Diversity of Surface-Active Terrestrial Invertebrates in Forested Landscape Ecosystems at Guthrie-Bancroft Farm, Lincoln and Bristol, Vermont

Mark A. Ward, Jeffrey M. Collins, and Susan M. Young
September 2001

Introduction

Invertebrates dominate the earth's biota. The number of described species approximates 2 million, but some estimates of invertebrate species richness are as high as 80 million (New 1998). Despite their important contribution to biological diversity, however, terrestrial invertebrates have generally received little attention in conservation planning.

The development of state endangered species lists in the mid-1980's was one of the first actions with clear implications for the conservation of invertebrates in New England (McCollough 1997). It resulted in some conservation efforts focused on rare and endangered species. Unfortunately the breadth of invertebrate taxa represented on state lists is extremely limited and reflects an inter-state disparity of invertebrate expertise at academic institutions that influences status and listing (McCollough 1997).

In addition to their contribution to biodiversity, invertebrates have recently begun to receive more attention from conservationists and ecological planners for their potential usefulness in biomonitoring (Kremen et al., 1993). Invertebrates can provide an attractive alternative to larger animals in ecosystem monitoring for several reasons including their wide distribution relative to vertebrates, their rapid population turnover, and the ease with which they can be sampled in statistically significant numbers (Kremen et al., 1993). Terrestrial invertebrates are also low on the food chain and thus respond more rapidly to subtle environmental changes than vertebrates. In small preserves, invertebrates offer a way of monitoring ecological integrity that may not be feasible with relatively small vertebrate populations.

One of the challenges of working with invertebrates is that conducting a thorough inventory is both time-consuming and costly. The dedication of numerous taxonomic specialists is required to achieve species level identification for many groups. To address this problem, some efforts have been made by ecologists (Oliver and Beattie, 1996a; Colwell and Coddington, 1994; Hammond, 1994) to establish time- and cost-effective shortcut methods for the estimation of invertebrate species richness and diversity. The current study employs two of these methods by using extrapolation (Colwell and Coddington, 1994) to estimate taxa richness and focal groups (Hammond 1994) as surrogates for larger invertebrate assemblages.

The Colby Hill Ecological Project is a local effort to describe the biological diversity in a mid-elevation landscape of the Green Mountains in Lincoln and Bristol, Vermont. One of the goals of the project is to provide baseline data on the taxa present. As part of the Colby Hill Ecological Project, we examined the terrestrial invertebrate diversity in three forested landscape ecosystems at the Guthrie-Bancroft Farm in Lincoln and Bristol, Vermont. The ecosystems targeted were: a rich, moderately well drained, seepy, northern hardwood forest (RFW); a well drained, beech-red maple-red oak-sweet birch transition hardwood forest (THF); and a somewhat poorly drained, red spruce-balsam fir-hemlock-yellow birch forest (SF). Our study focused on the ecological niche occupied by surface-active terrestrial invertebrate. We used sampling methods that capture those species primarily active on the ground surface or within the forest litter.

Two important criteria used to assess the conservation value of an ecosystem are diversity and rarity (Magurran 1988). Within each forest type, we calculated the α-diversity of invertebrate families and estimated the family richness. We also estimated the overall family richness of the three ecosystems taken as a whole. We compared the ecosystems to assess their similarity (β-diversity) to one another. We identified three focal groups to the species level and estimated the species richness of the focal groups within each forest ecosystem and overall. Finally, we reported on rare and uncommon species.

Methods

In each of three forested ecosystems RFW (44°09.537′ N, 73°01.719′ W), THF (44°09.197′ N, 73°01.837′ W), and SF (44°08.994′ N, 73°01.134′ W) on the Guthrie-Bancroft parcel (Figure 1), pitfall and litter samples were collected in May and July of 1999 and 2000. Six pitfall traps were set approximately 5 m apart and left open for one week. When the traps were recovered, three 4-L samples of forest litter were collected near the pitfall traps. The litter samples were placed into Berlese funnels to extract the litter-dwelling invertebrates. Collection dates were May 13 & July 25, 1999 and May 27 & July 15, 2000. During the July 1999 collection, several of the traps at THF were disturbed (probably by a bird or a mammal). The disturbed pitfall traps were reset and collected on August 1, 1999. One pitfall trap from RFW was also disturbed, but the trap was not reset.

To avoid the problem of having to reset pitfall traps in 2000, ten pitfall traps were set at each location, but only six were analyzed for inclusion in calculations. The specimens from 24 pitfall traps and 12 litter samples were analyzed over the two years for a total of 36 subsamples from each ecosystem (only 35 from RFW because of one overturned pitfall trap in 1999). In addition to the collections made at the three forest ecosystems, pitfall and litter samples were also collected on the same dates in 2000 from a rich hardwood forest (RHFE), floristically similar to RFW, but located east of the other three (44°08.700′ N, 72°59.692′ W) on the Wells parcel (Figure 1).

All adult specimens recovered from pitfall traps and litter samples were identified to the family level, except for three problematic orders (Acarina, Pseudoscorpionida, and Psocoptera). The Acarina are an extremely difficult group to identify to the family level and are typically lumped by order in data analyses. Similar difficulties with the Pseudoscorpionida and the Psocoptera forced us to treat them at the order level. Three focal groups were identified to species: ground beetles (Family: Carabidae), ants (Family: Formicidae), and spiders (Order: Areneida). In the case of the spiders, each specimen was identified to the finest level of classification possible. In most cases, this meant identification to the species level (some specimens were immature or damaged in a way that prevented species identification). Only those specimens that were successfully identified to the species level, or which belonged to a genus or family not otherwise represented, were used in the calculations of species richness estimates. The total number of spiders used in the species richness estimates was therefore slightly smaller than the number collected.

