Ground Beetle assemblages on Illinois algific slopes: a rare habitat threatened by climate change

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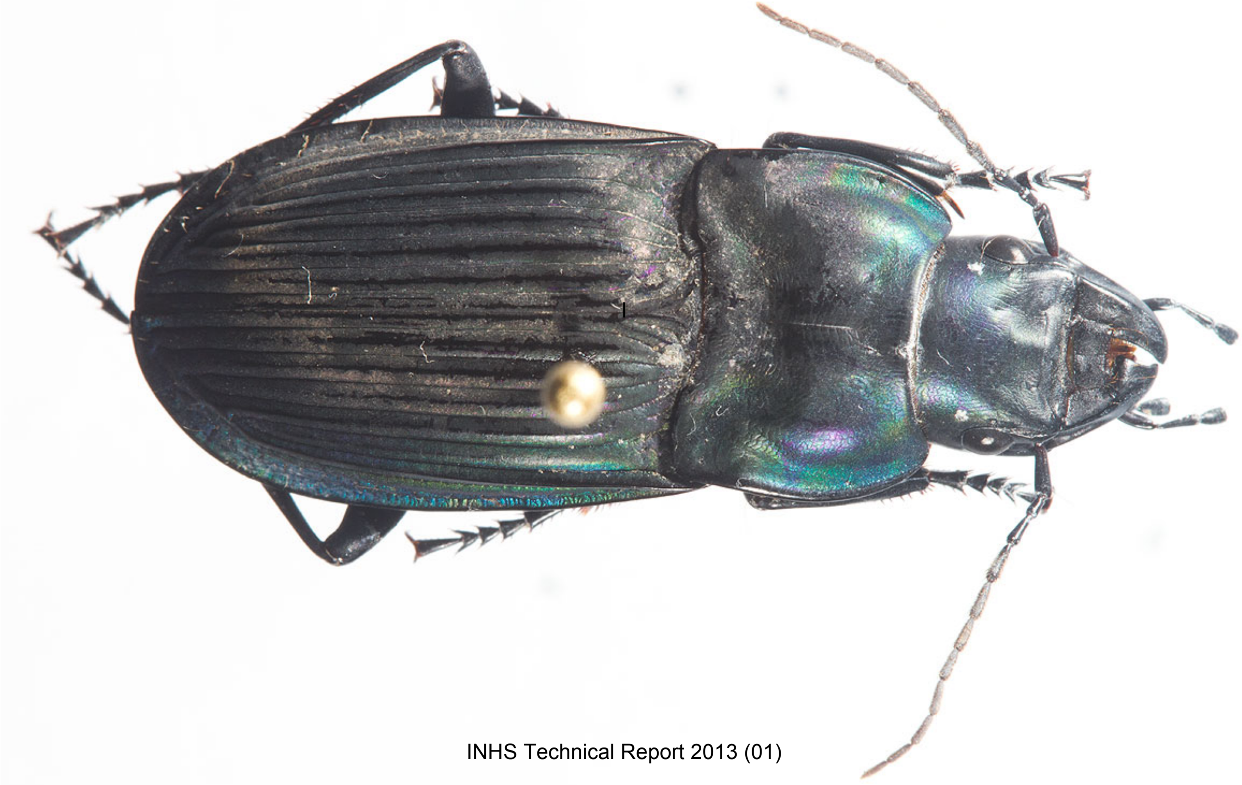

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During the Pleistocene, glacial advances left a small gap in the northwestern corner of Illinois, southwestern Wisconsin, and northeastern Iowa, which were never covered by the advancing Pleistocene glaciers (Taylor et al. 2009, p. 8, fig. 2.2). This is the Driftless Area – and it is one of Illinois' most unique natural regions, comprising little more than 1% of the state.

Illinois' Driftless Area harbors more than 30 threatened or endangered plant species, and several unique habitat types. Among these habitats are talus, or scree, slopes, some of which retain ice throughout the year. The talus slopes that retain ice through the summer, and thus form a habitat which rarely exceeds 50 °F, even when the surrounding air temperature is in the 90's °F, are known as "algific slopes." While there are numerous examples of algific slopes in Iowa and Wisconsin, this habitat is very rare in Illinois (fewer than ten truly algific sites are known in the state). These slopes are typically at the base of tall limestone bluffs, with northwestern or western exposures. The plant community of Illinois' algific slopes is unusual, and Schwegman (1982) describes an assemblage of northern plants occurring in this habitat, including some at the southern extent of their range. In short, plant communities of algific slopes and other habitats such as cool, shaded ravines, and bases of cliffs and bluffs, harbor relict populations of some of our most distinctive northern woodland plants.

This habitat is also home to the Iowa Pleistocene Snail, *Discus macclintocki* (F.C. Baker 1928), a species that is federally listed as endangered and occurs only in algific slope habitats in the Driftless Area, with only one known site in Illinois.

Algific slopes in Carroll and Jo Daviess counties, then, clearly represent a unique habitat harboring glacial relict species more typical of northern climates. As global warming proceeds, it is conceivable that this habitat type, the coldest in Illinois (Mohlenbrock 1986, p. 6), will be lost from Illinois. Indeed, Illinois' portion of the Driftless Area is the southern tip of the region, and we might expect our algific talus slopes to be even more imminently imperiled than those in Iowa and Wisconsin. Thus, we have limited time remaining to begin to understand the composition of natural communities in algific slope and other talus slope habitats of Illinois' Driftless Area - an important step towards effective management of this imperiled natural community type.

Beyond *D. macclintocki*, what do we know of the rest of the terrestrial invertebrates of algific slopes? The answer is, almost nothing. In IDNR's assessment of the Wisconsin Driftless Natural Division in its' Wildlife Action Plan, the only terrestrial insects noted in this area among the Species in Greatest Need of Conservation are those associated with prairie habitats: the Gorgone checkerspot (*Chlosyne gorgone* Hübner 1806-1816), the prairie walking stick (*Diapheromera velii* Walsh 1864), three leafhoppers (*Polyamia herbida* DeLong 1935, *Polyamia obtectus* Osborn & Ball 1898, & *Scaphytopius cinereus* Osborn & Ball 1897), Edward's hairstreak

(*Satyrium edwardsii* [Grote and Robinson, 1867]), the lead plant flower moth (*Schinia lucens* [Morrison 1875]), and the regal fritillary (*Speyeria idalia* [Drury 1773]). While the Plan acknowledges the importance of algific slopes for the Iowa Pleistocene snail, we could find no published data on any other invertebrates associated with talus slopes in Illinois' Driftless Area. Indeed, only one Carabid beetle is listed among the Species in Greatest Need of Conservation. Messer (2009) records 489 species of Carabidae from Wisconsin. Given that this group reaches its greatest diversity in the tropics, we expect that Illinois should have well over 500 species. The lack of representation of these, and indeed most invertebrates, on the Species in Greatest Need of Conservation list reflects only the extent to which they have been studied.

Here, we report on a preliminary inventory of ground beetles (Insecta: Coleoptera: Carabidae) conducted in the Driftless Area by sampling three algific slope sites and three non-algific slope sites. The ground beetles are a fairly diverse family with a variety of degrees of generalist and specialist predators (such as those feeding only on snails) and scavengers, ranging from widely distributed common species found even in agricultural settings, to narrowly endemic species known only from a single site. These beetles in general are easily captured using pitfall traps, making it possible to obtain quantifiable data with relative ease (Julio 2010). Ground beetles are found in a wide variety of habitat types, from prairies to bottomland forests, and from the arctic to the tropics, with unique community assemblages in differing habitats (Lövei and Sunderland 1996, Ribera et al. 2001). Finally, these beetles repeatedly have been shown to be useful bioindicators (Eyre et al. 1996, Rainio and Niemelä 2003) and have already been successfully used in a wide variety of ecological studies (e.g., Stork 1990).

We studied ground beetle communities of talus slopes in the Driftless Area in relation to a variety of habitat parameters, 1) to gain an understanding of the diversity of species present at these sites; 2) to associate assemblages of species, or shifts in species assemblages with differences in habitat parameters, especially temperature; and 3) to evaluate ground beetle assemblages associated with colder talus slopes relative to those associated with talus slopes generally lacking properties of algific slopes, in hopes of predicting possible changes in ground beetle assemblages that might be experienced as algific slopes are lost in Illinois due to changing climatic conditions, perhaps identifying species in danger of being extirpated from the state.

Methods

We selected three sites previously identified as algific slopes (Asgard 01, Asgard 02 [**Figure 1**], and Princess Mine 01 [**Figure 2**]) and, by our observation at least having cooler air and some of the unique vegetation associated with Illinois algific slopes. We also selected three other hill slope sites lacking algific qualities (Hanover Bluff 01 [**Figure 3**], Hanover Bluff 02, and Stevenson [**Figure 4**]), all located in western Jo Daviess County, Illinois (**Figure 5**). The Princess Mine site is part of Princess Mine Algific Slope (Princess Mine Algific Slope Natural Heritage Landmark), the Asgard sites are part of Asgard Algific Slope (Asgard Natural Heritage Landmark), the Hanover Bluff sites are in Hanover Bluff Nature Preserve, and the Stevenson site is on other private property. Natural Heritage Landmarks do not require any permits (unless they also have some other status), but do require landowner permission (Kelly Neal, INPC, personal communication, 17 Mar 2011), which was secured prior to fieldwork.

We used a mixed sampling strategy to maximize Ground Beetle species recovery, and sampled during two sample periods: Fall [August 26-27, 2011 to September 9-10, 2011], Spring [May 15-16, 2012 to May 29-30, 2012]. Thus, each pitfall trap represents about 14 trap-days of sampling. Site characteristics including aspect, slope, average canopy cover, average herbaceous cover, average leaf litter depth, average air temperature during sampling, and average soil temperature during sampling are given in **Appendix I**. Weather during the sampling period (precipitation, temperature, wind direction and humidity) and historical averages (temperature, humidity) for the study area are given in **Appendix II**. At each site, we placed 5 pitfall traps in the slopes, and the traps were recovered after the 14-day sample period. A 20% propylene glycol (pet-safe antifreeze) solution was used as a preservative in the traps (**Figure 6**). Pitfall traps were constructed from plastic cups placed into the ground such that the upper lip was just below the soil surface (**Figure 7**). Traps were covered by a foam cover (**Figure 8**) to protect against flooding from rainfall, and these covers were elevated by ~1 cm to allow access by beetles. When the pitfall traps were recovered, the samples were brought back to the laboratory, rinsed, and transferred to ethanol prior to analysis.

Figure 1. Algific slope at the Asgard 02 study site, 10 September 2011.

Figure 2. Checking a pitfall trap (red cup) on the algific slope at the Princess Mine 01 study site on 10 September 2011. Pink square in foreground is trap cover which has been removed.

Figure 3. Preparing whirl-pak bags to receive pitfall trap samples at the non-algific site Hanover Bluff 01, on 9 September 2011.

Figure 4. Photo of the habitat at Stevenson, a non-algific site, on 10 September 2011.

