BAT SPECIES ABUNDANCE AND DISTRIBUTION, THE EFFECTS OF FOREST THINNING AND BURNING ON BAT FORAGING ACTIVITY, INCIDENCE OF WEST NILE VIRIS IN BATS, AND WATER HOLE EXPERIMENTS AT HEIL VALLEY RANCH, 2007

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Draft Submitted: (1) 15 Nov. 2007, **(2)** 14 December 2007

Final Report Submitted:

SUMMARY POINTS FOR 2007 FIELD SEASON

- 139 bats were captured and released
- Of all captures 53.5% were *Myotis evotis*
- Sonar grid data showed significant increase in activity in the Burn site
- We located a new maternity roost for Townsend's big-eared bat housing about 450 individuals
- West Nile Virus showed a spike in incidence in 2007 with
- We generate a model showing water loss due to climate change and potential effects on bat populations in Colorado

INTRODUCTION

In this, the 6th year of study of bats at Heil Valley Ranch, we continue to monitor populations, water use, habitat use, food base, incidence of WNV infection, and new roost site locations.

Part I: ***Tracking Species Abundance and Distribution:*** Because bats are difficult to catch and tend to change their foraging patterns and areas seasonally, long-term studies of bat populations are required to ascertain presence and abundance of bat populations. In 2004, a previously undocumented eastern bat species (*Pipistrellus subflavus*) was found on OSMP property in north Boulder (Armstrong et al., 2005) In addition, because bats are susceptible to human disturbance, infectious diseases, and are responsive to climate variation, year-to-year patterns may shift and thus require long-term efforts to understand regional ecology, population dynamics and stability. In this third year of capture and release data collection, we are beginning to better understand ecological patterns of bats at HVR in Boulder County.

In 2002, we began mist netting bats at ephemeral and permanent water holes throughout HVR. In addition, radio tagging of some lactating females allowed us to locate and map maternity roost sites as well as conduct outflight counts and document emergence times of various colonies and species. These data are paramount in the management and conservation of bat species in the West. In 2007, we continued with our mist netting efforts that contributed new information on species abundance and species presence at HVR.

Part 2: Forest Thinning Practices: Protecting critical foraging habitats for bats is of paramount importance. Loss of critical foraging habitat can affect the stability and survivorship of bat populations. Several critical factors need be in balance. For insectivorous bats, foraging in less cluttered habitats is most energy efficient because obstacle avoidance is limited as they hunt. However, foraging in open areas has its own risks, such as predation from owls at night, or other raptors before darkness (Erickson and West, 2002). *Myotis* bats also show choice in selecting habitat types along a riparian corridor in Utah, whereas *Eptesicus fuscus* showed no significant differences among habitats (Rogers, 2006).

Human impacts to foraging habitats usually come in the form of forest cutting and various other degradations. Clear-cutting practices have likely caused the loss of some bat populations, however, the overall effects will never truly be known due to lack of precutting sampling for bats. Studies in the West indicate bat activity is low where clear-cutting has occurred. Conversely, the less-severe practice of forest thinning may enhance bat foraging areas (Parker et al., 1996; Perdue and Steventon, 1996; Humes et al., 1999; Patriquin and Barclay, 2003). However, Tibbels and Kurta (2003) found that thinned areas of red-pine did not enhance foraging areas for bats which instead used intra-forest clearing more predominately. In 2003, we began a study to understand the effects of forest thinning practices currently underway at HVR using set 0.25 hectare plots in four habitat types. This study continued in 2006, but monitoring for insects occurred in each plot beginning in 2006.

Part 3*: *Incidence of West Nile Virus in HVR Bat Populations: Insectivorous bats are the predominant foragers of night-flying insects, including adult mosquitoes (Gould 1955; Griffin et al. 1960; Findley, 1993; Altringham, 1996). In Colorado, myotis species consume mosquitoes in variable amounts (Adams, 2003). In Moffat County, *M. lucifugus* consumed 21% of their diet in flies and mosquitoes (Diptera), with other myotis species consuming about 10% of their diet in flies (Freeman, 1984). Diets of bats, however, differ regionally. Adams (1993, 1997) found seasonal differences in consumption of species of Diptera by *M. lucifugus*, from 28% in spring to 38% in fall. The relationship between mosquito consumption and incidence of WNV in bats remains unknown. However, some bat species have tested positive for WNV infection in New York (Marra et al., 2003; Davis et al., 2005). Because Boulder, Larimer, and Weld counties were the "hot-zone" for human cases of WNV infections in 2003, we initiated a study to document the incidence of WNV infection in *Myotis* species at HVR in 2004 and continued this monitoring in 2005. We did not intend to check for WNV in bats in 2006, but we did gather blood samples in September because there was a sudden rise in incidence of WNV in Boulder County.

Part 4.—Water Hole Visitation Patterns: Of 29 *M. thysanodes* individuals PIT-tagged in 2006, 14 were reacquired (48%) by the PIT-tag antenna placed in the artificial water hole. Of the 24 female *M. thysanodes* PIT-tagged 13 were reacquired (54%). Of seven *M. evotis* PIT-tagged, two were reacquired. Three *M. lucifugus* were PIT-tagged, but none were reacquired. Two male *C. townsendii* were PIT-tagged and none were reacquired. We will replicate this experiment in 2007.

Part 5.—Census at Caribou Ranch: We began a census of bats at Caribou Ranch which offers unique challenges for bat survey work. Like any new site, data were scarce, but provided us a beginning to understanding bats species abundance and distribution at this high-elevation site.

METHODS

Capture and Release: We continued mist netting bats in Geer Canyon and at Ingersol Quarry. All captures were made in mist nets, and all individuals were released within one hour of capture.

Radio-telemetry: We telemetried lactating female Townsend's big-eared bat (*Corynorhinus townsendii*) at Ingersol Quarry in an attempt to find this maternity roost. This was the third transmitter placed on this species at this site over the last two years.

Marking & PIT-tag data acquisition.—As in 2006, bats captured in Geer Canyon were PIT-tagged with BioMark 12mm tags under the dorsal skin between the shoulder blades. Individuals were kept for 20 minutes to ensure closure of the entry wound, and then released. A plate antennae and recorder were positioned in an artificial water holes west of a maternity colony of *Myotis thysanodes*.

Figure 1. (left) plate antennae placed 1 cm below water surface in artificial water hole, (middle) water proof data recording station with solar panel, data reader, antennae tuner, and car battery, and (right) PIT-tagging station with ring antennae reader.

We tested two ***Null Hypotheses***: **$H0_1$**: There will be no significant differences in drinking patterns between reproductive and none reproductive female *M. thysanodes*. **$H0_2$**: There will be no significant difference in number of drinking passes recorded for female reproductive *M. thysanodes* between the artificial calcium water hole and the natural water hole.

Bat foraging pattern surveys: Pettersson 240x time-expansion, sonar detectors interfaced with

Sony tape recorders were position in 0.25 hectare fixed plots in unthinned forest, recently thinned forest, open meadows, and a burned site in Geer Canyon. ***Null hypotheses:*** **H_0:** There are no significant differences in bat foraging activity as measured by sonar pass recordings between unthinned, human-thinned, montane meadow, and natural burned habitats (i.e. treatment plots). **H_1:** Bat species composition will not be significantly different between treatment plots.

Sonar Library Hand-Release Recordings: As in previous years, we continue to develop a call-library for Colorado bats using recording from hand-released known individuals for comparison to unknown calls collected in the sonar plots.

