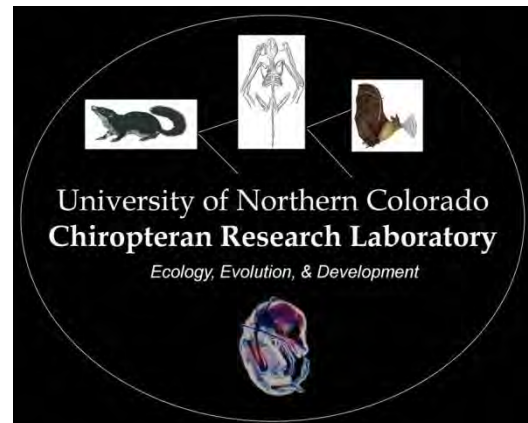
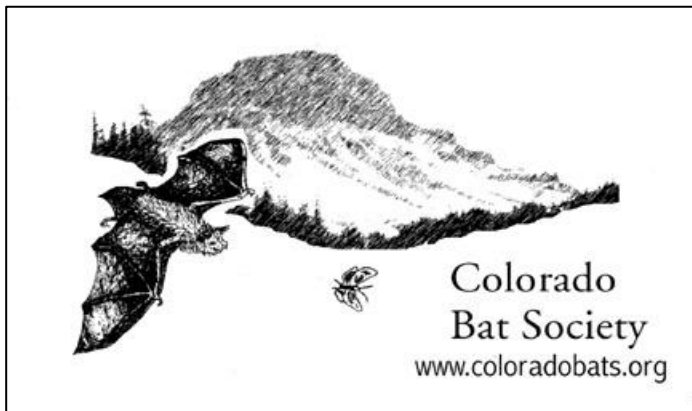


Modeling of the Effects on Bats of Forest Structure Changes Caused by Fire and Human Manipulation

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Abstract

Few studies have quantified the effects of fire on the foraging patterns of bats and no studies have occurred in the western US. We compared usage by bats of burned and thinned forest sites as well as meadows to that of unmanipulated forest stands (control). Our data showed extensive use by bats of both burn areas, however, the burn site that had a perimeter of live trees was used most extensively and in terms of activity was equivalent to our meadow and forest plots. Burn 2 was centered in the large Overland Burn area and did not receive as much activity. However, in terms of bat biodiversity defined as species richness and species evenness, Burn 2 had the higher Shannon Index score. In comparative plots set in meadow, forest and thinned sites near Ingersol Quarry, Thinned and Meadow sites had similarly high bat biodiversity. Forest had much less, but this was because it was dominated by the gleaner specialist *M. evotis* that has established this area around the quarry as a major breeding grounds. We also report herein on the third year of our study on bat use of masticated forest sites, capture data from Ingersol Quarry and Plumely Canyon, a preliminary study on comparison of wet (Geer) versus dry (Plumely) canyons in terms of bat activity and insect biomass. In addition, we report on the 6th year of data acquisition from our PIT-tag reader in Geer Canyon.

OVERLAND BURN STUDY

Introduction

Nearly no studies have quantified the use of post-fire forest stands by bats. A study of the response of northern bats (*Myotis septentrionalis*) to prescribed burns fires in eastern Kentucky forests showed that bats responded positively to burned habitat by utilizing these sites on nightly foraging bouts and the authors noted that the abundance of insects (as collected in black-light traps) known to be eaten by this species increased significantly following prescribed burns (Lacki et al. 2009). Loeb and Waldrop (2008) compared sites manipulated using prescribed burns, thinning, and thinning followed by prescribed burning and found that big brown bats (*Eptesicus fuscus*), eastern pipistrelles (*Perimyotis subflavus*) and eastern red bats (*Lasiurus borealis*) has overall greatest activity in Thinned sites than in Control (no treatment) stands, whereas activity in the Burn and Thinned and Burn stands were also greater than in Control stands. In addition, successional habitats are important foraging and commuting sites for bats in the Central Hardwood Region of the US (Loeb & O'Keefe 2011).

Forest thinning and prescribed burns as well as human-caused or naturally occurring wildfires are an important aspect of the ecology of Colorado. Thinning techniques and prescribed burns are important management tools for foresters and wildlife biologists trying to control unintended wildfires. Changes in habitat structure have different effects on different wildlife species. However, bats are recognized as important indicators to ecosystem health because they are the only major foragers on nighttime insects (moths and mosquitoes) and by keeping these insect populations in check bats keep tree-stands healthy and viable.

Objectives of the study were: **A)** quantify the use by bats of burned forest as this is an area of research that is sorely lacking, **B)** expand the study of bat species and habitat use to a landscape-level and multivariate statistical analysis, **C)** link the relationships between natural and prescribed burns with human mechanical alterations of forests stands, **D)** quantify the tolerance of various bat species and community structure to altered landscapes, **E)** provide BOCO alternatives to forest management techniques in relation to maintenance of wildlife diversity.

Hypotheses and Alternative Hypotheses. H1: Use of burn and newly thinned sites by bats will be species-specific. **H1A:** Use of burn and newly thinned sites by bats will not be species-specific (i.e. all species will be present) and abundance be in line with expectations based upon estimated local population numbers. **H2:** Use of burn and newly thinned sites by bats will be similar that observed for sites thinned by humans. **H2A:** Bat species will use burn and newly thinned sites differently (as measured by richness and abundance) than observed for burn sites. **H3:** Ambient temperatures and insect diversity and biomass will vary among the survey plots. **H3A:** These factors will not vary among sites.

Methods for Burn and Thinned Site Studies

Study Areas. The study took place at Heil Valley Ranch (Fig. 1) where various forest treatment activities have been underway since 1996. We compared bat usage patterns in seven plots including two control sites (unmanipulated/untreated forest), unmanipulated/untreated meadow, two sites in the Overland Burn area and one thinned site forest using Wildlife Acoustics SM2 BAT sonar detectors.

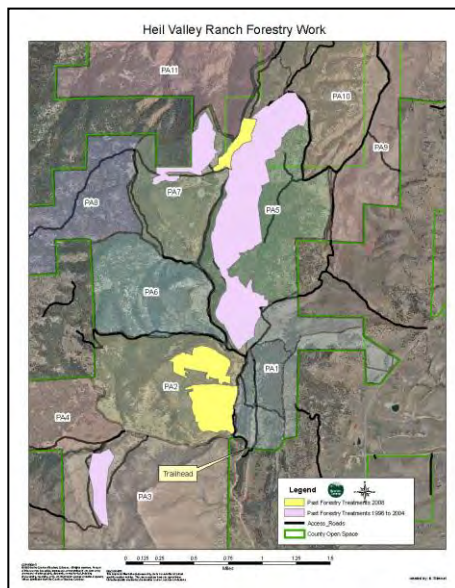


Figure 1. Map of Heil Valley Ranch showing forest treatment areas between 1996 and 2008. Significant retreatment and initial treatment of areas in PA5, PA2, and PA7 occurred in 2011 and 2012.

Bat Sonar Sampling: Overland Burn Site. We measured and marked 100m² survey areas in four plots (temporary flagging marked corners) (Fig. 2). All plots, with the exception of Meadow, were located on an east facing aspect. Within each 100m² survey area were 25 40m² plots numbered 1 - 25 beginning in the SW quadrant of each plot (SM2s have sensitivity reach of 30m). We moved each SM2 on the same dates after 10 nights of sampling in a 40m² plot with placements determined by a random numbers table of digits 1-25. By rule, SM2s were never moved to another 40m² plot cannot be within 40m of the previously surveyed plot and each surveyed plot was removed from the random numbers generator to avoid replication.