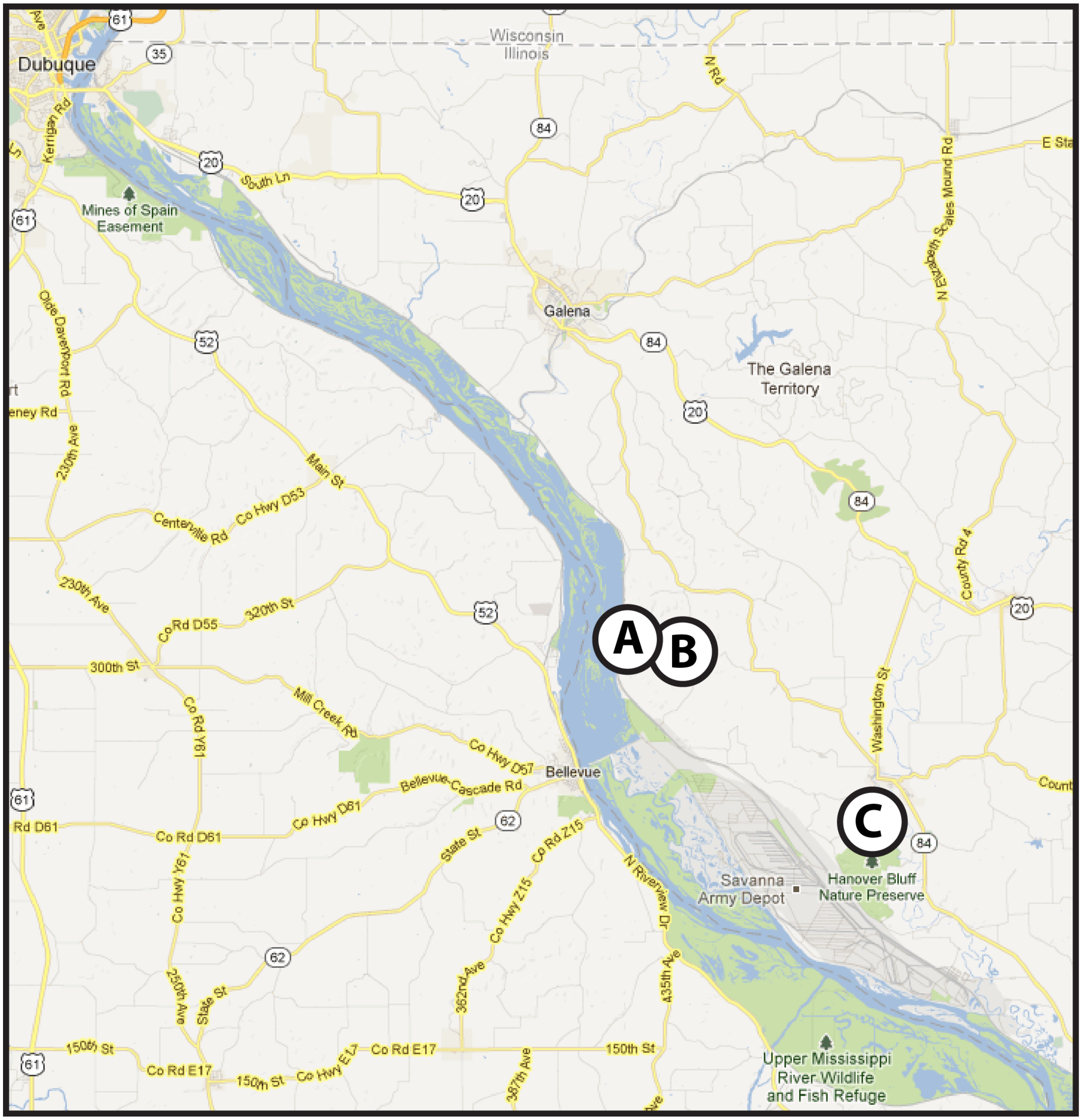

Figure 5. Extreme northwestern Illinois with approximate locations of sample sites: A) Asgard and Princess Mine sites, B) Stevenson site and C) Hanover Bluff site.. Coordinates for specific sites have been provided to IDNR, but are excluded from this report to protect sensitive biotic resources.

Figure 6. Pouring propylene glycol and sample contents into double-labeled sample bag at end of sampling period, Hanover Bluff 01, 9 September 2011.

Figure 7. Pitfall trap at Hanover Bluff 01, with cover removed, just before recovering sample on 9 September 2011.

Figure 8. Pitfall trap at Princess Mine 01 on 10 September 2011. Pink foam cover protects trap from rain and excessive debris, while nails function as legs to suspend the cover about 1 cm above ground surface. Wire flags were used to mark each trap to facilitate recovery.

At each site, we recorded environmental parameters. The slope and aspect of each talus slope was recorded (**Appendix I**). Probe-type temperature probes were used to measure soil temperature and air temperature during each seasonal visit. Ground cover (bare soil, rock, woody plants, grass, dead wood, leaf litter) was characterized by photographing 0.5 m^2 quadrats placed around each of the pitfalls. Cover was scored in a digital photograph using an overlaid grid of points. Canopy cover was scored in a similar manner, using a digital camera image pointing straight up from each pitfall. Leaf litter depth was measured with a ruler at four points in each quadrat and these data were then used to calculate an average leaf litter depth for the slope.

Once pitfall samples were back in the lab, the arthropods in the samples were sorted and Carabidae were identified to genus and species (in one case, only morphospecies was possible). Voucher material will be deposited in the Illinois Natural History Survey Insect Collection.

Data from the Ground Beetle collections were analyzed to calculate seasonal and site specific species diversity, abundance, and richness. We used EstimateS 8.2.0 (Colwell 2009) to perform calculations for species accumulation curves to assess completeness of sampling, and to make estimates of the true number of Ground Beetle taxa at each site. Species accumulation curves are displayed by plotting the number of species versus the number of samples. As sampling becomes more complete, the species accumulation curve should approach an asymptotic value, becoming nearly horizontal. Several estimators of true species richness have been implemented, and these are described in Colwell (2009). The observed species accumulation (Mao Tau), is plotted for 1000 randomizations, and these data inform calculations of an abundance based coverage estimator (ACE), a first order Jackknife estimator (Jackknife 1), a bootstrap richness estimator, and Chao 1 (another richness estimator). In addition to comparing the various estimators of species richness to Mao Tau, we used the software to characterize the accumulation of singletons (species represented by only 1 individual in the accumulated samples) and doubletons (species represented by only 2 individuals in the accumulated samples). Finally, it was convenient to use EstimateS 8.2.0 to calculate species diversity and evenness metrics.

Similarities among sites based on species presence absence were evaluated using cluster analysis (UPGMA clustering). We also evaluated species composition among sites in relationship to environmental variables to look for any patterns.

Mean number of beetles per trap, based on total abundance, was compared between algific and non-algific pitfall traps using a Welch Two Sample t-test, in addition to being displayed with a boxplot.

We also examined the whole dataset using a multivariate technique, nonmetric multidimensional scaling (NMDS), conducted using the package ‘vegan’ version 2.0-5 running in R 2.15.2, an open source programming language and software environment used primarily for statistical analyses. For this approach, we excluded not only the pitfalls from which no samples could be recovered, but also those pitfall samples for which no ground beetles were recovered. For the remaining samples the total abundance of beetles per trap per species was used to calculate the Bray-Curtis dissimilarity distances among samples. UPGMA average linkage cluster analysis was used to assess possible patterns in the similarity among individual pitfall traps.

Results

Five traps were placed at each of the six sites (algific sites: Asgard 01 [AS1], Asgard 02 [AS2], Princess Mine 01 [PM1]; non-algific sites: Hanover Bluff 01 [HB1], Hanover Bluff 02 [HB2], Stevenson [STV]) in two seasons (Fall 2011, Spring 2012), for a total of 60 pitfall traps. All of the pitfall traps placed at STV in the spring were damaged by wildlife, and thus no samples were recovered from STV in the spring. Similarly, in the Fall, traps 2 & 3 at STV, and trap 1 at PM1 had no data recovery. As a result, a total of 52 pitfall traps are available for analyses. The species recorded from this study (**Table 1**) represent nine tribes, 19 genera, and 25 species. The subfamily Pterostichinae, tribe Pterostichini was the richest taxonomic group, with seven species recorded, five of which belong to the genus *Pterostichus* and belong to four different subgenera (**Table 1**). The next richest taxonomic group was the subfamily Harpalinae, tribe Harpalini, represented by six species in five genera, followed by the subfamily Platyninae, tribe Platynini, which was represented by four species in four genera. One genus and species, *Amphasia interstitialis*, is recorded on the basis of a single specimen from an incidental hand collection from STV in May 2012, with all remaining 264 specimens obtained from the pitfall samples. Analyses will focus only on the pitfall data (**Appendix III**). We attempted to evaluate the conservation status of the species listed in **Table 1**, hoping to apply global and state ranks (**Appendix IV**) to each species. All species listed in **Table 1** were found to be G5 taxa, and there was insufficient data to assign a state-level imperilment rank to any of the species, due to a lack of more detailed information about their distributions and occurrence throughout Illinois. Similarly, a review of the available literature leads us to believe that there are insufficient data to allow us to propose any of these species for potential inclusion on the Illinois list of species in greatest need of conservation, as the criteria for inclusion (**Appendix V**) could not be assessed for these species. Images of select species help give a sense of the diversity of form and coloration within the family (**Figures 9-22**).

Species accounts

Carabus (Hemicarabus) serratus Say, 1825 (**Figure 9**)

Found throughout much of the conterminous United States and southern Canada (Bousquet 2012), *C. serratus* is found on "open, gravelly ground, usually moraine, with sparse vegetation; at the foot of rock-falls, on railway embankments, in gravel pits, on sun-exposed wood-glades" (Lindroth 1961 [as cited in Erwin 1981]), where it is active during both night and day (Larochelle 1972 [as cited in Erwin 1981]). In Newfoundland, hibernation is in the adult stage (Lindroth 1961 [as cited in Erwin 1981]). Flight has not been observed in this species (Bousquet 2010). This species is previously known from Illinois (Bousquet and La Rochelle 1993).

Cicindela (Cicindela) sexguttata Fabricius, 1775 (**Figure 10**)

Occurs in "open/covered places: roads, roadsides, paths, trails, pastures, vacant fields, forest edges, shady trails, usually on loam" (Bousquet 2010) & readily uses flight to escape (Bousquet 2010). This species is previously known from Illinois (Bousquet and La Rochelle 1993), and occurs through eastern Canada and the Eastern United States from Maine and Florida west to Texas and South Dakota (Bousquet 2012).

Amphasia (Amphasia) interstitialis (Say, 1823) (**Figure 11**)

This species is known from Illinois and occurs in Ontario & Quebec and through portions of the eastern USA from South Carolina and Arkansas to Texas and South Dakota (Bousquet 2012).

Anisodactylus (Anisodactylus) agricola (Say, 1823) (**Figure 12**)

Little is known about the habitats of this temperate species, which has not been observed in flight (Bousquet 2010). This species is previously known from Illinois (Bousquet and La Rochelle 1993, Willand and Wodika 2011), and ranges from Maine and Quebec west to Minnesota, Arkansas, and Alabama (Bousquet 2012).

*Harpalus (Pseudoophonus) vagans LeConte, 1865 (**Figure 13**)*

This species is known from Illinois and occurs from Ontario and Quebec south to Georgia, Kansas, and South Dakota (Bousquet 2012).

Harpalus morphospecies 1

The genus *Harpalus* contains some 59 species occurring in North America (Bousquet 2012), we were not able to assign a species name to this morphospecies. More than 15 species are recorded from Illinois, and species occurring in adjacent states roughly doubles the possibilities in this difficult genus.

Agonoleptus thoracicus (Casey, 1914)

This species is known from Illinois and occurs from Vermont and North Dakota south to Kansas and Virginia (Bousquet 2012).

Trichotichnus (Trichotichnus) vulpeculus Say, 1823 (**Figure 14**)

This species is known from Illinois and occurs from New Brunswick and Ontario south to Arkansas and Georgia (Bousquet 2012).

Chlaenius (Anomoglossus) emarginatus Say, 1823 (**Figure 15**)

This species is known from Illinois and occurs from eastern Canada, through much of the eastern USA south to Florida, and west to Oklahoma and South Dakota (Bousquet 2012).

Chlaenius (Chlaenius) platyderus Chaudoir, 1856 (**Figure 16**)

This species is known from Illinois and occurs from Massachusetts to Manitoba south to New Mexico, east to Georgia, and throughout much of the eastern United States (Bousquet 2012).

Apenes (Apenes) lucidula lucidula (Dejean, 1831) (**Figure 17**)

This more southern species occurs from Massachusetts and Minnesota south to Texas, Mexico, and Florida, as well as southern Arizona, with two other species recorded from the West Indies (Bousquet 2012).

Cymindis (Cymindis) americana Dejean, 1826

This species is known from Illinois and occurs from Quebec and Maine south to South Carolina and Louisiana, west to South Dakota (Bousquet 2012).

Dicaelus (Dicaelus) purpuratus Bonelli, 1813 (**Figure 18**)

This species is known from Illinois and occurs from Massachusetts to Ontario and Wisconsin, west to Colorado and Arizona, and southeast to Texas, Louisiana and Georgia (Bousquet 2012). There are two subspecies, both recorded from Illinois (Bousquet 2012). This is one of the largest species recovered during our study, and it is pictured on the cover of this report.

Agonum (Olisares) melanarium Dejean, 1828

This species is known from Illinois and occurs widely across the United States and Canada (Bousquet 2012).

Calathus (Neocalathus) gregarius (Say, 1823) (**Figure 19**)

This species is known from Illinois and is found through eastern Canada west to North Dakota and south to Alabama and Georgia (Bousquet 2012).

Platynus (Platynus) decentis (Say, 1823)

This species is known from Illinois and occurs from Alaska, through much of Canada and the United states, from Maine to Georgia, and west to Alabama, Kansas, and Oregon (Bousquet 2012).

Synuchus (Synuchus) impunctatus (Say, 1823)

This species is known from Illinois and occurs throughout Canada and occurs in the United States from Washington, Idaho, and Kansas east to Georgia, and through the northeastern states (Bousquet 2012).

Myas (Neomyas) cyanescens Dejean, 1828 (**Figure 20**)

This species is known from Illinois and occurs from Nova Scotia and Minnesota south to Alabama and Georgia (Bousquet 2012).

Poecilus (Poecilus) lucublandus (Say, 1823) (**Figure 21**)

This widespread species is known from Illinois and occurs through much of Canada, south to Oregon, New Mexico and Texas, and eastward to Georgia and South Carolina, and north to Maine and adjacent Canadian provinces (Bousquet 2012).