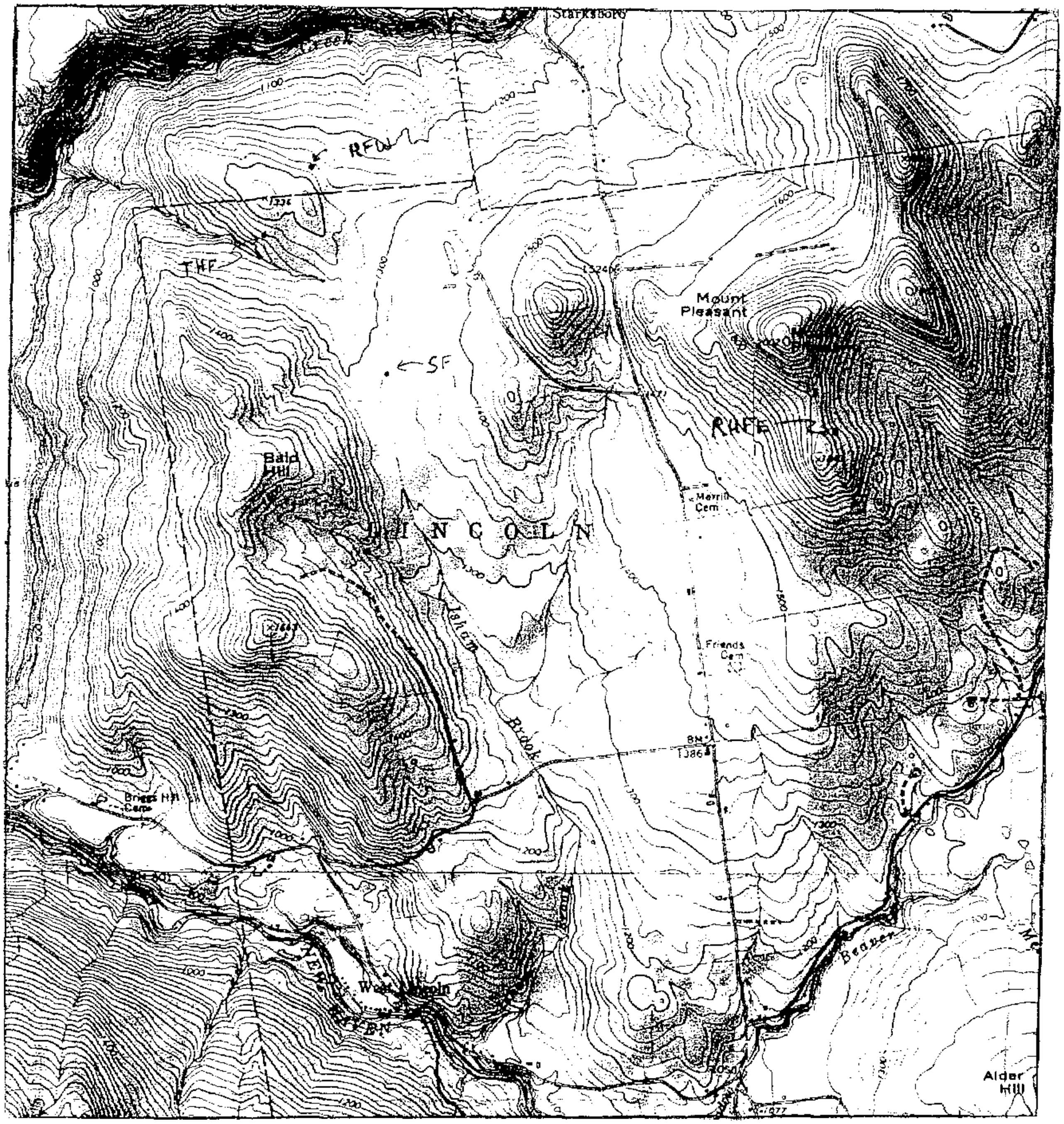

Figure 1. Sampling locations in forest ecosystems at Guthrie-Bancroft Farm in Lincoln/Bristol, Vermont, 1999 and 2000. RFW = Rich hardwood forest west; SF = Spruce-fir forest; THF = transition hardwood forest; RHFE = Rich hardwood forest east.

Calculations and Data Analysis

Taxa Richness Estimates

We pooled the 1999 and 2000 data for each ecosystem type and tallied the observed number of families in each ecosystem. We then used non-parametric methods for the estimation of taxa richness from small samples (Colwell and Coddington, 1994) to obtain family richness estimates. Of several estimators reviewed by Colwell and Coddington (1994), we chose three:

$$F_1^* = F_{obs} + (a^2/2b), \qquad (1)$$

$$F_2^* = F_{obs} + (L^2/2M), \qquad (2)$$

$$F_3^* = F_{obs} + L\,(n\text{-}1/n), \qquad (3)$$

where:

F_1^*, F_2^*, and F_3^* are estimates of the family richness in an assemblage;

F_{obs} is the observed number of families in the sample;

a is the number of families represented by a single individual;

b is the number of families represented by exactly two individuals;

L is the number of families that occur in only one subsample;

M is the number of families that occur in exactly two subsamples;

and n is the number of subsamples (a subsample corresponded to a pitfall trap or litter collection).

Two of these formulas, (1) and (2), were first employed by Chao (1984) and the third (3) by Burnham & Overton (1979). We utilized modified forms of equations (1), (2), and (3) to estimate the species richness of focal groups at each of the three forest ecosystems with S_1^*, S_2^*, and S_3^* representing estimates of species richness.

Shannon Diversity Index

The Shannon index of diversity was calculated for families in each ecosystem. The widely used Shannon index takes into account both richness and evenness and is calculated from the equation:

$$H' = -\Sigma p_i \ln p_i \qquad (4)$$

where p_i is the proportion of individuals belonging to the ith family (Magurran 1988). The diversity values were tested for significant differences between ecosystems (Magurran 1988) by pairwise t-tests using the formula:

$$t = H_1' - H_2' / (\text{Var } H_1' + \text{Var } H_2')^{1/2} \qquad (5)$$

where Var H_1' and Var H_2' are the variances in ecosystem 1 and 2 respectively.