Insect Diversity and Sonar Plots: As in 2006 we hung insect light traps in each plot on night when sonar recordings were in progress and at times when sonar plots were not in progress. The lights were hung at sunset and allowed to run for three hours after sunset to sample for insects during the time interval that bat sonar grids were run. Although we ordered Malaise traps to help with collecting insects of larger body size, they were backordered and did not arrive until September 2007. We plan to deploy these traps in 2008.

Blood Sampling for West Nile Virus**:** Because there was a significant increase in WNV incidence rates among humans in Boulder County, we once again drew blood from post-reproductive adult bats captured at Ingersol Quarry. Bats were captured in mist nets and anaesthetized using Isoflurane. Approximately 30 µL of blood was drawn from an artery in the interfemoral membrane by puncturing with a 25 gauge needle. Samples were collected in heparinized, glass capillary tubes (Lollar and Schmidt-French 2002; Kunz and Nagy 1988). Pressure was applied to the wound with the researcher’s index finger, until blood-loss ceased. Individuals were returned to capture sacs for 20 minutes to ensure that bleeding did not reoccur.

Individuals were then released. Blood samples were put on ice and later spun down using an Autocrit Ultra 2 micro-centrifuge and stabilized using Ambion, Ribopure blood kits. Samples were analyzed using a 1-step RT-PCR kit (Ambion) called Retroscript (Kauffman, et al., 2003).

***Null hypothesis*: H_0:** There will be no antibodies present for WNV in bats at HVR.

RESULTS

Capture Data: Netting began on 20 May and continued until 10 October. A total of 139 bats was captured (Table 1). Of these, 73 were *M. evotis*, 21 were *M. lucifugus*, 16 *M. thysanodes*, 13 *Eptesicus fuscus*, 8 *M. ciliolabrum*, , 4 *C. townsendii*, 3 *Lasionycteris noctivagans*, and 1 *Lasiurus cinereus*.

Table 1. *Capture and release data from 2006, organized by date and capture site.*

SPP	DATE	YEAR	SEX	REPRO	WGT	SITE	AGE
COTO	6/13/2007	2007	F	P	14	IQ	A
COTO	6/13/2007	2007	F	NLNP	9.7	IQ	A
COTO	6/26/2007	2007	F	NLNP	12.7	IQ	A
COTO	9/21/2007	2007	F	NLNP	12.7	IQ	A
EPFU	5/31/2007	2007	M	NS	NW	IQ	A
EPFU	6/13/2007	2007	M	NS	17.3	IQ	A
EPFU	6/13/2007	2007	M	NS	16.1	IQ	A
EPFU	6/13/2007	2007	M	NS	16.3	IQ	A
EPFU	6/13/2007	2007	M	NS	15.7	IQ	A
EPFU	6/13/2007	2007	M	NS	17.8	IQ	A
EPFU	6/13/2007	2007	F	P	12.1	IQ	A
EPFU	6/26/2007	2007	M	S	20.3	IQ	A
EPFU	6/26/2007	2007	M	S	18.5	IQ	A
EPFU	8/8/2007	2007	M	NS	17.7	IQ	A
EPFU	8/8/2007	2007	M	NS	16.3	IQ	A
EPFU	8/20/2007	2007	M	NS	20.2	IQ	A
EPFU	9/21/2007	2007	M	S	20	IQ	A
LACI	6/4/2007	2007	M	NS	NW	GEER	A
LANO	6/13/2007	2007	M	NS	10.5	IQ	A
LANO	6/13/2007	2007	M	NS	10.8	IQ	A
LANO	10/4/2007	2007	M	S	11	IQ	A
MYCI	6/13/2007	2007	M	NS	NW	IQ	A
MYCI	6/26/2007	2007	N	NS	7.6	IQ	A
MYCI	8/8/2007	2007	M	NS	3.7	IQ	A
MYCI	8/8/2007	2007	M	NS	6	IQ	A

MYCI	8/20/2007	2007	F	NLNP	3.9	IQ	A
MYCI	8/20/2007	2007	F	NLNP	5	IQ	A
MYCI	9/21/2007	2007	F	PL	5.7	IQ	A
MYCI	9/21/2007	2007	F	NLNP	7.6	IQ	A
MYEV	8/20/2007	2007	M	NS	5.8	IQ	A
MYEV	9/21/2007	2007	M	NS	7.1	IQ	A
MYEV	5/31/2007	2007	F	P	NW	IQ	A
MYEV	6/13/2007	2007	F	NLNP	7	IQ	A
MYEV	6/13/2007	2007	M	NR	NW	IQ	A
MYEV	6/13/2007	2007	M	NS	NW	IQ	A
MYEV	6/13/2007	2007	M	NS	5.7	IQ	A
MYEV	6/13/2007	2007	M	NS	6.8	IQ	A
MYEV	6/13/2007	2007	M	NS	6.3	IQ	A
MYEV	6/13/2007	2007	M	NS	6	IQ	A
MYEV	6/13/2007	2007	F	P	NW	IQ	A
MYEV	6/13/2007	2007	F	P	6.7	IQ	A
MYEV	6/13/2007	2007	M	NS	7.4	IQ	A
MYEV	6/13/2007	2007	M	NS	5.8	IQ	A
MYEV	6/13/2007	2007	M	NS	5.7	IQ	A
MYEV	6/13/2007	2007	M	NS	6.3	IQ	A
MYEV	6/14/2007	2007	M	NS	5.7	GEER	A
MYEV	6/26/2007	2007	M	NR	7.3	IQ	A
MYEV	6/26/2007	2007	M	S	6.8	IQ	A
MYEV	6/26/2007	2007	M	S	7.4	IQ	A
MYEV	6/26/2007	2007	M	S	5.9	IQ	A
MYEV	8/8/2007	2007	F	NLNP	5.8	IQ	A
MYEV	8/8/2007	2007	F	NLNP	5.5	IQ	A
MYEV	8/8/2007	2007	M	NS	5.8	IQ	A
MYEV	8/8/2007	2007	M	NS	5.7	IQ	A
MYEV	8/8/2007	2007	M	NS	7.4	IQ	A
MYEV	8/8/2007	2007	M	NS	5.6	IQ	A
MYEV	8/8/2007	2007	M	NS	5.3	IQ	A
MYEV	8/8/2007	2007	M	NS	5.5	IQ	A
MYEV	8/8/2007	2007	M	NS	6	IQ	A
MYEV	8/8/2007	2007	M	NS	4.5	IQ	A
MYEV	8/8/2007	2007	M	NS	5.8	IQ	A
MYEV	8/8/2007	2007	M	NS	5.6	IQ	A
MYEV	8/20/2007	2007	M	NS	NW	IQ	A
MYEV	8/20/2007	2007	M	NS	NW	IQ	A
MYEV	8/20/2007	2007	M	NS	NW	IQ	A
MYEV	8/20/2007	2007	M	NS	5.9	IQ	A
MYEV	8/20/2007	2007	M	NS	5.6	IQ	A
MYEV	8/20/2007	2007	M	NS	NW	IQ	A
MYEV	8/20/2007	2007	F	PL	NW	IQ	A
MYEV	8/20/2007	2007	F	PL	NW	IQ	A
MYEV	9/2/2007	2007	M	NS	NW	IQ	A
MYEV	9/2/2007	2007	M	NS	NW	IQ	A
MYEV	9/2/2007	2007	M	NS	NW	IQ	A