Pterostichus (Phonias) femoralis (Kirby, 1837)

This species is known from Illinois and occurs from the Canadian provinces south through Montana and New Mexico, east through northern Texas to the District of Columbia, and throughout the northeastern USA (Bousquet 2012).

Pterostichus (Bothriopterus) mutus (Say, 1823)

This species is known from Illinois and occurs from Canada south into New Mexico and Kansas, east to Georgia, and through much of the northeastern United States (Bousquet 2012).

Pterostichus (Bothriopterus) pensylvanicus Leconte, 1873

This species is known from Illinois and occurs through Canada south to South Dakota, Iowa and Virginia, through much of the northeastern United States (Bousquet 2012). A more northern species, it is not known from Missouri, Arkansas, or Kentucky.

Pterostichus (Petrophilus) stygicus (Say, 1823) (**Figure 22**)

This species is known from Illinois and occurs from Maine to Iowa and south to Kansas and Georgia (Bousquet 2012). This was the most abundant species in our samples.

Pterostichus (Hypherpes) tristis (Dejean, 1828)

This species is known from Illinois and occurs from Nova Scotia to Ontario, south to Iowa and Illinois, east to Kentucky, Georgia, and South Carolina, and throughout much of the northeastern United States (Bousquet 2012).

Amara (Bradytus) exarata Dejean, 1828

> This species is known from Illinois and occurs in Ontario and through much of the eastern USA, extending west to South Dakota and south to Texas and Georgia (Bousquet 2012).

The number of specimens collected per site ranged from 18 (HB2, STV) to 106 (HB1), with more specimens recorded from non-algific sites than from algific sites (**Table 2**). However, non-algific specimen records were dominated by collections from HB1, and STV collections are based on only 3 pitfall samples during one season. The number of species recorded per site ranged from 4 at STV (again, with only 3 samples), to 11 at the algific site AS2 (**Table 2**). More species were recorded from algific sites than non-algific sites (**Table 2**). The mean number of beetles/trap was not different between the algific and the non-algific pitfall traps (**Figure 23**); Welch Two Sample t-test: $t = -0.5677$, $df = 43.752$, p-value = 0.5731).

The number of individuals obtained from the 3 algific sites (122 from 29 pitfall traps) was significantly less than the number obtained from the 3 non-algific sites (142 from 23 pitfall traps) **(**$\chi^2=9.775$, df=1, p=0.0018) assuming as a null hypothesis that the number of specimens is linearly correlated with the number of pitfall traps. Similarly, the number of individuals obtained from Fall samples (180 from 27 pitfall traps) was significantly more than the number obtained from the Spring samples (84 from 25 pitfall traps) **(**$\chi^2=27.956$, df=1, $p<0.0001$) assuming as a null hypothesis that the number of specimens is linearly correlated with the number of pitfall traps. In addition, disproportionately more species (18) were taken from the traps at the algific sites than were found at the non-algific sites (12 species).

One species, *Pterostichus stygicus*, was dominant in our samples, accounting for slightly more than half of all ground beetles recovered (52.7%, 129 specimens) (**Figure 24**). Five other species (*Chlaenius platyderus*, *Calathus gregarius*, *Trichotichnus vulpeculus*, *Agonum melanarium* and *Chlaenius emarginatus*) accounted for 4.5% (12 specimens) to 7.2% (19 specimens) of the total catch, and combined they represent 29.2% (77 specimens) of the beetles recorded from the pitfall traps (**Figure 24**). Of the remaining taxa, six were recorded on the basis of two specimens, and six were recorded on the basis of only 1 specimen (**Figure 24**).

For all samples combined, the species accumulation curve, Mao Tau, in **Figure 25** has not reached an asymptotic value, but is beginning to level of, suggesting that further sampling would yield additional species. The estimators of true species richness achieve values ranging from a low value of 25.14 for Chao 1, up to values of 28.84 and 28.88 for ACE and Jacknife 1, respectively. Thus, for pitfall sampling at these sites during these two particular sampling periods, it is likely that the true species richness lies between 25 and 30 species, with more expected by other sampling methods (see for example, Maveety *et al*. [2011]). The accumulation curve for doubletons appeared to continue to increase in an approximately linear fashion as more specimens were sampled, whereas the accumulation curve for singletons is asymptotic.

A surprisingly high portion (79.2%) of the 24 species were found at only one or two of the sampling sites, with fully 58.3% recorded from only a single sampling site (**Figure 26**). Only 12.5% (3 species) of the species were present at five or six of the sites. The high uniqueness of each of the sites may help explain why the cluster analyses based on number of specimens per species per site did not match our a priori selection of sites as algific or non-algific (**Figure 27**). However, examining the same dataset using Bray-Curtis dissimilarity distances between traps (instead of sites) based on species composition, a more interesting pattern emerges (**Figure 28**). Most of the non-algific samples tended to cluster together, whereas many of the algific samples each appeared to be relatively unique in species composition.

Table 1. List of Ground Beetles (Coleoptera: Carabidae) collected at six sites in Jo Daviess County, Illinois in 2011 and 2012. Wing morph from Lindroth (1961-69), Purrington *et al*. (1989), Riley and Brown (2011), Usis and MacLean (1998), or Will *et al*. (1995): BR = brachypterous; DI = dimorphic; AP = apterous; MA = macropterous. Habitats from Bousquet (2010) or Lindroth (1961-69): HY = hygrophilous, ME = mesic, OG = open grassy areas, NA = not available, PL = planticolous, RB = river bank, XR = xerophilous.

Subfamily **Tribe** **Species Name**	**Wing**	**Habitat**
Carabinae Latreille, 1802		
Carabini Latreille, 1802		
Carabus (Hemicarabus) serratus Say, 1825 (**Figure 9**)	DI	XR
Cicindelinae Latreille, 1802		
Cicindelini Latreille, 1802		
Cicindela (Cicindela) sexguttata Fabricius, 1775 (**Figure 10**)	MA	OG
Harpalinae Bonelli, 1810		
Harpalini Bonelli, 1810		
Amphasia (Amphasia) interstitialis (Say, 1823) (**Figure 11**)	MA	ME,OG
Anisodactylus (Anisodactylus) agricola (Say, 1823) (**Figure 12**)	MA	NA
Harpalus (*Pseudoophonus*) *vagans* LeConte, 1865 (**Figure 13**)	MA	OG
Harpalus morphospecies 1		
Agonoleptus thoracicus (Casey, 1914)	NA	NA
Trichotichnus (Trichotichnus) vulpeculus Say, 1823 (**Figure 14**)	MA	NA

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Table 1. Concluded.

Subfamily **Tribe** **Species Name**	**Wing**	**Habitat**
Lebiinae Bonelli, 1810		
Chlaeniini Brulle, 1834		
Chlaenius (Anomoglossus) emarginatus Say, 1823 (**Figure 15**)	MA	ME
Chlaenius (Chlaenius) platyderus Chaudoir, 1856 (**Figure 16**)	BR	OG
Lebiini Bonelli, 1810		
Apenes (Apenes) lucidula lucidula (Dejean, 1831) (**Figure 17**)	MA	NA
Cymindis (Cymindis) americana Dejean, 1826	BR	ME,OG
Licininae Bonelli, 1810		
Licinini Bonelli, 1810		
Dicaelus (Dicaelus) purpuratus Bonelli, 1813 (**Figure 18**)	BR	ME
Platyninae Bonelli, 1810		
Platynini Bonelli, 1810		
Agonum (Olisares) melanarium Dejean, 1828	MA	HY
Calathus (Neocalathus) gregarius (Say, 1823) (**Figure 19**)	DI	XR,OG
Platynus (Platynus) decentis (Say, 1823)	MA	HY,RB
Synuchus (Synuchus) impunctatus (Say, 1823)	DI	ME
Pterostichinae Bonelli, 1810		
Pterostichini Bonelli, 1810		
Myas (Neomyas) cyanescens Dejean, 1828 (**Figure 20**)	BR	ME
Poecilus (Poecilus) lucublandus (Say, 1823) (**Figure 21**)	MA	XR,OG
Pterostichus (Phonias) femoralis (Kirby, 1837)	DI	OG
Pterostichus (Bothriopterus) mutus (Say, 1823)	MA	ME
Pterostichus (Bothriopterus) pensylvanicus Leconte, 1873	MA	ME
Pterostichus (Petrophilus) stygicus (Say, 1823) (**Figure 22**)	BR	ME,OG
Pterostichus (Hypherpes) tristis (Dejean, 1828)	AP	ME
Zabrini		
Amara (Bradytus) exarata Dejean, 1828	MA	XR

Figure 9. *Carabus (Hemicarabus) serratus* Say, 1825 (Carabidae: Carabinae: Carabini) from site Asgard 01, on 10 September 2011.

Figure 10. A tiger beetle, *Cicindela (Cicindela) sexguttata* Fabricius, 1775 (Carabidae: Cicindelinae: Cicindelini) from site Hanover Bluff 01, on 30 May 2012.

Figure 11. *Amphasia (Amphasia) interstitialis* (Say, 1823) (Carabidae: Harpalinae: Harpalini) from site Stevenson on 30 May 2012.

Figure 12. *Anisodactylus (Anisodactylus) agricola* (Say, 1823) (Carabidae: Harpalinae: Harpalini) from site Asgard 01 on 29 May 2012.

Figure 13. *Harpalus* (*Pseudoophonus*) *vagans* LeConte, 1865 (Carabidae: Harpalinae: Harpalini) from site Hanover Bluff 01 on 30 May 2012.

Figure 14. *Trichotichnus (Trichotichnus) vulpeculus* Say, 1823 (Carabidae: Harpalinae: Harpalini) from site Princess Mine 01, on 10 September 2011.

Figure 15. *Chlaenius (Anomoglossus) emarginatus* Say, 1823 (Carabidae: Lebiinae: Chlaeniini) from site Hanover Bluff 02, on 10 September 2011.

Figure 16. *Chlaenius (Chlaenius) platyderus* Chaudoir, 1856 Carabidae: Lebiinae: Chlaeniini) from site Asgard 01, on 10 September 2011.

Figure 17. *Apenes (Apenes) lucidula lucidula* (Dejean, 1831) Carabidae: Lebiinae: Lebiini) from site Asgard 02, on 29 May 2012.

Figure 18. *Dicaelus (Dicaelus) purpuratus* Bonelli, 1813 (Carabidae: Licininae: Licinini) from site Asgard 02, 10 September 2011.

Figure 19. *Calathus (Neocalathus) gregarius* (Say, 1823) (Carabidae: Platyninae: Platynini) from site Asgard 02, 10 September 2011.

Figure 20. *Myas (Neomyas) cyanescens* Dejean, 1828 (Carabidae: Pterostichinae: Pterostichini) from site Asgard 02, 29 May 2012.

Figure 21. *Poecilus (Poecilus) lucublandus* (Say, 1823) (Carabidae: Pterostichinae: Pterostichini) from site Hanover Bluff 01, on 30 May 2012.

Figure 22. *Pterostichus (Petrophilus) stygicus* (Say, 1823) (Carabidae: Pterostichinae: Pterostichini) from site Princess Mine 01, on 10 September 2011.

Table 2. Site-specific summary of ground beetle collections from pitfall traps.

Site	Site Type	Number of Specimens	Number of Species
Asgard 01 [AS1]	Algific	41	10
Asgard 02 [AS2]	Algific	26	11
Princess Mine 01 [PM1]	Algific	55	7
Subtotal	Algific	122	18
Hanover Bluff 01 [HB1]	Non-Algific	106	9
Hanover Bluff 02 [HB2]	Non-Algific	18	5
Stevenson [STV]	Non-Algific	18	4
Subtotal	Non-Algific	142	12
Total		**264**	**24**

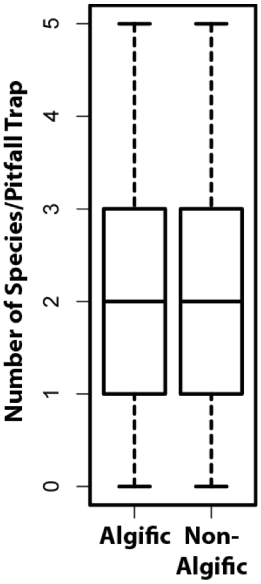

Figure 23. Boxplot of number of beetles recovered per trap, for all traps for which samples were recovered.