Similarity Indices (β-diversity)

We calculated several measures of β-diversity (or differentiation diversity) to examine the degree of similarity in family diversity between ecosystems. We used three different similarity indices to compare the ecosystems—Sorenson qualitative, Sorenson quantitative, and Morisita quantitative. The Sorenson qualitative index is a simple calculation, but it takes no account of relative taxa abundance (Magurran 1988). It is calculated from the equation:

$$C_s = 2j/(a + b) \qquad (6)$$

where j = the number of families found in both sites and a = the number of families in Site A with b the number of families in Site B. The Sorenson quantitative index takes into account relative taxa abundance:

$$C_N = 2\ \Sigma N_j / (N_a + N_b) \qquad (7)$$

where N_a = the total number of individuals in site A, N_b = the total number of individuals in site B, and N_j is the lower of the two abundances recorded for the jth family found in both sites. Thus if 12 individuals of a family were found in Site A and 29 individuals of the same family were found in Site B the value 12 would be included in the summation of N_j. The Sorenson quantitative index, like many quantitative similarity indices, is strongly influenced by family richness and sample size (Magurran 1988). Unlike the Sorenson quantitative index, the Morisita quantitative index is not influenced by family richness or sample size, but it is highly sensitive to the abundance of the most abundant family (Magurran 1988). The Morisita index is:

$$C_M = 2\ \Sigma\ x_i\, y_i / (L_a + L_b)\, N_a\, N_b \qquad (8)$$

where x_i is the number of individuals of the ith family in site A, y_i is the number of individuals of the ith family in site B, N_a and N_b are the total number of individuals in site A and site B, $L_a = x_i\,(x_i - 1)/\,N_a\,(N_a - 1)$ which is the probability that two randomly selected individuals from site A will belong to the same family and $L_b = y_i\,(y_i - 1)/\,N_b\,(N_b - 1)$ which is the same probability in site B.

Results

Family Diversity

Overall Family Richness

From the three ecosystems that were sampled in 1999 and 2000, we collected 11,990 specimens in 107 subsamples (71 pitfall traps and 36 litter samples). The specimens represented seven classes and 22 orders (Figure 2). The order with the largest number of specimens was the mites (Order: Acarina); the 6073 mite specimens comprised more than 50% of all specimens. The orders with next highest number of specimens were the springtails (Collembola) and the beetles (Coleoptera). The order Coleoptera was represented by the largest number of families (22).

We identified 5761 specimens to the family level and sorted them into 101 invertebrate families (Table 1). The three problematic orders were each treated as a single family for a minimum of 104 observed families. We calculated estimates of overall family richness by pooling the data from the three ecosystems sampled (Table 2). The overall family richness values ranged from 134-139 families.

Ecosystem Family Richness and Shannon Diversity

The number of observed families within an ecosystem did not differ greatly and ranged from 63-70 families (Table 2). The ecosystem family richness estimates values (Table 2) ranged from 86-97 families for RFW, from 89-115 families for SF and from 85-116 families for THF. Each forest ecosystem had several familes that were not found at any other site.

Figure 2. The relative abundances of surface-active invertebrate orders in three ecosystems at Guthrie-Bancroft Farm, Lincoln/Bristol, Vermont, 1999 and 2000.