MYEV	9/2/2007	2007	M	NS	NW	IQ	A
MYEV	9/21/2007	2007	M	NS	NW	IQ	A
MYEV	9/21/2007	2007	M	NS	NW	IQ	A
MYEV	9/21/2007	2007	M	NS	NW	IQ	A
MYEV	9/21/2007	2007	M	NS	NW	IQ	A
MYEV	9/21/2007	2007	M	NS	NW	IQ	A
MYEV	9/21/2007	2007	M	NS	NW	IQ	A
MYEV	9/21/2007	2007	M	NS	NW	IQ	A
MYEV	9/21/2007	2007	M	NS	NW	IQ	A
MYEV	9/21/2007	2007	M	NS	7.1	IQ	A
MYEV	9/21/2007	2007	M	NS	8.6	IQ	A
MYEV	9/21/2007	2007	M	NS	8.3	IQ	A
MYEV	9/21/2007	2007	M	NS	8.8	IQ	A
MYEV	9/21/2007	2007	F	PL	NW	IQ	A
MYEV	9/21/2007	2007	M	S	6.8	IQ	A
MYEV	9/21/2007	2007	M	S	7.6	IQ	A
MYEV	9/21/2007	2007	M	S	6.5	IQ	A
MYEV	9/21/2007	2007	M	S	6.8	IQ	A
MYEV	9/21/2007	2007	M	S	7.9	IQ	A
MYEV	9/21/2007	2007	F	PL	7.3	IQ	A
MYEV	9/21/2007	2007	F	NLNP	7.8	IQ	A
MYEV	9/21/2007	2007	M	NS	7.7	IQ	A
MYEV	9/21/2007	2007	M	NS	7.6	IQ	A
MYEV	10/4/2007	2007	M	S	NW	IQ	A
MYEV	10/4/2007	2007	M	S	NW	IQ	A
MYEV	10/4/2007	2007	M	S	NW	IQ	A
MYEV	10/4/2007	2007	M	S	NW	IQ	A
MYEV	10/4/2007	2007	M	S	NW	IQ	A
MYEV	10/4/2007	2007	M	S	NW	IQ	A
MYLU	6/13/2007	2007	M	NS	7.2	IQ	A
MYLU	6/13/2007	2007	M	NS	NW	IQ	A
MYLU	6/13/2007	2007	M	NS	7.3	IQ	A
MYLU	6/13/2007	2007	M	NS	7.2	IQ	A
MYLU	6/13/2007	2007	M	NS	6.7	IQ	A
MYLU	6/13/2007	2007	M	NS	7.8	IQ	A
MYLU	6/13/2007	2007	M	NS	9.5	IQ	A
MYLU	6/13/2007	2007	M	NS	7.8	IQ	A
MYLU	6/13/2007	2007	M	NS	8	IQ	A
MYLU	6/13/2007	2007	M	S	8.6	IQ	A
MYLU	6/25/2007	2007	F	NLNP	6.8	IQ	A
MYLU	6/26/2007	2007	M	NS		IQ	A
MYLU	6/26/2007	2007	F	P	9.2	IQ	A
MYLU	8/20/2007	2007	M	NS	NW	IQ	A
MYLU	9/21/2007	2007	F	NLNP	NW	IQ	A
MYLU	9/21/2007	2007	F	NLNP	NW	IQ	A
MYLU	9/21/2007	2007	M	NS	NW	IQ	A
MYLU	9/21/2007	2007	M	NS	NW	IQ	A
MYLU	9/21/2007	2007	M	NS	NW	IQ	A

MYLU	9/21/2007	2007	M	NS	10.4	IQ	A
MYLU	9/21/2007	2007	M	S	NW	IQ	A
MYTH	5/20/2007	2007	F	P	NW	GEER	A
MYTH	6/13/2007	2007	F	NLNP	8.2	IQ	A
MYTH	6/13/2007	2007	M	NS	6	IQ	A
MYTH	6/13/2007	2007	M	NS	7.8	IQ	A
MYTH	6/14/2007	2007	F	NLNP	6.4	GEER	A
MYTH	6/14/2007	2007	F	NLNP	7.6	GEER	A
MYTH	6/14/2007	2007	F	P	9.9	GEER	A
MYTH	6/25/2007	2007	M	S	7.4	GEER	A
MYTH	6/26/2007	2007	M	S	7.1	IQ	A
MYTH	8/8/2007	2007	M	NS	7.9	IQ	A
MYTH	8/8/2007	2007	F	PL	8.2	IQ	A
MYTH	8/20/2007	2007	M	NS	NW	IQ	A
MYTH	8/20/2007	2007	M	S	NW	IQ	A
MYTH	9/21/2007	2007	M	NS	NW	IQ	A
MYTH	9/21/2007	2007	M	NS	NW	IQ	A
MYTH	10/4/2007	2007	M	S	NW	IQ	A
	10/10/2007	**NO**	**BATS**	**PRESENT**		**IQ**	

Sonar Plot Analyses: Forest, Burn, Meadow, and Thinned plots were sampled (Fig. 1).

Fig. 1. Locations of ¼ hectare sonar plots in Meadow, Thinned, Forest, and Burn habitats **A**) near Ingersol Quarry and **B**) in Geer Canyon.

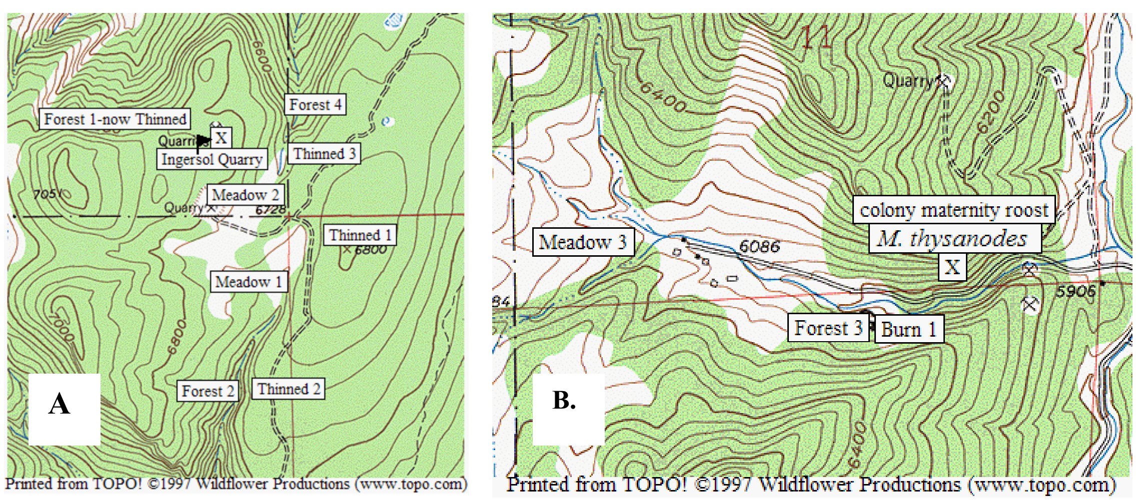
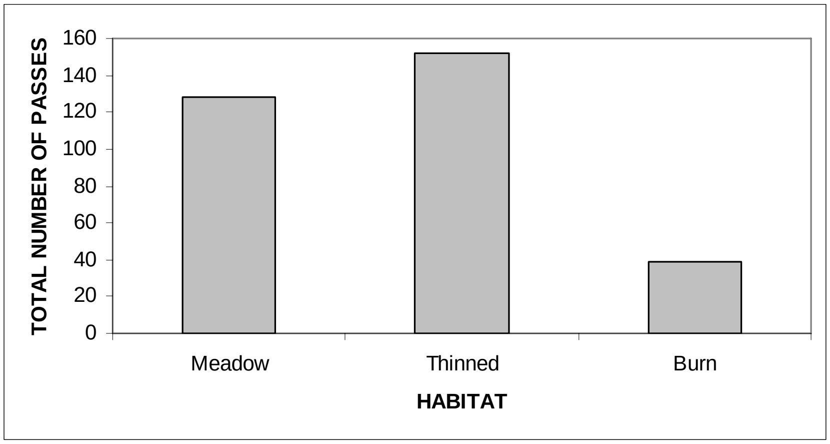