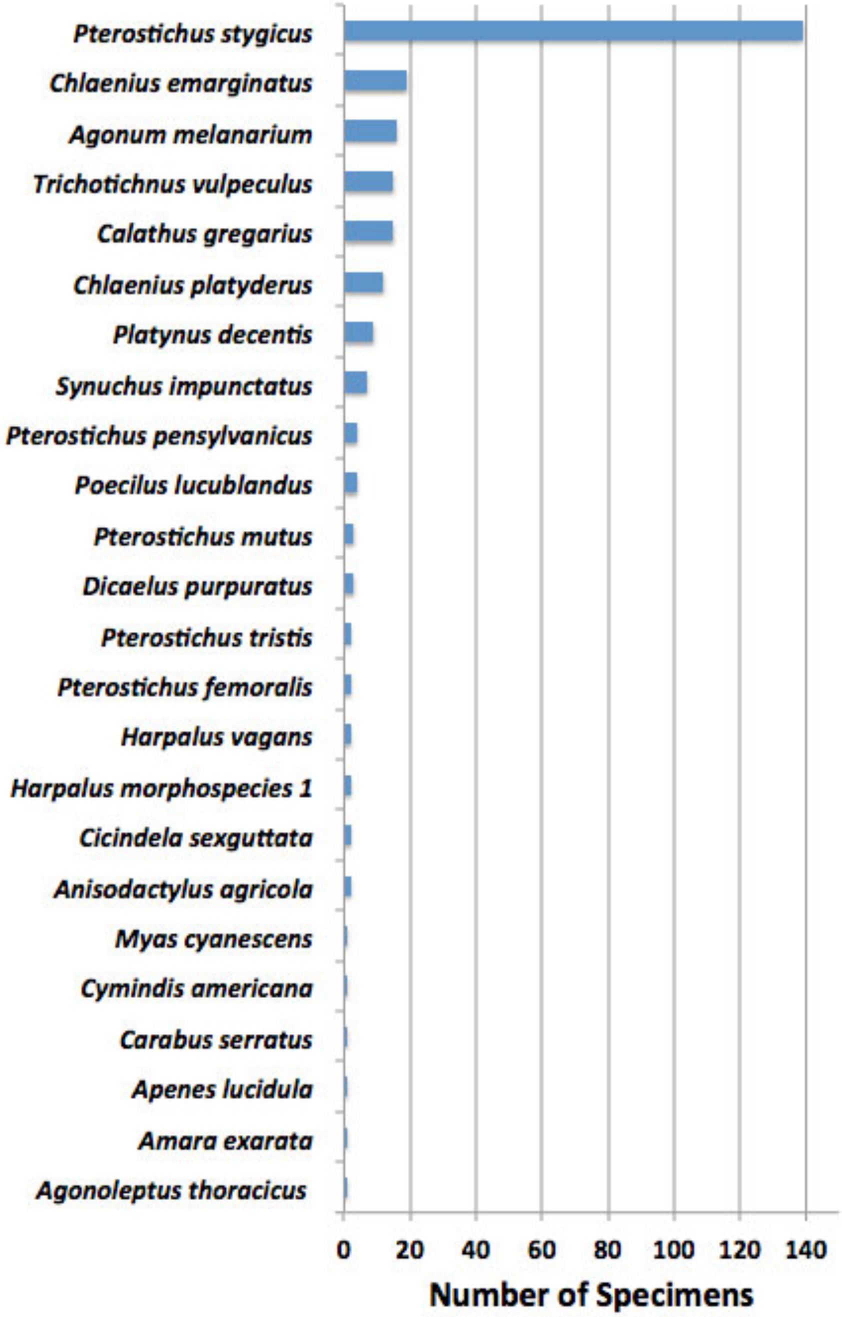

Figure 24. Number of specimens of each species recovered from pitfall traps during the present study.

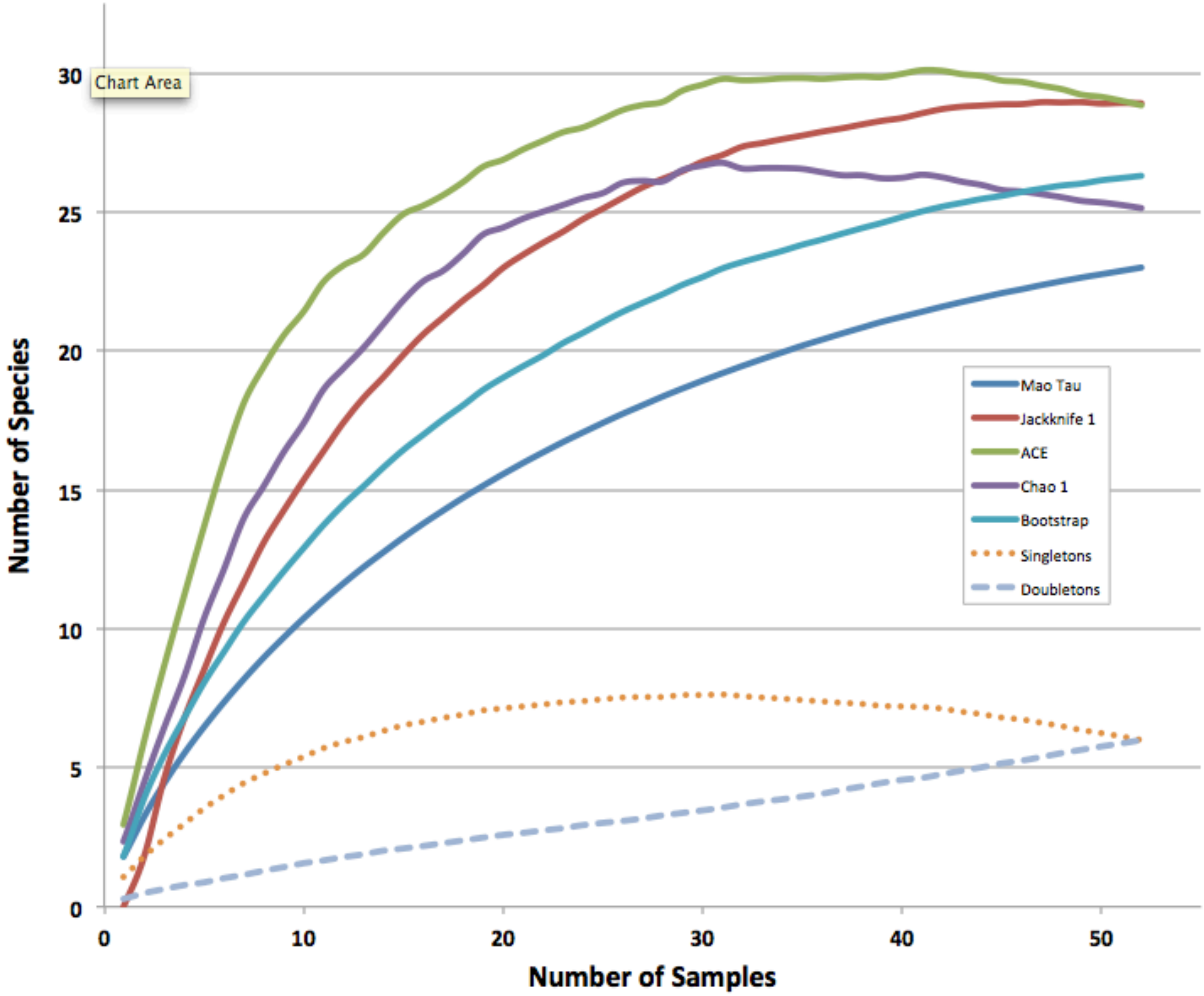

Figure 25. Species accumulation curve for ground beetles obtained from all pitfall samples based on 1000 randomizations (Mao Tau), shown along with several estimators of true species richness and accumulation of singletons and doubletons.

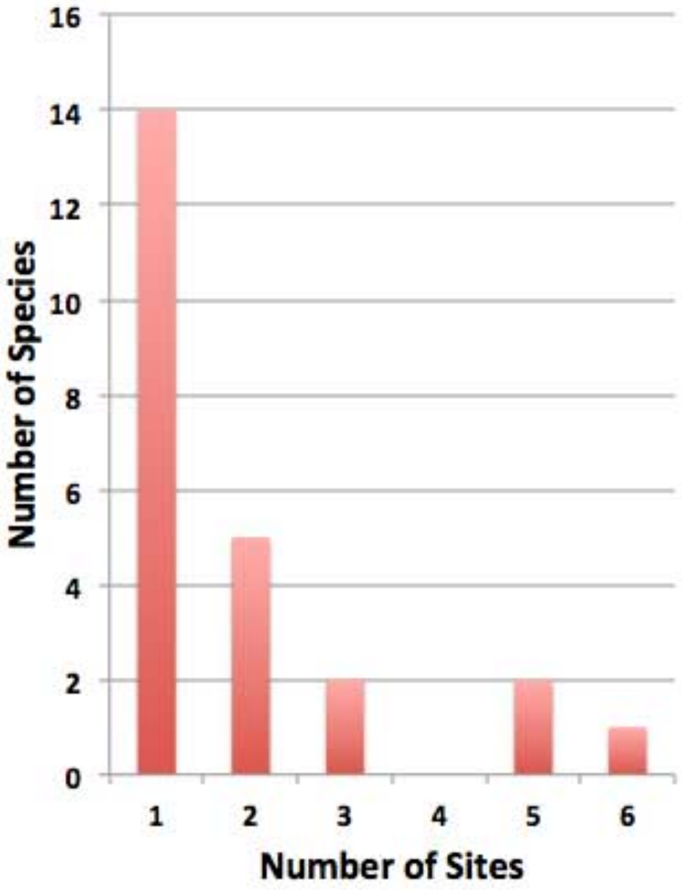

Figure 26. Number of sites at which each of the 24 species of ground beetles obtained from pitfall sampling was recorded.

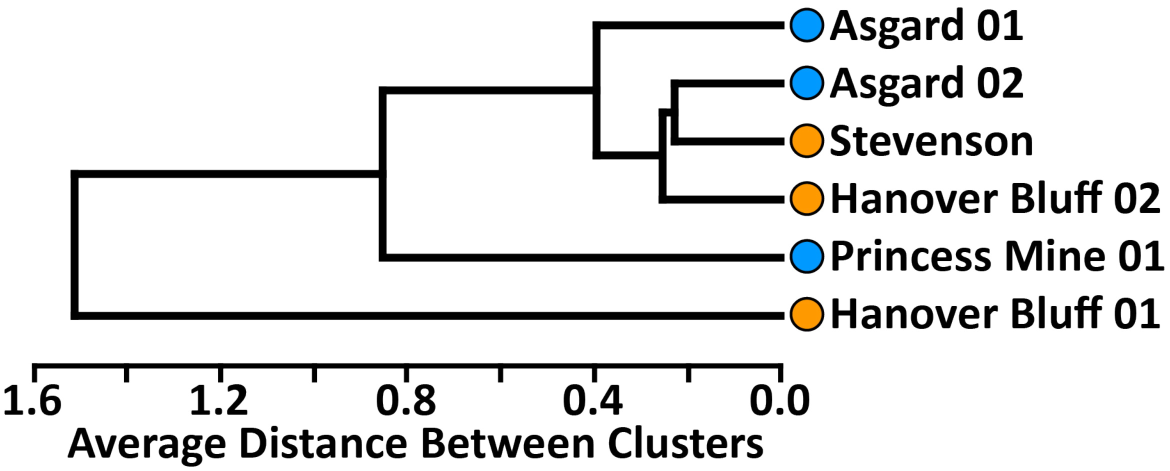

Figure 27. UPGMA Average Linkage Cluster Analysis of sample sites based on numbers of individuals per species collected at each site. Blue dots correspond to algific sites, orange dots to non-algific sites.