Survey areas in the Overland Burn area were labeled Forest (control) defined as 100m² of unburned forest, Natural Meadow defined as grassland habitat of deep, fine textured soils, lacking trees within the 100m² area, Burn with green edge defined as 100m² area having only dead trees but encompassed by a ring of proximate live trees, and Burn-Isolated defined as a

100m² area have dead standing trees but having no proximate live trees within 100m of the plot (Fig.2).

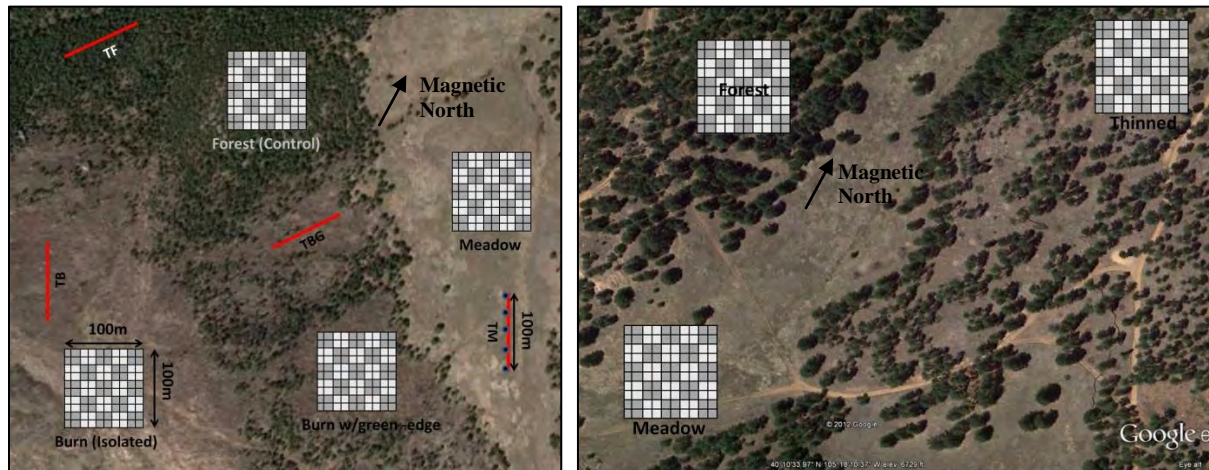


Figure 2. (Left) Illustration of placement of the four survey areas (gray and white squares) and four walking 100m transects with 20m survey points (blue dots) associated with the Overland Burn. TM = Transect Meadow, TBG = Transect with Green Edge, TB = Transect Burn Isolated, and TF = Transect Forest. (Right) Illustration of placement of the three survey areas (gray and white squares) of 100m² grids in Forest, Thinned and Meadow plots near Ingersol Quarry.

Ingersol Site. We also set up three 100m² survey areas near Ingersol Quarry (Fig. 2). One was located in untreated forest, another in a meadow habitat and a third in a thinned forest stand.

Data Analysis: Sonar call files were downloaded from SM2 recorders every 10 days. WAC0 files were converted to WAV files and then analyzed with SonoBat 3 analysis software to species. Species Richness was calculated for each 100m² survey area and compared to Forest controls using Kruskal-Wallis one-way ANOVA. In addition we calculated an Adjusted Activity Index (AI) for each 100m² survey area using the technique provided by Miller (2001) wherein one-minute time blocks in which a species was detected are summed thereby provided a standardized methods to compare each species' relative contribution to activity at multiple sites over time (Miller 2001; MacSwiney et al. 2009) and can thus be used to compare species abundance ratios across areas. We will calculate a Shannon Diversity Index [$H = \sum - (P_i * \ln P_i)$] for each 100m² area and compare activity indices using one-way ANOVA.

Linear Transect Point Monitoring: In addition to the grid system, we set up independent 100m walking transects with 15 minute six point monitoring positions every 30m. We began walking transects 30 minutes after bat activity has begun, stopped at 30m intervals and record sonar calls using Wildlife Acoustics EchoMeters. Two of four transects chosen at random were walked simultaneously and in-sync on a given night.

Abiotic Variable Sampling: Ambient Temperature. SM2 bat detectors contain in-house temperature data loggers that recorded temperature data during the sampling periods set up to monitor from dusk till dawn.

Results

Capture Data: Mist net results from Ingersol Quarry and Plumely Canyon are presented in Table 1. A total of 85 bats was captured between the months of June and September. Of these, two were Townsend's big-eared bats (*Corynorhinus townsendii*), 10 were big brown bats (*Eptesicus fuscus*), 14 were small-footed myotis (*Myotis ciliolabrum*), 38 were long-eared myotis (*M. evotis*), 14 were little brown bats (*M. lucifugus*) and seven were fringed myotis (*M. thysanodes*). For all bats captured, 17 were females and 68 were males. Of adult females, four were lactating, four were pregnant, and nine were nonreproductive. For adult males, three were scrotal, seven were inguinal (testes beginning to descend) and 58 were not reproductive. Of all captures, one was a juvenile, 4 were subadults, and 80 were adults.

Table 1. Capture data organized by date for 2012 captures from Ingersol Quarry and Plumely Canyon at Heil Valley Ranch.

DATE	SITE	SPP	AGE	SEX	REPRO	MASS	UTMS
6/2/2012	IQ	MYCI	A	M	NS	4.3	474091-4447417
6/2/2012	IQ	MYEV	A	F	L	7.7	474091-4447417
6/2/2012	IQ	MYCI	A	M	NS	4.4	474091-4447417
6/2/2012	IQ	MYTH	A	M	NS	5.9	474091-4447417
6/2/2012	IQ	MYEV	A	M	NS	6.2	474091-4447417
6/2/2012	IQ	EPFU	A	M	NS	14.8	474091-4447417
6/2/2012	IQ	MYEV	A	M	NS	6.2	474091-4447417
6/2/2012	IQ	EPFU	A	M	I	14.8	474091-4447417
6/2/2012	IQ	MYEV	A	M	NS	6.5	474091-4447417
6/2/2012	IQ	EPFU	A	M	I	14	474091-4447417
6/2/2012	IQ	MYTH	A	F	L	9.4	474091-4447417
6/2/2012	IQ	EPFU	A	M	I	12.5	474091-4447417
6/2/2012	IQ	MYTH	A	M	NS	8.1	474091-4447417
6/2/2012	IQ	EPFU	A	M	I	14.5	474091-4447417
6/2/2012	IQ	MYTH	A	M	NS	7.5	474091-4447417
6/2/2012	IQ	MYTH	A	F	P	7.7	474091-4447417
6/2/2012	IQ	MYEV	A	F	P	6.5	474091-4447417
6/2/2012	IQ	MYEV	A	M	NS	6.5	474091-4447417
6/2/2012	IQ	EPFU	A	M	I	NW	474091-4447417
6/23/2012	IQ	MYLU	A	M	NS	6.9	474091-4447417
6/23/2012	IQ	MYLU	A	F	NLNP	7.2	474091-4447417
6/23/2012	IQ	MYEV	A	M	NS	5.6	474091-4447417
6/23/2012	IQ	MYCI	A	F	P	5.7	474091-4447417
6/23/2012	IQ	MYCI	A	M	NS	3.8	474091-4447417
6/23/2012	IQ	MYLU	A	M	NS	6.5	474091-4447417
6/23/2012	IQ	MYLU	A	M	NS	6	474091-4447417
6/23/2012	IQ	MYCI	A	M	NS	4.1	474091-4447417