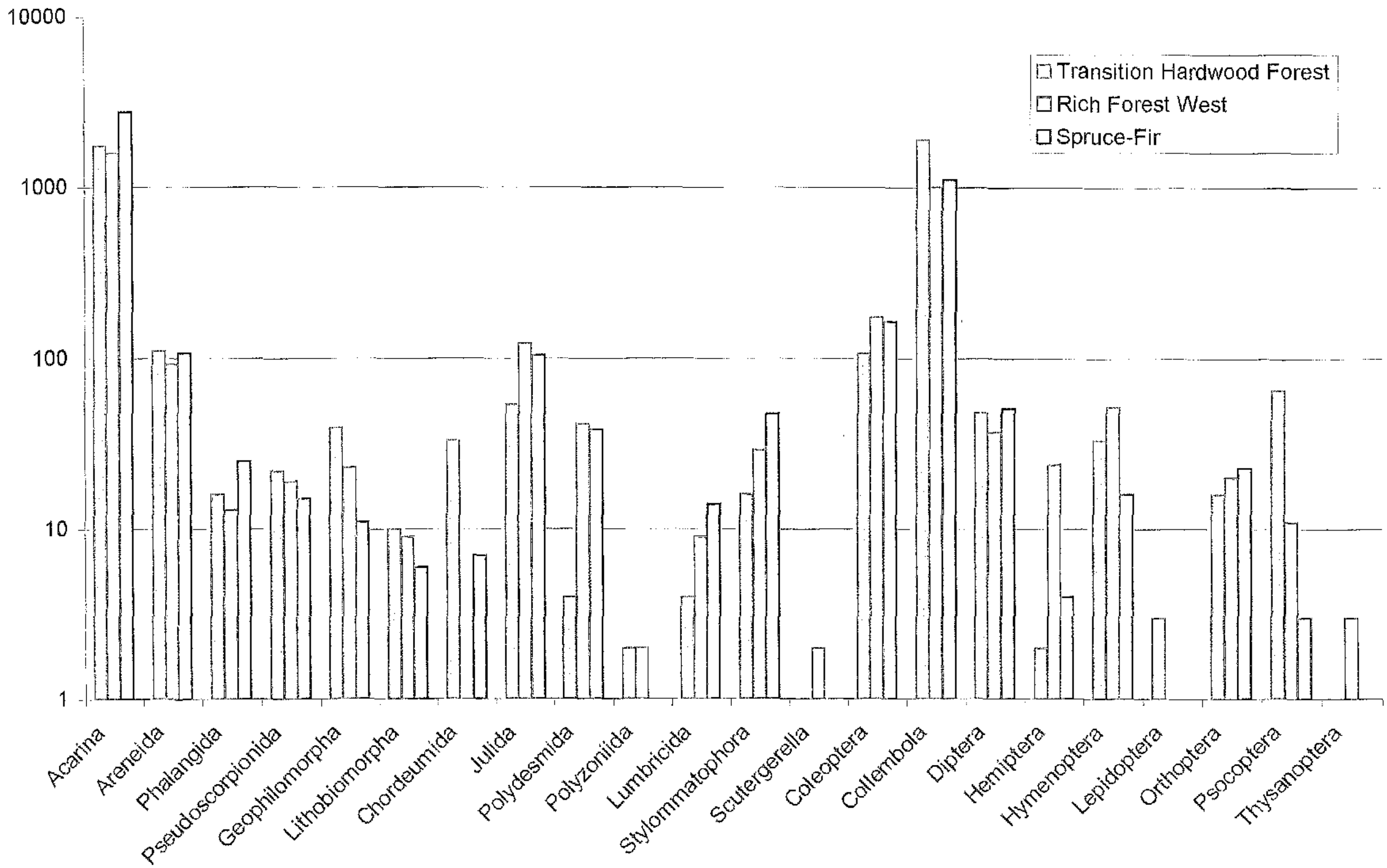

Table 1. A list of the classes (italics), orders (bold), and families of invertebrates collected from three forest ecosystems at Guthrie-Bancroft Farm in Lincoln/Bristol Vermont, 1999 and 2000. RFW = Rich hardwood forest west; SF = Spruce-fir forest; THF = Transition hardwood forest.

	THF 99-00	RHF 99-00	SF 99-00	Total 99-00
Arachnida				
Acarina	**1746**	**1581**	**2746**	**6073**
Areneida	**2**	7	**12**	**21**
Amaurobiidae	17	8	21	46
Dictynidae	17	8	16	41
Gnaphosidae			1	1
Hahniidae	12	17	9	38
Liocranidae	10	1	1	12
Linyphiidae	43	33	23	99
Lycosidae	2	11	18	31
Salticidae	4	7	3	14
Theridiidae	2			2
Theridiosomatidae			1	1
Thomisidae			2	2
Phalangida				
Caddidae			6	6
Ceratolasmatidae		1		1
Phalangidae	14	12	19	45
Sabaconidae	2			2
Pseudoscorpionida	**22**	**19**	**15**	**56**
Chilopoda				
Geophilomorpha				
Dignathodontidae		3	1	4
Geophilidae	21	14	10	45
Schendylidae	18	6		24
Lithobiomorpha				
Lithobiidae	10	9	6	25
Diplopoda				
Chordeumida				
Conotylidae	33		7	40
Julida				
Julidae	12	107	96	218
Parajulidae	42	15	7	64
Polydesmida				
Polydesmidae	4	41	38	83
Polysoniida				
Polyzoniidae	2	2	1	5
Oligochaeta				
Lumbricida				
Enchytraeidae	1			1
Lumbricidae	3	9	14	26
Gastropoda				
Stylommatophora				
Arionidae	1		20	21
Carychiidae	1		7	8
Cionellidae		2		2
Endodontidae	6	8	6	22
Pupillidae	5	6	6	17
Vallonidae		6	1	7
Zonitidae	3	7	7	17
Symphala				
Scutigerella				
Scutigerellidae		2		2
Insecta				
Coleoptera				
Alleculidae			1	1
Byrrhidae			2	2
Carabidae	34	72	89	193
Chrysomelidae		1		1
Ciidae			1	1
Cryptophagidae		4		4
Cupedidae	1			1
Curculionidae	8	17	18	43
Dermestidae		1		1
Lampyridae		1		1

Table 1. (Continued)

	HH	KH	SI	Total
Lathridiidae	1	1		2
Leiodidae	1	1		2
Leptodiridae	20	6		26
Mycetophagidae		2		2
Pselaphidae		1		1
Ptiliidae		15	1	16
Scaphidiidae	1	6	1	8
Scarabeidae	1	2		3
Scolytidae		1	1	2
Scydmaenidae	3	4	7	14
Staphylinidae	14	37	43	94
Collembola				
Entomobryiidae	214	301	268	783
Hypogastruridae	1572	429	244	2245
Isotomidae	97	217	552	866
Sminthuridae	22	60	43	125
Diptera				
Anisopodidae			1	1
Anthomyiidae			1	1
Calliphoridae			1	1
Cecidomyiidae	10	6	17	33
Chironomidae	3		7	10
Chloropidae	1			1
Dolichopodidae		1	1	2
Drosophilidae			1	1
Muscidae			1	1
Mycetophilidae	1	1	7	9
Phoridae	12	24	3	39
Psychodidae	6	2	3	11
Sarcophagidae	1			1
Scathophagidae	1			1
Sciaridae	13	2	8	23
Xylophagidae		1		1
Hemiptera				
Aphididae		7	2	9
Cixiidae		1		1
Coccoidea (superfamily)		4		4
Cydnidae		1		1
Dipsocoridae		8		8
Lygaeidae		2		2
Miridae	1	1		2
Ploiaridae	1			1
Reduviidae			1	1
Tingidae			1	1
Hymenoptera				
Aphelinidae			1	1
Ceraphronidae	2		1	3
Chalcidoidea (superfamily)		2		2
Diapriidae		1	2	3
Formicidae	27	37	6	70
Ichneumonidae	1		1	2
Megaspilidae		1		1
Scelionidae	2	11	2	14
Xyelidae	1			
Lepidoptera		**1**		
Blastobasidae	1			1
Pyralidae	1			1
Tineidae	1			1
Orthoptera				
Gryllacrididae	16	20	23	59
Psocoptera	**65**	**11**	**3**	**79**
Thysanoptera				
Thripidae		3		3
Number of specimens	**4233**	**3269**	**4488**	**11990**
Number of families	**63**	**70**	**67**	**104**

Table 2. The family richness estimates of surface-active invertebrates for three forest ecosystems at the Guthrie-Bancroft Farm, Lincoln/Bristol Vermont, 1999 and 2000. RFW = Rich hardwood forest west; SF = Spruce-fir forest; THF = Transition hardwood forest; F_1^*, F_2^*, and F_3^* = family richness estimators; F_{obs} = number of observed families; a=number of families represented by a single individual b = number of families represented by exactly two individuals; L = number of families in only one subsample; M = number of families in only two subsamples; N = number of subsamples.