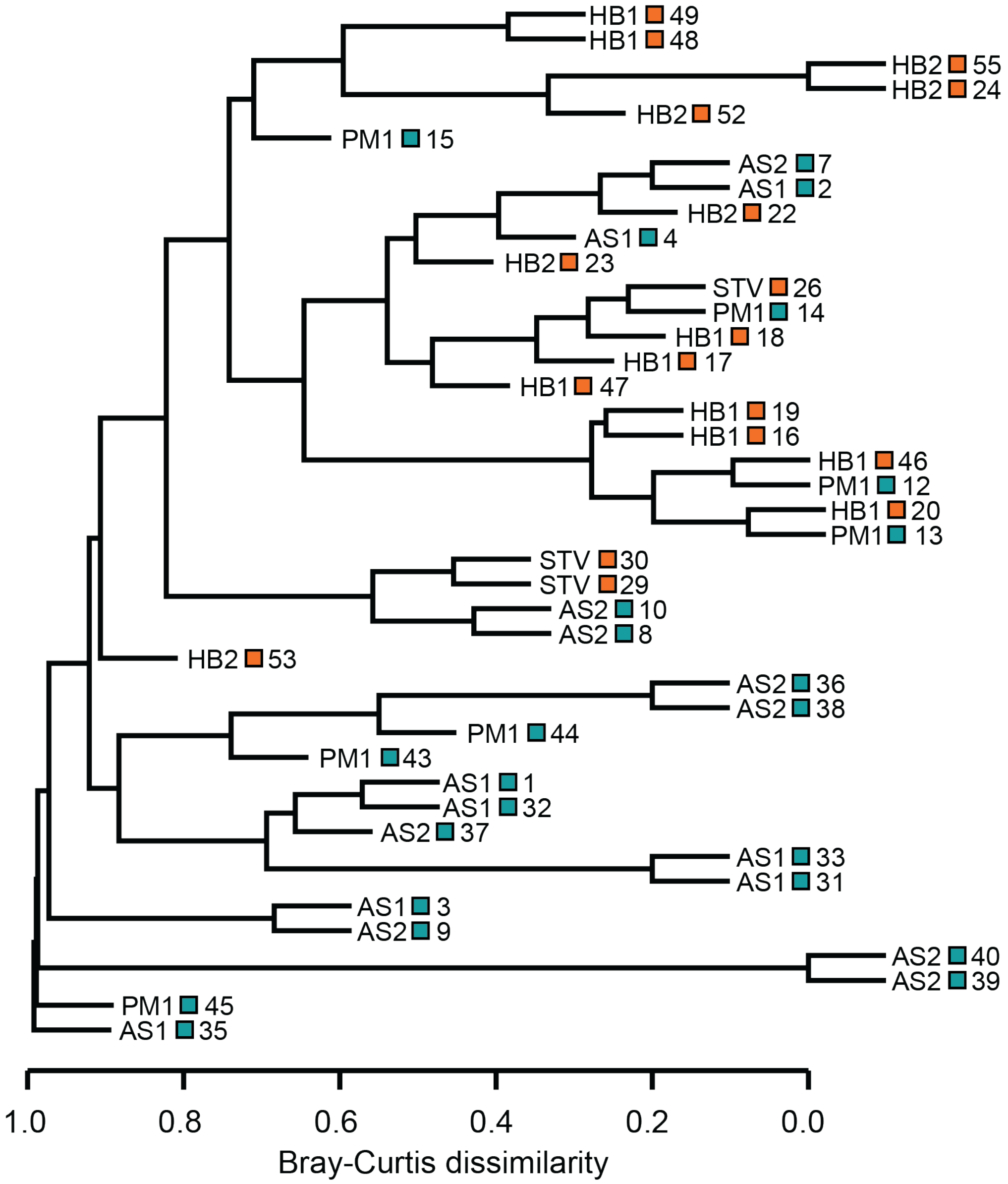

Figure 28. UPGMA average linkage cluster analysis Bray-Curtis dissimilarity among individual pitfall trap samples based on species abundances in traps. Each trap coded by site acronym, a colored box (blue=algific, orange=non-algific), and pitfall trap number (see **Appendix III**). Traps that were damaged and had no sample, as well as traps which had no ground beetles in them, are excluded from this analysis, leaving a total of 42 traps.

The rate of species accrual appeared to differ among sample sites (**Figure 29**), though Stevenson was not sampled sufficiently to assess this. Not surprisingly, none of the sites' species accumulation curves (**Figure 29**) appear to be reaching an asymptotic value, and thus more species are likely to occur at each of the sites than were recorded during this study. Because the limited number of samples (maximum 10 per site) would make these metrics unreliable, we did not calculate estimators of true richness as were shown in **Figure 24** for the larger dataset. Differences in rates of species accumulation are also evident for seasons and sample type (algific/non-algific) **(Figure 30**), though more data would be useful to assess whether or not there is a real pattern present. Abundance, species richness and diversity varied among sites (**Figure 31**), and in general richness and diversity were higher at the algific sites and in the Spring sampling period, while abundance was higher in the Fall and at non-algific sites (**Figure 32**).

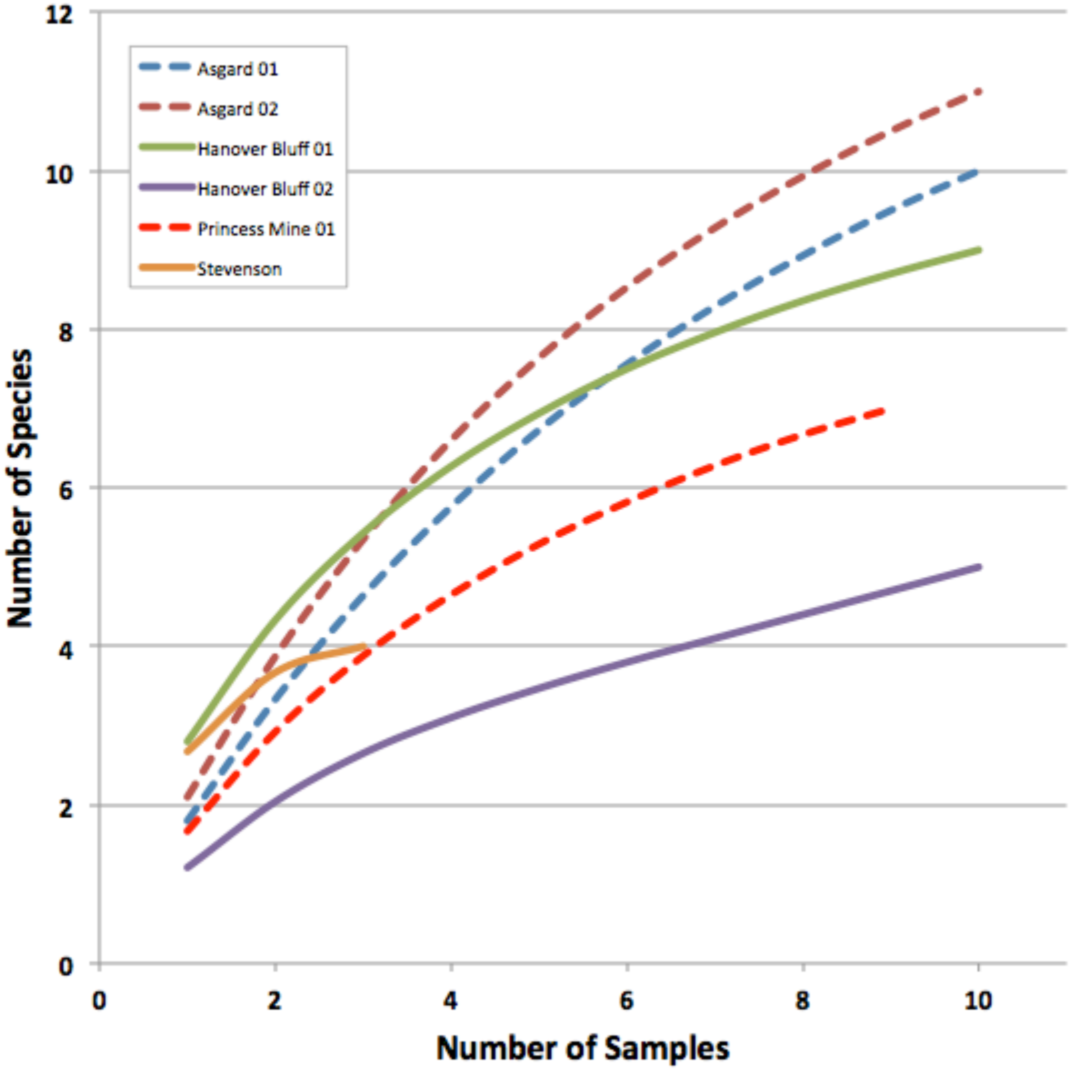

Figure 29. Species accumulation curve for ground beetles, by site, for all pitfall samples based on 1000 randomizations (Mao Tau). Dashed lines are algific sites, solid lines are non-algific sites.

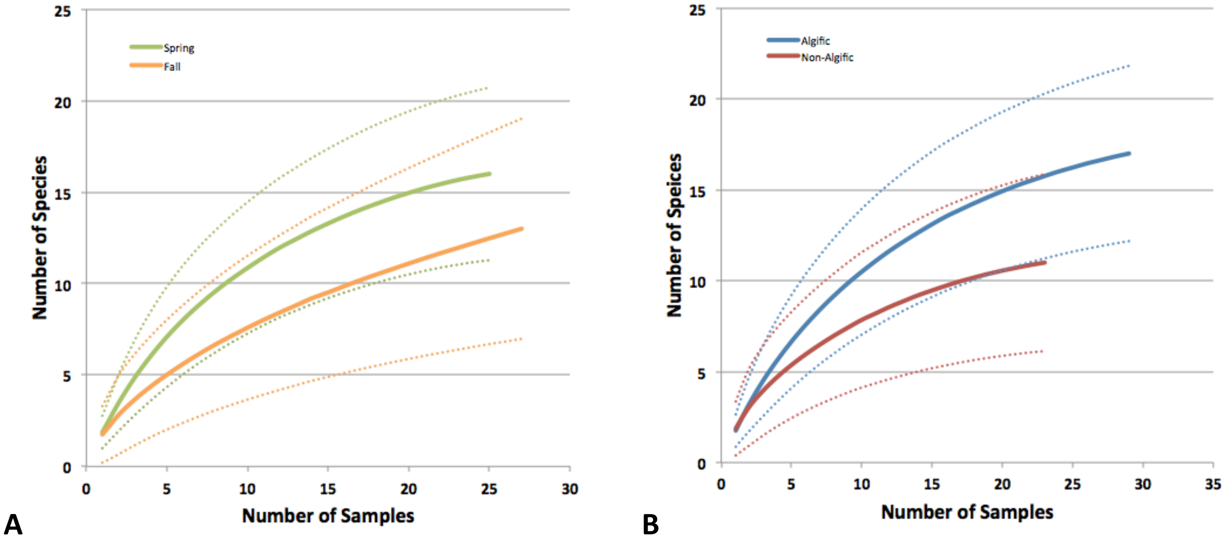

Figure 30. Species accumulation curve for ground beetles, by season (A) and type [algific/non-algific] (B), for all pitfall samples based on 1000 randomizations (Mao Tau). Dotted lines represent 95% confidence intervals.

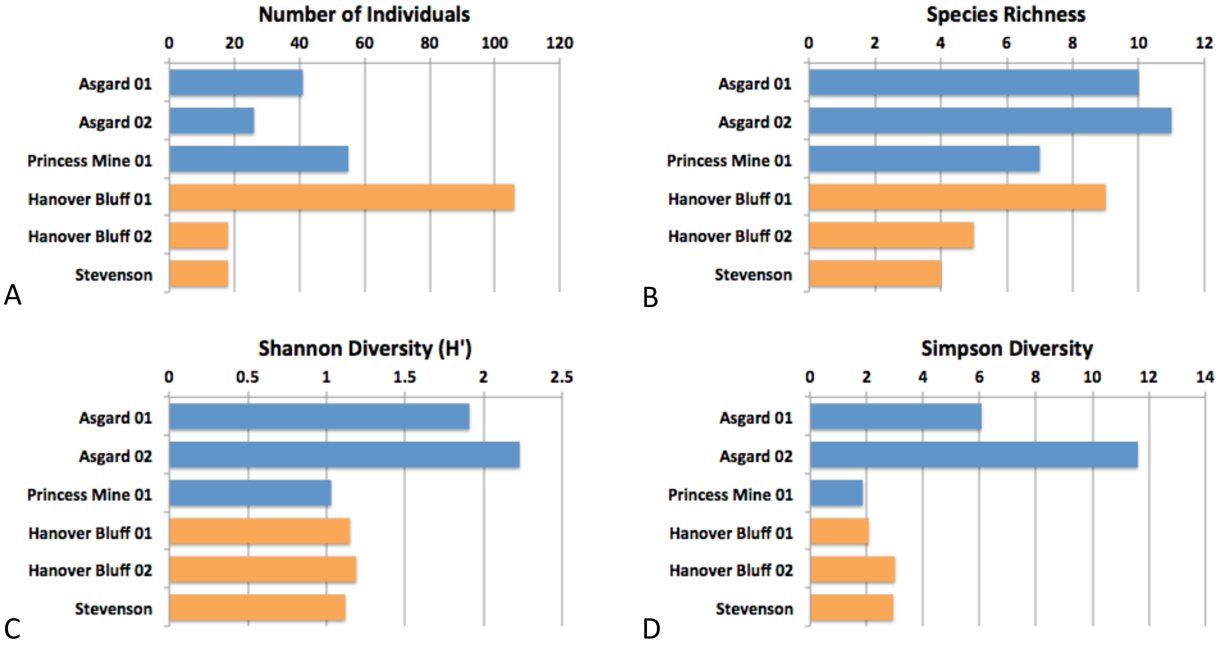

Figure 31. Carabidae abundance (A), species richness (B), Shannon diversity (C), and Simpson diversity (D) by sample site. Blue bars are algific sites, orange bars are non-algific sites.