Figure 2. shows distribution of sonar activity by plot for 2007. Thinned habitats showed the highest activity by foraging bats, followed by Meadow habitat. Although the burn habitat was lower in activity that meadow and thinned, 2007 showed much higher activity in this area than in previous years. For example in 2006, only four passes were recorded in the Burn site,

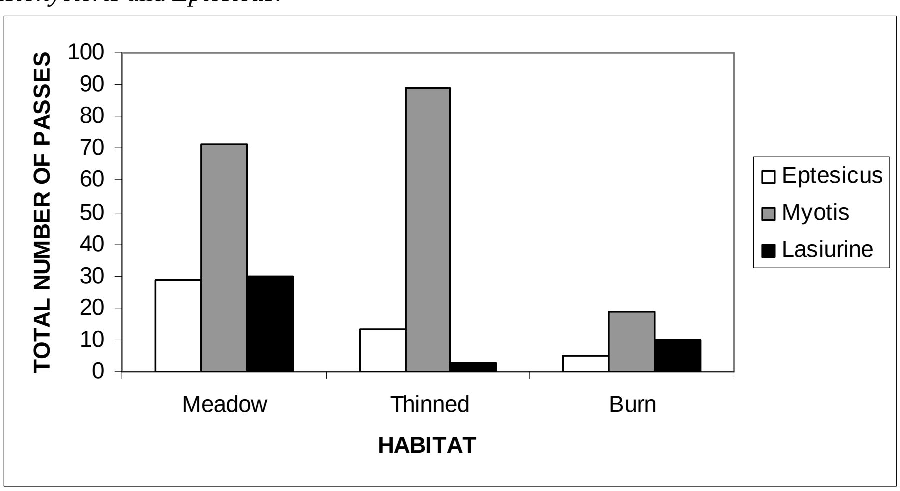
whereas in 2007, 39 passes were recorded.

Figure 2. Number of passes by foraging bats in the different habitat plots, Meadow, Thinned, and Burn. As in other years, Thinned habitat had the highest number of passes. There has been a distinctive change in use of the Burn site in 2007, with 39 passes recorded, the highest over the four years that we have been tracking this site.



In terms of species associates for each habitat type, myotis species were most common in all habitats. Surprisingly, lasiurines (Lasiurus cinereus and Lasionycteris noctivagans) were more common than in other years in Thinned and Burn habitats (Fig. 3). The increase in use of the Burned habitat by all three groups suggests a more profitable foraging arena for bats as this area recovers.

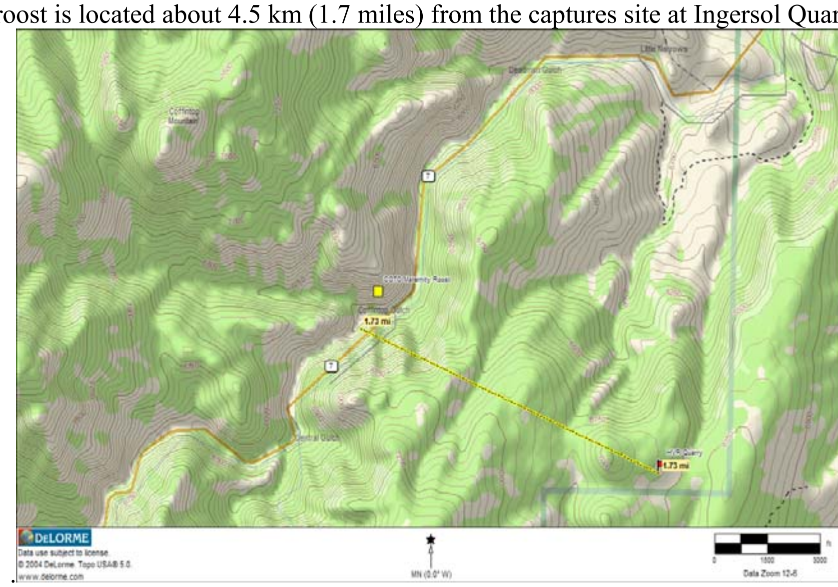
Figure 3. Distribution of three genera of bats inhabiting HVR. Most common were myotis species, followed by *Lasiurus* and *Lasionycteris* and *Eptesicus*.



Radio-Telemetry Results

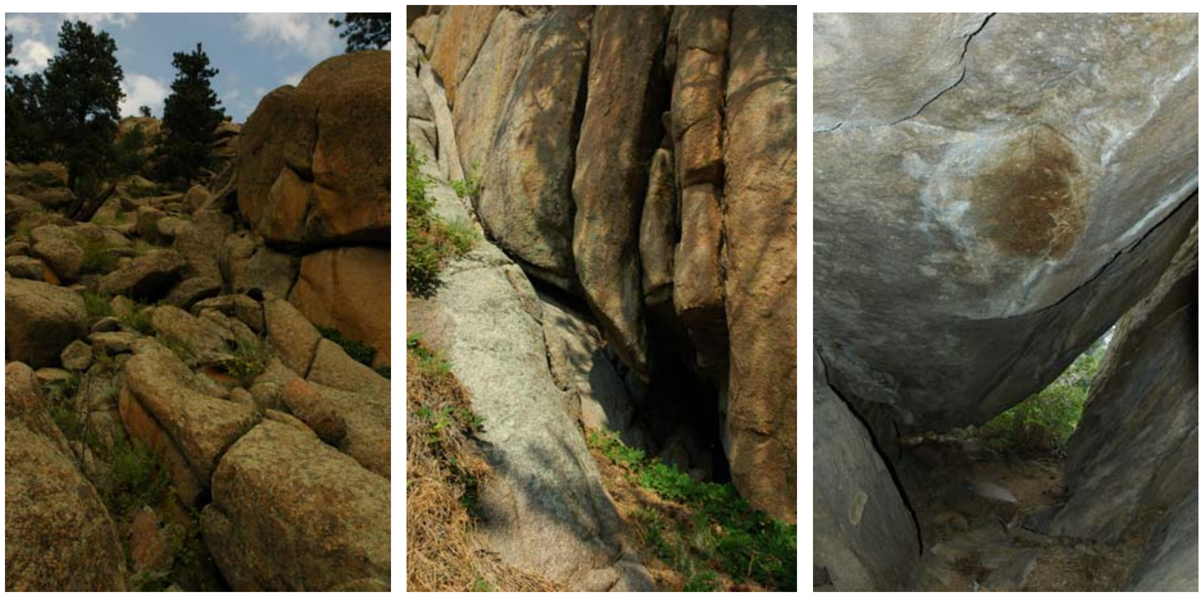
On August 8, 2007, a post-lactating female Townsend's big-eared bat (*Corynorhinus townsendii*) (weight 11.2g and 46.0 forearm), was captured at the Ingersol Quarry at Heil Valley Ranch, Boulder County, Colorado (UTM coordinates 13T/0474000/444710 NAD 27, elevation 6800 feet, Fig. 4). The bat was radio-tagged and tracked during the following days. On August 12, the bat was located in a rock crevice in the South Saint Vrain Canyon on the south-east side of Coffintop Mountain (UTM 13T/0471588/4448442 NAD 27, elevation 6200 feet).

Fig. 4. Map showing location of newly found Townsend's big-eared bat (*C. townsendii*) roost along Colorado Highway 7. This roost is located about 4.5 km (1.7 miles) from the captures site at Ingersol Quarry, HVR.



