Small Mammals of the Guthrie-Bancroft Farm - Year 7

Colby Hill Ecological Project, Lincoln and Bristol, Vermont

2011 Final Report

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Summary

During July/August of 2011, after a four-year hiatus (2007-2011), small mammals were re-sampled again in ecosystems 1, 6, 14 and 20 on the Guthrie-Bancroft parcel on Colby Hill, Lincoln. A total of 174 captures were made, including 10 species of small mammals. Average trap success among the different habitats was 21.6%. One species, the American Water Shrew *(Sorex palustris)*, was captured for the first time at Guthrie-Bancroft this year, raising the number of species verified from Colby Hill to sixteen since the beginning of the project in 2000. This slow accumulation of species underscores the need for long-term survey work in biodiversity monitoring and environmental impact assessments.

Introduction

There are few long-term (>5-years) studies of small mammal populations. Typically projects last only two to three years, and only some field stations, like the Powdermill Biological Station in Pennsylvania, allow for more long-term studies on mammals (see for example Jaffe et al. 2005). To our knowledge, in Vermont only one long-term (16-year) field study on terrestrial small mammals on Salisbury Ridge in Addison County was published (Brooks et al. 1998). Other long-term work is in progress at the Northwoods Stewardship Center in northeastern Vermont (http://www.northwoodscenter.org/). Since 2000 the Colby Hill Ecological project has offered a unique opportunity to monitor small mammal populations on private land and in more or less successional (farm to forest) ecosystems at mid-level elevation on the west slope of the Green Mountains. The small mammal data from Colby Hill have also made a valuable contribution to the state-wide Small Mammal Project started in 2008, the first phase of which was just completed (Kilpatrick and Benoit 2011). This survey results will eventually be made available online in the form of a Vermont state mammal atlas.

Materials and Methods

In 2011 the number of traps used in each habitat was slighty increased from past years (compare Appendix I). This year, two traplines of 15 stations with two Sherman live traps each were placed in each of the four sampled ecosystems (ES). The pitfall traps were increased to nine in each ecosystem. As in previous years, bait was "old fashioned" oatmeal flavored with peanut butter. Traplines were checked for three consecutive days in the early morning and reset for the next night. A "weather station", consisting of a multi-channel cable-free minimum–maximum Thermo Hygrometer (Oregon Scientific. Inc.) and an all-weather rain gauge (Productive Alternatives, Inc., MN) were placed in ES 20 for the duration of the sampling period and checked and re-set every morning during trap check. During the sampling individuals of *Peromyscus* were marked with a rodent ear punch (National Band & Tag Company, Newport, KY) to identify recaptures. Field procedures complied with guidelines recommended by the American Society of Mammalogists (Animal Care and Use Committee 1998) and in Wilson et al. (1996).

Thirteen individuals of *Peromyscus* sp. were kept for molecular identification to species, also kept were all other animals that died in Sherman or pitfall traps. These specimens have been prepared as scientific vouchers and will be permanently preserved in the Zadock Thompson Natural History Collection (ZTNHC) of the University of Vermont. For the molecular identification of *Peromyscus* genomic DNA from 13 individuals from ES 1, 6 and 14 was extracted from liver, spleen or kidney tissue stored in 95% ethanol using a modified Gentra Puregene (Qiagen, Valencia, CA) Mouse Tail extraction protocol. The quantity and quality of the extracted DNA was assessed using a NanoDrop 1000 spectrophotometer (NanoDrop, Bethesda, MD) and the first 400 bp of the cytochrome *b* mitochondrial gene was amplified by PCR using the primers L14115 and H14541 described by Sullivan et al. (1997). Double-stranded polymerase chain products were purified with an exonuclease and shrimp alkaline phosphatase digestion. Cycle sequencing was accomplished with the forward primer (L14115) and dye terminators (ABI, PRISM ver. 3) and excess dye-labeled terminators were removed by G-50 Sephadex spin columns (Maniatis et al. 1982). Cycle sequencing products were fractionated and visualized on an Applied Biosystems 373 automated DNA sequencer (Applied Biosystems, ABI, Foster City, CA). Sequences obtained were compared to sequence data for *Peromyscus leucopus* and *P. maniculatus* deposited in GenBank® using the BLAST search

procedure (http://www.ncbi.nlm.nih.gov/). In unconstrained parsimony analyses (PAUP) *Peromyscus leucopus* and *P. maniculatus* cluster in separate small clades or species groups, thus can be easily distinguished genetically (Bradley et al. 2007).

Results

2011 Data Overview

Key coordinates for traplines and pitfalls from a Garmin 60csx GPS unit were plotted with reasonable accuracy on a USGS topographic map layer in Google Maps, using GPS Visualizer (Fig.1). The map shows grassland and the old beaver meadow in ES 20 in white and forest in green.