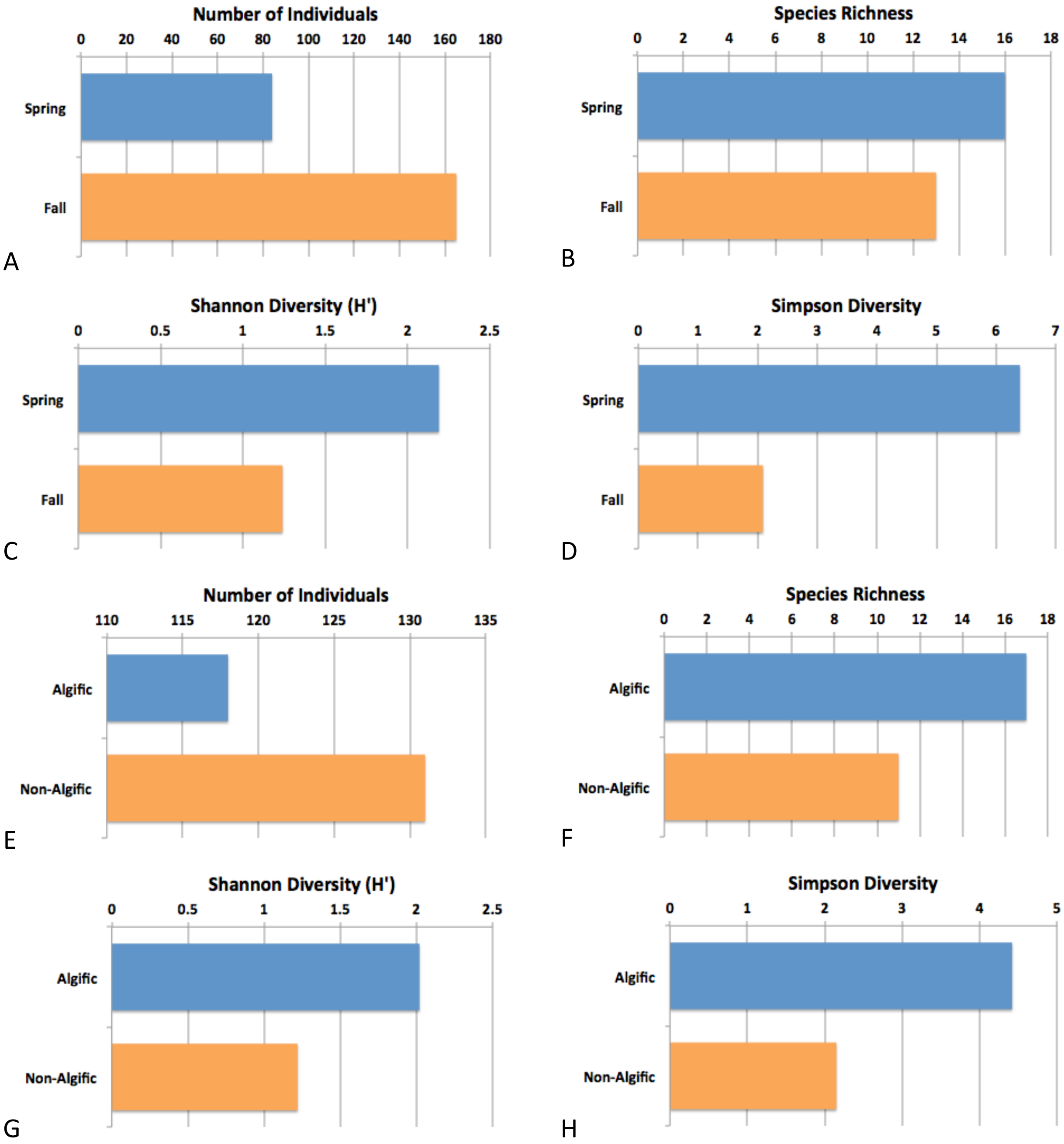

Figure 32. Carabidae abundance (A,E), species richness (B,F), Shannon diversity (C,G), and Simpson diversity (D,H) by Season (A-D) and by type [algific/non-algific] (E-H).

It is possible to rank the six sites using a "simple greedy" algorithm (Csuti *et al*. 1997) to rank the sites in the order of maximum number of additional species recorded as a means of potentially assessing, for ground beetles, which sites, and in what order, would provide the greatest conservation or protection value for the effort or cost of conserving the sites. Using this approach (**Table 3**), Asgard 02 is ranked highest, encompassing 45.8% (11) of the 24 species. The next site added, Hanover Bluff 01, adds another six species resulting in the protection of 70.8% of the taxa, then Asgard 01 (four more species) brings the total to 87.5%, and finally, Princess Mine 01 adds three more species resulting in the potential to protect 100% of the taxa recorded (**Table 3**), thus, by protecting a careful selection of half of the sites, it is possible to protect habitat for 87.5% of the ground beetle taxa recorded. Hanover Bluff 02 and Stevenson added no new species, although it is worth noting that the Stevenson site is under-represented due to loss of most of the pitfall traps.

Table 3. Maximum number of additional ground beetle taxa added by including an additional site, using the Csuti *et al*. (1997) "simple greedy" algorithm for pitfall trap samples.

Type	**Site**	**Total Additional Taxa**	**Cumulative Total Taxa**	**Cumulative Percent of Taxa**
Algific	Asgard 02	11	11	45.8
Non	Hanover Bluff 01	6	17	70.8
Algific	Asgard 01	4	21	87.5
Algific	Princess Mine 01	3	24	100.0
Non	Hanover Bluff 02	0	24	100.0
Non	Stevenson	0	24	100.0

Environmental Parameters

Air temperature was similar at all six sample sites, while soil temperatures averaged markedly lower at algific sites than at non-algific sites (**Figure 33**). Canopy cover varied among sites and was on average perhaps somewhat greater at non-algific sites, and the algific sites had steeper average slopes than did the non-algific sites (**Figure 33**). Ground cover (**Figure 34**) varied among the six sample sites, and some types of cover differed between algific and non-algific sites. Grass and dead wood were more dominant ground covers at non-algific sites, whereas rocks and herbaceous vegetation were more abundant at algific sites. Correlations among most environmental variables (**Figure 35**) were weak, but some significant correlations were found. In particular, different ground cover types were most likely to be negatively correlated, because quadrat samples added up to 100% cover: the strongest negative correlation was between ground cover types woody vegetation and herbaceous vegetation, followed by herbaceous vegetation and percent leaf litter cover. Canopy cover was poorly correlated with most metrics, though weakly positively correlated with leaf litter cover (but not litter depth). While there was an unsurprising positive correlation between soil and air temperatures, soil temperature was also positively correlated with "soil" ground cover and negatively correlated with herbaceous ground cover (**Figure 35**).

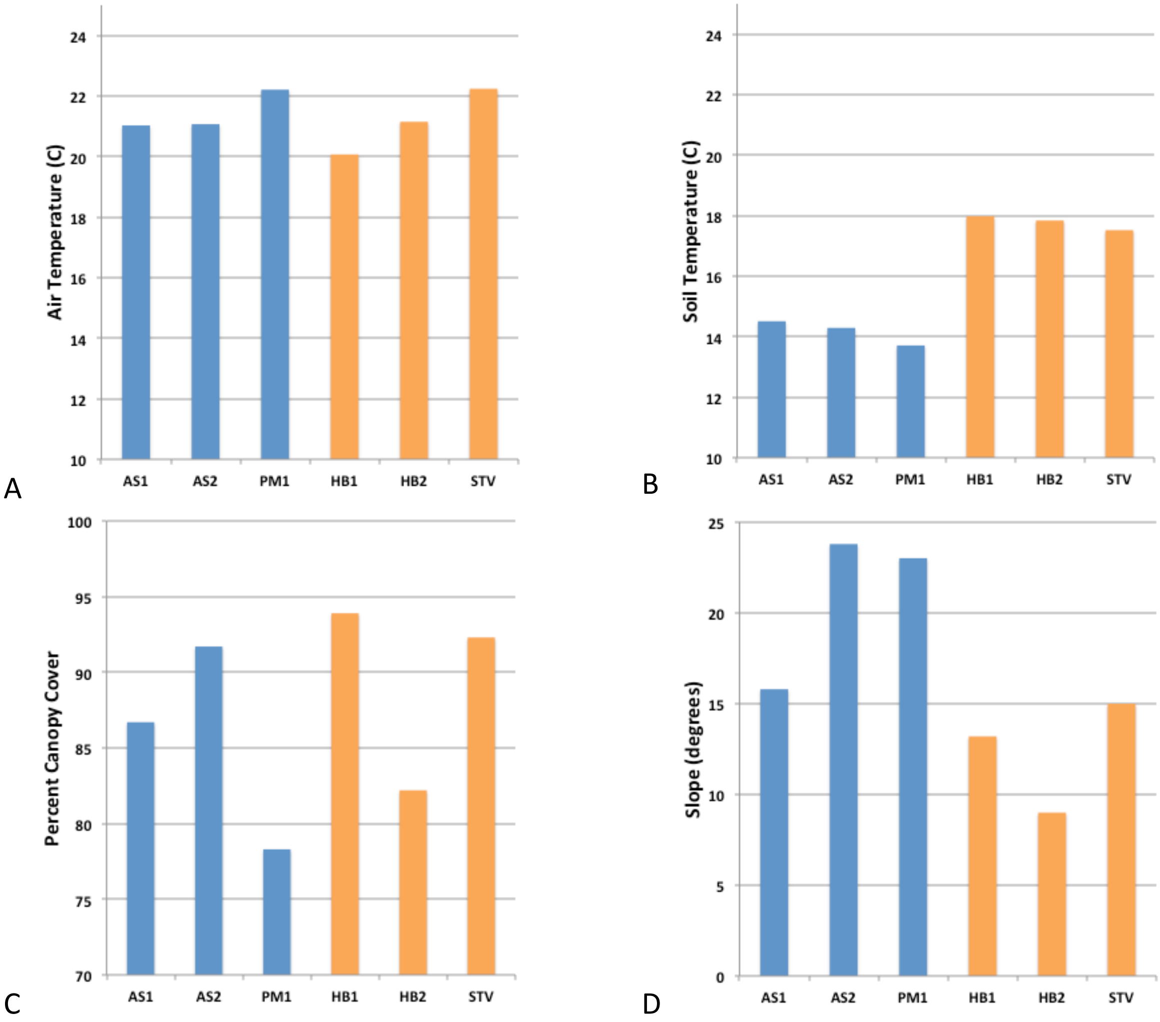

Figure 33. Average air temperature (A), and soil temperature (B), canopy cover (C), and slope (D) at each of the six study sites. Blue bars are algific sites, orange bars are non-algific sites.

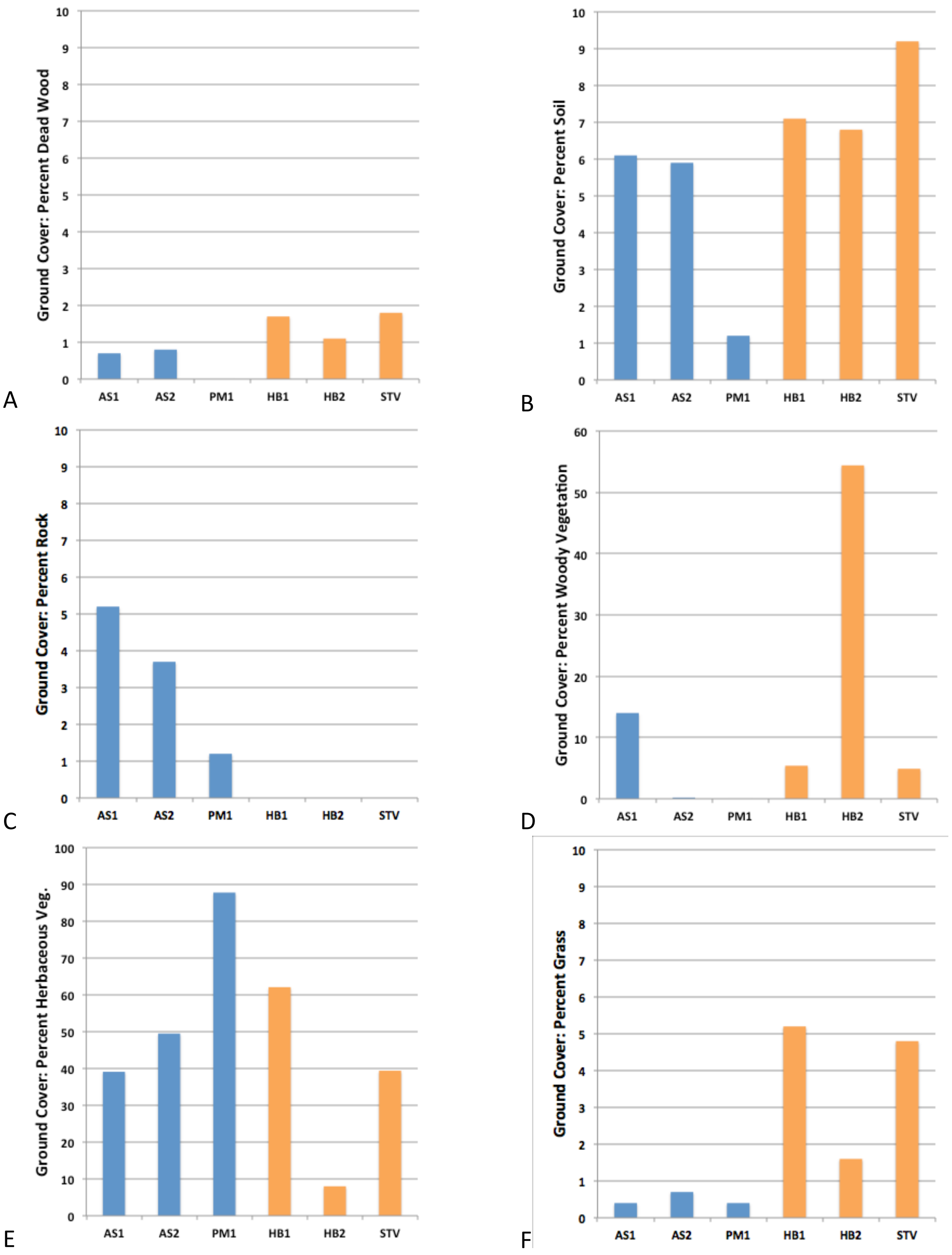

Figure 34. Ground cover types as average percentage at each study site. Blue bars are algific sites, orange bars are non-algific sites.