DATE	SITE	SPP	AGE	SEX	REPRO	MASS	UTMS
6/23/2012	IQ	MYEV	A	F	NLNP	5	474091-4447417
6/23/2012	IQ	MYEV	A	M	NS	5.3	474091-4447417
6/23/2012	IQ	MYCI	A	M	NS	4.1	474091-4447417
6/23/2012	IQ	MYCI	A	M	NS	4.7	474091-4447417
6/23/2012	IQ	MYLU	A	F	NLNP	7.4	474091-4447417
6/23/2012	IQ	EPFU	A	M	S	NW	474091-4447417
6/23/2012	IQ	MYEV	A	M	NS	6	474091-4447417
6/23/2012	IQ	MYLU	A	F	NLNP	5.6	474091-4447417
6/23/2012	IQ	MYCI	A	M	NS	5	474091-4447417
6/23/2012	IQ	MYEV	A	M	NS	6.9	474091-4447417
6/23/2012	IQ	MYLU	A	M	NS	5.8	474091-4447417
6/23/2012	IQ	MYCI	A	M	NS	5.9	474091-4447417
6/23/2012	IQ	MYLU	A	F	P	7.9	474091-4447417
6/23/2012	IQ	MYCI	A	M	NS	6.4	474091-4447417
6/23/2012	IQ	MYEV	A	M	NS	6.4	474091-4447417
6/23/2012	IQ	MYEV	A	M	NS	6	474091-4447417
6/23/2012	IQ	MYLU	A	M	NS	6.7	474091-4447417
6/23/2012	IQ	MYTH	A	M	NS	6.7	474091-4447417
6/23/2012	IQ	MYEV	A	M	NS	6.6	474091-4447417
6/23/2012	IQ	MYLU	A	M	NS	6.1	474091-4447417
6/23/2012	IQ	MYEV	A	M	NS	6.2	474091-4447417
6/23/2012	IQ	MYEV	A	M	NS	6.1	474091-4447417
6/23/2012	IQ	MYLU	A	M	NS	6.4	474091-4447417
6/23/2012	IQ	EPFU	A	M	NS	12	474091-4447417
6/23/2012	IQ	MYEV	A	M	NS	6.5	474091-4447417
6/23/2012	IQ	MYEV	A	M	NS	7.6	474091-4447417
6/23/2012	IQ	MYEV	A	M	NS	6.7	474091-4447417
6/23/2012	IQ	COTO	A	M	NS	10	474091-4447417
6/23/2012	IQ	MYLU	A	M	NS	6.5	474091-4447417
6/23/2012	IQ	MYLU	A	M	NS	7	474091-4447417
6/23/2012	IQ	MYEV	A	M	NS	7	474091-4447417
6/23/2012	IQ	EPFU	A	M	S	14	474091-4447417
6/23/2012	IQ	MYEV	A	M	NS	6.9	474091-4447417
6/23/2012	IQ	EPFU	A	M	S	15.9	474091-4447417
6/23/2012	IQ	MYEV	A	M	NS	6.8	474091-4447417
6/23/2012	IQ	MYEV	A	F	NLNP	7.4	474091-4447417
6/23/2012	IQ	MYEV	A	M	NS	6.2	474091-4447417
6/23/2012	IQ	MYEV	A	M	NS	6.7	474091-4447417
6/23/2012	IQ	COTO	A	F	L	11.7	474091-4447417
6/23/2012	IQ	MYEV	A	M	NS	6.4	474091-4447417

DATE	SITE	SPP	AGE	SEX	REPRO	MASS	UTMS
7/12/2012	Plumely	MYCI	J	F	NLNP	3.8	465478-4459315
7/18/2012	Plumely	MYCI	SA	F	NLNP	3	465478-4459315
7/18/2012	Plumely	MYCI	SA	F	NLNP	3.6	465478-4459315
7/18/2012	Plumely	MYTH	A	F	L	8.8	465478-4459315
9/2/2012	IQ	MYCI	A	F	NLNP	3.6	474091-4447417
9/2/2012	IQ	MYEV	A	M	NS	5.9	474091-4447417
9/2/2012	IQ	MYEV	A	M	NS	6.3	474091-4447417
9/2/2012	IQ	MYEV	A	M	NS	6.2	474091-4447417
9/2/2012	IQ	MYEV	A	M	NS	5.2	474091-4447417
9/2/2012	IQ	MYLU	A	M	S	7.1	474091-4447417
9/2/2012	IQ	MYEV	A	M	NS	6.6	474091-4447417
9/2/2012	IQ	MYEV	A	M	NS	6.9	474091-4447417
9/2/2012	IQ	MYEV	SA	M	NS	5.3	474091-4447417
9/2/2012	IQ	MYEV	A	M	I	6.8	474091-4447417
9/2/2012	IQ	MYEV	A	M	I	7.1	474091-4447417
9/2/2012	IQ	MYEV	A	M	NS	6.9	474091-4447417
9/2/2012	IQ	MYEV	A	M	NS	6.9	474091-4447417
9/2/2012	IQ	MYEV	SA	M	NS	5.3	474091-4447417

Sonar Call Data: A total of 39,658 sonar call files were recorded in study grids and walking transects in the Overland Burn and Ingersol area grid plots. Of these, 11,649 were of a quality allowing for analysis to species by SonoBat 3.1.

Overland Burn Site: A total of 16,939 call files was recorded in the Overland Burn study area, with 4,710 of call quality allowing analysis to species. Figure 3 shows total number of calls per grid along with number of calls analyzed to species.

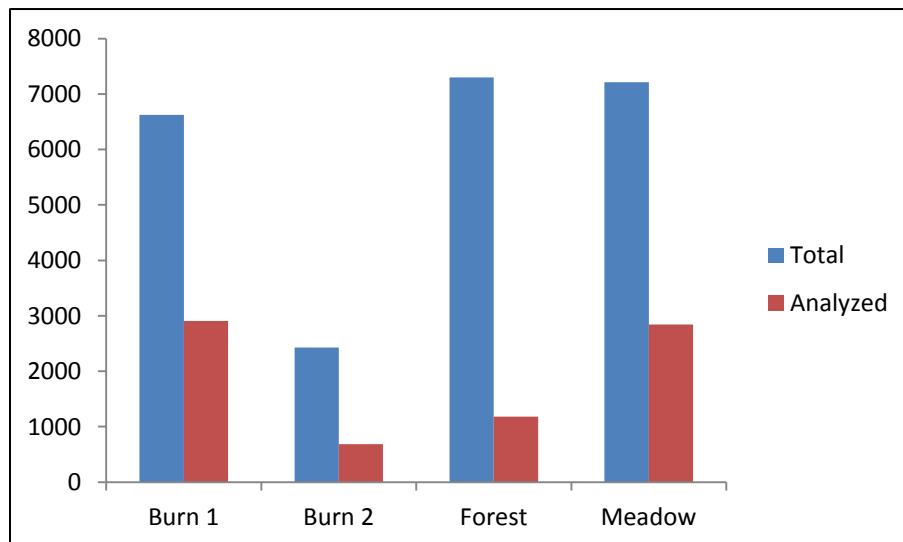


Figure 3. Total number of calls recorded in each grid compared to total number of calls analyzable to species recorded in each grid.

Total number of call files recorded in Burn Sites was 9,048 with 3,589 analyzed to species. The highest amount of activity in the burn sites was in Burn 1 ($N_{\text{calls}} = 6,621$) that had trees outlining its perimeter. Burn 2 ($N_{\text{calls}} = 2,427$) did not have trees lining its perimeter and had significantly less activity than did Burn 1 having a treed perimeter (Wilcoxon Rank Sum Test, $P = 0.04$).

Species diversity in Burn 1 and Burn 2 was eight species. However, the distribution of the eight species differed between each burn site (Fig. 4A and B). In both Burn plots, the order of species dominance was *E. fuscus*, *Lasionycteris noctivagans*, *Lasiurus cinereus* for open aerial foragers. However, for myotis species there was difference between plots. In Burn 1, *M. lucifugus* was followed by *M. evotis*, then *M. ciliolabrum* and *M. thysanodes*. In Burn 2, *M. lucifugus* was followed by *M. ciliolabrum*, *M. evotis* and *M. thysanodes*.

