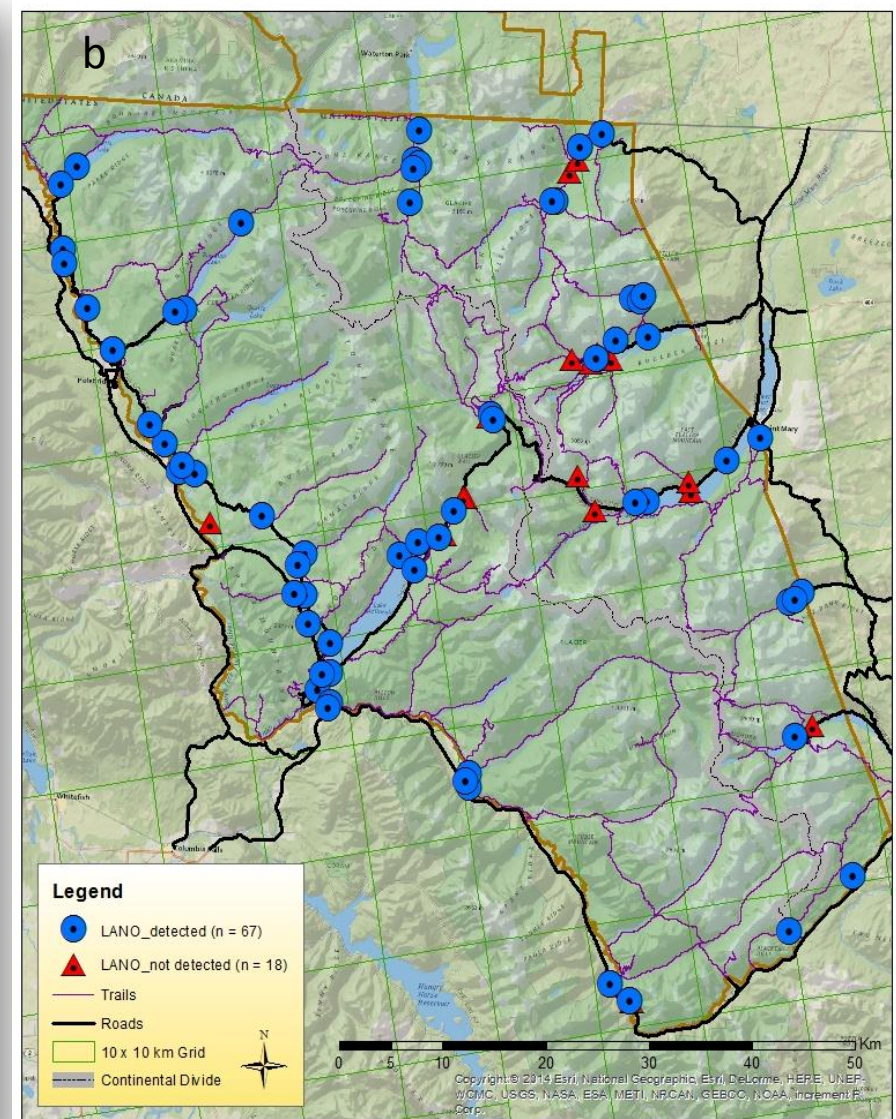
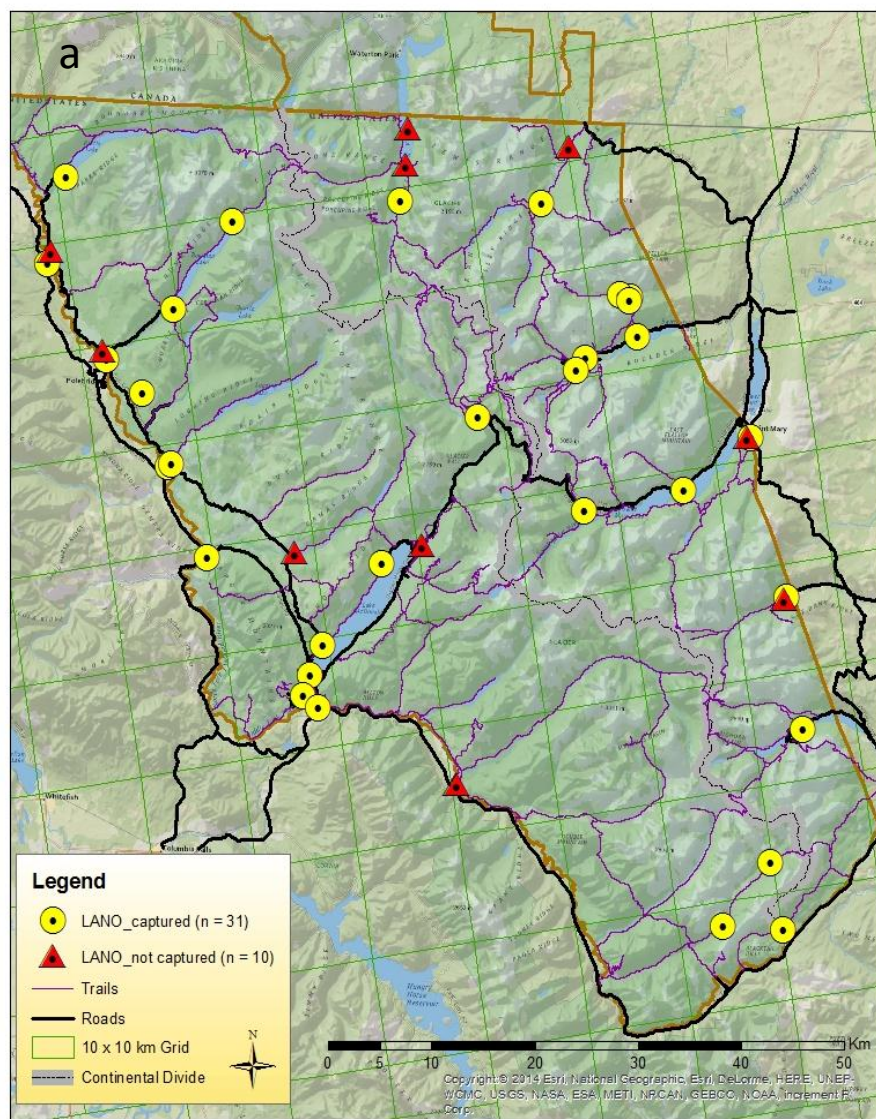


Figure 8. Locations where Silver-haired Bats (LANO) were, and were not, captured (a) or detected acoustically (b) during bat inventories in GNP from 2011-2014.