The temperature sensitive radio-tag indicated a temperature of 94°F, indicating body temperature of that individual during roosting. The bat was located in a cluster of other Townsend's big-eared bats that was about 3 feet (1 m) in diameter. Assuming that there was approximately 1 bat per 2 inches square gives an estimate of 450 bats in this cluster. This is one of about 15 known maternity roosts of this species in Colorado and is one of the larger maternity roosts found in the state thus far. The roost is located on a rocky hillside dominated by ponderosa pine. The opening of the roost faces south-east (Fig. 5).

Figure 5. Three photographs taken on 13 August showing a newly found maternity roost of Townsend's big-eared (*Corynorhinus townsendii*) bat previously unknown, located in St. Vrain Canyon on the south-east side of Coffintop Mountain (UTM 13T/0471588/4448442 NAD 27, elevation 6200 feet). Photo left shows approach to roost opening. Photo middle shows emergence opening to roost site. Photo right shows internal structure of roost site after the bats had left for the season. Stained area indicated where bats were roosting. Estimated colony size was 450 individuals, a highly significant roost site, one of only 15 known sites in the state.



On August 23, Lea' Bonewell and Mark Hayes returned to the roost site, but all bats had vacated the roost. Presumably the bats had begun dispersal to fall or winter roost sites. Significant amounts of ceiling stains were found, which is characteristic of this species. A significant amount of fresh and older guano was present.

PIT-tagging

A total of 29 bats were PIT-tagged at HVR. Of these, 8 were tagged in Geer Canyon and consisted of 5 *M. thysanodes*, 1 *M. evotis*, 1 *M. lucifugus*, and 1 *L. noctivagans*. The other 21 were tagged at Ingersol Quarry and consisted of 8 *M. evotis*, 4 *M. lucifugus*, 3 *E. fuscus*, 3 *M. thysanodes*, 1 *M. ciliolabrum*, and 2 *C. townsendii*. Thus far, a total of 70 bats have been PIT-tagged at HVR.

PIT-Tag Reacquisition at Plate Antenna

The plate antenna was placed in an artificial water hole in Geer Canyon as in 2006.

Table 2. *Numbers of PIT-tagged bats reacquired by the plate antenna by species and sex in 2007.*

	M. thysanodes	***M. evotis***	***M. lucifugus***	***C. townsendii***
Males	0	0	0	0
Females	7	1	1	0

Reacquisition data were gathered for repeated visitations by nine bats. Of these, three were tagged in 2006 (Table 3).

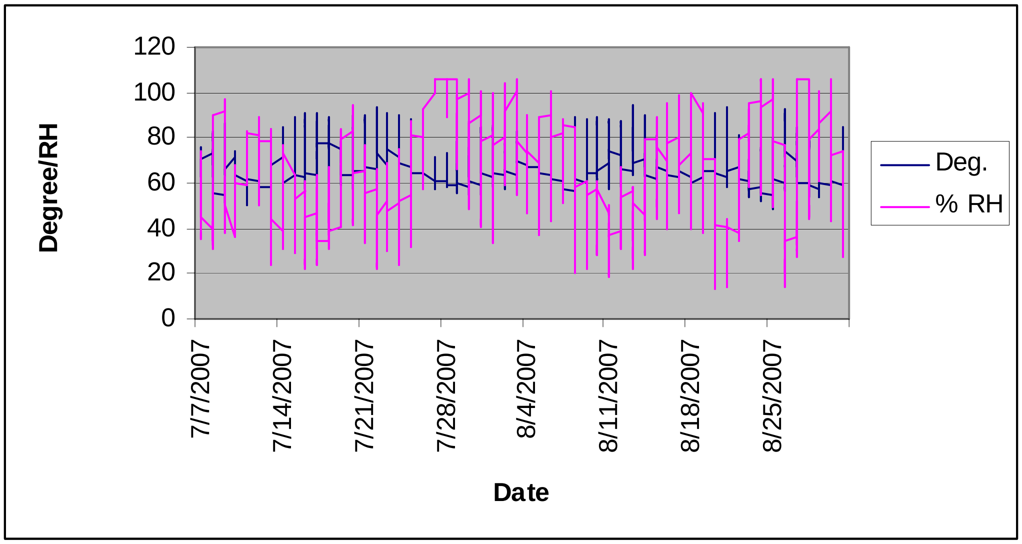
Table 3. *PIT-tagging data showing year tagged (TAGYR) reacquired years (REACYR)for 2006 & 2007 by site and species (SPP). Reproductive condition at time of tagging is also presented.*

SITE	NUMBER	TAGYR	REACYR	REACYR	SPP	REPRO
GEER	579	2006	2006		MYLU	NS
GEER	FEB	2006			MYTH	L
GEER	AD5	2006			MYTH	L
GEER	AF0B	2006			MYLU	NS
GEER	C746	2006	2006	2007	MYEV	L
GEER	D460	2006			MYLU	NS
GEER	C8CE	2006		2007	MYTH	L
GEER	F018	2006	2006		MYTH	L
GEER	B8FB	2006		2007	MYTH	L
GEER	EDAF	2006			MYEV	NS
GEER	3FB3	2006			MYEV	NS
GEER	821	2006			MYEV	NLNP
GEER	F1C9	2006	2006		MYTH	NS
GEER	D63C	2006			MYTH	NS
GEER	2B9E	2006			MYTH	L
GEER	CEF4	2006			MYTH	NS
GEER	DIE1	2006	2006	2007	MYTH	NLNP
GEER	A3FD	2006	2006		MYTH	L
GEER	BF62	2006	2006		MYEV	NS
GEER	48F6	2006	2006		MYTH	L
GEER	BF06	2006	2006		MYTH	L
GEER	A778	2006	2006		MYTH	NLNP
GEER	CDE6	2006			MYEV	L
GEER	386A	2006			MYTH	L
GEER	3237	2006	2006		MYTH	L

GEER	8E8C	2006			MYLU	NS
GEER	0FE5	2006			MYEV	NLNP
GEER	45E0	2006			MYTH	L
GEER	802D	2006	2006		MYTH	L
GEER	7767	2006	2006		MYTH	L
GEER	42C4	2006			COTO	NS
GEER	DCE0	2006			COTO	NS
GEER	E06E	2006			MYTH	L
GEER	783B	2006			MYTH	L
GEER	C2BC	2006	2006		MYTH	NS
GEER	948C	2006			MYTH	L
GEER	494C	2006			MYTH	L
GEER	BC7D	2006		2007	MYTH	NLNP
GEER	15E3	2006			MYTH	L
GEER	3890	2006	2006	2007	MYTH	L
GEER	094F	2006	2006		MYTH	NLNP
GEER	DED7	2007			MYTH	P
GEER	453C	2007			LACI	NS
GEER	3821	2007		2007	MYTH	NLNP
GEER	352A	2007			MYEV	NS
GEER	DC0D	2007			MYTH	P
GEER	BD85	2007		2007	MYTH	P
GEER	1F17	2007			MYTH	S
GEER	D959	2007		2007	MYLU	P
QUARRY	5CD4	2007			MYEV	P
QUARRY	35EA	2007			EPFU	NS
QUARRY	60B5	2007			MYEV	NS
QUARRY	530E	2007			MYEV	P
QUARRY	8ED7	2007			MYEV	NS
QUARRY	D245	2007			MYLU	NS
QUARRY	42AC	2007			MYLU	NS
QUARRY	B6E2	2007			MYTH	P
QUARRY	3510	2007			COTO	P
QUARRY	519B	2007			MYTH	NS
QUARRY	C608	2007			MYEV	NS
QUARRY	1579	2007			MYCI	NS
QUARRY	F6EF	2007			EPFU	S
QUARRY	DEE7	2007			MYLU	P
QUARRY	CBC4	2007			MYTH	S
QUARRY	CE4F	2007			MYEV	S
QUARRY	44FF	2007			MYEV	S
QUARRY	8933	2007			MYEV	S
QUARRY	740E	2007			EPFU	S
QUARRY	42DB	2007			MYLU	NS
QUARRY	D491	2007			COTO	P