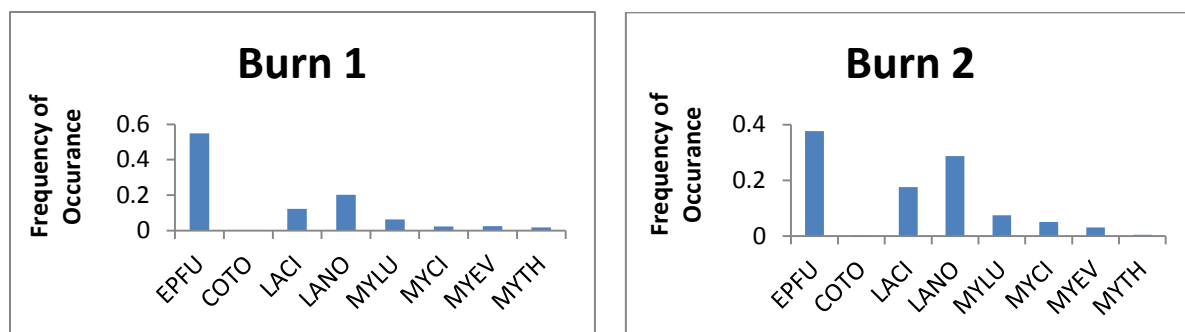


Figure 4. Comparison of Burn 1 and Burn 2 species distributions. Both sites were used by eight species, but differed in proportional abundance of species. Shannon Index (H') indicated that Burn 2 had greater evenness and thus greater biodiversity. It should be noted that both sites recorded a single *Corynorhinus townsendii* pass, but its proportional abundance does not register on the graphics due to scaling.

Species richness calculated using the Shannon Index (H') showed that Burn 2, even though there was significantly less overall bat activity, had greater diversity ($H' = 0.65$) compared to Burn 1 ($H' = 0.58$). The greater H' for Burn 2 was due to greater evenness of species usage. Burn 1 was heavily dominated by *E. fuscus* and *L. noctivagans* which made up nearly 75% of all sonar recording, whereas in Burn 2, these two species composed 66% of all analyzed call sequences. Of the four study grids, Forest had the highest diversity ($H' = 0.75$), followed by Burn 2 ($H' = 0.65$), Meadow ($H' = 0.62$), and Burn 1 ($H' = 0.57$).

Walking Transects: We walked independent transects of 100m positioned at least 100m away from sonar grids, stopping at 30m points and censusing for 15 minutes using EM3 handheld detectors. A total of four nights along each transect accumulated 1,440 minutes (24 hours) of detection resulting in 322 call files analyzable to species. Of these 29 were recorded in Burn 1 that included *E. fuscus*, *M. ciliolabrum*, and *M. lucifugus*, 80 in Burn 2 that included *E. fuscus*, *L. noctivagans*, *M. ciliolabrum*, *M. evotis*, and *M. lucifugus*, eight in Forest that included *M. ciliolabrum* and *M. evotis*, and 205 in Meadow that included *E. fuscus*, *L. noctivagans*, *M. evotis*, and *M. thysanodes*.

Ingersol Site: A total of 22,397 call files were recorded between the dates of 7.25.12 and 8.28.12 and 6,617 were analyzable to species. Figure 5 gives ratios of analyzable call sequences to total recorded per grid.

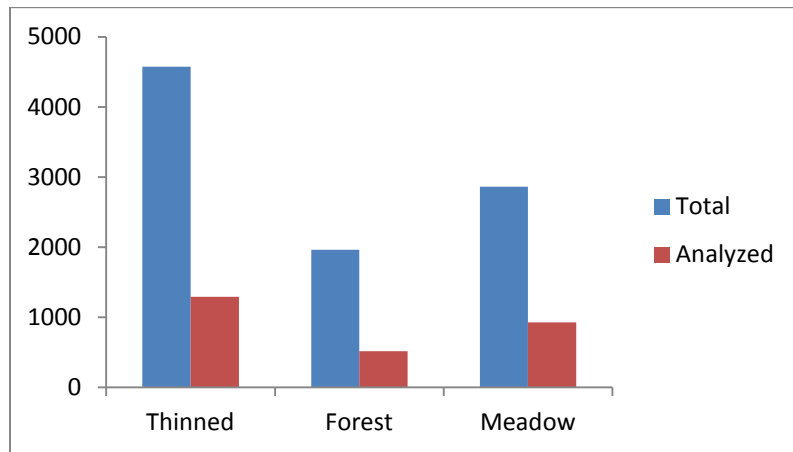


Figure 5. Analyzable versus total call sequences recorded in each grid in thinned area plots.

Species diversity determined by Shannon Indices (H') showed that the Meadow had the highest diversity ($H' = 0.729$), followed by the Thinned plot ($H' = 0.727$) with the Forest plot having lowest diversity ($H' = 0.482$). In the Forest plot, *M. evotis* composed nearly 70% of all call recorded, making the evenness among species in the forest heavily skewed thereby affecting the Shannon Index outcomes. Frequencies of occurrence of each species in each habitat grid is shown in Fig. 6.

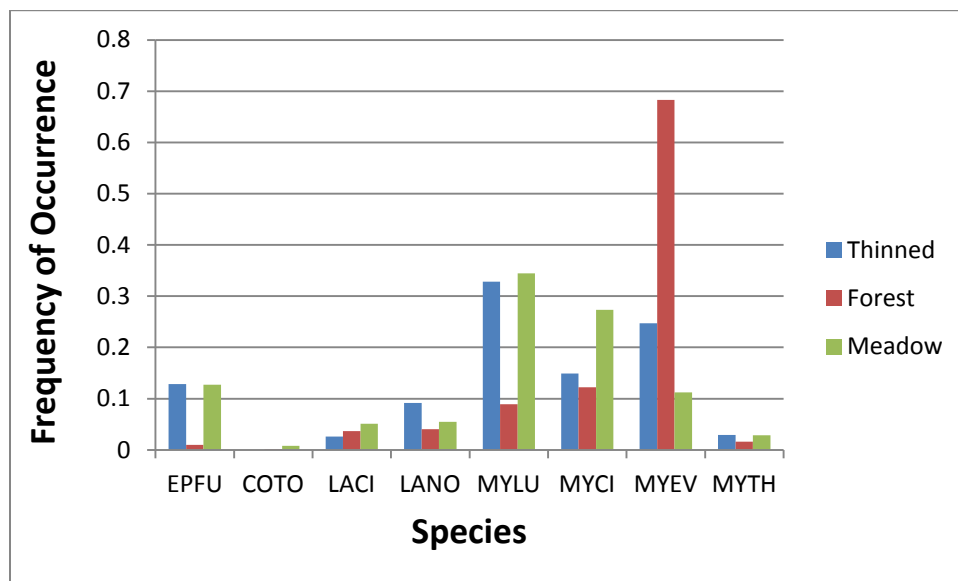


Figure 6. Species occurrences in each habitat grid based upon sonar call analyses.