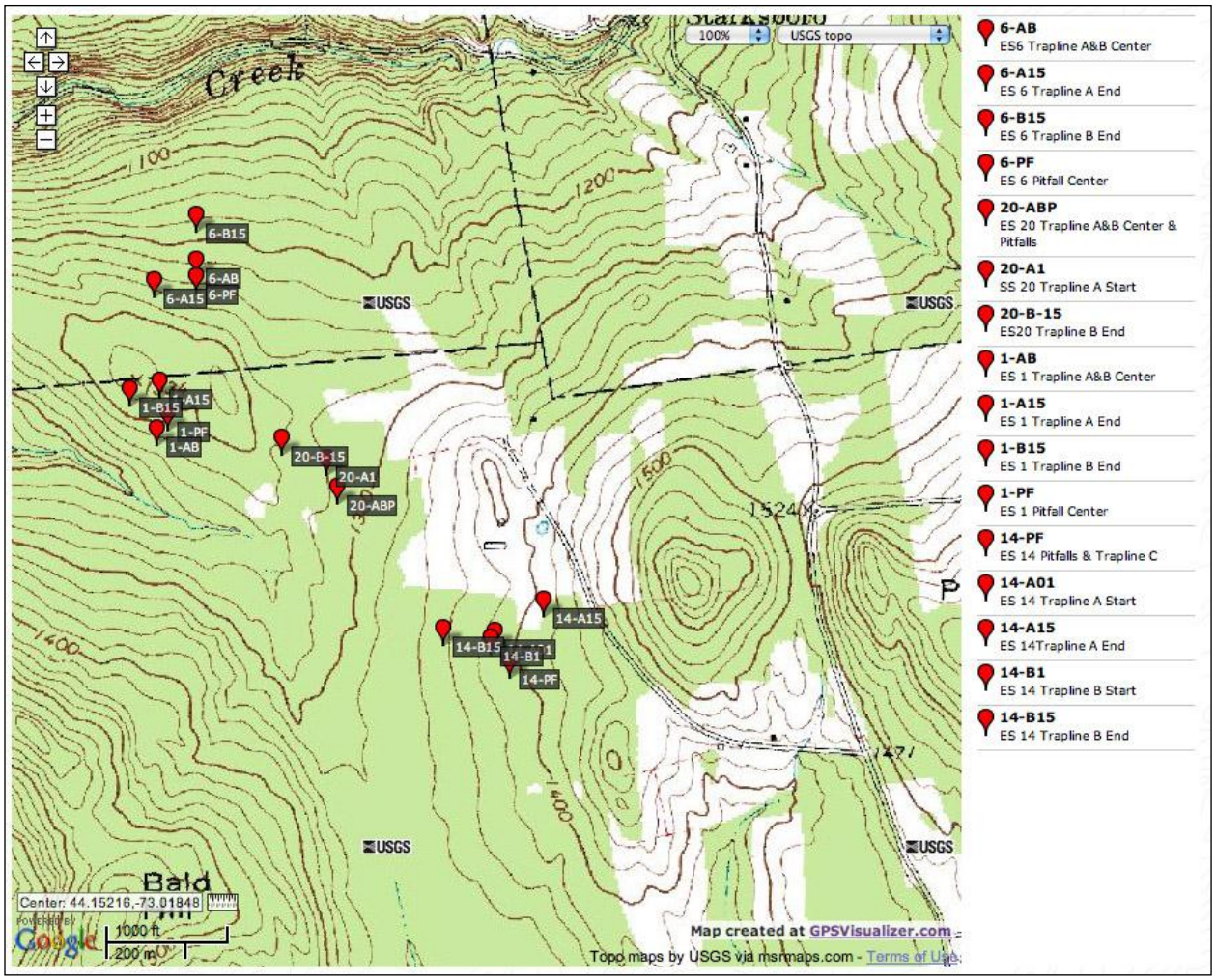

Fig 1: 2011 GPS readings of end and center points of traplines and pitfall trap locations for the four ecosystems (ES 1, 6, 14 and 20) plotted on the USGS topographic map layer for the Guthrie-Bancroft land in Google Maps using GPS Visualizer (http://www.gpsvisualizer.com/).

Table 1 provides an overview of the 2011 captures, trap nights and trap success. This year 174 captures (including recaptures) were made from 10 species of small mammals with a trap effort of 807 trap nights, considerably fewer captures than in the peak year 2007 (290 captures, 12 species in 744 trapnights; see Appendix I). Trap success in 2011 ranged from 9.1% in ES 20 to 31.4% in ES 1 (average 21.6%), also considerably less than in 2007.

Ecosystem (ES) No.	1	6	14	20	Totals 2011
ES Definition:	well-drained mesic red oak hardwood forest	seepy terrain rich northern hardwood forest	poorly drained spruce-fir northern hardwood forest	alder swamp/sedge meadow edge of former beaver pond	
No. of nights trapped	3	3	3	3	12
No. of Traps	68	69	70	69	n/a
Trapnights	204	207	210	186	807
Shrews & Moles					
Blarina brevicauda	10	10	4	4	28
Sorex fumeus					0
Sorex cinereus	3		1		4
Sorex palustris				**1**	**1**
Parascalops breweri					0
Rodents					
Peromyscus sp.	25	23	21		69
Napaeozapus insignis			2	4	6
Zapus hudsonius					0
Microtus pennsylvanicus				3	3
Microtus pinetorum					0
Myodes gapperi	20	5	24	3	52
Synaptomys cooperi					0
Tamias striatus	6		2		8
Tamiasciurus hudsonicus				1	1
Glaucomys volans					0
Carnivores					
Mustela erminea			1	1	2
No. of Species	5	3	7	7	10
No. of Captures	64	38	55	17	174
Trap Success (%)	31.4	18.4	26.2	9.1	21.6

Table 1: 2011 small mammal captures showing ecosystems sampled, species caught and trap success. The new shrew species verified this year is highlighted in bold face.

Captured for the first time on Colby Hill this year was the American Water Shrew (*Sorex palustris*). Previously verified from Colby Hill, but not encountered this year were Smoky Shrew (*Sorex fumeus*), Hairy-tailed mole (*Parascalops breweri*), Meadow Jumping Mouse (*Zapus hudsonius*), Pine Vole (*Microtus pinetorum*), Southern Bog Lemming (*Synaptomys cooperi*), and the two species of flying squirrels (*Glaucomys volans* and *G. sabrinus*).

Detailed comments on species captured in 2011

Shrews

***Blarina brevicauda* (Short-tailed Shrew)**

In 2011 *Blarina brevicauda* was the third most abundant species with 28 individuals captured. It was also slightly more abundant this year than in all previous years (see Appendix I). At the ecosystem level (Appendix II), in six years of sampling in ES 1, the short-tailed shrew had the second highest abundance (N=10) in in 2011. Similarly in six years of sampling in ES 6 this species had the second highest abundance (N=10) in ES 6. In seven years of sampling in ES 14 captures were low this year (N=4) as compared to some previous years (N = 12 in 2001). Only four individuals of *B. brevicauda* were captured in the dense herbaceous cover of ES 20 this year. All year totals for each habitat show that *B. brevicauda* has had very similar abundances in ES1, 6 and 14 and only significantly less in ES 20 (Table 3). George et al. (1986) summarized findings that *Sorex* populations might be negatively correlated with the density of *Blarina*, however in our study both *Sorex cinereus* and *S. fumeus* were also more common in the three ecosystems with high levels of *Blarina* than in ES20 (Table 3). The average weight of *B. brevicauda* captured this year was 17.3 g (range: 12.5 - 21.5g). In 2011 it was captured twice as often (N=10) in traps placed low in the micro-topography than in traps placed high (N=5). The average distance to the nearest log was only 0.74 m, and it showed the largest average nearest log diameter for all species (14.9 cm). The dominant average ground cover was leaf litter (38.6%), followed by herbaceous cover (27.3%) and woody debris (12.7%; see Appendix III for other microhabitat values). Only one individual out of the 28 captures this year was captured in a pitfall trap, all others were captured in Sherman traps.

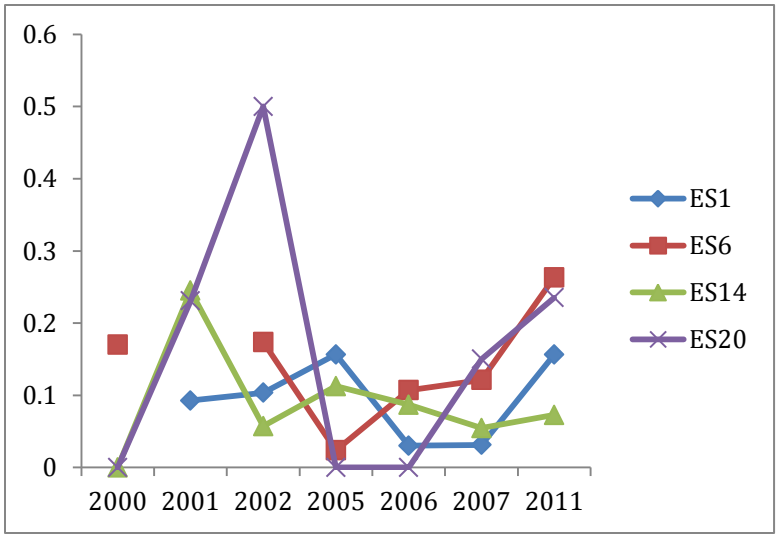

Fig. 2: Proportional abundance (of total catch) of *Blarina brevicauda* over the 7 (6) years in each of the four ecosystems.

***Sorex cinereus* (Masked Shrew)**

With only four individuals, three in ES 1 and one in ES 14, numbers of this tiny shrew were low this year (see Appendix I). All were captured in pitfall traps. The average weight was 4 g (range: 3 - 5.1 g). Average distance to the nearest log was 0.8 m and the average nearest log diameter 8.4 cm. Dominant groundcover was herbaceous (46.3%) followed by leaf litter (43.8%; see App. III for other microhabitat values). Masked shrews have a wide range and broad habitat requirements (Whitaker 2004; Whitaker and Hamilton 1998), which was confirmed in our study by the species' occurrence in all four ecosystems over the seven years of sampling, although they occurred in only two ES's this year (App. II). On Colby Hill, across all years, this species seems to be two to three times more abundant in the dense, well-drained and fern-covered areas where we place our pitfall lines in ES 1, 6 and 14, than in the dense grass and sedge covered areas of the easily waterlogged habitat of ES 20 (Table 3).