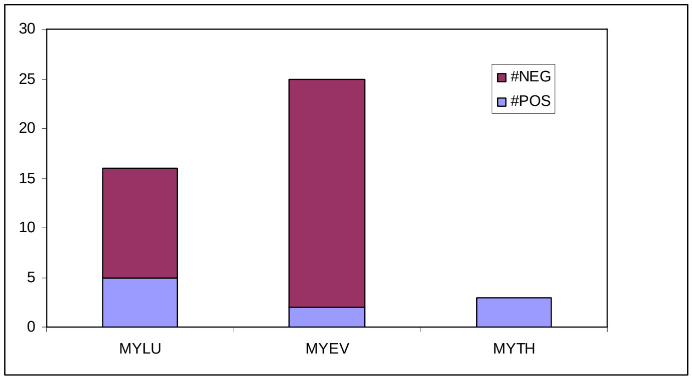
Ambient Temperature at the Artificial Water Hole.—The temperature/humidity data logger placed at the artificial water hole showed that these variables tended to covary inversely as in 2006 (Fig. 6).

Figure 6. Line graph of ambient temperature and relative humidity at the artificial water hole in Geer Canyon



West Nile Virus at HVR. Of 44 samples collected in 2007, 10 were positive (22.7%). Species incidence rates were as follows: For *M. lucifugus* 5 of 16 (31.2%) were positive, 2 of 25 (8%) *M. evotis* were positive, and 3 of 3 (100%) *M. thysanodes* were positive (Fig. 10). These data indicate a definite spike in incidence of WNV in bats at HVR. Of course, these individuals with high antibody counts have likely cleared the virus and are survivors of the infection.

Figure 10. Incidence of individuals affected by WNV as measures by antibody titers in blood. MYLU = *Myotis lucifugus*, MYEV = *M. evotis*, MYTH = *M. thysanodes*.



DISCUSSION

Bat population trends at HVR. Capture data over the last six years shows that the majority of captures at HVR are males. Of the 671 individuals captured over the six years, 470 (70%) were males, whereas females compose about 30% of all captures (201 of 671). In 2007, approximately 83.3% of captures were males, whereas 16.7% were females (Table 7).

Table 7. *Comparative capture data by male/female across four years at HVR for individuals of known sex.. BNN = bats per net per night.*

Species	2002	2003	2004	2005	2006	2007	Total
MYCI	1 (♀)	7 (4♀, 3♂)	7 (1♀, 6♂)	5 (1♀, 4♂)	3 (♂)	7 (♂)	**23 (7 ♀, 16 ♂)**
MYEV	21 (6♀, 11♂)	15 (9♀, 6♂)	34 (9♀, 25♂)	61 (19♀, 42♂)	53 (19 ♀, 34 ♂)	73 (11 ♀, 62 ♂)	**184 (62 ♀, 118 ♂)**
MYLU	23 (12♀, 11♂)	14 (7♀, 7♂)	9 (1♀, 8♂)	50 (7♀, 43♂)	44 (6 ♀, 38 ♂)	20 (3 ♀, 17 ♂)	**139 (32 ♀, 10 ♂)**
MYTH	17 (13♀, 4♂)	22 (9♀, 11♂)	14 (11♀, 3♂)	16 (11♀, 5♂)	36 (26 ♀, 10 ♂)	16 (6 ♀, 10 ♂)	**103 (70♀, 33 ♂)**
MYVO	0	1 (♀)	4 (♀)	14 (6♀, 8♂)	1 (♂)	0	**20 (8 ♀, 12 ♂)**
EPFU	7 (♂)	38 (♂)	18 (1♀, 17♂)	9 (♂)	0	13 (1 ♀, 12 ♂)	**72 (2 ♀, 62 ♂)**
LACI	1 (♂)	0	2 (♂)	0	0	1 (♂)	**3 (0 ♀, 3 ♂)**
LANO	1 (♂)	1 (♂)	2 (♂)	0	0	3 (♂)	**4 (0 ♀, 4 ♂)**
COTO	1 (♂)	0	2 (♀)	3 (2♀, 1♂)	2 (♂)	4 (♀)	**8 (4 ♀, 4 ♂)**
Total	**32 ♀, 36 ♂**	**30 ♀, 66 ♂**	**25 ♀, 63 ♂**	**46 ♀, 112 ♂**	**47 ♀, 88 ♂**	**21 ♀, 105 ♂**	**693 (206 ♀, 461 ♂)**
BNN	**6.8**	**5.6**	**7.3**	**15.8**	**11.25**		

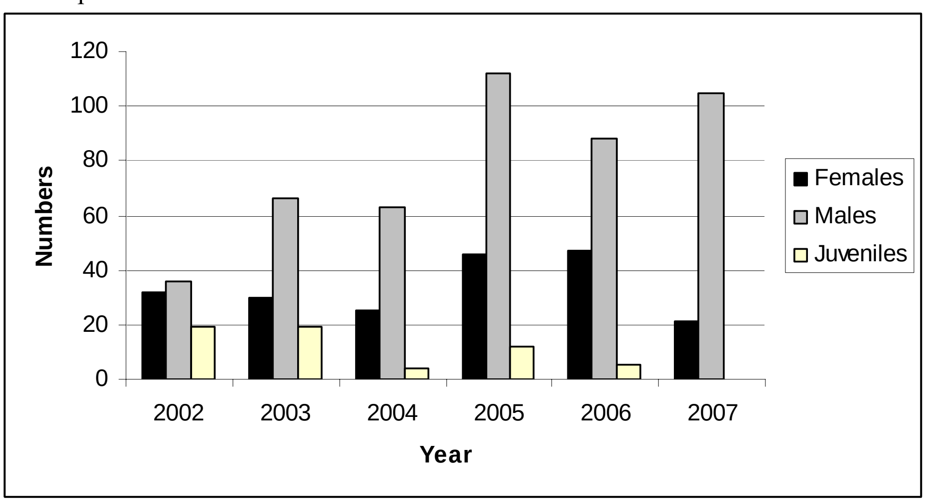
The age distribution at HVR continues to favor adults. Of all captures in 2007, none included juveniles (Table 4). The general trend over the last six years had been a decline in number of captures of juvenile bats at HVR. This pattern remains inexplicable.

Table 8. *Comparative age distributions per species across years at HVR.*

Species	2002	2003	2004	2005	2006	2007
M. ciliolabrum	A(1) J(0)	A(3) J(2)	A(6) J(1)	A(3) J(2)	A (4) J (0)	A (7) J (0)
M. evotis	A(8) J(9)	A(8) J(7)	A(32) J(2)	A(55) J(6)	A (53) J (1)	A (73) J (0)
M. lucifugus	A(19) J(4)	A(14) J(0)	A(9) J(0)	A(49) J(1)	A (37) J (3)	A (20) J (0)
M. thysanodes	A(13) J(4)	A (12) J(10)	A(13) J(1)	A(13) J(3)	A (38) J (1)	A (16) J (0)
M. volans	A(1) J(0)	A(1) J(0)	A(4) J(0)	A(14) J(0)	A (1) J (0)	A (0) J (0)
E. fuscus	A(5) J(2)	A(38) J(0)	A(18) J(0)	A(9) J(0)	A (0) J (0)	A (13) J (0)
Total	**A(47) J(19)**	**A(76) J(19)**	**A(82) J(4)**	**A(143) J(12)**	**A (133) J (5)**	**A (137) J (0)**

Graphically, the trend data show declines in relative captures of females and juveniles across six years of the study (Fig. 8). A general shift in sex ratio is being observed at HVR, skewed towards increase in males is also apparent. 2002 showed a relatively equal sex ratio. The shift toward male sex dominance began in 2003and continued through 2007. Whether or not this is due to actual changes in reproductive effort and age-recruitment or due to changes in visitation patterns to the water holes remains unclear.