The forest plot was dominated by *Myotis evotis*, a gleaning specialist, followed by *M. ciliolabrum* (an edge specialist), *M. lucifugus* (a generalist), *M. thysanodes* (an dense clutter aerial pursuit specialist), *Lasionycteris noctivagans* (a slow-flying open area forager), *Lasiurus cinereus* (an high-speed fling open aerial

pursuit specialists) and *Eptesicus fuscus* (an open aerial generalist forager). The forested plot also registered *Corynorhinus townsendii*, a specialized gleaner that is of highest conservation concern. The Thinned plot had highest frequency of occurrence of *M. lucifugus* and *M. evotis*, followed by *M. ciliolabrum*, *L. noctivagans*, *L. cinereus*, *M. thysanodes*, and *E. fuscus*. Curiously, no *C. townsendii* were recorded in Thinned plots. The Meadow plot registered *M. lucifugus* and *M. ciliolabrum* in highest frequencies, followed by *E. fuscus*, *M. evotis*, *L. cinereus*, *L. noctivagans*, and *M. thysanodes*. the Meadow also had the highest frequency of occurrence of *C. townsendii*. It should be noted that frequencies of occurrence should not be viewed necessarily as active foraging in a given plot as individuals may simply be travelling through various forest stand types on ways to preferred foraging areas.

Ambient Temperature Overland Burn Sites: There was no significant differences in mean ambient temperatures among the Overland Burn site grids, however, there was slightly less variation in temperature in the Forest ($T_{\text{mean}} = 22.4$, $SD = 3.51$) and Burn 2 ($T_{\text{mean}} = 20.4$, $SD = 3.40$) plots. Burn 1 ($T_{\text{mean}} = 22.1$, $SD = 3.78$), Meadow ($T_{\text{mean}} = 21.9$, $SD = 4.06$)(Fig. 7).

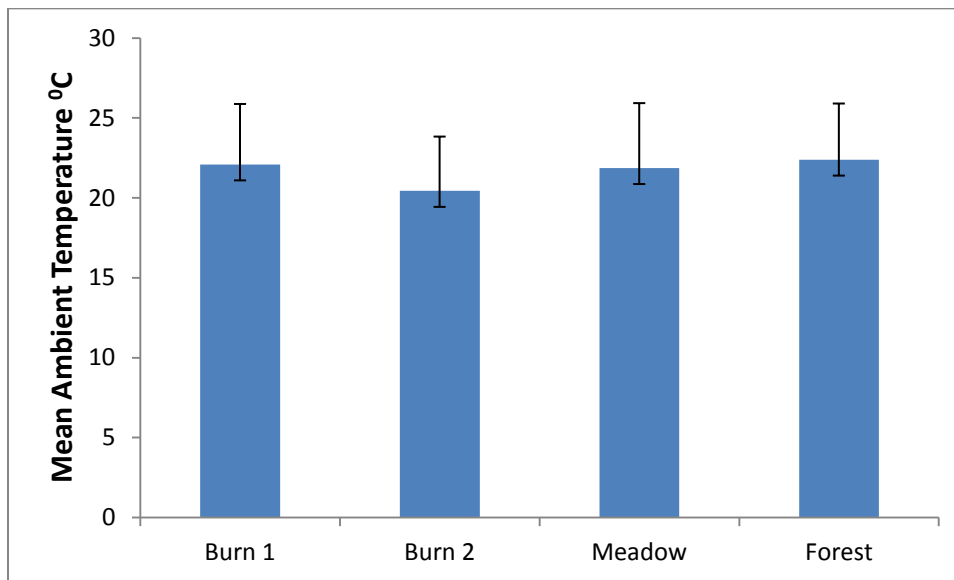


Figure 7. Means and standard deviations of ambient temperatures recorded in all Overland Burn plots in June and July. There was no significant differences among groups ($P = 0.711$).

Ambient Temperature Ingersol Sites: In Thinned plots grids, Meadow had the lowest mean ambient temperature, but had the highest standard deviation ($T_{\text{mean}} = 17.7$, $SD = 4.50$), followed by Forest ($T_{\text{mean}} = 19.8$, $SD = 3.96$), and Thinned ($T_{\text{mean}} = 21.2$, $SD = 3.90$)(Fig. 8)

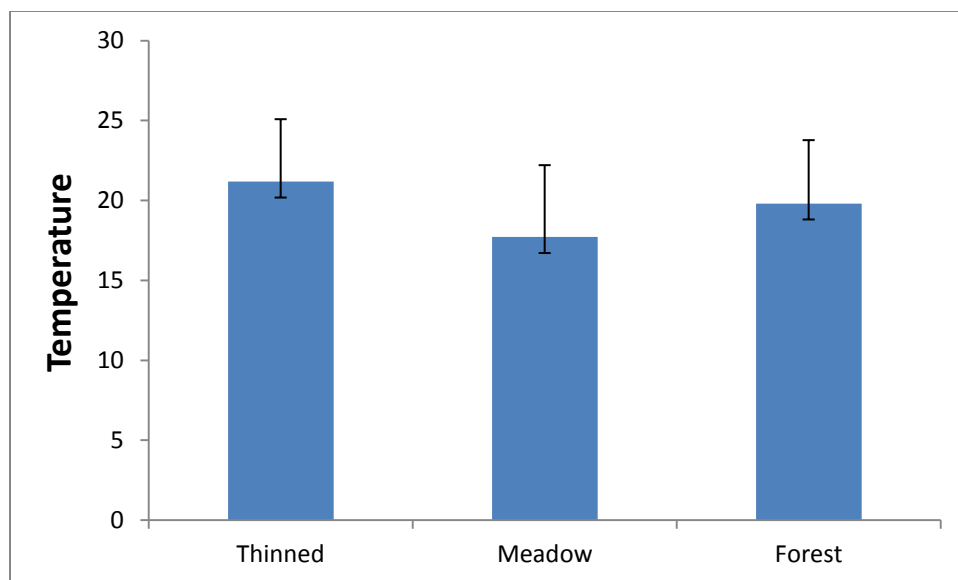


Figure 8. Means and standard deviations of ambient temperatures recorded in all Thinned area plots near Ingersol Quarry in August. There was no significant differences among groups ($P = 0.611$).

Conclusions: First year data on the use of Burn sites by bats showed differing patterns of use depending on whether or not the plots had live trees lining its perimeter. Burn 1 that had a treed perimeter had by far significantly higher bat activity than did Burn 2. These data suggest that having live trees in a given local increases the use by bats significantly, likely due to nearby cover for avoiding predation by owls. However, counter intuitively, species diversity calculated by the Shannon Index showed that Burn 2 had greater evenness across species because Burn 1 was dominated by *E. fuscus* whereas Burn two had greater activity of myotis species that one would think would be more tied to having live trees nearby. More fine-grained analysis will be necessary as well as replication of data collection to fully discern these patterns.

For plots associated with Thinned areas near Ingersol Quarry, we found that thinned areas had highest use and was essentially tied in biodiversity with the Meadow grid. Forested areas had lowest activity and diversity, but was the main foraging areas for myotis species, especially *M. evotis*. The area around Ingersol Quarry as the highest incidence and density of reproductive *M. evotis* colonies known to us in the Front Range region.

MASTICATION STUDY OUTCOMES AFTER YEAR 3

Sonar calls gathered over 126 detector-nights (2010-2012) resulted in 1,564 analyzable call sequences. There were a significant differences in numbers of calls recorded in Open ($N = 843$) versus Edge ($N = 369$, $P \leq 0.05$) and Open versus Forest ($N = 342$, $P \leq 0.05$)(Fig. 9).

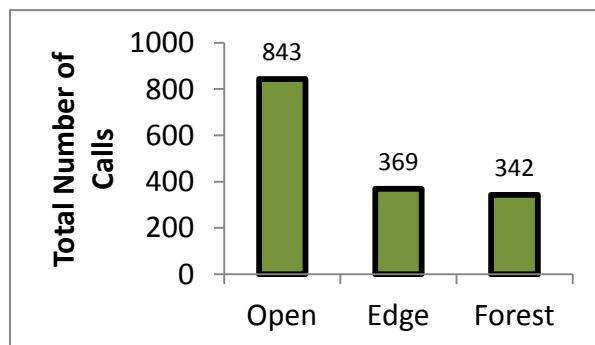


Figure 9. Raw number of calls recorded in the three habitat types pooled across years.