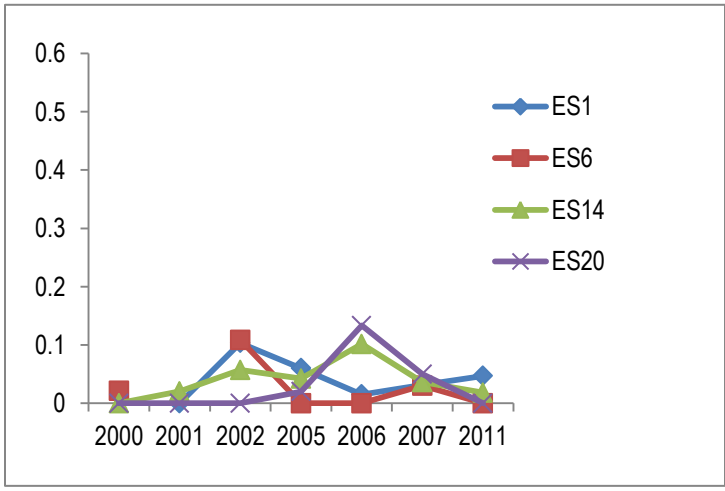

Fig. 3: Proportional abundance (of total catch) of *Sorex cinereus* over the 7(6) years in each of the four ecosystems.

***Sorex palustris* (American Water Shrew)**

This species was caught for the first time this year in the seventh year of sampling in a pitfall trap in ES 20 in 40% herbaceous and 55% grass/sedge groundcover not far from standing and some flowing water (remnant of old beaver pond with small draining creek). Our capture site agrees well with some of the descriptions of habitat characteristic of this species. These include "the sphagnum swamps bordering beaver meadows, grass/sedge marshes, or willow/grass or willow/sedge associations" (Whitaker and Hamilton 1998:51). In Manitoba "most were trapped in grass-sedge marshes and willow (*Salix*)-alder (*Alnus*) shrub zones along creeks and ponds; few water shrews were caught in wet habitats…" (Beneski and Stinson 1987:4). Recent work, using still photography and video, has shows how this shrew detects and captures prey under water (Catania 2008, Catania et al. 2008). Whereas this shrew has only been caught in the seventh year of trapping in ES 20 on Colby Hill, we should keep in mind that "although the species is not often collected and densities apparently are often low, the water shrew is far more abundant than museum collections would indicate" (Whitaker and Hamilton 1998:52). In Vermont only one other individual was taken in the Buck Lake WMA in Washington Co. during the 2008 – 2011 state survey effort and there are only three other Townships with documented records since 1990 (Kilpatrick and Benoit 2011). *Sorex palustris* is a species on Colby Hill that might be worth studying in greater detail, especially its exact distribution in ES 20, population trends, and resource use.

Fig. 2: Photos of the American Water Shrew (*Sorex palustris)* captured on 19 July 2011 in ES 20 on Colby Hill. Total length = 147mm, Tail Length = 64mm, Weight = 11 g. Notice the fringe of stiff hairs along the outer margins of the hind feet in the close-up photograph, an adaptation for swimming.

Rodents

***Napaeozapus insignis* (Woodland Jumping Mouse)**

Only six individuals of this species were recorded in 2011, two in ES 14 and four in ES 20, down from 47 total captures in the record year 2007. Recorded mostly in ES 20 this year *Napaeozapus* was associated with the second highest percentage of herbaceous groundcover (48.3%) this year after *Mustela* (see Appendix III). It is possible that *N. insignis* competes with the Meadow Jumping Mouse *(Zapus hudsonius)* along forest edges (Whitaker 1972). With the increasing succession towards forest in the former beaver meadow in ES20, *Napaeozapus* was captured more often there in 2005 and 2007, whereas *Zapus* was only recorded in small numbers. *Zapus hudsonius* was last evidenced by three individuals captured in ES 20 in 2007 and was not recorded this year. According to Whitaker and Hamilton (1998:274) a third of the food of *Napaeozapus* "may be subterranean fungi, especially *Endogone* and its relatives." It would be interesting to examine if there is a correlation between the proportion of these fungi in the soil and the long-term abundance of this rodent in the different ecosystems on Colby Hill (see Table 3).

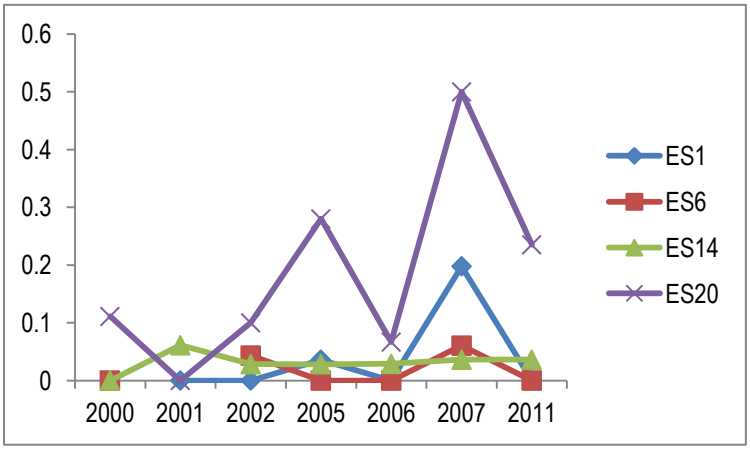

Fig. 4: Proportional abundance (of total catch) of *Napaeozapus insignis* over the 7(6) years in each of the four ecosystems.

***Microtus pennsylvanicus* (Meadow Vole)**

Since its peak occurrence in 2005 (23 individuals), the meadow vole was again recorded in low numbers (N=3) in ES 20 for the third year in a row. As suggested by its common name, this species was associated with the lowest canopy (58.1%), high grass (20%) and herbaceous cover (46.7%), but also with the highest percentage of bare soil (10%) of all species recorded this year, if we ignore the extreme values for the single individual of *Sorex palustris* (see Appendix III). Reich (1981) summarized evidence that annual population densities of *M. pennsylvanicus* seem

to be inversely related to the number of short-tailed shrews (*Blarina brevicauda*). Our data from ES 20 (App. II) do not clearly confirm this relationship, however, no *Blarina* were caught in ES 20 during the peak *Microtus* year (2005).

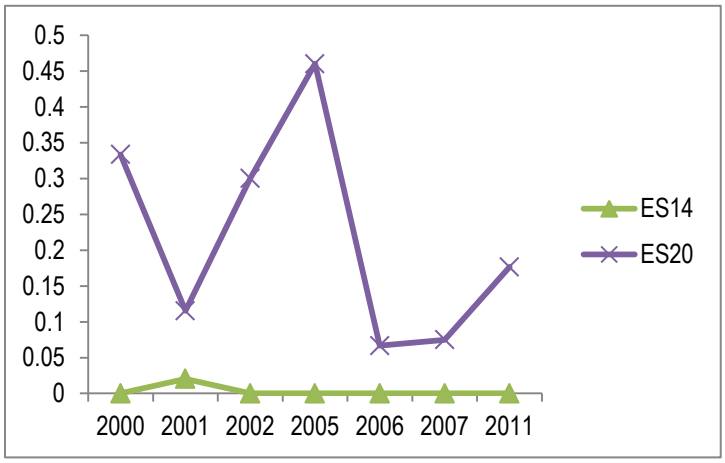

Fig. 5: Proportional abundance (of total catch) of *Microtus pennsylvanicus* over the 7 years in ES 14 (2001 only) and ES 20.