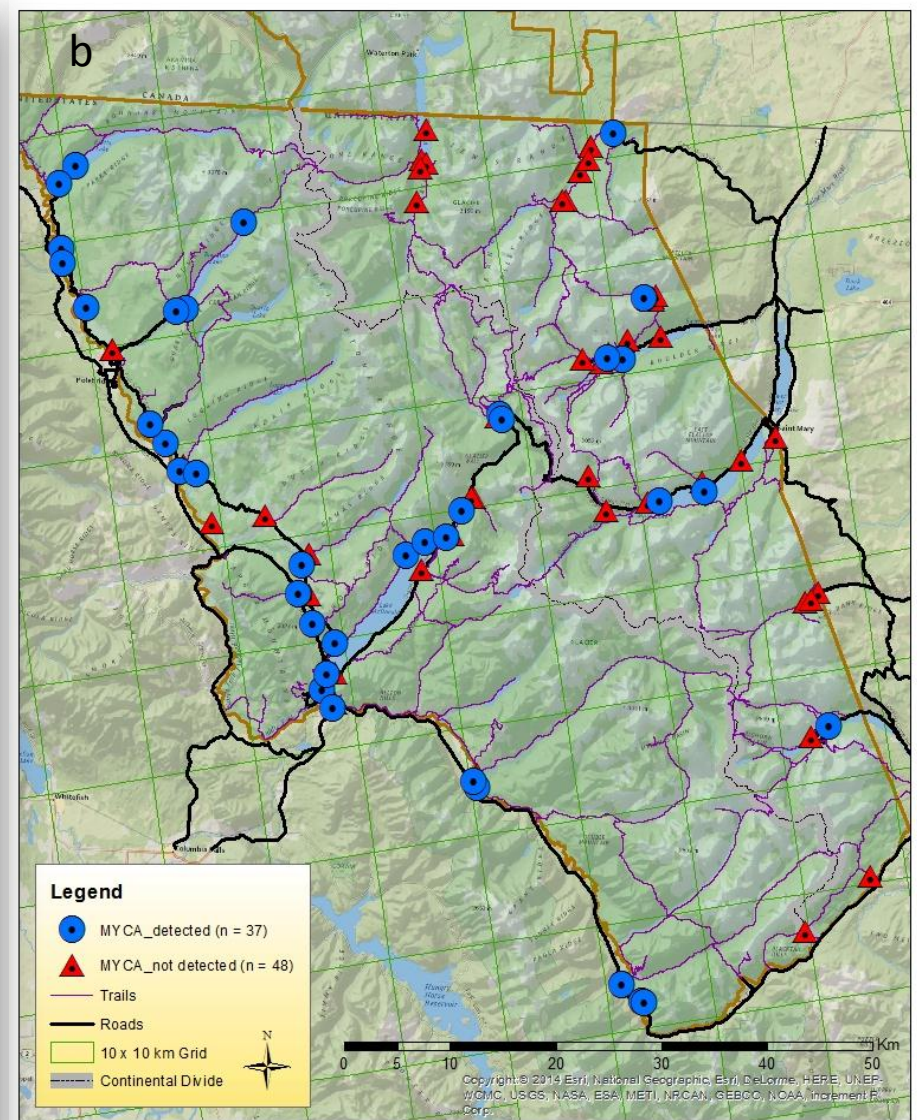
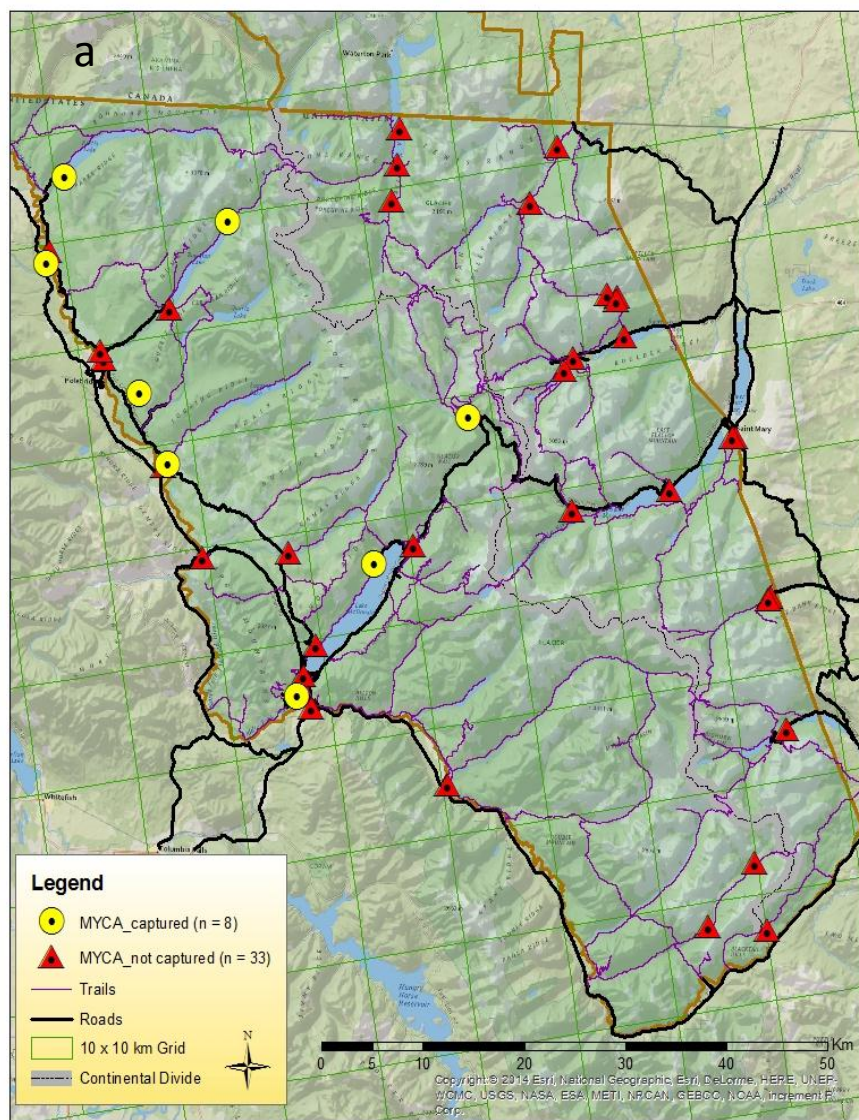


Figure 9. Locations where California Myotis (MYCA) were, and were not, captured (a) or detected acoustically (b) during bat inventories in GNP from 2011-2014.

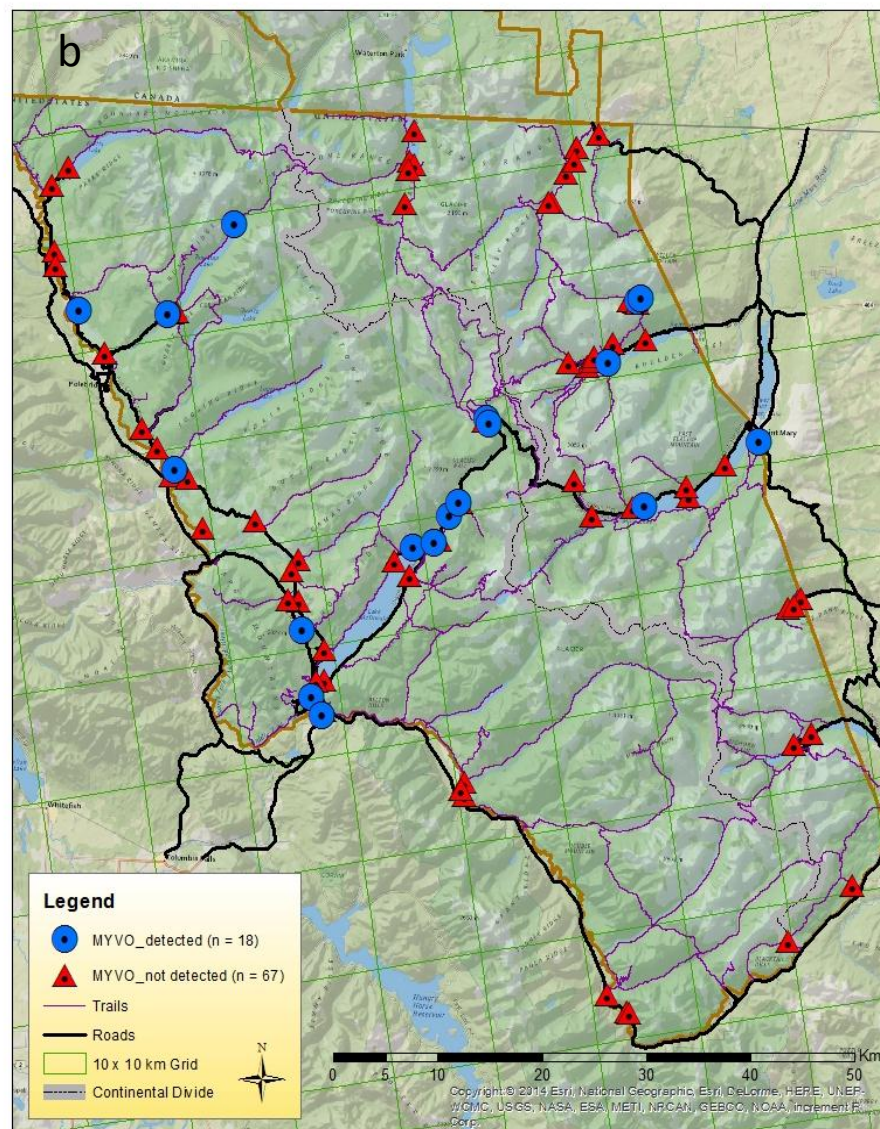
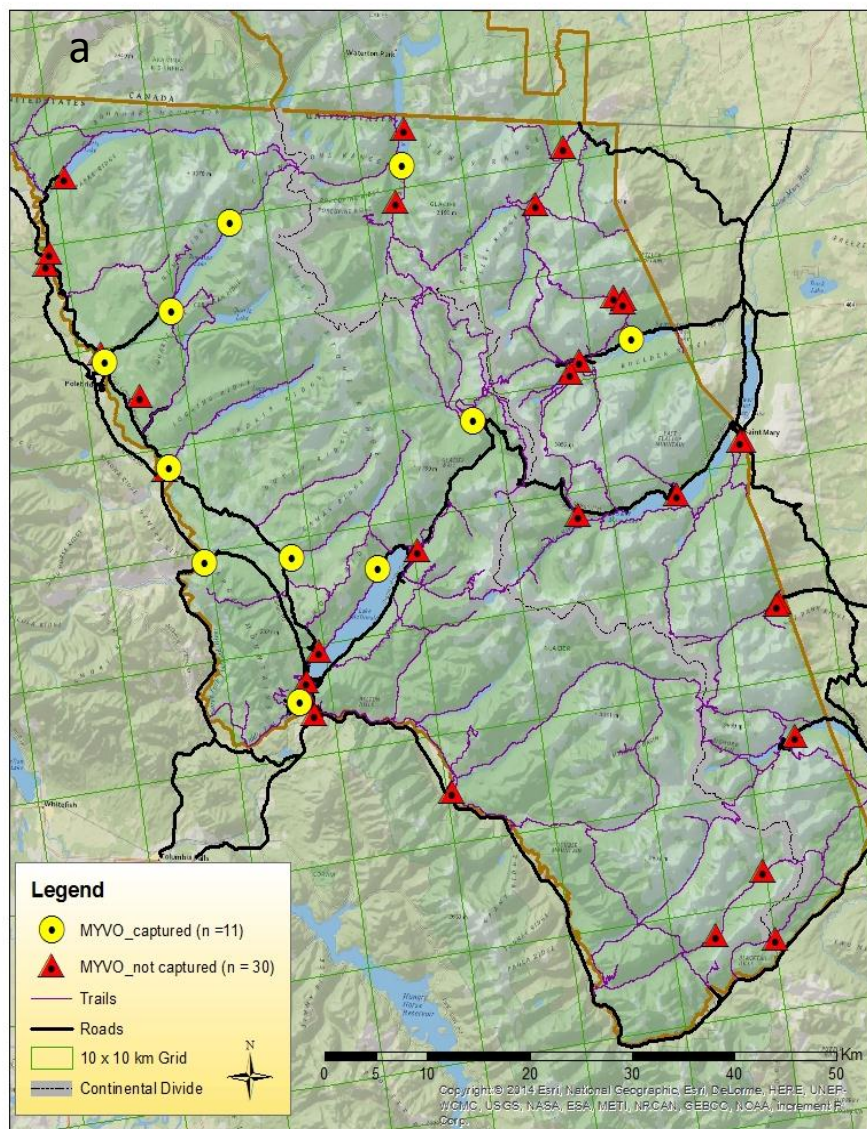


Figure 10. Locations where Long-legged Myotis (MYVO) were, and were not, captured (a) or detected acoustically (b) during bat inventories in GNP from 2011-2014.