	RFW 99-00	SF 99-00	THF 99-00	Pooled data 99-00
$F_1^* = F_{obs} + (a^2/2b)$	86	115	93	134
$F_2^* = F_{obs} + (L^2/2M)$	97	91	116	138
$F_3^* = F_{obs} + L\,(n\text{-}1/n)$,	91	89	85	139
N	35	36	36	107
a	17	22	19	30
b	9	5	6	15
L	22	23	23	35
M	9	11	5	18
F_{obs}	70	67	63	104

The Shannon Diversity Index values for the three ecosystems were numerically close and ranged from 1.71 - 1.84 (Table 3) with RFW having the highest value. Pairwise t-tests of the three ecosystems showed no significant difference in the Shannon diversity values of SF and THF, but did show a statistically significant difference in the diversity of RFW when compared to each of the other two ecosystems.

Table 3. Shannon family diversity index values for surface-active invertebrates from three forest ecosystems at the Guthrie-Bancroft Farm, Lincoln/Bristol Vermont, 1999 and 2000. RFW = Rich hardwood forest west; SF = Spruce-fir forest; THF = Transition hardwood forest; H' =.Shannon diversity index; Var H'= variance.

	RFW 99-00	**SF 99-00**	**THF 99-00**
H'	1.8433	1.7130	1.7414
Var H'	6.7321	6.1021	5.7550

Ecosystem Similarity (β-Diversity)

The three indices of ecosystem similarity yielded no clear trends in similarity across ecosystems. The Sorenson qualitative index values were very similar for all pairwise comparisons. Both quantitative indices yielded results suggesting that SF and RFW were most similar and that THF and RFW were least similar.

Table 4. Ecosystem similarity values for three forest ecosystems at the Guthrie-Bancroft Farm, Lincoln/Bristol Vermont, 1999 and 2000. RFW = Rich hardwood forest west; SF = Spruce-fir forest; THF = Transition hardwood forest.

	RFW vs. THF	SF vs. RFW	THF vs. SF
Sorenson Qualitative Index C_s	65.7%	66.2%	68.1%
Sorenson Quantitative Index C_N	71.2%	72.6%	59.8%
Morisita Index C_M	88.3%	96.0%	78.7%

Species Richness Estimates

Spiders (Order: Areneida)

We collected a total of 369 spiders from 11 families (Table 1) represented by 33 species (Table 5). The number of observed spider species did not differ greatly between ecosystems (Table 6). The estimates of species richness were also similar (Table 6) and appeared to be statistically identical (though this was not tested). Each ecosystem contained several species that were not found at either of the two other sites (Table 5). The overall number of observed spider species was twice the number observed in any one ecosystem and estimates of overall spider species richness ranged from 42-46.

Table 5. Abundance of spider species collected in pitfall and litter samples from three forest ecosystems at the Guthrie-Bancroft Farm, Lincoln/Bristol Vermont, 1999 and 2000. RFW = Rich hardwood forest west; SF = Spruce-fir forest; THF = Transition hardwood forest.

Family *Species name*	**RFW 99-00**	**SF 99-00**	**THF 99-00**	**Total 99-00**
Amaurobiidae				
Amaurobius borealis	3		1	4
Callobius sp.			1	1
Cybaeopsis sp.			3	3
Wadotes calcaratus	3	12	8	23
Wadotes hybridus		1		1
Dictynidae				
Cicurina arcuata	1		2	3
Cicurina brevis	2	2	2	6
Cicurina pallida	2	9	2	13
Cicurina placida	1		1	2
Gnaphosidae				
Zelotes fratris		1		1
Hahniidae				
Cryphoeca sp.			1	1
Neoantistea magna	12	7	8	27
Linyphiidae				
Bathyphantes pallidus		1		1
Bathyphantes sp. A	1			1
Centromerus persolutus	4	2	4	10
Ceraticelus sp. A	1			1
Ceratinella brunnea	2			2
Eperigone maculata			2	2
Lepthyphantes zebra	2			2
Sisicottus montanus		1		1
Tapinocyba simplex		2	1	3
Tunagyna debilis		2		2
Walckaeneria directa	1			1
Liocranidae				
Agroeca ornata			2	2
Phrurotimpus alarius (Hentz, 1847)	1		4	5
Lycosidae				
Pirata insularis		1		1
Pirata montanus	4	6		10
Trochosa pratensis		2		2
Salticidae				
Metaphiddipus canadesis	1			1
Neon nellii	1		1	2
Theridiidae				
Robertus riparius (Keyserling, 1886)			2	2
Theridiosomatidae (imm.)		1		1
Thomisidae				
Misumena vatia		1		1
Number of specimens	**39**	**40**	**45**	**124**
Number of species	17	16	17	33

Table 6. Species richness estimates of spiders in three forest ecosystems at the Guthrie-Bancroft Farm, Lincoln/Bristol Vermont, 1999 and 2000. RFW = Rich hardwood forest west; SF = Spruce-fir forest; THF = Transition hardwood forest; S_1^*, S_2^*, and S_3^* = species richness estimators; S_{obs} = number of observed species; a=number of species represented by a single individual b = number of species represented by exactly two individuals; L = number of species in only one subsample; M = number of species in only two subsamples; n = number of subsamples.

	RFW 99-00	SF 99-00	THF 99-00	Overall 99-00
$S_1^* = S_{obs} + (a^2/2b)$	25	21	20	42
$S_2^* = S_{obs} + (L^2/2M)$	24	21	20	42
$S_3^* = S_{obs} + L\ (n\text{-}1/n)$,	26	23	23	46
N	35	36	36	107
a	8	7	6	13
b	4	5	6	9
L	9	7	6	13
M	6	5	6	9
S_{obs}	17	16	17	33

Ground Beetles (Family:Carabidae)

We collected a total of 193 ground beetles representing 22 species (Table 5). Both SF and RFW contained several species that were not found in other habitats and THF had one such species.

Table 7. The abundance of ground beetle species (Family: Carabidae) collected in pitfall and litter samples from three forest ecosystems at the Guthrie-Bancroft Farm, Lincoln/Bristol Vermont, 1999 and 2000. RFW = Rich hardwood forest west; SF = Spruce-fir forest; THF = Transition hardwood forest.