***Myodes gapperi* (Red-backed Vole)**

Fifty-two captures of *M. gapperi* were made this year, the lowest capture since 2005 (Appendix I). This species was caught in all habitats with the most captured in ES 14 (N=24) and the fewest captures in ES 20 (N=3). According to Merritt (1981), high numbers of *M. gapperi* may suppress the abundance of *Napaeozapus insignis*. At least three individuals captured had large active or obvious signs of previous parasitism by botflys (*Cuterebra* spp.). Although one recent paper on botfly parasitism suggested that botfly infestation in *M. gapperi* decreases the probability of survival in Red-backed voles in live traps (Lemaître et al. 2009), all three specimens were caught alive and released. Based on our habitat data *M. gapperi* prefers high canopy cover (96.6%) and leaf litter (46.5%), low grass cover (0.58%) and in areas with some exposed soil (2.98%) often resulting from overturned root balls where the species takes shelter, a common occurrence in ES14.

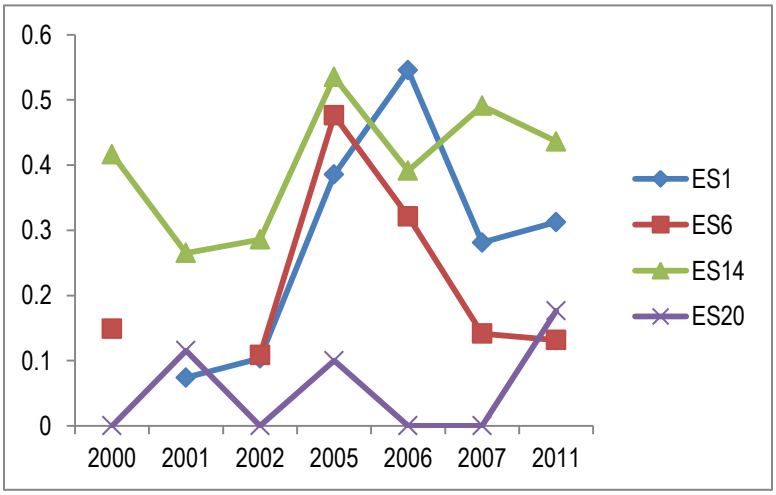

Fig. 6: Proportional abundance (of total catch) of *Myodes*

gapperi over the 7(6) years in each of the four ecosystems.

***Tamias striatus* (Eastern Chipmunk)**

Just as in 2007 eight individuals of the Eastern Chipmunk (*Tamias striatus*) were captured this year, six in ES 1 and 2 in ES 14. With 13 out of 24 individuals captured in ES 1 over all years, this appears to be the preferred of the four ecosystems sampled for this sciurid (Table 3). The microhabitat (App. III) is characterized by large average diameter of nearest trees (25.8 cm) and (consequently) dense average canopy cover (96.1%), and the highest average leaf litter of all species sampled (58.8%). In contrast to our well-drained upland ES 1 habitat, in the long-term study on the Salisbury Ridge in Addison County Eastern chipmunks were most common on the more mesic lower slope dominated by red and sugar maple, American beech and northern red oak (Brooks et al. 1998). ES1 is the warmest ES on the Guthrie Bancroft parcel and a predominantly deciduous hardwood forest as it is preferred by chipmunks (Snyder 1982), but there are pine and spruce trees and a concentration of beech nearby (M. Lapin, pers. comm.).

***Tamiasciurus hudsonicus* (Red Squirrel)**

Only one individual of the Red Squirrel was captured in 2011 at the edge of ES 20 (successional beaver meadow), but still under relatively dense canopy cover (94.8%). Only three other individuals of this squirrel species were captured over the 7 years, one in ES 1, one in ES 6 and a second one in ES20. However, the presence of this species is often observed while trapping in the four ecosystems due to their active diurnal and vocal behavior and it was captured repeatedly by our camera trap in ES 5 this year (see 2011 Camera Trap Report).

***Peromyscus* sp. (White-footed and Deer Mouse)**

As in previous years these were the most abundant species in the study in 2011. However with 69 individuals they showed the third-lowest abundance of the seven years of the study so far. The peak was in 2007 with 119 individual captures. *Peromyscus* showed the highest abundance in ES 6 (N=189) and ES 1 (N=181) across all years. In ES 14 *Peromyscus* has a lower abundance (N=133) than *Myodes gapperi* (N=149) across all years. The two species may be competing for some of the same resources here. *Peromyscus* showed the second highest preference for dense leaf litter ground cover (after *Tamias striatus*) and the second lowest preference for herbaceous

ground cover. Identification to species was addressed this year using molecular techniques on a subset of voucher specimens collected.

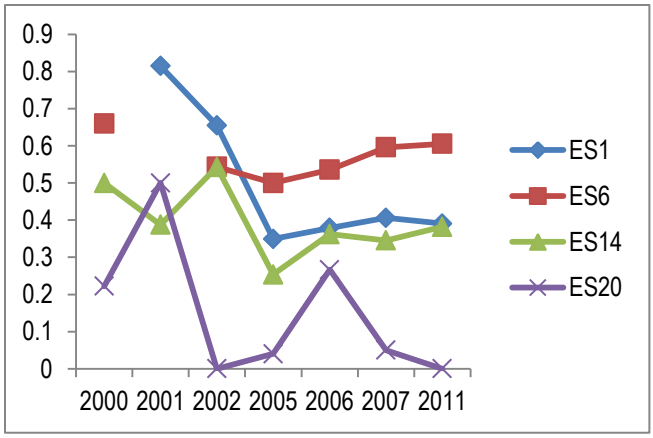

Fig. 7: Proportional abundance (of total catch) of *Peromyscus sp.* over the 7(6) years in each of the four ecosystems.

Peromyscus Species Identification

Table 2 shows the results of the DNA extraction, amplification and sequencing protocol described above. To date this protocol revealed the presence of both Deer Mouse (*Peromyscus maniculatus*) and White-footed Mouse (*P. leucopus*) in Ecosystem 6 (seepy terrain rich northern hardwood forest) and ES 1 (well-drained mesic red oak hardwood forest).

Prep. No.	ES	Stn	DATE	SEX	REP	WT	TL	T	HF	EAR	Nat. Spec.	BLAST Result for mitoch. cyt *b* gene
JD 795	14	A-5	4-Aug-11	F	5 embs	21	158	67	20	11	SS	*P. leucopus*
JD 796	14	B-15	4-Aug-11	M	T=11x5	18.5	163	75	20	14	SS	*P. leucopus*
JD 797	14	B-14	4-Aug-11	F	4 embs	19	164	74	20	14	SS	no result
JD 799	14	B-9	3-Aug-11	M	T=11x6	20	164	78	20	16	SS	*P. leucopus*
JD 800	1	B-9	21-Jul-11	F	3 embs	16	158	79	21	15	SS	*P. leucopus*
JD 801	1	B-13	21-Jul-11	F	no embs	23	168	80	21	16	SS	*P. leucopus*
JD 802	1	A-9	21-Jul-11	F	no embs	18.5	182	82	20	16	SS	*P. leucopus*
JD 803	1	A-5	21-Jul-11	M	T=10x6	24	179	94	21	17	SK	*P. maniculatus*
JD 804	1	A-5	21-Jul-11	F	5 embs	21	178	89	21	16	SS	no result
JD 805	6	A-5	14-Jul-11	F	no embs	23.5	187	92	21	16	SS	*P. maniculatus*
JD 806	6	A-15	14-Jul-11	M	T=11x6	22.5	177	87	20	15	SS	*P. leucopus*
JD 807	6	B-12	14-Jul-11	M	T=11x6	20.5	158	79	22	15	SS	no result
JD 808	6	B-13	14-Jul-11	F	4 embs	17.5	157	76	20	14	SS	*P. leucopus*

Table 2: Origin, reproductive data, external measurements, and BLAST results comparing sequences to sequence data in GenBank®. of 13 *Peromyscus* voucher specimens collected on Colby Hill in 2011.