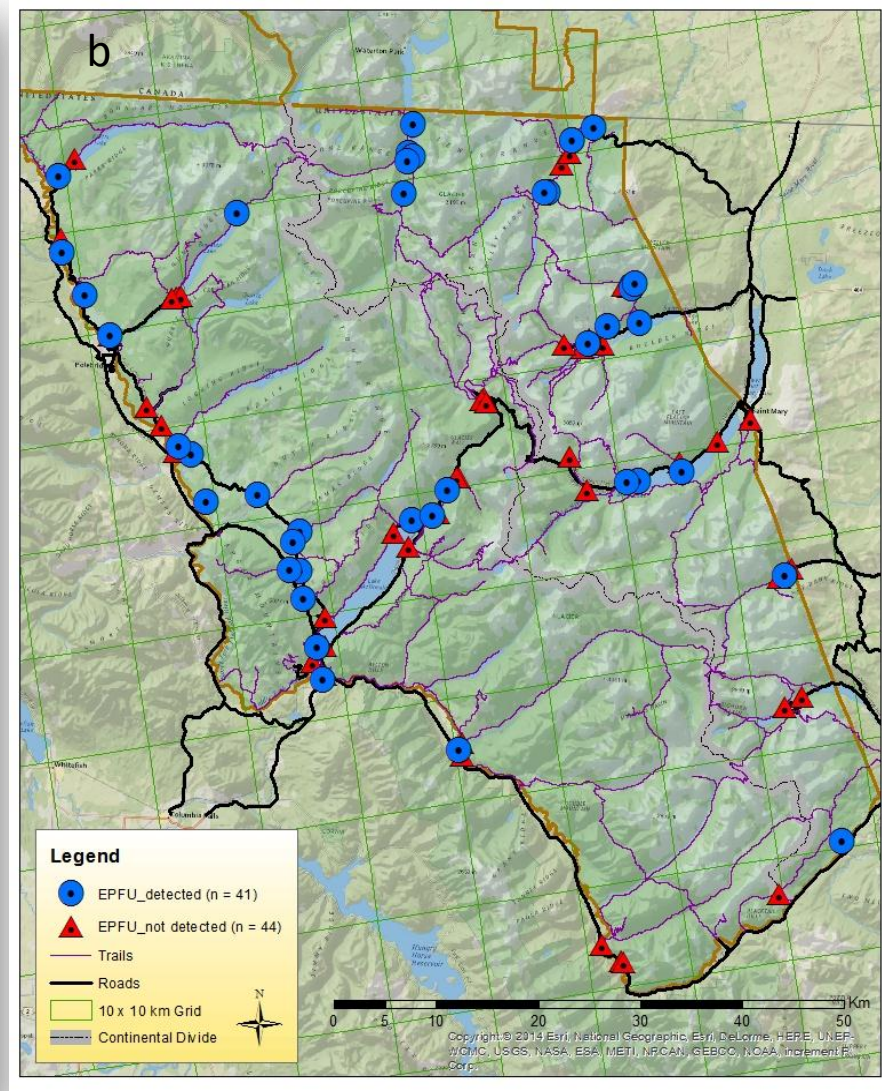
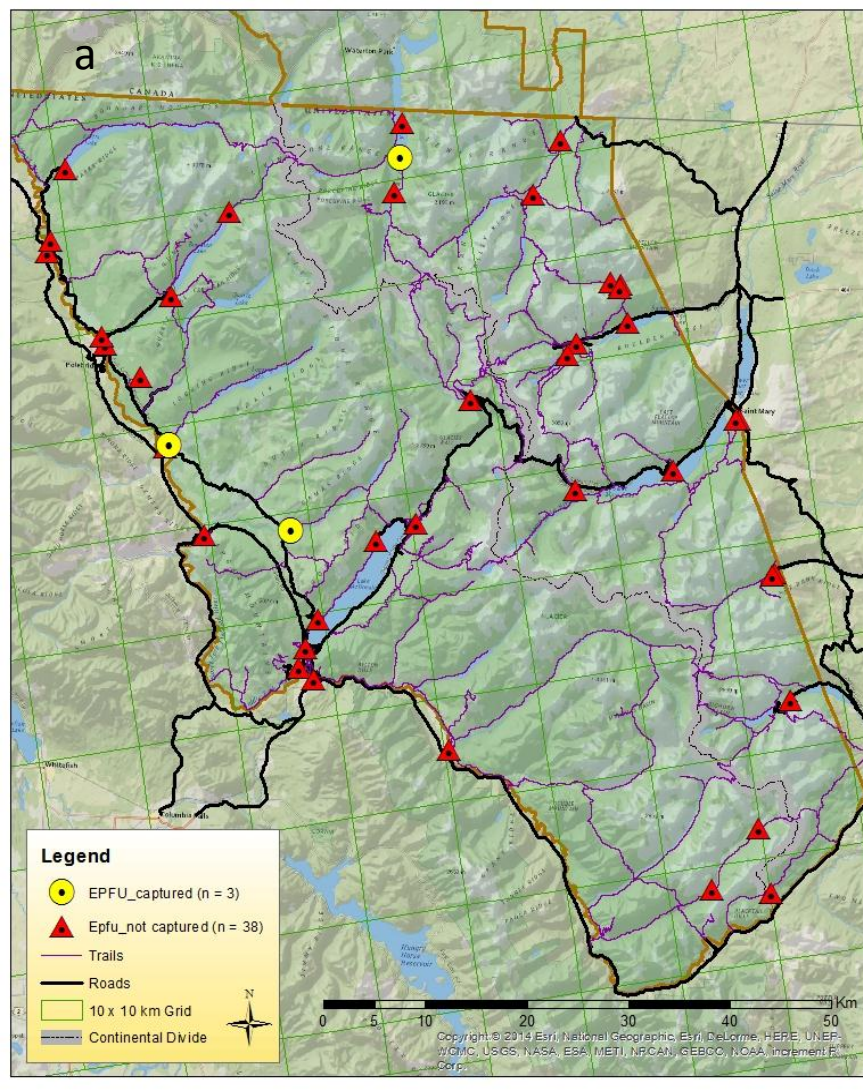


Figure 11. Locations where Big Brown Bats (EPFU) were, and were not, captured (a) or detected acoustically (b) during bat inventories in GNP from 2011 through 2014.