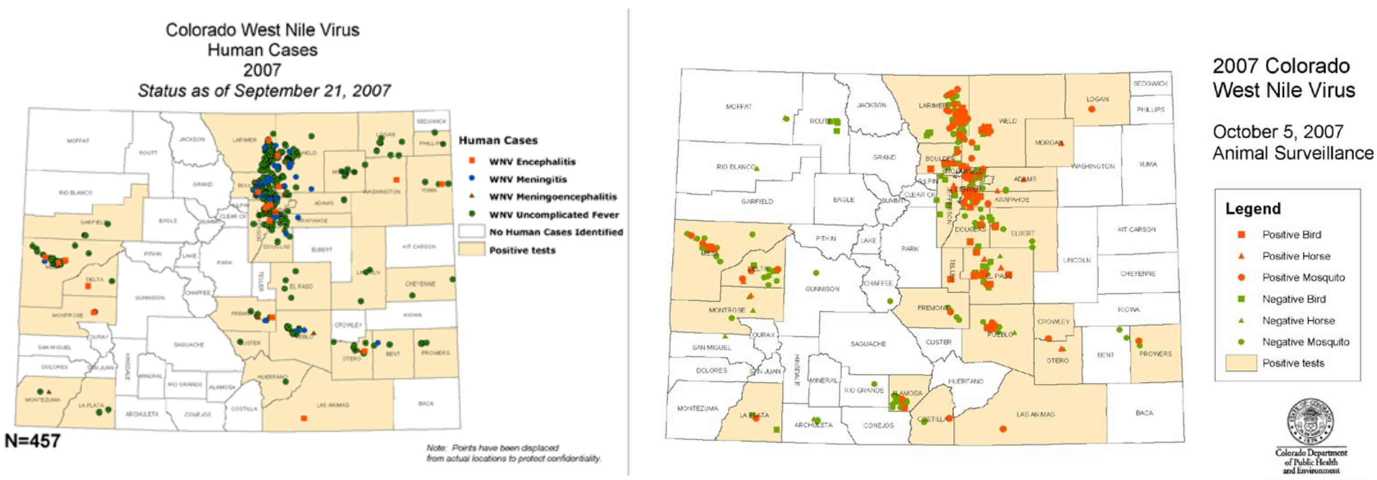
Fig. 8. Raw capture data showing trend from 2002 to 2007 for incidence of female, males, and juveniles across years. All species are pooled. Data from Table 7.



The ratio of juveniles to adults has also decreased over the six years. Figure 9 shows the patterns of decrease in reproductive frequency across years calculated as percent capture of juveniles per year.

West Nile Virus. There were 95 cases of human/nonhuman animal incidence reported in 2007 for Boulder County with two deaths resulting, which was the county with highest incidence in the state (Fig. 9). Continued monitoring is important as clearly bats are being infected by WNV. Although we don't know infection rates, antibody test outcomes that indicate survival of the virus, may also indicate that a reduction in bat species populations may occur in 2008, as we observed in 2004.

Figure 9. Map provided by the CDC showing human and nonhuman animal incidence rates by County in Colorado.



Sonar Plot Analyses.--Sonar data from 2007 showed the continued importance of meadows and thinned plots for foraging by bats. Despite the thinning efforts, *M. evotis*, a clutter specialist, continues to occur in very high numbers at HVR, with highest percentage of captures occurring in 2007 (53% of all captures). One of the major changes in foraging activity and species richness in our sonar plots, was apparent recovery of the Burn area which in 2007 recorded the highest number of passes over the last four years (39) and included myotis species as we ll as *Eptesicus fuscus*, the hoary bat (*Lasiurus cinereus*) and the silver-haired bat (*Lasionycteris noctivagans*). We intend to continue this part of the survey in 2008. It appears that Burn is composed of more insects than in previous years thereby attracting bat to forage there.

BOULDER COUNTY BAT REPRODUCTION AND CLIMATE CHANGE

The effects that climate change may have on wildlife populations are of keen interests to ecologists, and large-scale effects are already being documented for some species (see Walther, Burga & Edwards 2001; Humphries, Umbanhowar & McCann 2004). Changes in global climate are expected to show sever outcomes relative to seasonal ambient temperatures, amount of precipitation, and snowpack levels in the West. Indeed, current climate models indicate that snowpack in western North America is already in serious decline due to significant warming (Mote et al. 2005) and the projected adverse effects on regional hydrology are of serious concern (Hamlet & Lettenmaier 1999; Cayan et al. 2001; Mote 2003a, 2003b, Mote et al. 2005; McCabe & Clark 2005; Regonoda et al. 2005; Knowles et al. 2006). For example, timing of stream flow measured from 1948 to 2002 from 302 western North America gauges show coherent trends towards earlier onset of springtime snowmelt (Stewart, Cayan & Dettinger 2005), having significant effects on water availability during the hottest summer months.

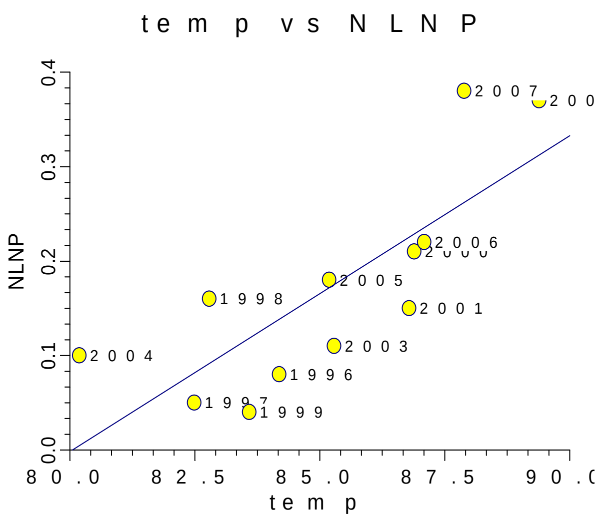
Data from the Earth Systems Research Laboratory (ERSL) managed by the National Oceanic and Atmospheric Administration (NOAA) shows that warming has been increasing at accelerated rates in Colorado. Mean January temperature for Denver, Colorado for 2006 was up 4.4^0 C from average. Further, much of the warming has occurred at higher elevations (> 3000m), affecting snow pack levels. In the upper Colorado River basin temperatures were 1.3^0 C above average between 1999 and 2004 and in 2005 were 1.8^0 C above average. Temperatures in most upper river basins in Colorado showed increases of 2.1^0 C above average between 1999 and 2004 and 3.55^0 C in 2005 during January. Climate change is not only restricted to temperature, but also precipitation levels throughout the West. A recent best-case scenario for climate changes in the Colorado River basin between 2010-2039 is that 1^0C more heat, will result in

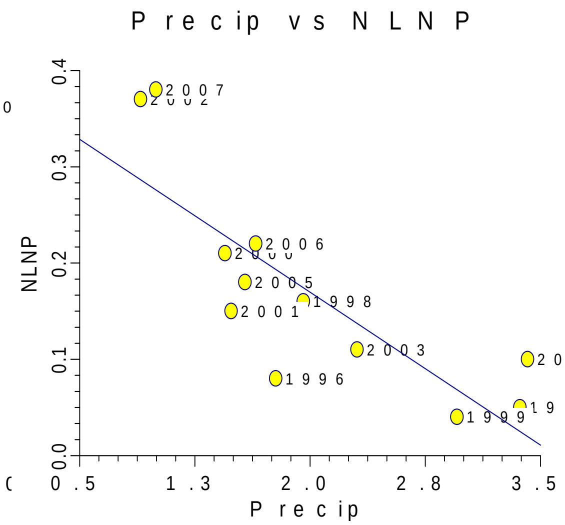
24% less snow, 3% less precipitation and 36% less water storage (Christensen et al. 2004). Such changes will have profound effects on regional wildlife.