Both individuals genetically identified as *Peromyscus maniculatus* in Table 2 (JD 803, JD 805) have relatively long tails (52.5 and 49.2% of total length) and JD 805 exhibits the "distinctly bicolored tail" with a "well-defined pencil", and the "soft and luxuriant" fur mentioned for *P. maniculatus* in the classic morphometric comparison of the two species in New England (Choate 1973). However, all these external characteristics may be obscured by individual variation, molt patterns and general condition of the animals. The challenge of correctly identifying these two *Peromyscus* species in the field in New England was already noticed by Osgood (1909). Rich et al. (1996) improved on the morphometric method reported by Choate (1973) achieving a 100% success rate in distinguishing the two species morphometrically with a 12-variable discriminant analysis based on skull measurements and 94% success rate with an 11-variable equation. Reliable non-destructive identification of *Peromyscus* in this region is only possible with the salivary amylase electrophoresis method (Aquadro and Patton 1980, Lindquist et al. 2003), or with the molecular systematic method used here based on Sullivan et al. (1997).

Small Carnivores

***Mustela erminea* (Ermine or Short-tailed Weasel)**

Two individuals of the short-tailed weasel or ermine were caught this year, one in ES 14 and one in ES 20. This species has been most common in ES 20 with seven individuals caught since 2002 (Appendix II). King (1983:4) summarized habitat characteristics stating that "in the Holarctic, ermine tend to…settle in successional or forest edge habitats, in scrub, alpine meadows, marshes, riparian woodlands, hedgerows, and riverbanks rich in small mammals, especially *Microtus* and *Arvicola*…", a characterization met best by our ES 20. Our microhabitat measurements show that the highest herbaceous cover was measured for *Mustela* (Appendix III, f).

Although our reports from previous years expressed some caution in assigning all *Mustela* caught on Colby Hill to *M. erminea* given the overlap in size with the rarer, long-tailed weasel (*Mustela frenata*) described by St. Pierre et al. (2006), we are quite certain that all weasels caught on Colby Hill to date were *M. erminea*.

Species Accumulation and Ecosystem Diversity

The species accumulation curve for the six (ES 1 & 6) and seven (ES 14 & 20) years of sampling small mammal data on Colby Hill is shown in Figure 8. Shown is the actual species

accumulation curve (red) and the Sobs curve (blue) generated with the program EstimateS 8.2.0 and defined as the "number of species expected in the pooled *Quadrat* samples, given the empirical data" (Colwell 2009), or as Gotelli and Colwell (2001:380) put it: "The smoothed rarefaction curves thus represent the statistical expectation for the corresponding accumulation curves."

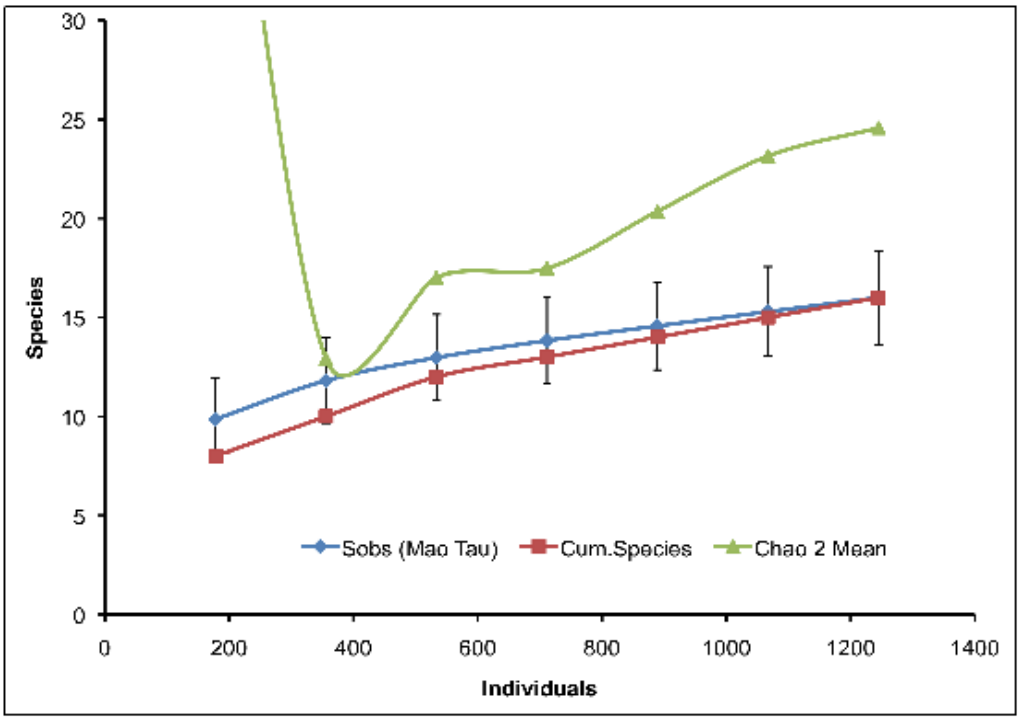

Fig. 8. Cumulative Species curve (Sample–based Rarefaction curve **(**"Mao Tau"-curve; Colwell et al. 2004), and Richness Estimator (Chao 2 Mean) for 6 (7) years and four Ecosystems sampled on Colby Hill between 2000 and 2011. Vertical bars: ± 1 *SD.*

This is based on 1245 total captures over the six or seven year sampling in the four habitats (see App. I + II), with 16 total species (*Peromyscus maniculatus* and *P. leucopus* pooled). Also added was the curve for the Chao 2 richness estimator (green) but it appears to over-estimate the potential number of species occurring on Colby Hill (~24 species), probably because sampling gradually kept adding species over the years and no asymptotic plateau has been reached in the accumulation curves yet.

After 6 (7) years of sampling on the Guthrie-Bancroft we can attempt to describe diversity more rigorously using widely used indices. Table 3 shows the multi-year totals for each ecosystem and a number of widely used diversity indices calculated following Magurran (2004):

Species	ES1	ES6	ES 14	ES20	Totals
Blarina brevicauda	36	45	35	21	137
Sorex fumeus	1	1	5	0	7
Sorex cinereus	15	9	16	5	45
Sorex palustris	0	0	0	1	1
Parascalops breweri	0	1	0	0	1
Peromyscus sp.	181	189	133	23	526
Napaeozapus insignis	22	8	12	41	83
Zapus hudsonius	0	0	0	13	13
Microtus pennsylvanicus	0	0	1	39	40
Microtus pinetorum	1	0	0	0	1
Myodes gapperi	122	69	149	11	351
Synaptomys cooperi	0	0	1	0	1
Tamias striatus	13	3	4	4	24
Tamiasciurus hudsonicus	1	1	0	2	4
Glaucomys volans	0	1	0	0	1
Mustela sp.	0	1	2	7	10
Totals:	392	328	358	167	1245
No. of Species (S):	9	11	10	11	16
a) Simpson' Index D	**0.322**	**0.395**	**0.322**	**0.158**	
b) 1-D	**0.678**	**0.605**	**0.678**	**0.842**	
c) Evenness E = (1/D)/S	**0.345**	**0.230**	**0.310**	**0.574**	
d) Shannon Index H'	**0.945**	**1.268**	**0.846**	**0.552**	
e) Evenness J'=H'/lnS	**0.430**	**0.529**	**0.367**	**0.230**	