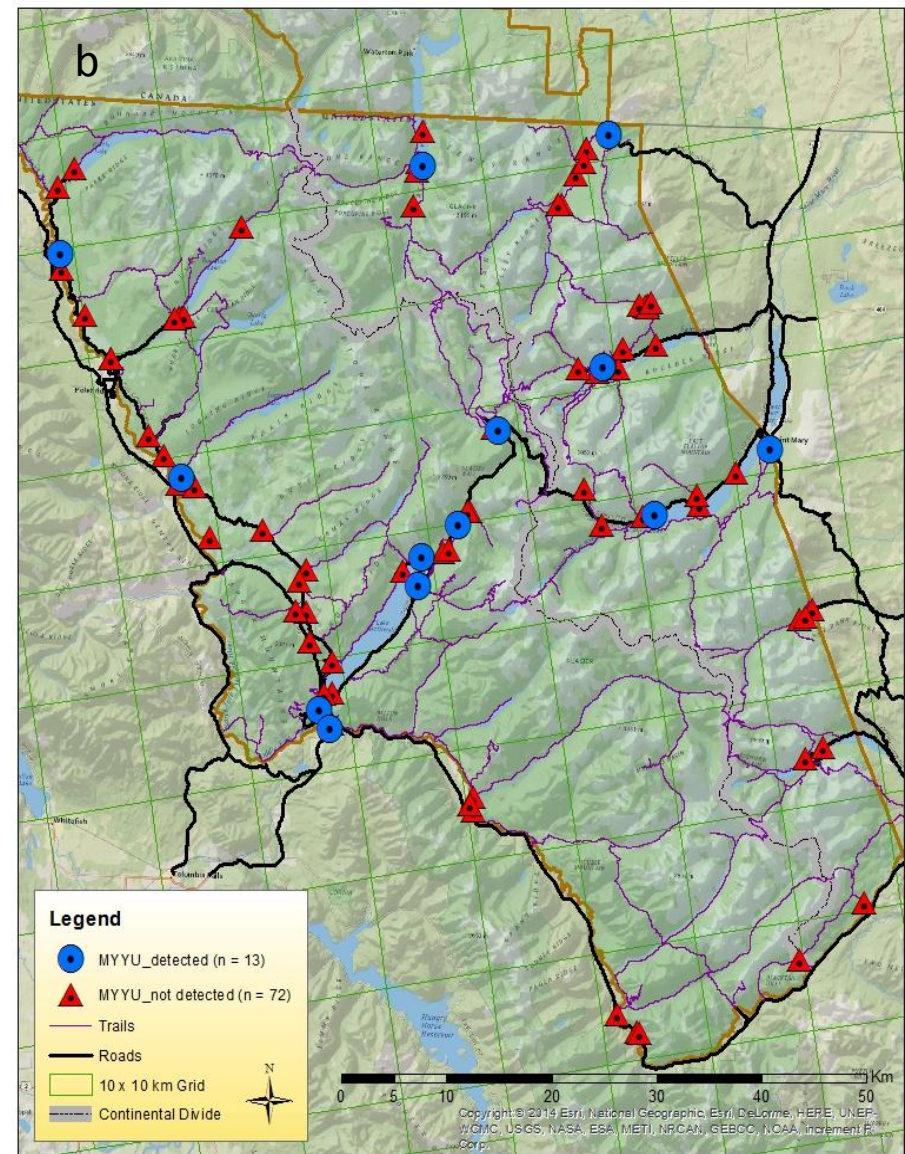
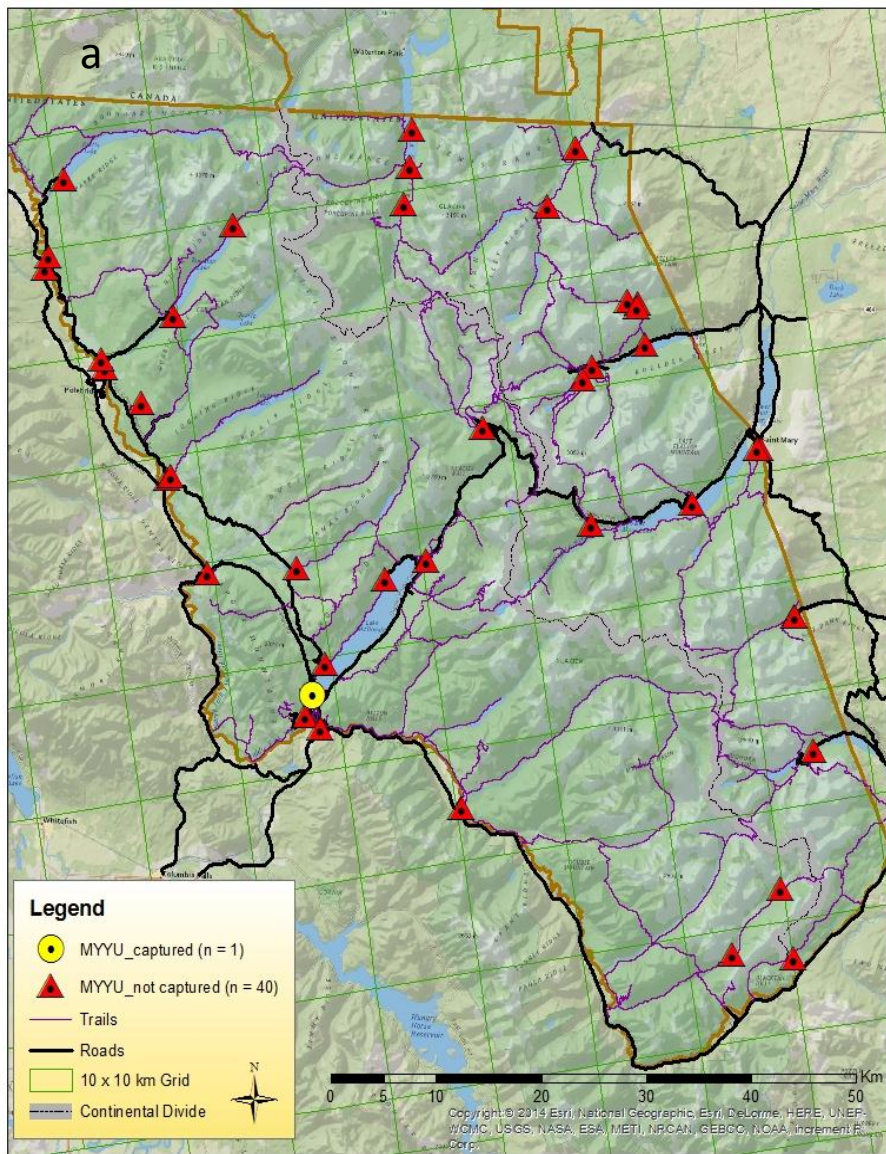


Figure 12. Locations where Yuma Myotis (MYYU) were, and were not, captured (a) or detected acoustically (b) during bat inventories in GNP from 2011-2014.

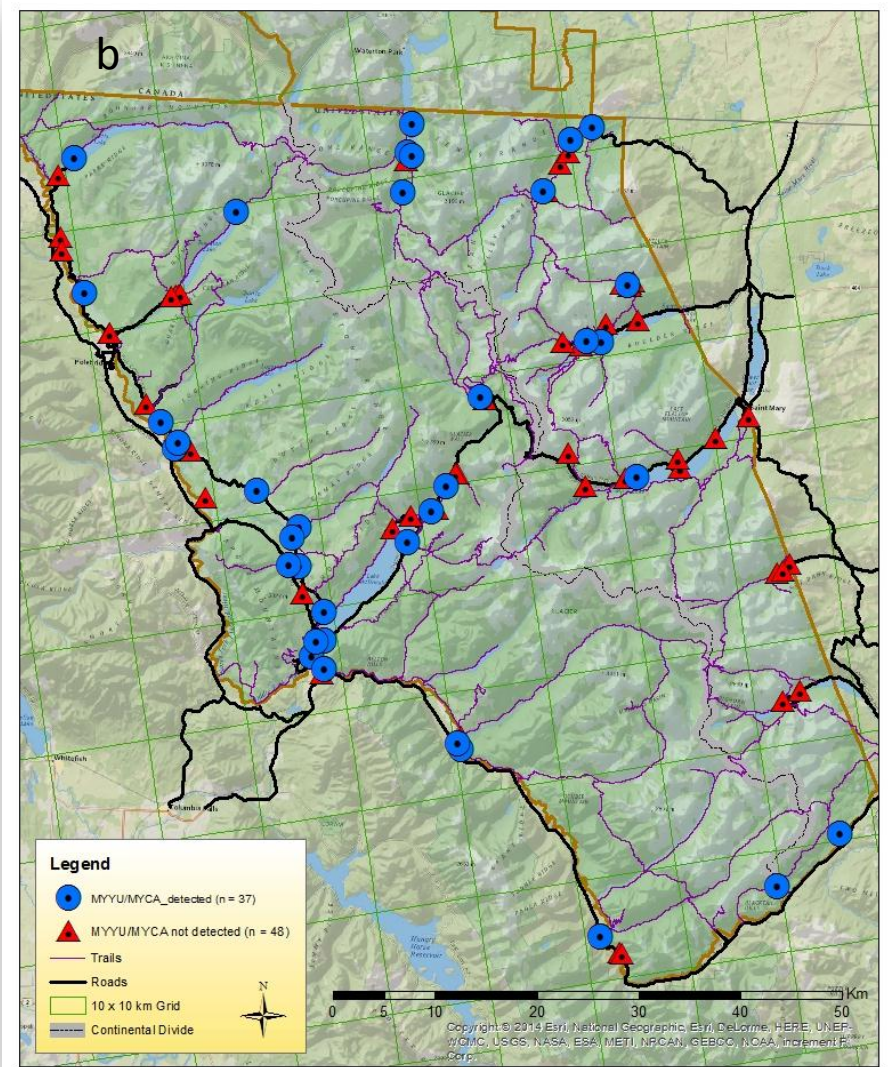
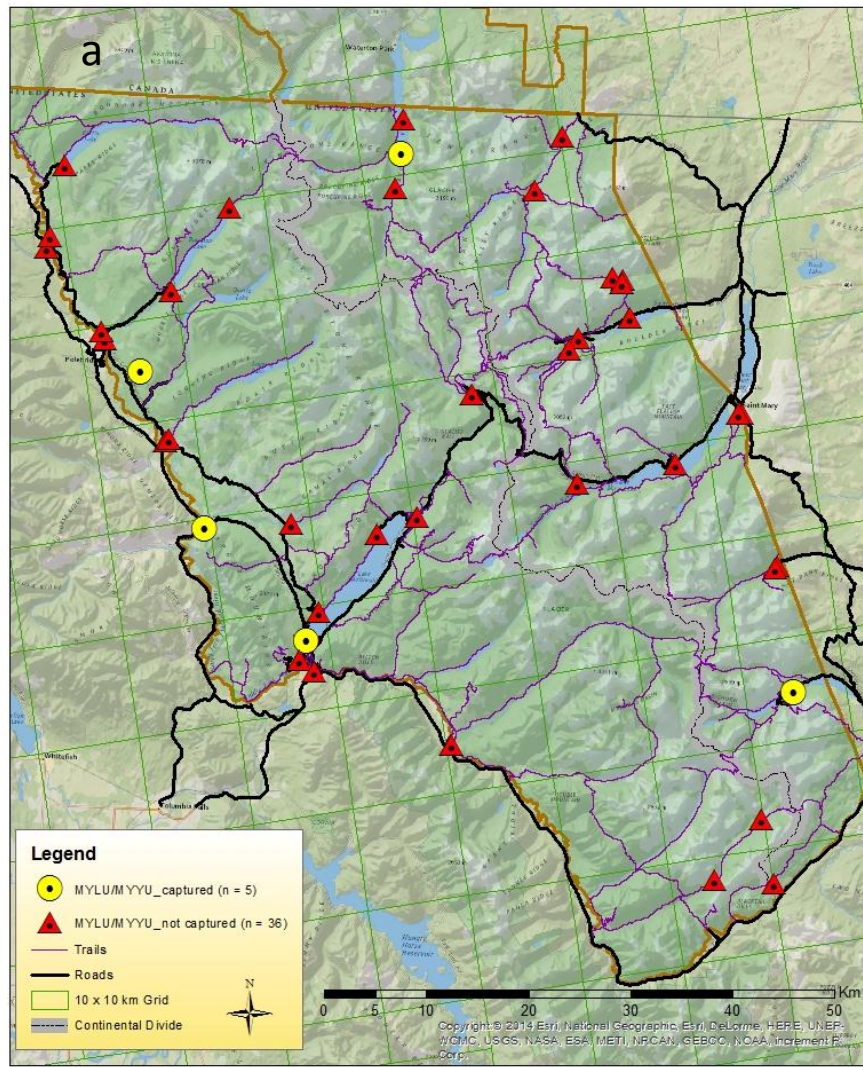


Figure 13. Locations where bats identified as either Little Brown or Yuma Myotis were, and were not, captured (a) and where bats identified acoustically as either California or Yuma Myotis were, or were not, detected (b) during bat inventories in GNP from 2011-2014.