Bat Population Trends: Long-Term Analysis: Data gathered over the last 12 years on reproductive trends in Boulder County bat reproductive efforts are presented here in reference to estimated changes in regional climate towards a warming trend. Herein I plot capture data on female reproductive effort cast as frequency of females captured that were not reproductive by year. These data are plotted against mean annual temperature and mean annual precipitation by year (Fig. 10).

This 12 year data set rivals any other study known to me for collecting from the same region over such a long time interval. This has now allowed us to have preclinate change data to compare with those gathered as warming beginning to take effect in Colorado. Because of their microclimate specializations and propensity for losing large amounts of body water during roosting, bats can be considered as a "canary in the coal mine" as an indicator species for what will eventually cascade though ecosystems, affecting all forms of life. The data thus far collected from local bat population, shows a disturbing trend toward declining populations (Fig. 10).

Fig. 10. A. Number of nonreproductive females (NLNP) plotted against mean temperature for the months of June, July and August of each year (1995-2007). $r = 0.81$, $r^2 = 0.65$, $P = 0.001$. B. Number of nonreproductive females (NLNP) plotted against mean precipitation for the months of June, July and August of each year (1995-2007). $r = 0.78$, $r^2 = 0.61$, $P = 0.002$.





For temperature, female bats show a significant trend in suppressed reproductive output as ambient temperature increases. Conversely, female bats show significantly suppressed reproductive output when precipitation is lower.

Further, we have used the PIT-tag data from the artificial water hole to construct a model that predicts how environmental water loss will affect lactational ability and reproductive effort in the fringed myotis, *M. thysanodes*. What follows is a model showing how the curves in Figure 11 were obtained.

Model
Our general model is based upon average number of visits per night by lactating females of a *M. thysanodes* colony and extrapolated to account for the predicted water resource needs for a hypothetical colony of 100 lactating females. *M. thysanodes* is a medium-sized bat and is representative of *Myotis* species throughout North America. We estimated an average amount of water taken on each pass by myotis bats in the field by injecting water into their mouths and recording amount holding capacity (*n* = 6, mean 2.5 ml, SD 0.8ml).

The Generalized Model for estimating climate-induced loss of water resources and resultant decline in bat lactation effort

We calculated the following variables based upon our field data and the published literature on lactation in insectivorous bats.

PN = mean water hole passes per night among lactating females
C = mean water consumption per pass per individual in milliliters
N = number of individuals
WCI = nightly water consumption per individual
WCT = nightly water consumption of total individuals
LN = mean number of lactation nights across individuals
WGRS = water needed for group reproductive success

If:

PN x C = WCI

21.6 x 0.25 = 5.40 ml nightly averaged consumed per individual per night

then

WCI x N = WCT

5.40 ml x 100 individuals = 540 ml/night consumed per colony of 100 lactating female bats

and thus

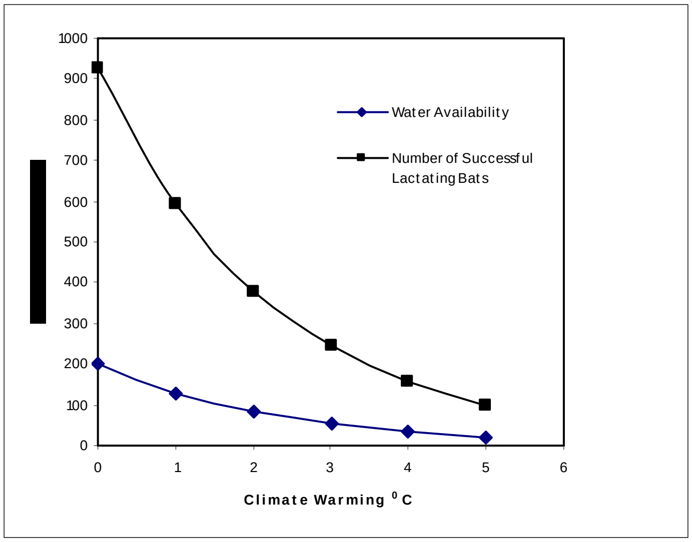
WCT x LN = WGRS

540 x 40 = 21,600 ml (216 liters) of water minimally required to support a colony of 100 lactating female myotis bats for 40* days. Each individual will require about 216 ml (0.216 liters) of water over the 40 day period (* mean number of lactation days for vespertilionid bats (Barclay & Harder 2003).

Taking these calculation and relating them to the average volume of water (200,000 cm^3) contained among four natural water holes near maternity colonies at our field site, we calculated, using the volume of one liter of water (1000cm^3), that on average these water holes hold about 200 liters of water. From our model calculation above, we estimate that each lactating female will require about 0.216 liters of water over a 40 day lactation period. Thereby, each water hole can support approximately 926 lactating female myotis, assuming that stream flow to and/or precipitation at the water hole during this time is zero and that evaporation of the water resource base is near zero. These calculations also do not take into account water removed by other wildlife over the same time period. Combining these data with our data quantifying water visitation by lactating female bats, we can model how declines in water storage by these, and similar, water holes, will affect lactation ability of local female bats (Fig. 11)

For this model we use the conservative scenario of Christensen et al. (2004) where 1^0 C climate change will result in 36% less water storage regionally. We begin our model using 200 liters of available water, our average water hole volume for supporting local lactation efforts for 926 female myotis. From this we generate a decay curve for water loss per degree increase in regional climate warming as predicted by Christensen et al. (2004) (Fig. 4). As modeled, a 1^0 C increase in warming leading to 36% less storage would result in only enough water availability to support 593 of the 926 lactating females, only 593 individuals over the 40 day lactation period. A 2^0 C warming results in only 41% (379) of the 926 females supported during the 40 days lactation period. The model carries out to 5^0 C, where only about 11% of the 926 females would be supported by water availability (Fig. 11).

Fig. 11. Plot of mathematical model showing the relationships between climate warming, loss of storage in natural water holes, and declines in bat lactation ability. See text for further explanation.



Caribou Ranch Census

Several trips were made to Caribou Ranch to census the bat populations. Weather was a major obstacle this summer to our capture success. We did record sonar data from the Ranch to begin to understand what species are resident. Thus far, analysis of sonar calls gives the fringed myotis (*Myotis thysanodes*), the small-footed myotis (*Myotis ciliolabrum*), either the long-legged myotis (*M. volans*) or little brown myotis (*M. lucifugus*) in determinant based upon call fragment, the hoary bat (*Lasiurus cinereus*) as documented species.

FUTURE NEEDS

- Continue to monitor bat populations at HVR in relation to WNV incidence
- Continue to monitor newly discovered *C. townsendii* roost
- Test water samples from Ingersol Quarry and Geer Canyon for water quality
- Continue sonar data collection from forest thinning operation with insect collection
- Continue collecting data on water visitation patterns with the PIT-tag reader
- Continue to gather data on species richness and abundance at Caribou

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