Table 3: Small Mammal Diversity indices calculated from 6 and 7-year data collected in the Guthrie-Bancroft parcel on Colby Hill. See text for details on the indices.

a) Simpson's index $D = \Sigma\, n_i\,[n_i - 1]/N[N-1]$, or the probability of any two individuals drawn at random from an finite community belonging to the same species.

b) The complement of Simpson's index, 1-D, or the probability of any two individuals drawn at random from a finite community belonging to different species.

c) Evenness of the community. E = (1/D)/S, were S is the number of species in the sample.

d) Shannon Index H' = $-\Sigma\, p_i \ln p$, the average degree of uncertainty in predicting to what species an individual chosen at random from a sample will belong.

e) Evenness J' = H'/ln S

Climate Data 2011

Figure 3 a) and b) show the temperature, humidity and rainfall recordings from ES 20 during the study period. The greatest shifts are in daytime (maximum) temperature and nighttime (minimum) humidity. Total Rainfall during the study period in 2011 (373.4 mm) was almost twice as high as in 2007 (191.1 mm).

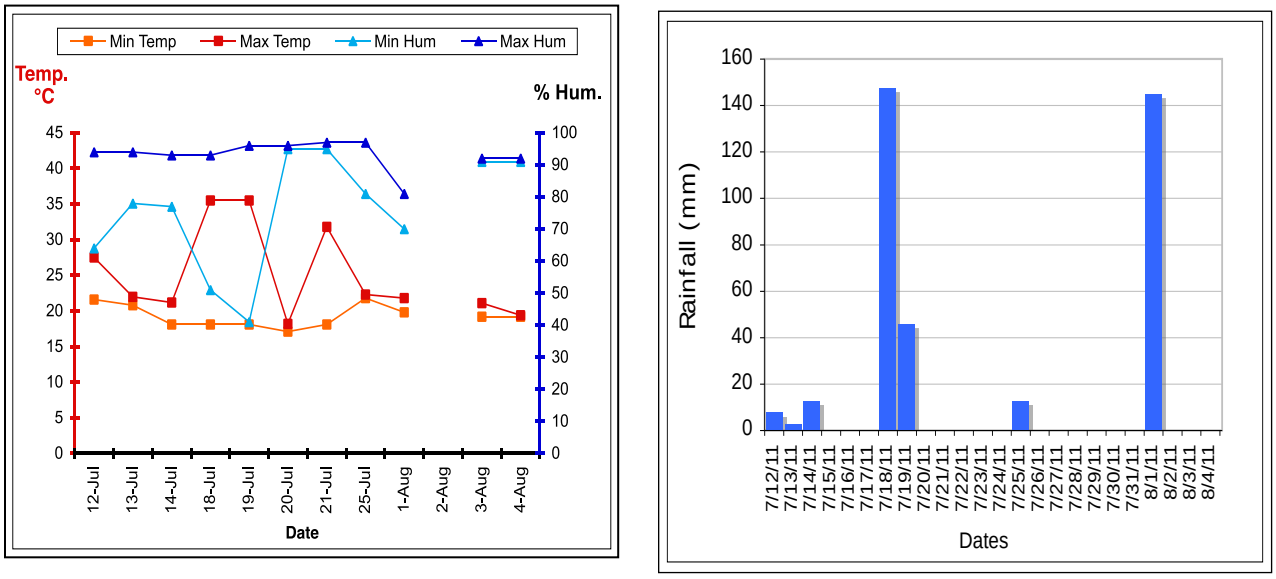

Fig. 3 a) 2011 Min/Max Temperature (°C) and Humidity (%) measured in Ecosystem 20 (2 Aug = no value due to battery failure). **b)** 2011 Field Season Rainfall (Total measured: 373.4 mm)

Discussion

With 174 individual captures and 10 species recorded the 2011 small mammal trapping fall in between the low trapping success of the first three years (2000-2002) and the high trapping success of the next three years (2005-2007). Small mammal species diversity on Colby Hill is perhaps best described by Simpson's 1-D measure, which "provides a good estimate of diversity at relatively small sample sizes…" (Magurran 2004:101) as well as Simpson's measure of

evenness which emphasizes the dominance component of diversity, hence the relatively high evenness (E = 0.574; Table 3) in ES 20, a successional habitat where one or two species (*Peromyscus, Myodes*…) have not yet established themselves as the dominant species as in ES 1,6 and 14.

The capture of a new species (*Sorex palustris*) after 7 years of trapping in ES 20 echoes the findings of the long-term survey from Salisbury Ridge in Addison Co., Vermont (Brooks et al. 1998). Those authors used equal numbers of Sherman and pitfall traps on a 7 x 7 station grid for five and in later years four consecutive nights in each of three habitats at three different elevations. They did not capture the star-nosed mole *(Condylura cristata)* until the 12th year and the Long-tailed shrew (*Sorex dispar*) until their 15th year of sampling both species, which are still missing from our 7-year study. The star-nosed mole should be present on Colby Hill because it is not a rare species in Vermont. The Long-tailed shrew is rarer and often associated with particular talus slope habitat (Kilpatrick and Benoit 2011); it is ranked as a species of special concern (SC) by the Vermont Fish & Wildlife Department Nongame and Natural Heritage Program (Vermont Fish & Wildlife 2011). This underlines the importance of long-term studies to record most species of a small mammal community, which is especially important for environmental impact and baseline studies some of us have been involved in locally and abroad (Decher et al. 2009, 2010), where large-scale habitat destruction may be at stake.

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Appendix I

7-year Annual Small Mammal Captures in all four Habitats

Year:	2000	2001	2002	2005	2006	2007	2011	Total
No. of nights trapped	9	11	12	12	12	12	12	**80**
No. of Traps	124	90	197	248	248	248	276	**1431**
Trapnights	372	332	591	744	744	744	807	**4334**
Shrews/Moles								
Blarina brevicauda	8	23	18	22	14	24	28	**137**
Sorex fumeus	2	0	0	1	1	3	0	**7**
Sorex cinereus	1	1	10	9	10	10	4	**45**
Sorex palustris	0	0	0	0	0	0	1	**1**
Parascalops breweri	0	0	0	0	0	1	0	**1**
Rodents								
Peromyscus sp.	45	76	63	70	84	119	69	**526**
Napaeozapus insignis	1	3	4	19	3	47	6	**83**
Zapus hudsonius	3	0	0	4	3	3	0	**13**
Microtus pennsylvanicus	3	4	3	23	1	3	3	**40**
Microtus pinetorum	0	0	0	0	1	0	0	**1**
Myodes gapperi	17	20	18	95	81	68	52	**351**
Synaptomys cooperi	0	0	0	1	0	0	0	**1**
Tamias striatus	0	1	2	1	4	8	8	**24**
Tamiasciurus hudsonicus	0	1	0	0	0	2	1	**4**
Glaucomys volans	0	0	1	0	0	0	0	**1**
Carnivores								
Mustela sp.	0	0	1	1	4	2	2	**10**
Total Captures:	**80**	**129**	**120**	**246**	**206**	**290**	**174**	**1245**
Species Detected:	**8**	**8**	**9**	**11**	**11**	**12**	**10**	**16**
Cumulative Species:	**8**	**10**	**12**	**13**	**14**	**15**	**16**	**16**