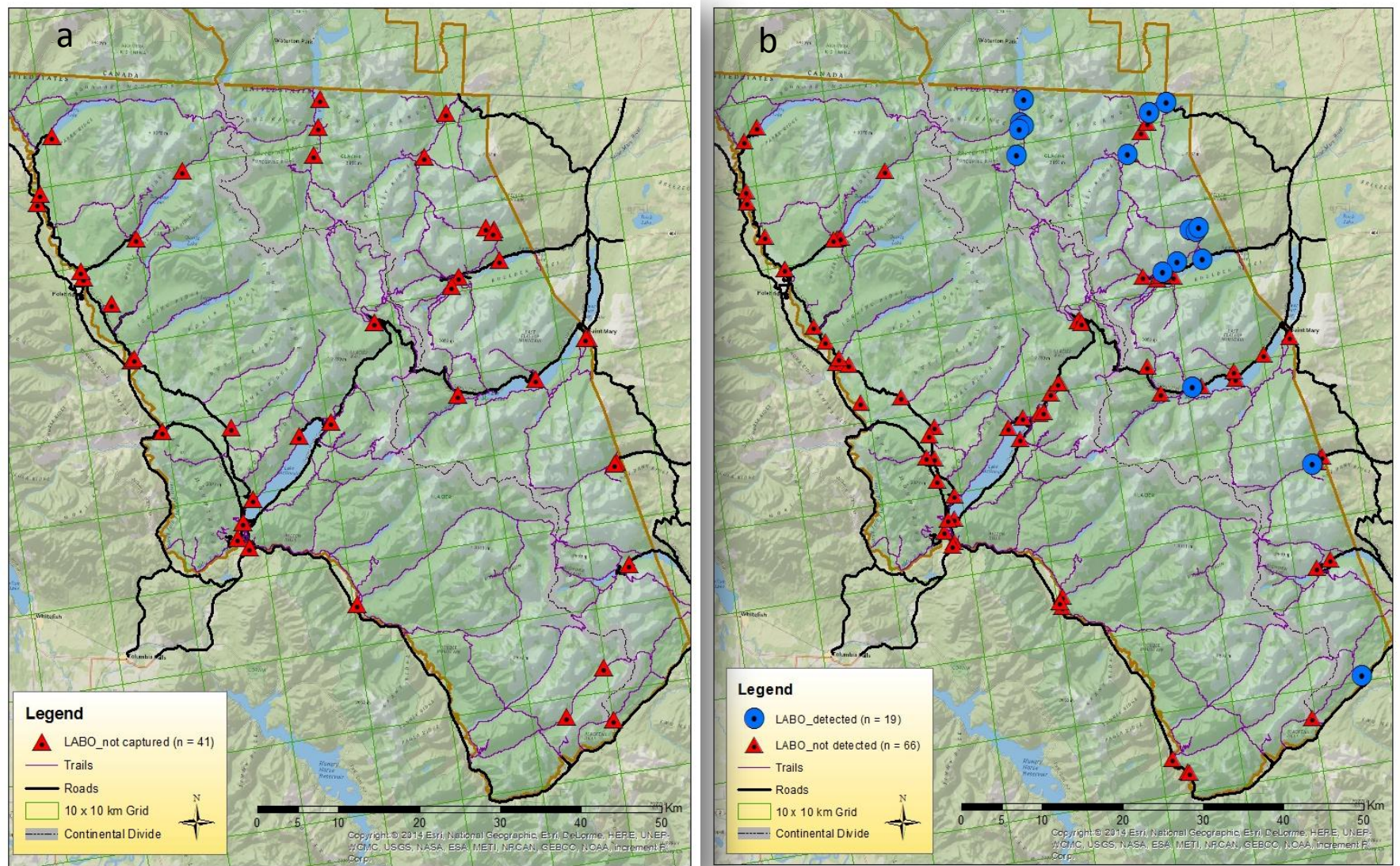


Figure 14. Locations where Eastern Red Bats (LABO) were, and were not, captured (a) or detected acoustically (b) during bat inventories in GNP from 2011 through 2014.

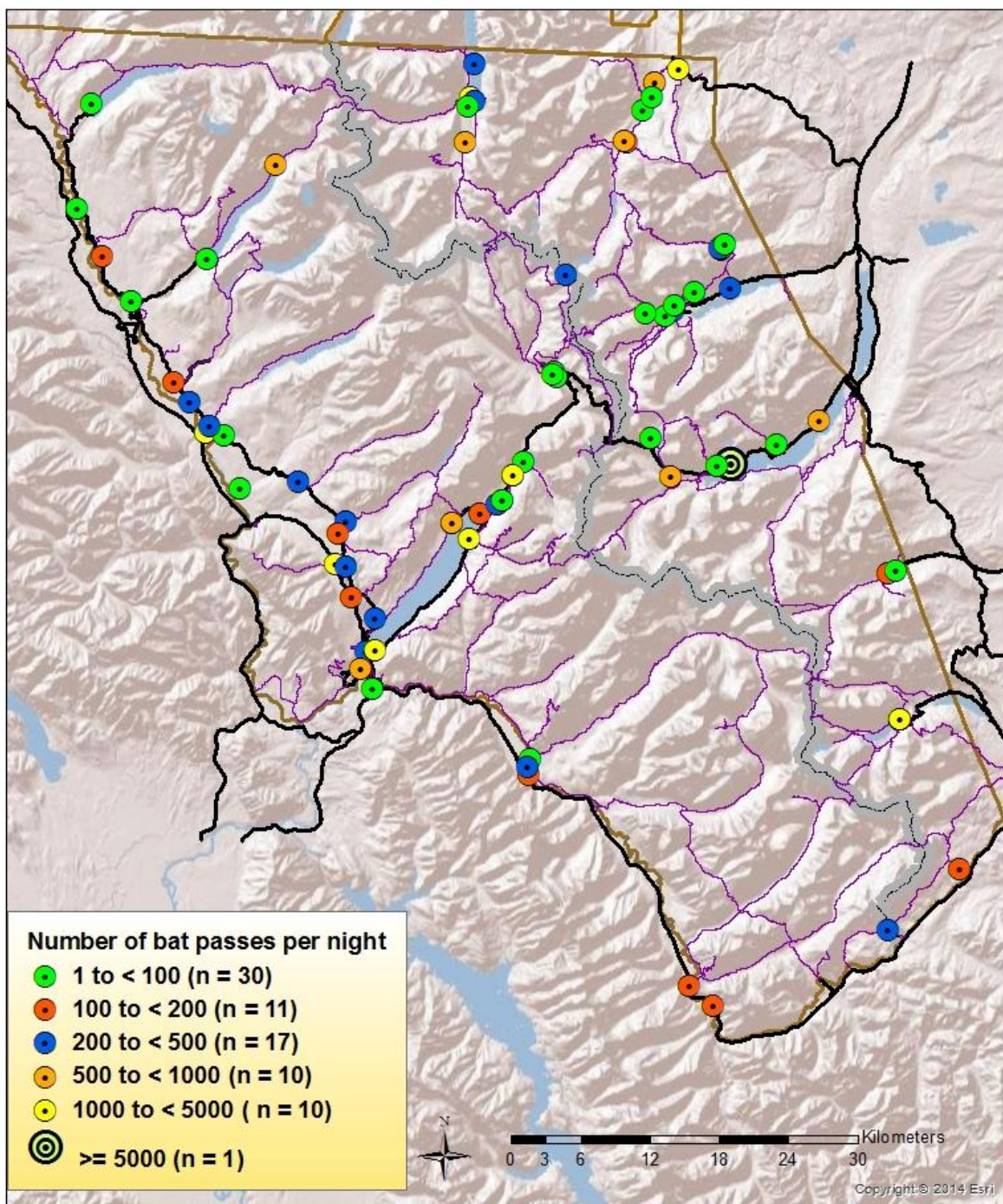


Figure 15. Average number of bat passes per night at each of 85 acoustic monitoring sites established in GNP during warm season months (May through September). All data collected in GNP, 2011-2014.