Species name	RFW 99-00	SF 99-00	THF 99-00	Totals 99-00
Agonum fidele	1			1
Agonum mutatum	1			1
Agonum retractum	7		8	15
Calasoma frigidum		2		2
Calathus ingratus		10		10
Cymindis cribricollis	1		1	2
Gastrellarius honestus		2		2
Notiophilus aeneus		5		5
Platynus decentis	21	30		51
Pterostichus adoxus			1	1
Pterostichus adstrictus		6		6
Pterostichus coracinus	13	5	1	19
Pterostichus diligendus	2	5		7
Pterostichus lachrymosus	3			3
Pterostichus pensylvanicus		1	3	4
Pterostichus rostratus			3	3
Pterostichus stygicus	4	2	1	7
Pterostichus tristis	2		2	4
Sphaeroderus canadensis	5			5
Sphaeroderus lecontei	6		1	7
Synuchus impunctatus	7	14	14	35
Total Count	**72**	**87**	**34**	**193**

The number of observed species and estimates of species richness were higher in SF and RFW than in THF (Table 8). The overall estimates of species richness were similar (24-26).

Table 8. Species richness estimates of ground beetles in three forest ecosystems at the Guthrie-Bancroft Farm, Lincoln/Bristol Vermont, 1999 and 2000. RFW = Rich hardwood forest west; SF = Spruce-fir forest; THF = Transition hardwood forest; S_1^*, S_2^*, and S_3^* = species richness estimators; S_{obs} = number of observed species; a=number of species represented by a single individual; b = number of species represented by exactly two individuals; L = number of species in only one subsample; M = number of species in only two subsamples; n = number of subsamples.

	RFW 99-00	**SF 99-00**	**THF 99-00**	**Overall 99-00**
$S_1^* = S_{obs} + (a^2/2b)$	15	16	13	25
$S_2^* = S_{obs} + (L^2/2M)$	21	18	13	24
$S_3^* = S_{obs} + L\ (n\text{-}1/n)$.	17	19	13	26
N	35	36	36	107
a	3	3	4	4
b	2	3	1	3
L	4	5	4	4
M	1	3	1	4
S_{obs}	13	14	9	22

Ants (Family: Formicidae)

We collected 70 ants representing 5 species (Table 9). RFW and SF each had one species that was not collected in either of the other ecosystems. The small number of species collected at each site was insufficient to calculate meaningful estimates of ecosystem species richness. Similarly, estimates overall species richness yielded a dubious overall ant species richness value of 5 species (because both a=0 and L=0).

Table 9. Ant species (Family: Formicidae) collected from three forest ecosystems at the Guthrie-Bancroft Farm, Lincoln/Bristol Vermont, 1999. RFW = Rich hardwood forest west; SF = Spruce-fir forest; THF = Transition hardwood forest.

Species name	**RFW 99-00**	**SF 99-00**	**THF 99-00**	**Overall 99-00**
Aphaenogaster rudis	3		10	13
Camptonotus hurculeanus		2		2
Formica lasioides		1	1	2
Lasius alienus	10			10
Stenamma diecki	24	3	16	43
Number of specimens	**37**	**6**	**27**	**70**

Rare and Uncommon Species

We found one species on the list of rare and uncommon animals in Vermont (Nongame and Natural Heritage Program, 1996). The ground beetle species, *Pterostichus lachrymosus*, was collected in pitfall traps in RFW in both 1999 and 2000. The species has a state rank of S3 (Nongame and Natural Heritage Program, 1996), which means that it is uncommon in Vermont and worthy of occurrence-tracking and monitoring. The global status of this species is unknown. *Pterostichus lachrymosus* has not been collected from many locations in Vermont and, unlike many other ground beetles, its ecology is not well understood (Ross Bell, pers. comm.). Three field seasons (1994, 1998, and 1999) of intensive ground beetle collection (more than 10,000 specimens) in the Green Mountain National Forest yielded only one individual of this species (Rykken, 1995 and Catherine Dickert, unpublished results).

Our spider species identifications also turned up two unusual specimens belonging to the genera *Bathyphantes* and *Ceraticelus* in the family Linyphiidae. Consultation with an arachnologist revealed that they likely represent undescribed species (Dan Jennings, pers. comm.). Both specimens were found in RFW and were referred to as *Bathyphantes* sp. A and *Ceraticelus* sp. A (Table 3).

Several unusual specimens from outside of the focal groups were also noted. The most remarkable of these was a specimen of the carrion beetle, *Necrophilus pettitii*, which had never before been collected in New England. The specimen was collected in one of the pitfall traps at RFW that was not included in the data analysis, and its identity was only uncovered because it was mistaken for a carabid during initial sorting. Another noteworthy find was a single specimen of the family Ceratolasmatidae found at RFW. This family has only one species in our fauna, *Crosbycus dasycnemus*, and although the species is known from Vermont, it has rarely been collected here (Ross Bell, pers. comm.).

Comparison of RFW and RHFE

In addition to the collections made at RFW, THF, and SF, 910 specimens were collected from the rich hardwood forest (RHFE) on the Wells parcel for comparison with RFW. The number of invertebrate families observed in RHFE was not appreciably different than the number observed in RFW in 2000 (Table 10). The family richness estimates at RHFE were lower than those at RFW for all three estimators (Table 10). There were, however, three families observed in RHFE that were not observed in any of the other ecosystems in either year. Each of these families was represented by a single specimen.

The observed number of focal groups species in RHFE and RFW were similar for ants and spiders but there were nearly twice as many carabid species observed in RHFE as in RFW (Table 10). All of the focal group species observed at RHFE were also observed at one of the other three ecosystems in either 1999 or 2000. However, six species of carabids were found in RHFE that were not observed at RFW in either year.