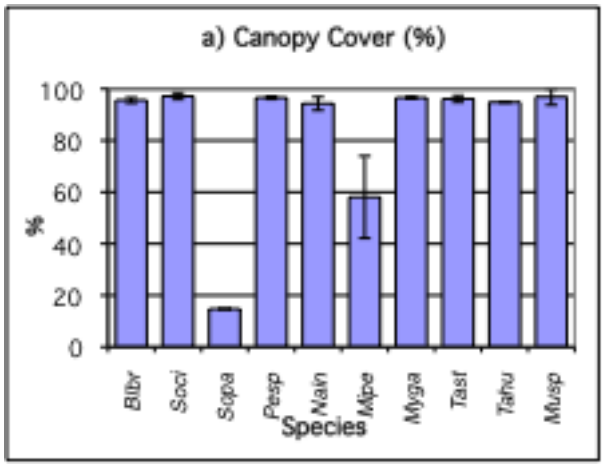
Appendix II

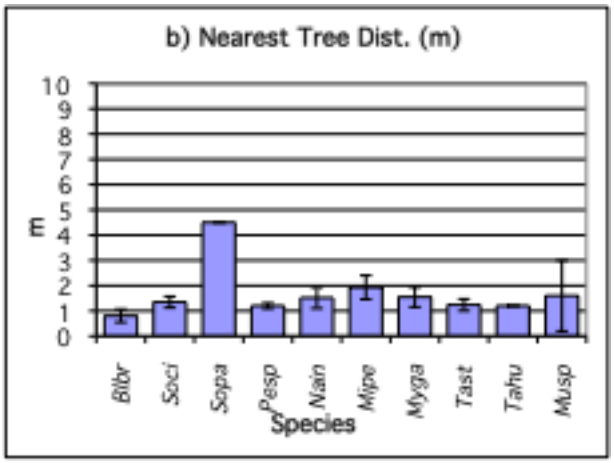
Detailed Overview of results from all 6 or 7 years of small mammal sampling in each Ecosystem on the Guthrie-Bancroft parcel. Red = new species verified in 2011.

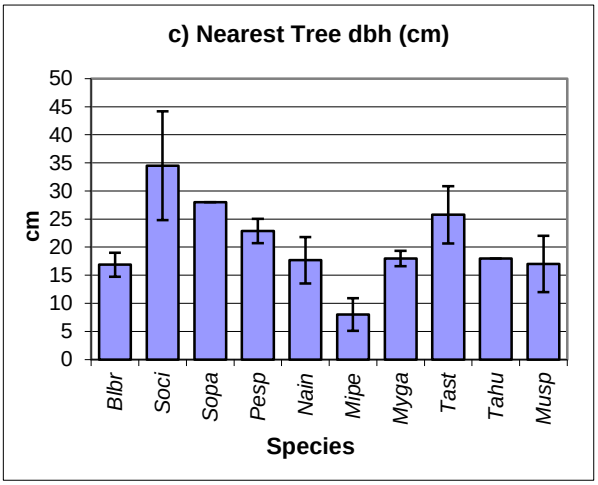
Ecosystem (ES) No.	1 (6 years)						6 (6 years)						14 (7 years)							20 (7 years)							Total	Total
ES Type:	well-drained mesic red oak HW forest (see Appendix VI-a)						seepy terrain rich northern HW forest (see Appendix VI-b)						poorly drained spruce-fir northern HW forest (see Appendix VI-c)							alder swamp/sedge meadow edge of former beaver pond (see Appendix VI-d)							2011 only	All Years
Year 20.. :	01	02	05	06	07	11	00	02	05	06	07	11	00	01	02	05	06	07	11	00	01	02	05	06	07	11		
No. of nights trapped	4	3	3	3	3	**3**	3	3	3	3	3	**3**	3	4	3	3	3	3	**3**	3	3	3	3	3	3	**3**		**80**
No. of Traps	32	56	62	62	62	**68**	52	58	62	62	62	**69**	52	30	59	62	62	62	**70**	20	28	24	62	62	62	**69**		**1431**
Trapnights	128	168	186	186	186	204	156	174	186	186	186	207	156	120	177	186	186	186	210	60	84	72	186	186	186	**186**	**807**	**4334**
Shrews & Moles																												
Blarina brevicauda	5	3	13	2	3	**10**	8	8	1	6	12	**10**		12	2	8	6	3	**4**		6	5			6	**4**	**28**	**137**
Sorex fumeus					1						1		2			1	1	1										**7**
Sorex cinereus		3	5	1	3	**3**	1	5			3			1	2	3	7	2	**1**				1	2	2		**4**	**45**
Sorex palustris																										**1**	**1**	**1**
Parascalops breweri											1																	**1**
Rodents																												
Peromyscus sp.	44	19	29	25	39	**25**	31	25	21	30	59	**23**	12	19	19	18	25	19	**21**	2	13		2	4	2		**69**	**526**
Napaeozapus insignis			3		19			2			6			3	1	2	2	2	**2**	1		1	14	1	20	**4**	**6**	**83**
Zapus hudsonius																				3			4	3	3			**13**
Microtus pennsylvanicus														1						3	3	3	23	1	3	**3**	**3**	**40**
Microtus pinetorum				1																								**1**
Myodes gapperi	4	3	32	36	27	**20**	7	5	20	18	14	**5**	10	13	10	38	27	27	**24**		3		5			**3**	**52**	**351**
Synaptomys cooperi																1												**1**
Tamias striatus	1	1	1	1	3	**6**				1	2				1			1	**2**					2	2		**8**	**24**
Tamiasciurus hudsonicus					1						1										1					**1**	**1**	**4**
Glaucomys volans								1																				**1**
Carnivores																												
Mustela sp.										1							1		**1**			1	1	2	2	**1**	**2**	**10**
No. of Species	4	5	6	6	8	**5**	4	6	3	5	9	**3**	3	6	6	7	7	7	**7**	4	5	4	7	7	8	**7**	**10**	**16**
No. of Captures	54	29	83	66	96	**64**	47	46	42	56	99	**38**	24	49	35	71	69	55	**55**	9	26	10	50	15	40	**17**	**174**	**1245**
Trap Success (%)	42.2	17.3	44.6	35.5	51.6	**31.4**	30.1	26.4	22.6	30.1	53.2	**18.4**	15.4	40.8	19.8	38.2	37.1	29.6	**26.2**	15.0	31.0	13.9	26.9	8.1	21.5	**9.1**	**21.6**	**28.7**