Species-specific foraging patterns showed that for clutter specialist *M. evotis*, there was a significant difference between open and edge activity with individuals of this species using mostly edge habitat (Fig. 9). For clutter specialist *M. thysanodes*, there were no significant differences among habitat use, however, edge was the highest use category (Fig. 10).

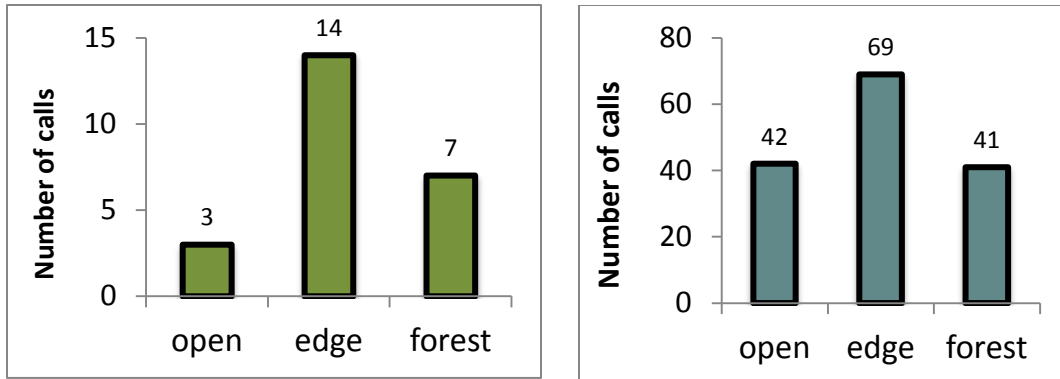


Figure 10. (Left) Foraging distribution of *M. evotis* based upon sonar calls (N = 24). Most calls were recorded in edge habitat and edge was significantly different than open area in usage ($Z = 2.42$, $P \leq 0.05$). (Right) Foraging distribution of *M. thysanodes*, based upon sonar calls (N = 152). Most calls were recorded in edge habitat, but there was no significant differences among habitat usage ($P > 0.05$).

The edge-specialist species *M. ciliolabrum* (N = 240), showed most call recording from Open areas, followed by Forest and then Edge. There was significant difference in usage between Open and Forest habitats ($z = 2.56$, $P \leq 0.05$)(Fig. 11).

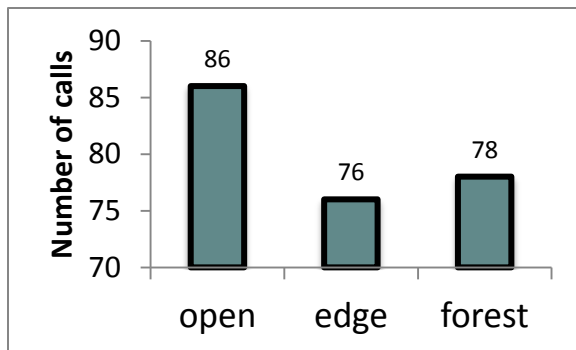


Figure 11. Distribution of habitat use for *M. ciliolabrum*, an edge specialist.

For the generalist species *M. lucifugus*, most use was in Open habitat which was significantly different than the use of either Edge or Forest habitats ($z = 3.82$, $P \leq 0.05$)(Fig. 12).

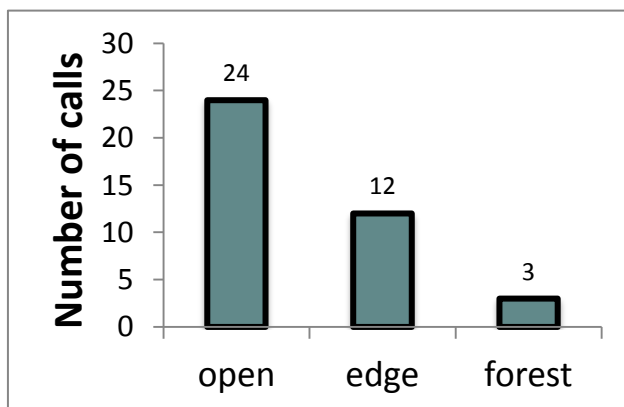


Figure 12. foraging distribution of *M. lucifugus*, a generalist species.

For open-aerial specialists, *Lasiurus cinereus*, there was surprising usage of forested habitat. In fact, *L. cinereus* used forest about 37% (49 of 134 calls) of the time (Fig. 13).

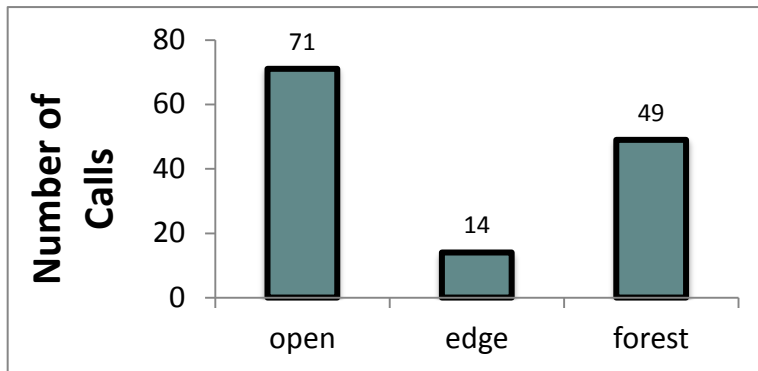


Figure 13. Habitat use patterns of *Lasiurus cinereus*. There was significant differences between Open and Edge habitats ($P \leq 0.05$) and Open and Edge habitat use ($P \leq 0.05$).

The species *Eptesicus fuscus* (N = 231) showed significant differences among habitats during foraging with Open habitat by far the highest usage ($z = 4.52, P \leq 0.05$)(Figure 14).

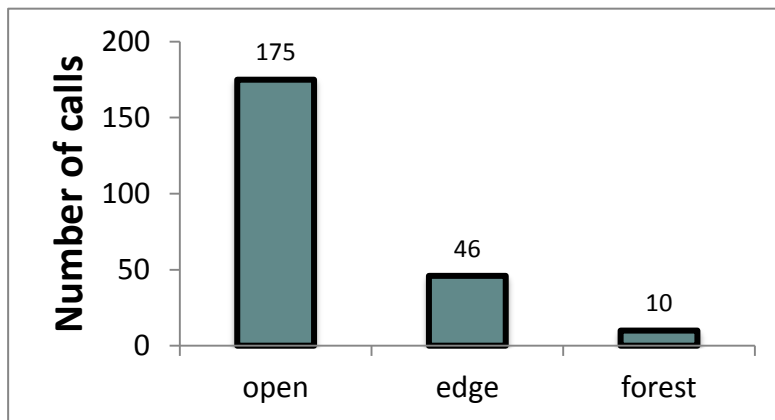


Figure 14. Habitat use patterns of *E. fuscus* indicating significant usage of Open habitat as compared to Forest or Edge.

Sonar analysis of *Lasionycteris noctivagans* calls (N = 62) indicated that they also preferred Open habitat that it used 79% of the time. There was significant differences between Open and Edge and Open and Forest usage ($z = 3.95, P \leq 0.05$)(Fig. 15).