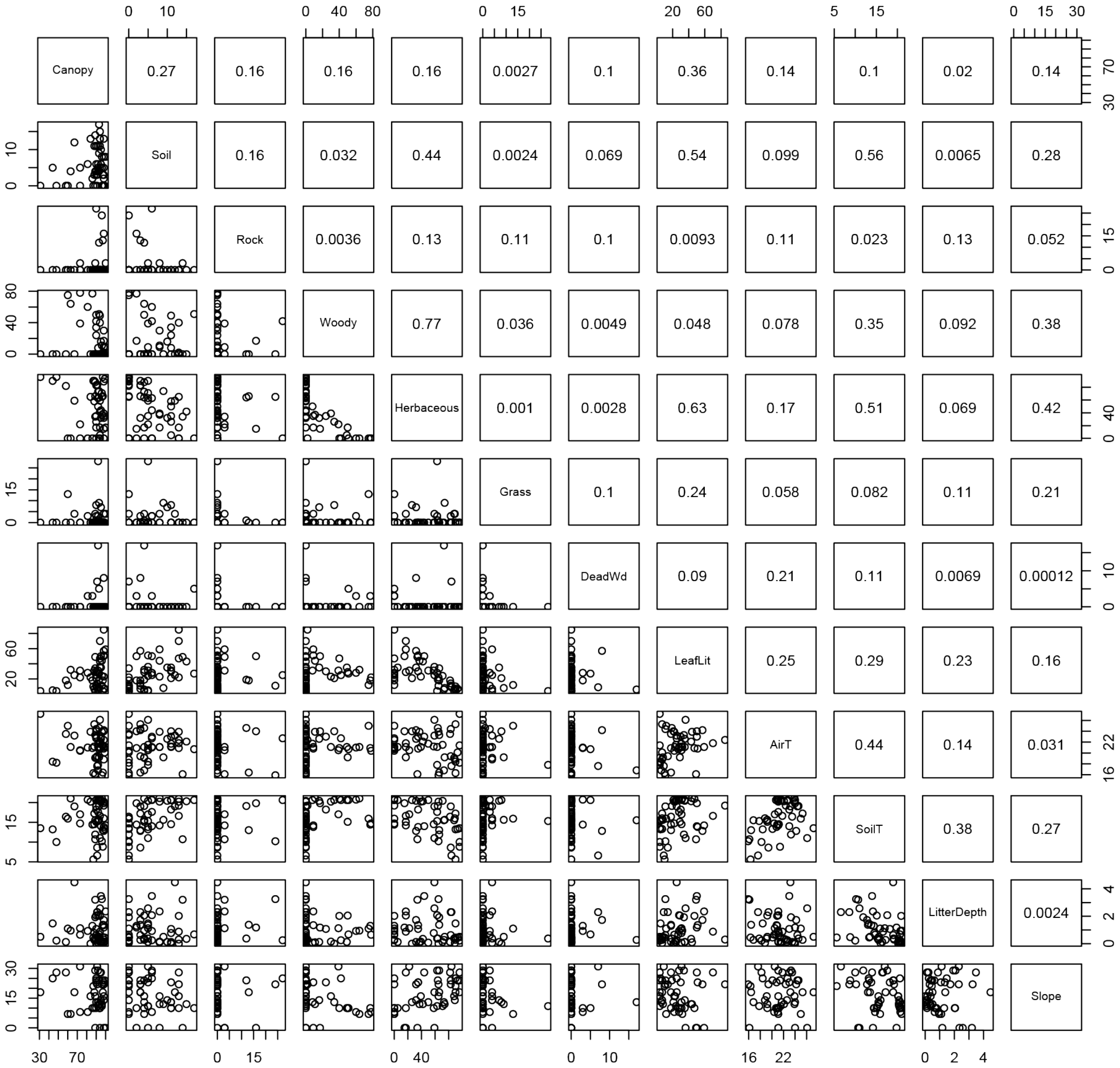

Figure 35. Pairwise correlations among all environmental parameters measured at each pitfall trap (excluding those with no sample). Numbers in cells in upper right half are Pearson correlation coefficients.

Ordination

The data from the pitfall trap samples (**Appendix III**) was used to produce a Bray Curtis dissimilarity matrix of distances between pitfall samples. Through repeated iterations of multiple initial configurations of the pitfall trap samples in multidimensional space (i.e., Iterative search for the best positions of *n* samples on *k* dimensions, the algorithm converged toward a best solution, which had a stress value of 0.1033643 (rmse 0.1021391, maximum residual 0.3284806), a stress value which is considered good (**Figure 36**). We plotted traps on the nonmetric multidimensional scaling axes NMDS1 and NMDS2, which are based on species composition as Euclidean distance relationships among pitfall trap samples compressed into two dimensions. The resulting plot shows that the pitfall trap samples for non-algific samples tended to be more similar to one another than were the algific samples, whose range of variation was much broader, but fully encompassed the range of variation in the non-algific samples (**Figure 37**). When we look at the distribution of sample sites on the NMDS ordination (**Figure 38**), we see that the six sites are not well separated from one another (the observed pattern is not merely between-site differences), and that the range of variation for each of the three non-algific sites is less than that observed for the algific sites. The positions of individual species in this ordination are shown in **Figure 39**.

We can relate this ordination to the environmental parameters measured in this study to gain additional insights into the observed patterns. In **Figure 40**, we overlaid the environmental variables over the same plot as in **Figure 39**. The environmental variables (**Figure 40**) vary considerably in the importance of their relationship with the species & trap data, as is indicated by the lengths of the vector lines in the plot. The direction of the arrow roughly shows the positive direction of the gradient for the variable, but because gradients are not necessarily linear across **Figure 40**, a Gaussian surface (see below) provides a better interpretation of the true gradient. Therefore, to better evaluate those environmental variables that appeared to have a stronger relationship with the observed pattern, we plotted each of six environmental variables as Gaussian surfaces on the ordination (**Figure 41**). A permutation test (**Table 4**) showed that Soil temperature was significant – indicating that the composition and abundance of species differs between the algific and non-algific samples. The Gaussian surface for Soil Temperature showed a non-linear relationship to the compositional space (**Figure 41**). Leaf litter depth, which showed a linear relationship in the ordination (**Figure 41**) was marginally significant (at the 0.10 level), and likely would achieve greater significance with additional sampling.

Finally, for the six most abundant species (**Figure 24**), we evaluated their distribution and abundance in relation to the environmental variables and to the similarity among traps (**Figure 42**). *Agonum melanarium* was more abundant at warmer soil temperature sites, especially where greater canopy cover and bare soil was present (**Figure 42A**). *Calathus gregarious* was more abundant and was more associated with higher cover of soil and rock, and with reduced herbaceous vegetation cover (**Figure 42B**). *Chlaenius emarginatus* was not strongly associated with any of the extremes of environmental variables (**Figure 42C**). *Chlaenius platyderus* was associated with cooler soil temperatures and deeper leaf litter (**Figure 42D**). *Pterostichus stygicus* was associated with shallower leaf litter and warmer soil conditions (**Figure 42E**). *Trichotichnus vulpeculus* was found primarily in samples with warmer soil temperatures (**Figure 42F**). Overall species richness (**Figure 43**) did not reveal obvious patterns in relation to the ordination, though perhaps richness tended to be higher at sites with less soil cover and cooler temperatures.

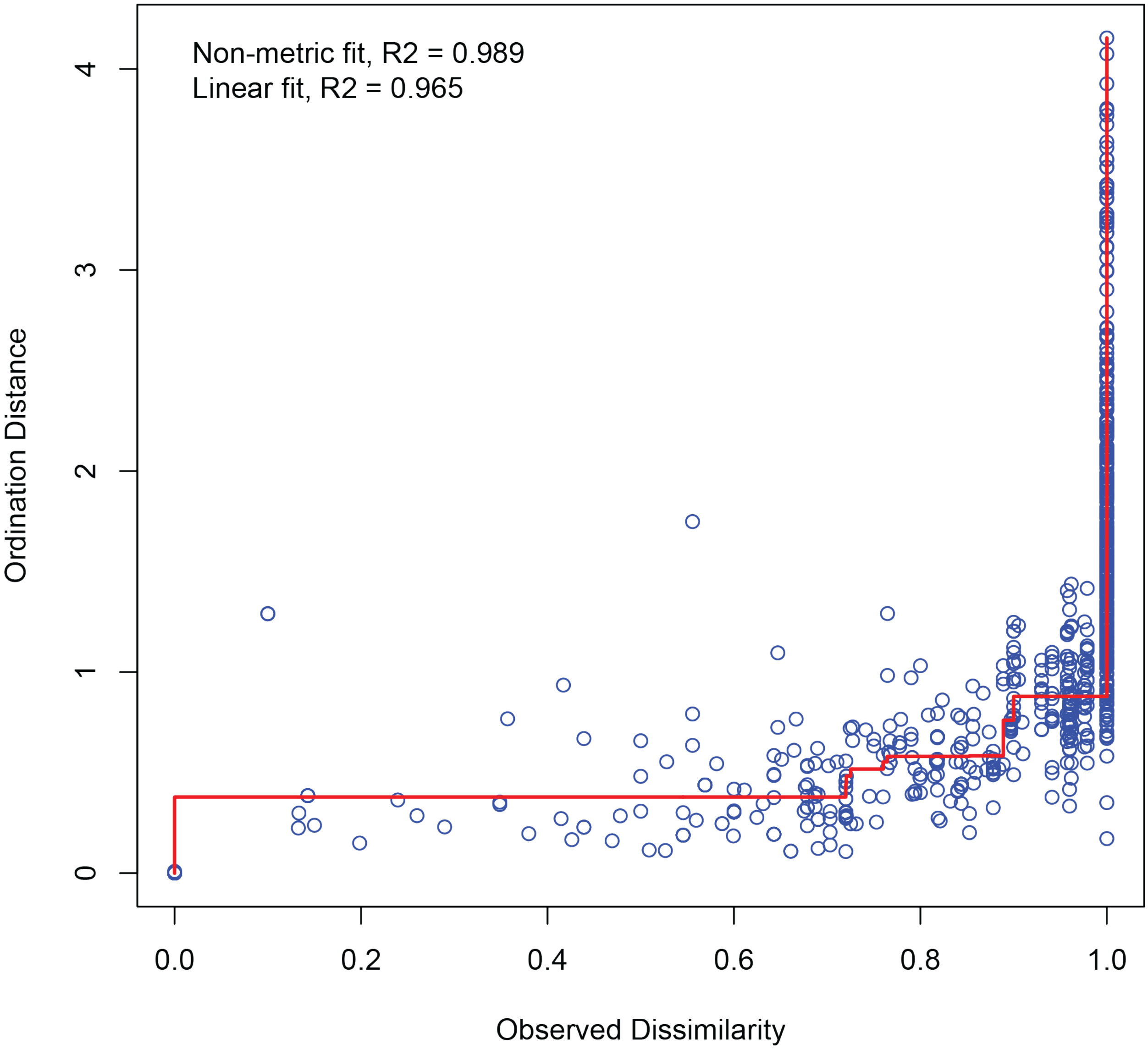

Figure 36. Stress plot of transformed Bray Curtis dissimilarity data evaluated for NMDS ordination.