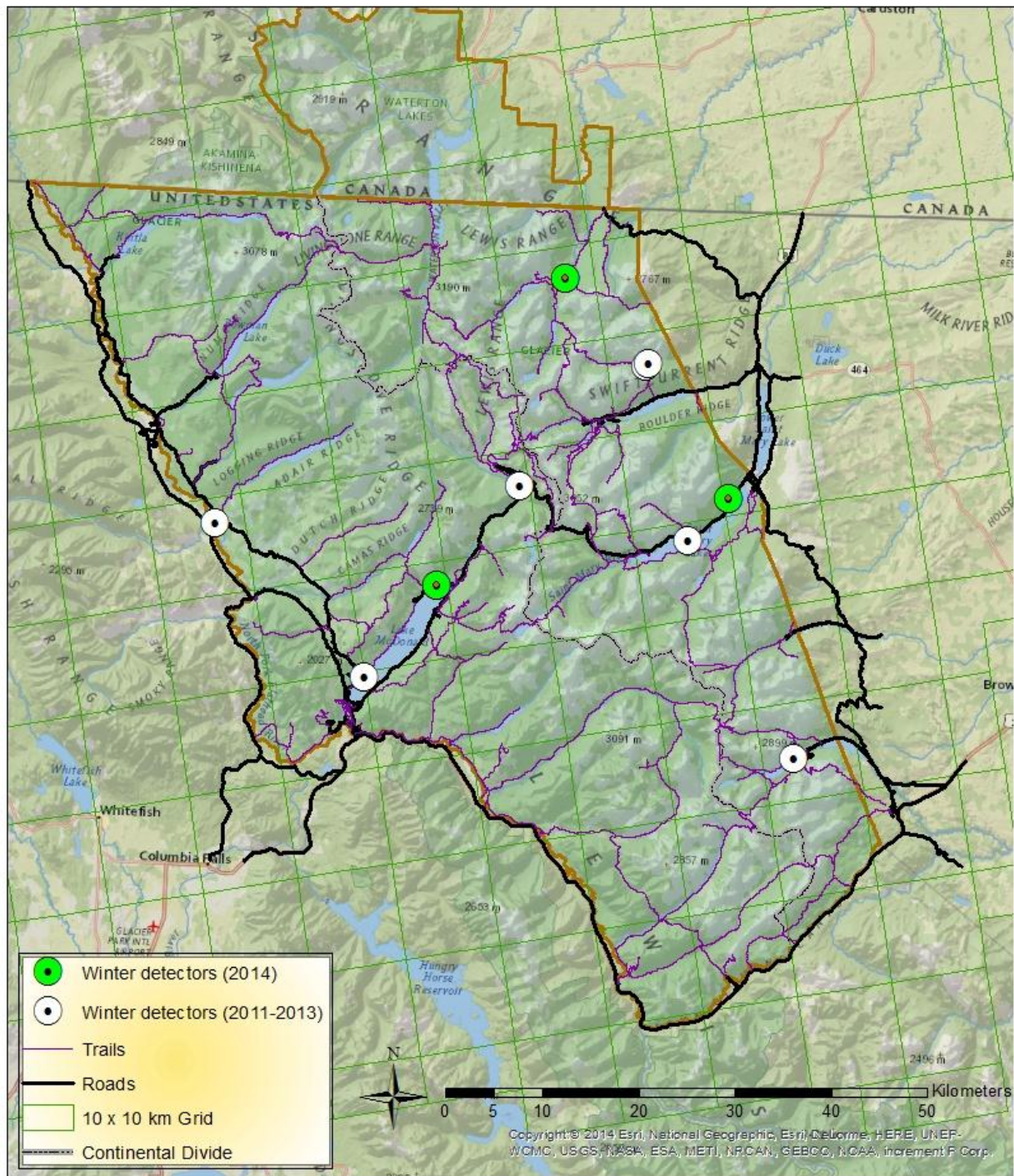


Figure 16. Locations of acoustic detectors deployed throughout GNP during winter months for Bat Inventory and Monitoring Project: 2011-2014

Tables

Table 1. Mist-netting site name, site description, date, zone, easting (UTM_e) and northing (UTM_n) coordinates, along with number of nets established at each site, number of bats and species processed at each site. Mean number of bats captured per night given at bottom.

Net Site	Type of Site	Date	Zone	UTM_e	UTM_n	Number of nets	Number of bats caught	Number of species caught
Lower McDonald Creek	Trail and bridge	7/9/2011	12	278779	5379041	8	19	4
John's Lake	Cedar-hemlock forest by small lakes	7/10/2011	12	289603	5391158	5	13	2
Packer's Roost	Trail through mixed-conifer forest	7/11/2011	12	295015	5403122	8	27	4
McDonald Lake Trail	Trail adjacent to burned/unburned forest	7/12/2011	12	285735	5389516	5	6	3
Kintla Lake Campground	Lakeshore	7/13/2011	11	694480	5423619	7	14	3
Round Prairie	River shore	7/14/2011	11	693297	5415415	8	6	2
Logging Ranger Station	Creek trail	7/15/2011	11	706443	5397458	9	1	1
Bowman Lake Campground	Trail set near lakeshore	7/17/2011	11	705843	5412139	10	40	3
Camas Bridge	Bridge	7/18/2011	11	710907	5389268	4	23	3
Nyack	Backwater off of Middle Fork of Flathead	7/20/2011	12	293033	5368785	6	8	1
Two Medicine	Riparian	7/21/2011	12	326582	5374015	8	24	2
Cut Bank	Beaver ponds	7/22/2011	12	324973	5386317	6	1	1
Rising Sun	Lakeshore in deciduous forest	7/23/2011	12	314966	5396317	8	10	1
Reynold's Creek	Trail	7/24/2011	12	305301	5394389	5	2	1
Poia Cave Entrance	Cave	7/26/2011	12	308781	5414564	1	0	0
Poia Lake Trail	Trail and pond	7/27/2011	12	309700	5414026	5	0	0

Net Site	Type of Site	Date	Zone	UTM_e	UTM_n	Number of nets	Number of bats caught	Number of species caught
Many Glacier Horse Trail	Horse trail and meadow	7/28/2011	12	305485	5408667	9	0	0
Many Glacier/Swift Current	Trail, near lake	7/29/2011	12	304555	5407579	10	39	2
St. Mary	Building complex/riparian and meadow	7/30/2011	12	321200	5401282	5	23	3
Fish Creek Boat House	Building at edge of water	7/11/2012	12	280023	5381872	4	40	2
Christensen Meadow	"Island" of trees in meadow	7/12/2012	11	719368	5390306	5	8	5
Sullivan Meadow	Road by creek/mixed-conifer	7/13/2012	11	706727	5397657	5	19	5
Three Bears	Meadow	7/14/2012	12	324573	5355245	4	0	0
Packer's Roost	Mixed conifer trail	7/15/2012	12	295015	5403122	9	6	2
Upper Bowman	Trail paralleling lake and along lake.	7/16/2012	11	710953	5420733	6	25	5
Akokala Creek	Slow creek	7/17/2012	11	699280	5407630	1	1	1
Polebridge Area	Bridge	7/17/2012	11	699709	5406909	3	32	3
Belly River-Two mile-2012	Trail/meadow by river	8/13/2012	12	303918	5428436	8	43	3
Belly River RS-Elizabeth Trail	Aspen trail	8/14/2012	12	301214	5423081	3	0	0
St Mary's Dorms	Roost	8/15/2012	12	321500	5401265	3	42	1
Nyack	Edge of Middle Fork of Flathead River	8/16/2012	12	292850	5369199	3	5	2
Cutbank	Near creek and in meadows	8/17/2012	12	324730	5386077	3	20	3
Many Glacier Gate	Deciduous by lake	8/18/2012	12	310462	5410716	6	26	4
Goat Haunt	Lakeshore/river	8/20/2012	12	288039	5426737	5	52	6
Waterton Lake - Street Creek	Lakeshore	8/21/2012	12	288264	5430106	3	36	4
West Glacier Bridge	Bridge	8/3/2013	12	279475	5375978	4	9	1
Quarter Circle Bridge	Near river and creek	8/4/2013	12	278041	5377148	4	14	4
Kennedy Creek	Near river and beaver ponds	8/6/2013	12	309854	5414370	3	5	1

Net Site	Type of Site	Date	Zone	UTM_e	UTM_n	Number of nets	Number of bats caught	Number of species caught
Belly River-Two mile-2013	Trail/meadow by river	8/7/2013	12	303918	5428436	5	3	1
Goat Haunt	Lakeshore/river	8/9/2013	12	288039	5426737	6	17	1
Kootenai Lakes	Lakeshore/river	8/10/2013	12	287490	5423394	6	19	2
Many Glacier Gate_2013	Deciduous by lake	8/22/2013	12	310462	5410716	8	1	1
Hidden Meadows	Lakeshore	8/23/2013	12	262458	5405419	4	21	3
Hidden Meadows	Lakeshore/meadow	7/15/2014	12	262458	5405419	5	3	1
Ford Creek	Riparian	7/16/2014	12	253647	5418674	5	15	3
Ole Creek	Old growth mixed-conifer/ small stream	7/30/2014	12	318845	5355627	5	8	1
Ole Lake	Lakeshore near mixed conifer forest	7/31/2014	12	323444	5361576	5	29	1
Belly River-Two mile-2014	Trail/meadow by river	8/12/2014	12	303918	5428436	5	1	1
Goat Haunt	Lakeshore	8/13/2014	12	288039	5426737	4	8	2
Mean number of bats caught per trap night							15.6	

Table 2. Scientific name, common name, four-letter species code of bats captured during mist-netting surveys in GNP from 2011 through 2014. Count presents the number of that species processed.