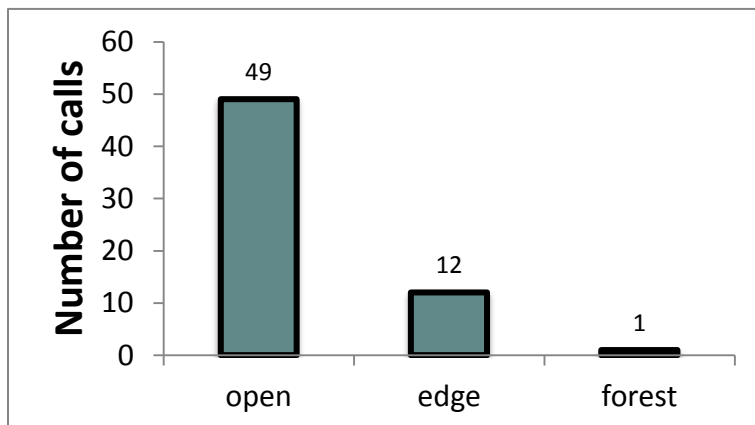


Figure 15. Distribution of foraging habitat use for *L. noctivagans*.

Insect Biomass Analysis: Data analysis. We will identify insects to order and used an Olympus stereoscopic dissecting scope to measure each individual insect's body length (± 0.1 mm). Insect biomass will be calculated using total body length measurements, and order-specific constants in the following regression equation: $M = e^{B \times L} \times A$, where M = dry mass (mg), e = Euler's number, L = length (mm), and A and B values are order-specific constants derived from previous studies. We will use the following order-specific constants derived from Scanlon and Petit (2007): Coleoptera $A = 2.492$, $B = -3.247$; Diptera $A = 2.213$, $B = -3.184$; Lepidoptera $A = 3.122$, $B = -5.036$; and Trichoptera $A = 3.044$, $B = -4.610$. Insect biomass will be grouped by plot and compared using a one-way ANOVA and a post hoc Bonferroni pair-wise test.

Insect biomass was higher in the forest than in the open masticated areas. However, this patterns was not significant because it was driven by a particular night in 2010 when there was a massive midge emergence in the Forest. However, this incident underscores that because Forest areas are more humid and somewhat cooler, these stands may be hotbeds of insect reproduction (Fig. 16).

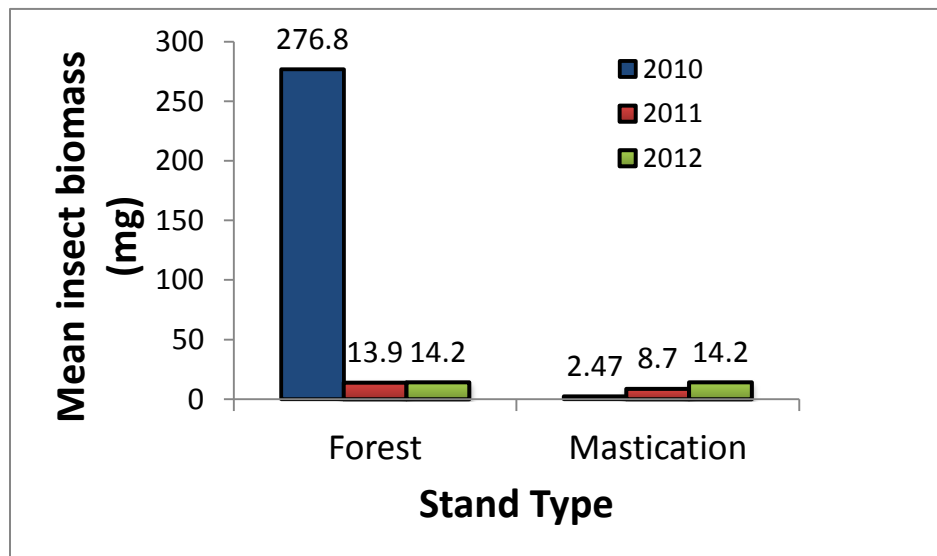


Figure 16. Insect biomass as measured for Forest versus open Mastication plots. No significant differences were found across years.

Effects of Moonlight on Bat Activity: We measured activity patterns of bats based on sonar analysis and compared to a Light Index derived from integrating NOAA data on moon rise/moon set times with estimations of cloud cover data from SURFRAD station using radiative flux analysis from long-wave radiation (Fig. 17). There was a significant difference between activity levels in Open areas with a significant decline in activity on high illumination night and significant increase in Forest activity ($X^2 = 31.1$, $P < 0.001$).

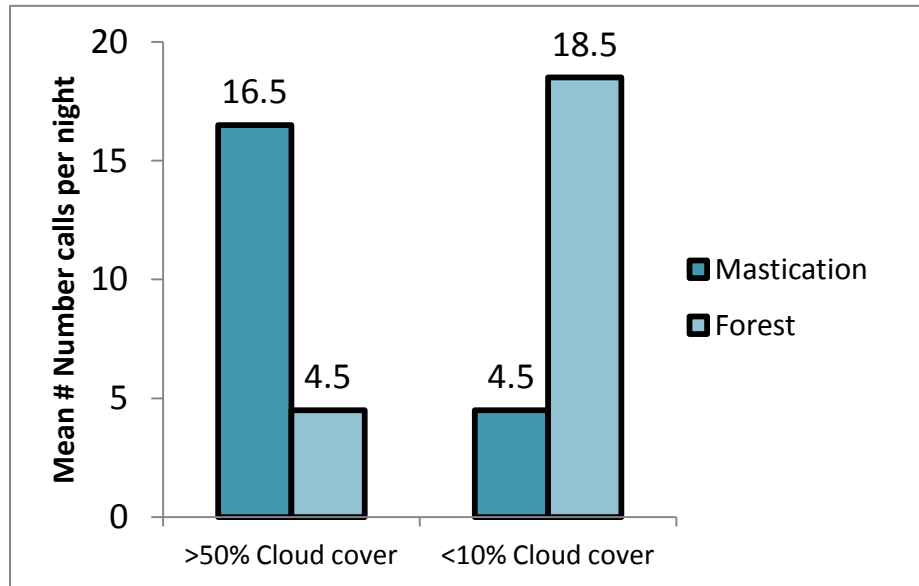


Figure 17. Mean number of calls per night compared across nights for Open area activity with > 50% cloud cover versus < 10% cloud cover.

Conclusions: Mastication treatments of forest stands provided a mosaic of habitat diversity in a localized area, providing for coexistence of eight bat species. Usage patterns among species differed relative to environmental conditions. These data clearly indicated that bats show high variation in habitat use that at times even goes against their foraging patterns predicted by ecomorphology theory. In particular, the use of forested areas by species more adapted to open areas when moonlight illumination was high illustrates the importance of forest stands even for these species. However, unnaturally thick forest stands may also effects how forests are used by forest specialists. For example, *M. evotis* and *M. thysanodes*, both known to use predominately cluttered forest habitats, were found to use Edge habitat more than predicted. Our data appear to suggest that because of this alteration of foraging strategy by clutter specialist, the edge specialist species *M. ciliolabrum*, moved into more cluttered habitat, possibly being displaced by high levels of use by *M. evotis* and *M. thysanodes*. In addition, insect biomass data did not find significant differences between open and forested habitats. However, because current methods do not allow for resolution of guano to the species level, species-specific analysis of insect diets is unknown.

GEER CANYON VERSUS PLUMELY CANYON BAT ACTIVITY AND INSECT STUDY

We compared bat activity patterns as well as insect availability between Geer Canyon that has year-round water availability with Plumely Canyon which does not. We used a borrowed SM2 detector from Bat Conservation Internationals Water and Wildlife Program to conduct the study. The SM2 was moved between canyons every nine days.

Results

Total number of calls recorded in Geer Canyon over was 1,536 and in Plumely Canyon 1,287. Wilcoxon Rank Sum Test indicated no significant differences between groups. Shannon Index comparisons also showed highly similar indices between the canyons ($H'_{\text{Geer}} = 0.754$, $H'_{\text{Plumely}} = 0.718$). Frequency of occurrence is illustrated in Fig. 18.