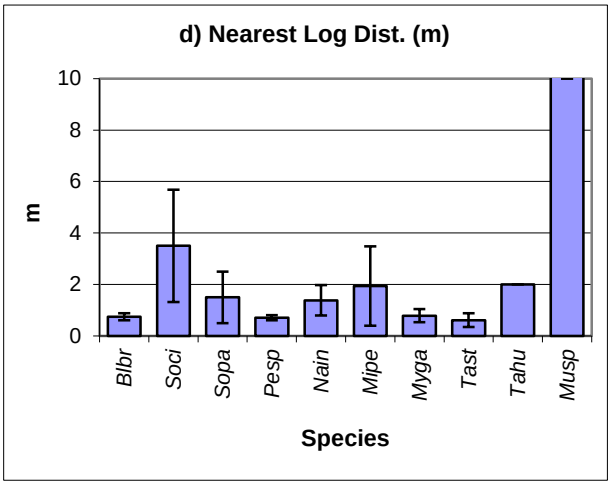
Appendix III

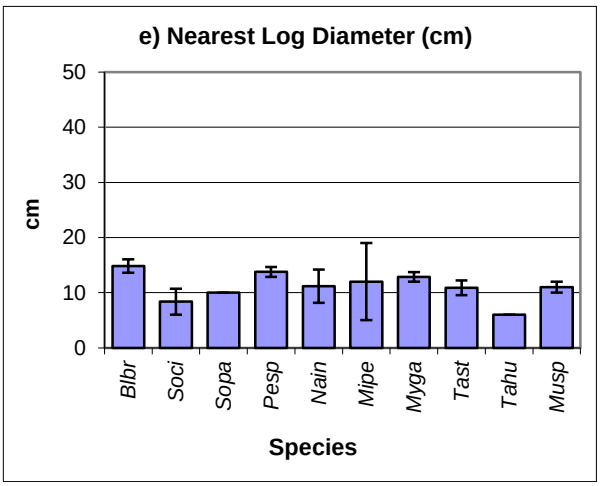
2011 Microhabitat Data from trap sites summarized by Small Mammal Species. Species abbreviations and sample sizes are: *Blbr = Blarina brevicauda* (n = 28), *Mipe = Microtus pennsylvanicus* (n = 3), *Musp = Mustela* sp. (n = 2), *Myga = Myodes gapperi* (n = 52), *Nain = Napaeozapus insignis* (n = 6), *Soci = Sorex cinereus* (n = 4), *Sopa = Sorex palustris* (n = 1), *Pesp = Peromyscus* sp. (n = 69), *Tast = Tamias striatus* (n = 8), and *Tahu = Tamiasciurus hudsonicus* (n= 1).

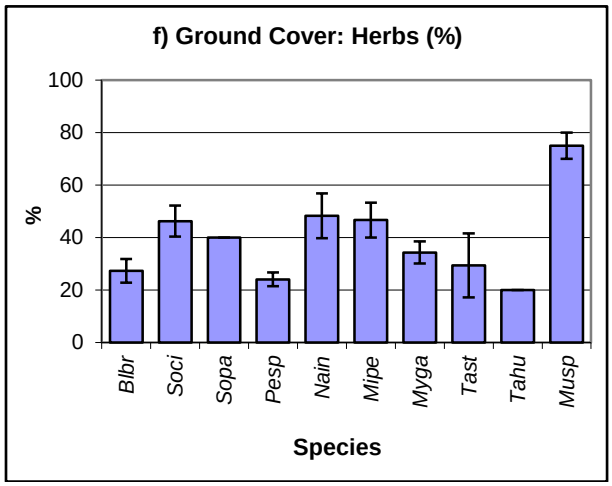






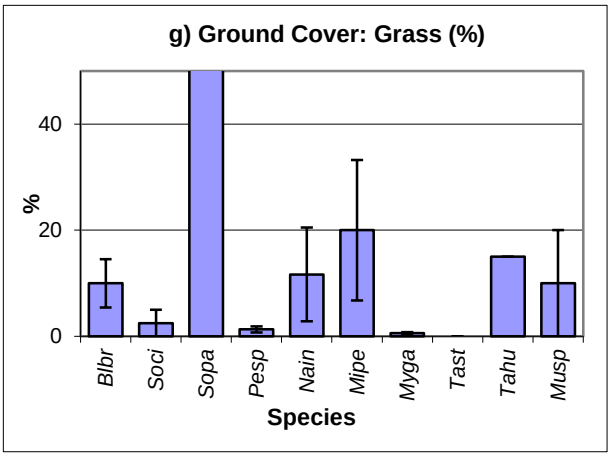


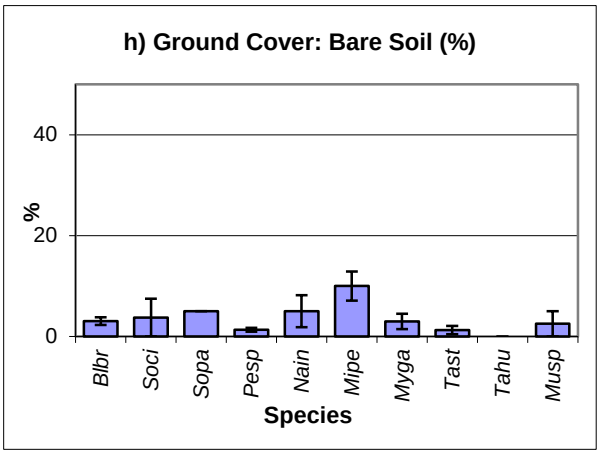


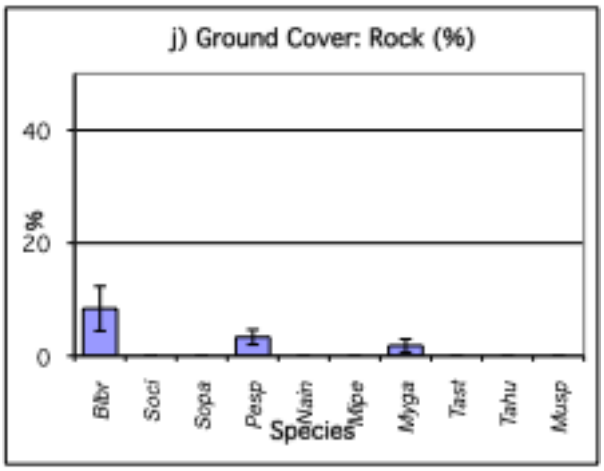


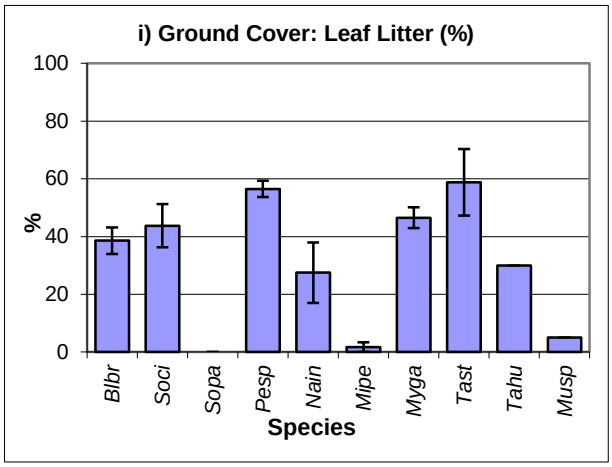
contd. App. III

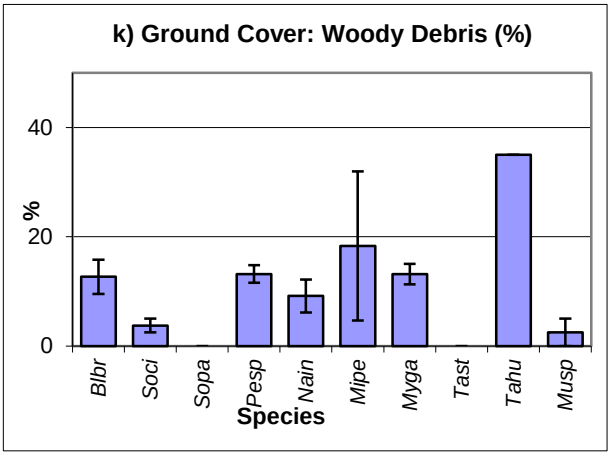
Microhabitat summarized by Small Mammal Species











Appendix IV
Panorama Photographs of Ecoystems 1, 6, 14 and 20
[separate file in Legal-size landscape format]