Table 10. A comparison of several measures of invertebrate richness at two florisitically similar ecosystems in Lincoln/Bristol, Vermont 2000. RFW = Rich hardwood forest west; RHFE = Rich hardwood forest east: F_1^*, F_2^*, and F_3^* = family richness estimators: F_{obs} = number of observed families: S_{obs} = number of observed families

	RFW 2000	RHFE 2000
F_1^*	76	69
F_2^*	72	67
F_3^*	64	62
F_{obs}	48	46
S_{obs} (spiders)	6	4
S_{obs} (carabids)	7	12
S_{obs} (ants)	2	2

Indices of similarity were calculated to compare RHFE to each of the three ecosystems on the Guthrie-Bancroft parcel (Table 11). The Sorenson qualitative index and Morisita index values comparing RHFE to RFW were higher than those comparing RHFE to either THF or SF (Table 11), but this was not the case for the Sorenson quantitative index.

Table 11. Ecosystem similarity values comparing a rich hardwood forest on the Wells Parcel to three forest ecosystems at the Guthrie-Bancroft Farm, Lincoln/Bristol Vermont 2000. RHFE= Rich hardwood forest east; RFW = Rich hardwood forest west; SF = Spruce-fir forest; THF = Transition hardwood forest.

	RHFE vs. THF 2000	RHFE vs. SF 2000	RHFE vs. RFW 2000
Sorenson Qualitative Index C_S	76.1%	70.8%	77.9%
Sorenson Quantitative Index C_N	46.1%	59.3%	54.3%
Morisita Index C_M	54.6%	83.4%	94.2%

Discussion

Family Diversity

Overall Family Richness

The range of estimated values for overall family richness was quite narrow (134-139) and was considerably narrower than the range of estimates generated in 1999 (120-159) suggesting that the estimates from the pooled data may be zeroing in on the actual family richness value. In general, however, extrapolation techniques tend to underestimate actual richness values (Colwell and Coddington, 1994) and this effect is compounded by treating the problematic orders (Acarina, Pseudoscorpionida, and Psocoptera) as single families.

Ecosystem Family Richness, Shannon Diversity, and Similarity

Neither the observed number of families nor the family richness estimates offered compelling evidence that any ecosystem was appreciably more diverse. The Shannon diversity index, which takes into account evenness as well as richness, indicated that RFW was more diverse than both THF and SF. Even though ecosystem comparisons suggested small differences between forest types, these data should be treated as preliminary for several reasons. The comparisons were based primarily on family level identifications (since this information was essentially complete for the specimens we collected), not on species identifications. Two factors that may contribute to the apparently higher diversity at RFW are moisture and nutrients. The rich hardwood forest has a number of seeps that supply moisture even under extremely dry conditions (like those encountered during the 1999 field season), and therefore may be a preferred habitat for many families that inhabit moist environments. The apparently higher diversity of RFW coupled with the presence of rare and uncommon species (*Pterostichus lachrymosus*, *Necrophilus pettitii*, two undescribed spider species, and *Crosbycus dasycnemus* were all found there) make it a high priority conservation area.

There were no clear trends that emerged from the similarity indices. The Morisita index should perhaps have been calculated by excluding the Acarina since it is highly sensitive to the most abundant family. The fact that the values of the Sorenson qualitative index for all pairwise comparisons were around 66% suggest that all three ecosystems make an essentially equivalent contribution to the overall family richness of the site.

Species Diversity

The relatively similar number of spider species observed in each ecosystem suggest that the spider diversity is about the same in each of the ecosystems. Several species were found in only one ecosystem, suggesting again that each of the ecosystems contribute to the overall diversity of the site. There are approximately 704 spider species in the northeastern states and Canadian provinces from the eight families that we collected with more than one species (Dan Jennings, pers. comm.). If the overall spider species richness estimates in this study are accurate, Guthrie-Bancroft Farm hosts approximately 6% of the surface-active spider fauna known for the entire region.

The low number of specimens and observed species of ground beetles at THF suggest that it may be less diverse in this focal group than the other two ecosystems. Approximately 55 species of surface-active ground beetles are known to occur in the nearby Green Mountain National Forest of Vermont (Ross Bell, pers. comm.). If our overall ground beetle species richness estimates are correct, Guthrie-Bancroft Farm hosts approximately 50 % of the surface-active ground beetles known for this nearby large region.

Comparison of RFW and RHFE

The comparison data for RHFE seem to indicate that continued sampling in this region for surface invertebrates will not add appreciably to the data being obtained from RFW, SF, and THF. The Sorenson qualitative similarity index data (Table 11) seem to indicate that RHFE is more similar to each of the three ecosystems in the Guthrie-Bancroft parcel than they are with one another (Table 4). The only cause for hesitation in this regard were the six ground beetle species found at RHFE that were not observed in RFW in 1999 or 2000. Therefore, although RHFE may not make as large a contribution to overall diversity as the other ecosystems, it should not necessarily be looked at as an equivalent ecosystem to RFW.

Significance of Findings

The findings of this study suggest that the protection of the overall biodiversity of surface-active invertebrates at Guthrie-Bancroft Farm should involve the preservation and management of the three forest ecosystems that were examined. In each forest ecosystem, we found families and species that were not found in either of the other two ecosystems. Therefore the loss of any one ecosystem might result in the local extinction of species from the property. Furthermore, the findings suggest that special attention be paid to the preservation of the rich hardwood forest ecosystem (RFW). Its apparently higher diversity together with the presence of rare and uncommon species warrant particular conservation attention and monitoring.

It should be emphasized that this study focused on only a small cross-section of all invertebrates at the site (i.e. those active on the ground or found within the litter). Nevertheless, it sampled invertebrates that were found in a number of habitat niches (within leaf litter, under stones, in fungi, in decaying bark, etc.) and that represented a variety of trophic levels (e.g. scavengers, decomposers, predators, etc). The management of biodiversity at a site should involve careful consideration of the various habitat niches and trophic levels for incorporation into a monitoring protocol. We recommend that a subset of invertebrates encompassing different habitat niches, trophic levels, and rarity be chosen for incorporation into a monitoring strategy used to indicate environmental change.

References

Burnham, K.P. and W.S. Overton. 1979. Robust estimation of the size of population size when capture probabilities vary among animals. *Ecology*, **60**:927-936.