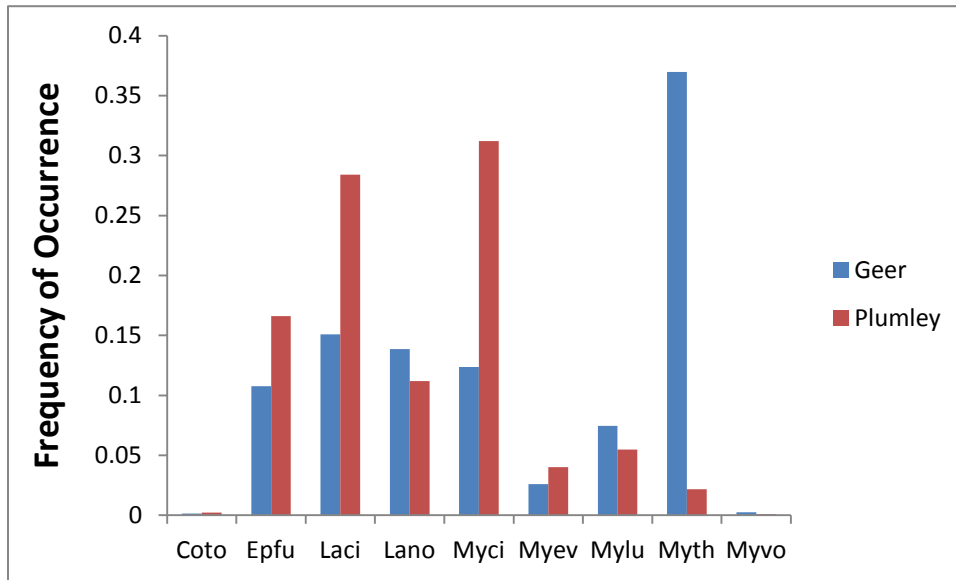


Figure 18. Frequency of occurrence of bat species comparing Geer Canyon with Plumely Canyon. No significant differences were found.

Insect Biomass per Canyon: Geer Canyon (Total Biomass = 470.8mg) had significantly higher biomass of insects than did Plumely Canyon (Total Biomass = 35.8 mg)($P = 0.01$). Species-specific distribution also varied between canyons (Fig. 19).

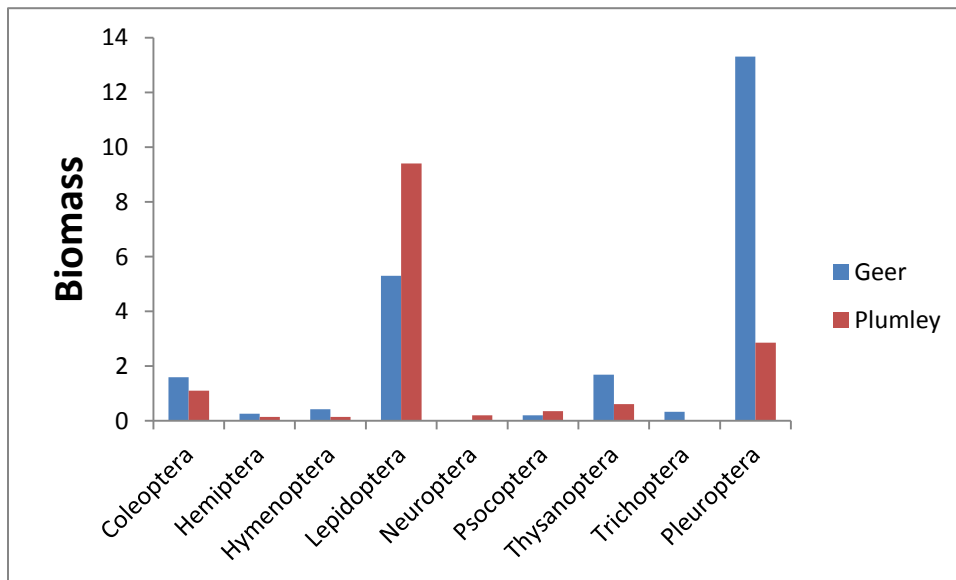


Figure 19. Distribution of insect orders and biomass between Geer and Plumely canyons. This graph does not show Diptera due to the pronounced difference between canyons that swamp all other species.

The largest difference between Plumely and Geer canyons was in the biomass of Diptera, which are water-emergent insects (Fig. 20). Geer Canyon had significantly more Diptera than did Plumely ($P = 0.01$). Shannon indices showed much higher insect diversity in Plumely Canyon ($H' = 0.48$) as opposed to Geer Canyon ($H' = 0.11$) which was dominated by Diptera during the sampling period.

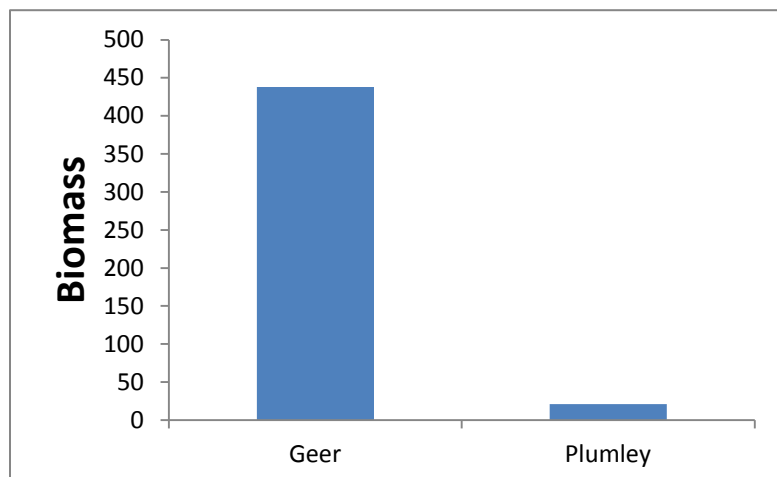


Figure 20. Distribution of the insect order Diptera between Geer and Plumley canyons.

Conclusions

Surprisingly, bat diversity was highly similar in both canyons. Geer Canyon was dominated by *M. thysanodes* due to the presence of a maternity colony. Plumely Canyon was dominated by *M. ciliolabrum*, *L. cinerues*, and *E. fuscus*, but had greater evenness among coexisting species than did Geer Canyon. Insect biomass was much higher in Geer Canyon, but most of this was due to extremely high numbers of Diptera. Plumely Canyon had much less biomass, but had greater evenness among insect species. In addition, Plumely was dominated by a preponderance of Lepidoptera, a prime food for many bats species and moths are not water-emergent insects. Further investigation will be necessary to determine how bats are using dry versus wet canyons especially in terms of sex distribution and roost site formation in relation to bachelor versus maternity colonies.

PIT-TAG REACQUISITION DATA FROM GEER CANYON YEAR 6

Four individuals PIT-tagged in 2006 registered drinking activity at Geer Canyon water hole. All individuals were female *M. thysanodes*. Three individuals, two female *M. thysanodes* and a female *M. evotis*, register in 2010 did not appear present in 2012. All of these reacquired individuals are at least 7 years old (Table 2).

Table 2. Reacquisition data for PIT-tag reader year six.

SITE	NUMBER	TAGYR	ACQYR	REACYR	REACYR	REACYR	REACYR	SPP
GEER	C8CE	2006		2007			2012	MYTH
GEER	B8FB	2006		2007	2008	2010	2012	MYTH
GEER	DIE1	2006	2006	2007	2008	2010	2012	MYTH
GEER	BC7D	2006		2007			2012	MYTH
GEER	CDE6	2006			2008	2010		MYEV
GEER	3890	2006		2007	2008	2010		MYTH

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