Four-letter species code*	Adult	% Adult	Juvenile	% Juvenile
EPFU	3	100	0	0
LACI	35	44	45	56
LANO	23	79	6	21
MYCA	28	97	1	3
MYEV	61	94	4	6
MYLU	448	86	71	14
MYLU/MYYU	7	88	1	13
MYVO	18	82	4	18
MYYU	1	100	0	0
All bats	624	83	132	17

* See Table 3 for species code definitions.

Table 3. Number and percentage of all bats captured that were adults or juveniles.

Scientific name	Common name	Four-letter species code	Count
<i>Eptesicus fuscus</i>	Big Brown Bat	EPFU	3
<i>Lasionycteris noctivagans</i>	Silver-haired Bat	LANO	30
<i>Lasiurus cinereus</i>	Hoary Bat	LACI	82
<i>Myotis californica</i>	California Myotis	MYCA	30
<i>Myotis evotis</i>	Long-eared Myotis	MYEV	66
<i>Myotis lucifugus</i>	Little Brown Myotis	MYLU	519
<i>Myotis lucifugus/yumanensis</i>	Little Brown or Yuma Myotis	MYLU/MYYU	8
<i>Myotis Volans</i>	Long-legged Myotis	MYVO	23
<i>Myotis yumanensis</i>	Yuma Myotis	MYYU	1
Unknown*		UNKN	2
Grand Total			764

* Two bats escaped before identified to species.

Table 4. Number of female bats captured compared to total number of each species captured, percentage of bats that were female (% Female), and the number of females in each of seven reproductive statuses*.

Four-letter species code*	Species capture total	Number of females captured	Percent Female	Nulliparous	Non-Reproductive	Not obviously pregnant	Parous	Pregnant	Lactating	Post lactating
EPFU	3	1	33					1		
LACI	81	11	14		10				1	
LANO	29	9	31		2		2	1	1	3
MYCA	30	8	27	2	1			3		2
MYEV	66	43	65	17	4	1	2	17	6	5
MYLU	519	311	60	41	61	63	14	71	28	26
MYLU/MYYU	8	2	25	1		1				
MYVO	23	15	65	5	2	4		3		1
MYYU	1	0	0							
Totals	760	400		66	80	69	18	96	36	37

* See Table 3 for four-letter code definitions.

** Nulliparous = never pregnant; Parous = has given birth in the past; Not obviously pregnant = may be pregnant but can't feel a pup.

Table 5. Number of male bats captured, compared to total number of each species captured, percentage of bats that were male (% Female), and the number of males in each of four reproductive statuses**

Four-letter species code*	Total	Number of males captured	% Male	Non-reproductive	Early scrotal	Scrotal	Very scrotal
EPFU	3	2	67		2		
LACI	81	70	86	15	50	5	
LANO	29	20	69	16	4		
MYCA	30	22	73	20	2		
MYEV	66	23	35	22			
MYLU	519	208	40	148	57	3	
MYLU/MYYU	8	6	75	4	2		
MYVO	23	8	35	8			
MYYU	1	1	100	1			
Totals	760	360	47	234	117	8	0

* See Table 2 for four-letter code definitions; ** Early scrotal = testes show a little enlargement, Scrotal = testes are moderately enlarged, Very scrotal= testes fully enlarged.

Table 6. Bridges and buildings inspected for signs of bat use. Data collected in GNP form 2011-2014.

Structure Name	Structure Type	Grid cell number	Zone	UTM X	UTM Y	Construction Materials	Construction Type	Evidence of Bats	Comments
Lower McDonald Creek bridge	Bridge	124187	12	278076	5379076	Concrete	Big openings	Yes, lots of large and small poo	Netted this site-day and night roost
Logging Creek Bridge	Bridge	125112	11	706538	5397747	Concrete	Low open	Minimal bat poo	Possible night roosting
Camas Bridge	Bridge	124649	11	710907	5389268	Concrete	Open steel	Lots of bat poo, day and night roost, site netted.	Removal of styrofoam at ends would free up roost sites.
Walton Goat Lick - East Underpass	Bridge	123726	12	308914	5348439	Concrete	Smooth, open, flat, expansion joints	Tiny bit of poo	Not impossible roost
Bowman Bridge	Bridge	126038	11	699736	5407222	Concrete	Open, low to water	Bit of old poo	Loud creek noise
Two Medicine Creek Bridge	Bridge	123729	12	326582	5374015	Concrete	Flat, no place to roost	None	
Rising Sun	Bridge	124654	12	314613	5396548	Concrete	Flat, no place to roost	None	
Rising Sun	Bridge	124654	12	314700	5396457	Concrete	Flat, no place to roost	None	Bridge rebuilt in 2014; two bat houses installed underneath.
Lee Creek Bridge	Bridge	126506	12	307578	5428841	Concrete	Open flat, expansion joints	Maternity roost	Pictures of MYVO with pup
Walton Goat Lick - West Underpass	Bridge	123726	12	308738	5348660	Concrete	Open, flat, expansion joints	Colony seen roosting in one expansion joint	
Middle Fork Bridge	Bridge	124187	12	280594	5376060	Creosote	Flat bottom wood	No bat sign	
Kelly Camp Bridge	Bridge	124651	12	288760	5390900	Creosote	Flat bottom wood	No bat sign	Water high and loud
St. Mary Bridge	Bridge	125118	12	320386	5402465	Masonry stone	Arched, smooth - concrete cracks well filled		None-no place to roost

Table 6 (con't). Bridges and buildings inspected for signs of bat use. Data collected in GNP form 2011-2014.

Structure Name	Structure Type	Grid cell number	Zone	UTM X	UTM Y	Construction Materials	Construction Type	Evidence of Bats	Comments
North Fork Bridge at Polebridge Ranger Station	Bridge	125575	11	699715	5406905	Metal with concrete ends and roof	Open steel	Poo and on one end one roosting EPFU Used to have roosting bats-old bat poo found No external bat sign but occupants hear bats in one wall Saw and recorded hundreds of bats swarming at south east corner	Net site in 2012-lots of bats-maternity roost
Polebridge Ranger Station - Cabins	Building	125575	11	699832	5406796	Wood	Wood siding		Building remodeled to exclude bats
Glacier Institute - log cabins	Building	124187	12	279041	5376831	Wood	Log cabins		Three bat houses on building; advised moving bat houses to better locations.
Many Glacier Hotel	Building	125579	12	304985	5408231	Wood	Lots of gaps between window sills and siding		Long-term records of bats inside, and outside, hotel. Was not able to access because locked, should check out
Walton Ranger Station Barn	Building	126801	12	306893	5350008	wood - log	Loft Two west boxes had zero bats; south wall box within the "L" of the building had zero bats. East box and second south box had lots of bats.	NA	
St. Mary Dorms	Building	125118	12	321411	5401297	Wood bat boxes		Estimate of bats in the boxes could be 150-200 minimum.	Netted site in 2012-MYLU maternity roost
Walton Ranger Station	Building	122801	12	306867	5349986	Wood building	Tight log with loft	Unknown	Must check, was locked

Table 6 (con't). Bridges and buildings inspected for signs of bat use. Data collected in GNP form 2011-2014.

Structure Name	Structure Type	Grid cell number	Zone	UTM X	UTM Y	Construction Materials	Construction Type	Evidence of Bats	Comments
Nyack Ranger Station	Building	123726	12	293177	5369002	Wood building	Wood falling apart	Unknown	Dilapidated building; not properly investigated for bats
Fish Creek Boat House	Building	124187	12	280023	5381872	Wood building	Wood siding	Lots of pregnant females	Remodeled in 2014-not sure will still be maternity roost
Headquarters building	Building	124187	12	279420	5376447	Mix	Mix	Maternity roost	Roosting below windows on south-facing side-can hear bats in wall every summer
St. Mary Offices/Cabin 152	Building	125118	12	321411	5401297	Wood building	Wood siding	Lots of squeaky bats in 4 buildings in a row.	Installing mini-bat condo adjacent to buildings before remodeling occurs to exclude bats from buildings.
1913 Historic Barn	Building	125118	12	320843	5401187	Wood building	Wood	Bit of bat poo in building and loft	Re-roofed in 2014 after bat inspection; minor day or night roost
House 41-West Glacier	Building	124187	12	279744	5376543	Mix	Mix	Bit of bat poo in attic-dead bats found in wood stove	Both stove pipe and chimney screened off in 2014 prior to remodeling
Lake McDonald RS Barn	Building	124651	12	288276	5391629	Wood	Logs	None	Only mice and bird signs

Table 7. Scientific and common name, four-letter species code, and number of individuals identified as a bat during acoustic surveys throughout GNP. Data collected in warm season months (May-September) from 2011 to 2014.