Chao, A. 1984. Non-parametric estimation of the number of classes in a population. *Scand. J. Stat.* **11**:265-270.

Colwell, R.K. and J.A. Coddington. 1994. Estimating terrestrial biodiversity through extrapolation. *Phil. Trans. R. Soc. Lond.* B **345**:101-118.

Hammond, P.M. 1994. Practical approaches to the estimation of the extent of biodiversity in speciose groups. *Phil. Trans. R. Soc. Lond.* B **345**: 119-136.

Kremen, C., R.K. Colwell, T.L. Erwin, D.D. Murphy, R.F. Noss and M.A. Sanjayan. 1993. Terrestrial arthropod assemblages: their use in conservation planning. *Conserv. Biol.*, 7(4):796-808.

Magurran, A. E. 1988. Ecological diversity and its measurement. Princeton University Press, Princeton, NJ. 179pp.

McCollough, M. A. 1997. Conservation of invertebrates in Maine and New England: Perspectives and prognoses. *Northeastern Naturalist* 4(4): 261-278.

New, T. R. 1998. Invertebrate surveys for conservation. Oxford University Press, New York, NY. 240 pp.

Nongame and Natural Heritage Program.1996. Vermont's rare and uncommon native animals. Vermont Department of Fish and Wildlife, Waterbury, Vermont.

Oliver, I. and A.J. Beattie. 1996a. Designing a cost-effective invertebrate survey: a test of methods for rapid assessment of biodiversity. *Ecol. Appl.*, **6**(2):594-607.

Oliver, I. and A.J. Beattie. 1996b. Invertebrate morphospecies as surrogates for species: a case study. *Conserv. Biol.* **10**(1):99-109.

Rykken, J. J. 1995. Ground beetles as indicators of ecological land types in the Green Mountain National Forest, Vermont. Master's thesis. University of Vermont, Burlington, Vermont.

FIRST RECORD OF FLIGHTLESS CARRION BEETLE, *Necrophilus pettitii*, IN NEW ENGLAND (Coleoptera: Agyrtidae)

Mark A. Ward, Jeffrey M. Collins, and Susan M. Young

The flightless carrion beetle (*Necrophilus pettitii* Horn, 1880) is the only member of the family Agyrtidae found in eastern North America (Peck, 1990). Very little is known of the biology of agyrtids (Peck 1990), a group that until recently had been included in the family Silphidae (Anderson and Peck 1985). Most agyrtids are found in wet habitats, particularly along margins of mountain streams, on high altitude snowfields, in leaf litter, and in association with some fungi (Anderson and Peck 1985). Members of the family seem to be cold-adapted and are primarily active in the colder months of winter, late fall and early spring (Anderson and Peck 1985). Unlike silphids, agyrtids are difficult to find and are rarely collected (Anderson and Peck 1985); although adults of some species, especially members of Necrophilus, are known to come to baited carrion traps (Anderson and Peck 1985).

In summarizing the known distribution of *Necrophilus pettitii*, Peck (1981) included New York, Ontario, and Michigan south to Alabama, Georgia, and northern Florida. The species is believed to be a deep litter and soil scavenger (Peck 1990). It is typically collected in forested habitats with dung and carrion baits or pit traps (Peck 1981). Many records come from cave entrances where soil fauna can often be sampled with comparative ease (Peck 1981). The species has been collected most frequently in high-elevation forests of the southern Appalachians during the summer months (Peck, 1981).

On July 15, 2000, a single specimen of *Necrophilus pettitii* was collected in a non-baited pitfall trap in Bristol, Vermont. The specimen was collected as part of a survey of surface-active terrestrial invertebrates for the Colby Hill Ecological Project, a biodiversity inventory and monitoring project on 680 acres of private conservation land on the western slope of the Green Mountains in Lincoln and Bristol, Vermont (Lapin in prep.). The pitfall trap containing the specimen was located in a rich northern hardwood forest near the Bristol/Lincoln town boundary (44°09.537′ N, 73°01.719′ W) at an elevation of approximately 1200 ft. (365m). The specimen was identified by Dr. Ross T. Bell (University of Vermont, USA). Dr. Stewart B. Peck (Carleton University, Canada), who recently described the distribution and biology of this species, confirmed the identification. The specimen is currently housed in the Thompson Natural History Collection at the University of Vermont.

The closest previously known records of *Necrophilus pettitii* are from two locations in southern New York state: Cooks Falls, Sullivan County in September, 1926 (Peck, 1981); and Armonk, Westchester County in 1974 (Pirone, 1974). Armonk lies less than 10 miles from the Connecticut border suggesting the likely presence of *N. pettitii* in southern New England. The present collection site is more than 200 miles north of either of the southern New York locations (Figure 1).

The rich northern hardwood forest ecosystem in which the specimen was found is characterized by numerous parallel seeps that produce a broadly corrugated terrain on a moderately well-drained slope with northern aspect. This ecosystem type is one of several rich, seepy northern hardwood forest types that appear to be common in the northern Green Mountains particularly on north and east slopes (Lapin and Engstrom 1999 and Lapin in prep.). Soils at the site consist of a loam over fine sandy loam spodosol with a notably deep and black A horizon (Lapin in prep.). The diverse canopy includes sugar maple, yellow birch, white ash, red oak, beech, paper birch and several standing-dead butternut trees. Lapin (in prep.) estimates the age of this second growth forest at 65 years (based on a tree core from a large white ash). The understory consists of sugar maple, beech, and striped maple, and dominant herbs include rich-woods species like plaintain-leaved sedge (*Carex plantaginea*) and blue cohosh (*Caulophyllum thalictroides*).

This first record of *Necrophilus pettitii* in New England represents a considerable northeastern expansion of the previously known range of the species. The significance of this expansion is even more marked when one considers that *N. pettitii* is flightless. This finding suggests that the species may also occupy other suitable habitat from southern New York to north central Vermont. Locations that hold considerable promise for future documentation of *N. pettitii* in New England include the Taconic Mountains and southern Green Mountains of Vermont and the Berkshire Mountains of Massachusetts and Connecticut.