Scientific name	Common name	Four-letter species code or category	Count
<i>Eptesicus fuscus</i>	Big Brown Bat	EPFU	278
<i>Lasiurus borealis</i>	Eastern Red Bat	LABO	131
<i>Lasiurus cinereus</i>	Hoary bat	LACI	3891
<i>Lasionycteris noctivagans</i>	Silver-haired Bat	LANO	1903
<i>Myotis californica</i>	California Myotis	MYCA	135
<i>Myotis evotis</i>	Long-eared Myotis	MYEV	710
<i>Myotis lucifugus</i>	Little brown Myotis	MYLU	4763
<i>Myotis yumanensi/californica</i>	Yuma or California Myotis	MYYU/MYCA	184
<i>Myotis volans</i>	Long-legged Myotis	MYVO	56
<i>Myotis yumanensis</i>	Yuma Myotis	MYYU	92
<i>Myotis spp.</i>	Myotis	Myotis	9678
	Low frequency bat: Hoary, Silver-haired or Big Brown	Low	2305
	High frequency bat: Eastern Red or Myotis	High	4945
Chiroptera	Unidentified bat	UNKN	28,002
Total			57,073

Appendices

Appendix 1. Locations of labs where bat biopsy samples from the GNP Bat Inventory and Monitoring Project were sent for analysis.

Little Brown Bat samples sent to:

Aryn Wilder
Dept. of Biology
Boston University
5 Cummington St.
Boston, MA 02215

Silver-haired and Hoary Bat biopsy samples:

Erin Baerwald
Department of Biological Sciences
University of Calgary
2500 University Dr. NW
Calgary, AB
T2N 1N4

Biopsy samples to distinguish between MYLU and MYYU:

Cori Lausen, PhD
WCS Canada, Research Fellow
Wildlife Genetics International Lab in Creston, BC
Box 606 Kaslo, B.C. V0G 1M0
Courier address: 202 B Ave, Kaslo, BC V0G 1M0
(250) 353-7339; cell 250-353-8204

Appendix 2. Echolocation call characteristics of Montana bats (Szewczak and Weller 2006).

	species	lo f	f _c	hi f	f _{max}	dur	upper	lower	special characteristics
50	<i>Myotis californicus</i> California myotis	40–50	47–55	85–135	50–60	2.5– 5.5	15–50 (>32)	5–25	FM sweep a smooth curve (i.e., no inflection), beginning steeply and then increasing in curvature*. Often a well-defined downward tail. Sometimes a lower inflection; with the appearance of a “ledge” or “shelf” before f _c . Peak power of call typically persists for at least 1 ms on non-saturated calls. *some calls may have an inflection, but the smoothly curved variant is diagnostic.
	<i>Myotis yumanensis</i> Yuma myotis	42–50	47–55	70–130	50–60	3–8 (>6)	15–28	2–20 (<3)	Power focused around f_c; gradually builds up to peak and attenuates rapidly. Typically exhibit only a hint of a tail. Sometimes insert longer duration calls within sequence of short duration calls.
	<i>Pipistrellus hesperus</i> western pipistrelle	43–50	45–50	58–90	42–43	4–5	5–25	0–3	Strongly inflected, almost vertical FM changing to low slope below 47 kHz for the majority of the call. Calls generally consistent across a sequence. Appear hockey stick-shaped in sonogram when FM sweep is present. Some calls exhibit “squiggles.”

How to use this table

Bold text indicates the most species–discriminating characteristics.

Analyze 1) well-formed calls, i.e., search phase calls recorded from bats in a steady mode of flight and not accelerating or performing some other maneuver that elicits rapid, short calls, e.g., like that from a hand-released bat, and 2) calls with a strong signal that clearly rise above the background noise level. It is generally preferable to avoid analyzing calls that saturate, i.e., overload, the detector or recorder. However, saturated call specimens may be used to interpret non-saturating low power call characteristics such as low and high f; but do not use saturated call specimens for interpreting power characteristics.

Terminology and key

lo f: lowest apparent frequency (kHz), **hi f**: highest apparent frequency (kHz); this can vary depending upon the distance to the bat, **f_c**: characteristic frequency, i.e., the frequency of the call at its lowest slope, or the lowest frequency for consistent FM sweeps (kHz), **f_{max}**: the frequency with the greatest power (kHz), **dur**: call duration from the beginning to the end of the call (ms), **upper**: the slope of the upper portion or onset of the call (kHz/ms), **lower**: the slope of the lower portion or body of the call (kHz/ms).

FM: frequency modulation, i.e., a change in frequency with time, **flat**: a call or portion of a call with a very low slope or no slope (horizontal), **inflection**: a pronounced change in the slope of a call, sometimes called a “knee,” **power**: the amplitude or sound energy of a call or portions of a call, **squiggle**: an S-shaped variation in frequency with time over a portion of the call.

Sources:

Characteristics gleaned from recordings acquired by T.J. Weller, USFS Redwood Sciences Lab, J.M. Szewczak, Humboldt State University, and P.C. Ormsbee USFS Pacific Northwest Research Station and from:

	species	lo f	f _c	hi f	f _{max}	dur	upper	lower	special characteristics
40	<i>Myotis ciliolabrum</i> western small-footed myotis	25–37	37–43	65–110	41–50	3–5	25–35	5–9	FM sweep a smooth curve (i.e., no inflection), beginning steeply and then increasing in curvature*. Often a well defined downward tail. Peak power of call typically persists for at least 1 ms on non-saturated calls. *some calls may have an inflection, but the smoothly curved variant is diagnostic.
	<i>Myotis volans</i> long-legged	30–46	40–46.5 (43–46.5)	90–120 (>110)	42–47	2.5–6	10–45 (>33)	>4 (>16)	May exhibit an upward sweep into the call; uncommon, but diagnostic when present.
	<i>Myotis lucifugus</i> little brown	30–40	37–43	55–105 (<85)	41–50	2.5–8 (>6)	6–28	0–15 (<3)	Sometimes with multiple power centers making calls look clumpy. Can make the longest duration and lowest slope of all <i>Myotis</i> .
	<i>Myotis septentrionalis</i> northern long-eared myotis	33–36	41–45	<125	44–48	3–4	20–45	10–22	Calls may have up to 100 kHz of bandwidth. Shaped like Myev or Myth but distinguished by f_c. FM sweep may be nearly linear making f _c difficult to recognize. Quiet but consistent calls.
	<i>Lasiurus borealis</i> western	38–50		50–90	35–50	4–20 (>10)		0–5	Up-turn at end of call; may exhibit variable f_c across sequence.

	species	lo f	f _c	hi f	f _{max}	dur	upper	lower	special characteristics
mid 30	<i>Myotis evotis</i> long-eared myotis	22–30	33–38 (33–36)	70–125	39–55	2.5–5.5	20–40	5–30	Calls may have up to 100 kHz of bandwidth. Shaped like Myth but distinguished by f _c . FM sweep may be nearly linear making f _c difficult to recognize.
	<i>Antrozous pallidus</i> pallid bat	26–30	26–30	50–70	30–40	3–10	3–20	0–10	Simple curved FM sweeps without “flair.” Can only distinguish from Epfu when <6 calls/sec. No tail. Presence of social calls diagnostic.
	<i>Eptesicus fuscus</i> big brown bat	26–32		32–90 (65–90) >65*	28–45	3–20 <7*	2–30	0.5–10	Variable; calls with high f below 60 kHz can be confused with Lano and/or Tabr. Calls with high f above 65 kHz distinguish from Lano , even long calls have some FM component. * Shorter calls recorded with full detail, i.e., ones that closely approached the microphone, as indicated by the presence of harmonics, exceed 65–70 kHz.
	<i>Lasionycteris noctivagans</i> silver-haired bat	25–28	26–28	27–65 (<30) <55*	26–40	4–15 <7*	0–15	0–5	Shorter calls reverse J-shaped; often with a distinct inflection. Some call variants can be confused with Epfu and/or Tabr. Flat calls ≥26 kHz diagnostic. Flat Laci calls are lower in f. Low slope calls in the 25–26 kHz range may be distinguished from Laci by the presence of an inflection. Epfu has more FM, typically with smooth curvature (no inflection). * Shorter calls recorded with full detail, i.e., ones that closely approached the microphone, as indicated by the presence of harmonics, still do not exceed 50–55 kHz.
	<i>Myotis thysanodes</i> fringed myotis	12–35	15–32 (<31)	90–125		2.5–6.5	15–50	6–40	Calls may have up to 100 kHz of bandwidth. Shaped like Myev but distinguished by f _c . FM sweep may be nearly linear making f _c difficult to recognize.

	species	lo f	f _c	hi f	f _{max}	dur	upper	lower	special characteristics
20	<i>Tadarida brasiliensis</i> free-tailed bat	18–27		22–65	22–43	6–18	<10	0–2	Variable; FM to flat; can be confused with Epfu, Lano, or Laci. Long calls that "turn on" power rapidly with high energy at beginning (oscillogram carrot-like). Calls often upswing into call and downswing out of call.
	<i>Corynorhinus townsendii</i> Townsend's big-eared bat	18–27		35–50	28–38	2–8	2.5–12		Low intensity, difficult to detect; harmonics often present. Call-shape simple linear FM sweep , (sometimes with upswing at onset). f _{max} may alternate between fundamental and second harmonic. *some linear Myth fragments can mimic Coto; use presence of <u>harmonics to confirm quality</u> .
	<i>Lasiurus cinereus</i> hoary bat	13–30 (≤ 23)		<50	30–17	4–20	0–12	0–5	Pronounced or subtle U- shape; very flat calls may have slight downturn into call or upturn at end. Low f may vary across sequence, power builds toward center then gradually declines. Short calls can be confused with Lano, Epfu, or Tabr.
10	<i>Euderma maculatum</i> spotted bat	7–10		13–22	10–14	3–8	1–3	0.3–3	Simple linear FM sweep , sometimes with a mild inflection. Short calls at low frequency. Harmonics often present, with second harmonic persisting beyond first.