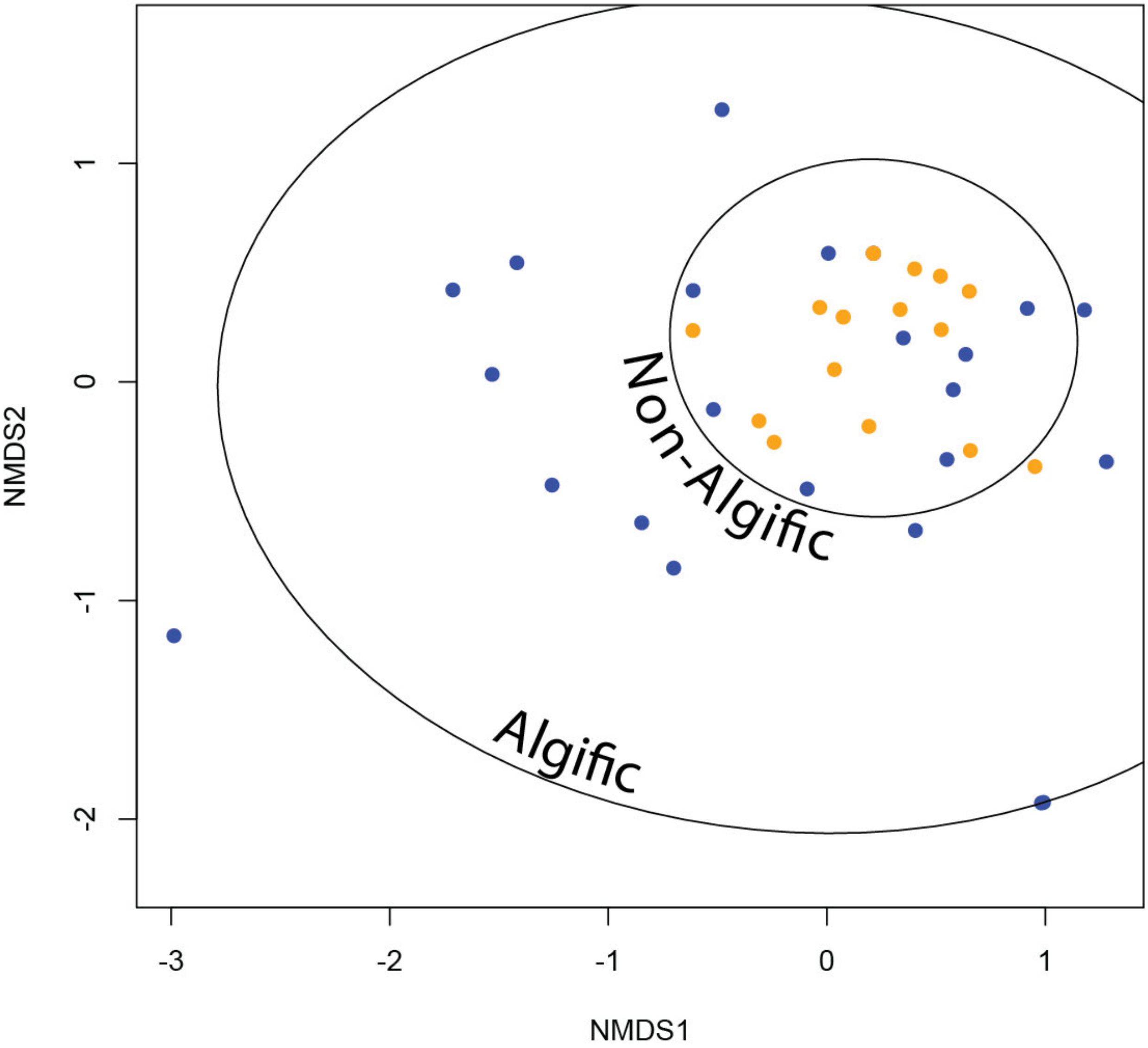

Figure 37. Nonmetric multidimensional scaling ordination of pitfall trap samples of ground beetles, coded as algific (blue points) or non-algific (orange points). 95% confidence ellipses are shown.

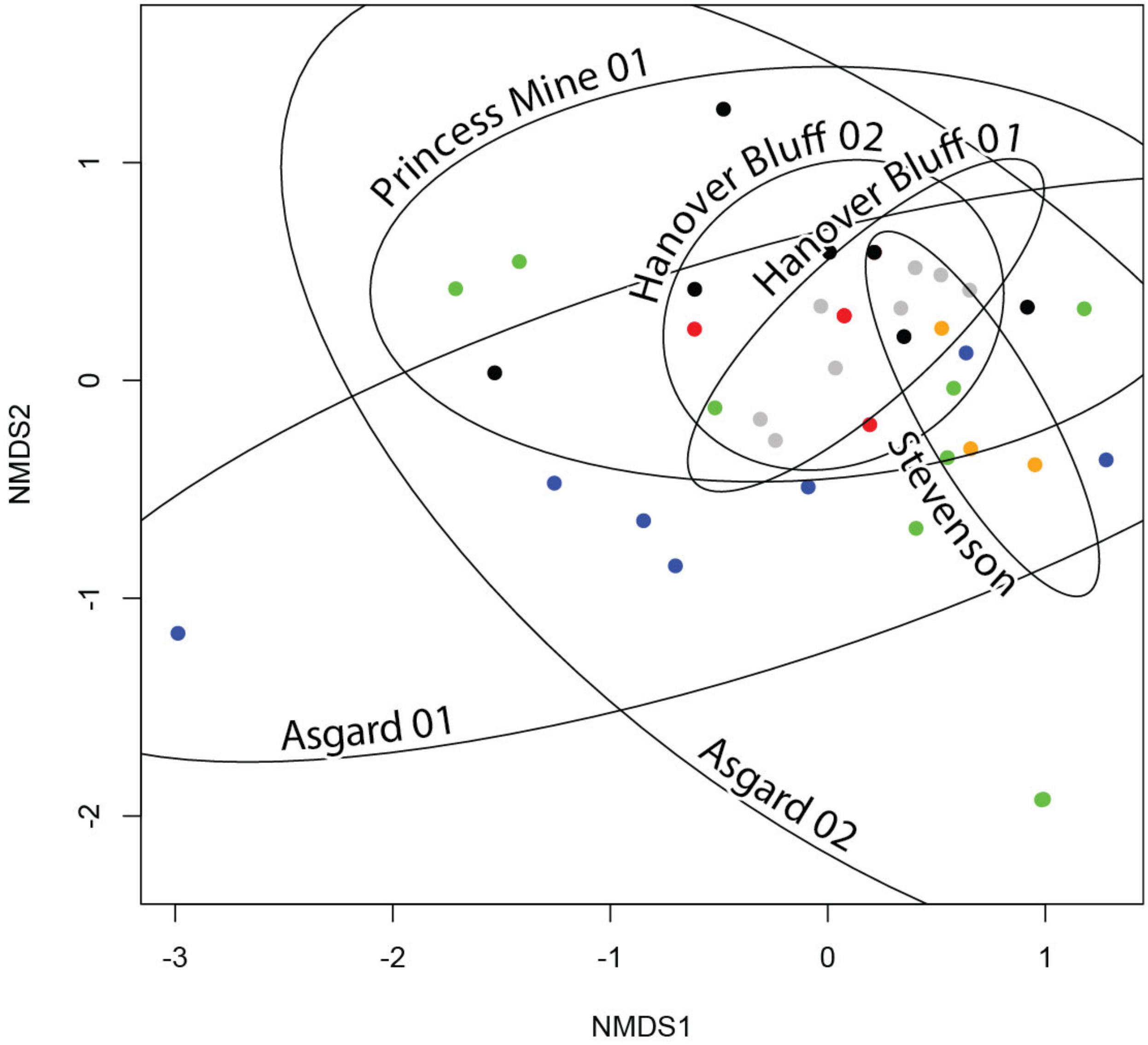

Figure 38. Nonmetric multidimensional scaling ordination of pitfall trap samples of ground beetles, coded by site as Asgard 01 (blue points), Asgard 02 (green points), Hanover Bluff 01 (gray points), Hanover Bluff 02 (red points), Princess Mine 01 (black points), and Stevenson (orange points). 95% confidence ellipses are shown.

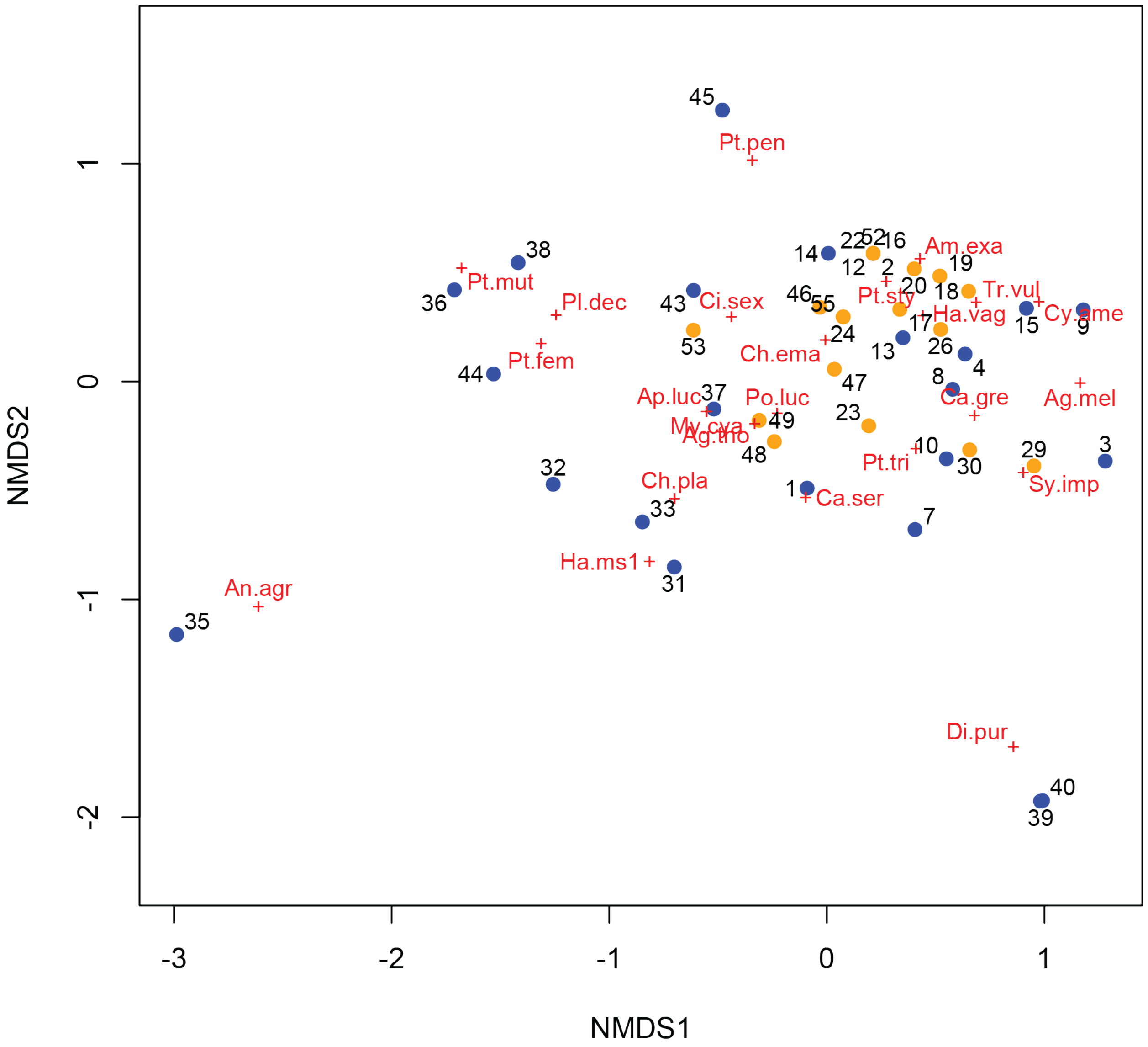

Figure 39. Nonmetric multidimensional scaling ordination of pitfall trap samples of ground beetles, coded as Algific (blue points) or Non-Algific (orange points). Beetle taxa are indicated by '+', with abbreviated names as follows: Ag.tho=*Agonoleptus thoracicus*, Ag.mel=*Agonum melanarium*, Am.exa=*Amara exarata*, An.agr=*Anisodactylus agricola*, Ap.luc=*Apenes lucidula*, Ca.gre=*Calathus gregarious*, Ca.ser=*Carabus serratus*, Ch.ema=*Chlaenius emarginatus*, Ch.pla=*Chlaenius platyderus*, Ci.sex=*Cicindela sexguttata*, Cy.ame=*Cymindis americana*, Di.pur=*Dicaelus purpuratus,* Ha.ms1r=*Harpalus* morphospecies 1, Ha.vag=*Harpalus vagans*, My.cya=*Myas cyanescens*, Pl.dec=*Platynus decentis*, Po.luc=*Poecilus lucublandus*, Pt.fem=*Pterostichus femoralis*, Pt.mut=*Pterostichus mutus,* Pt.pen=*Pterostichus pensylvanicus*, Pt.sty=*Pterostichus stygicus*, Pt.tri=*Pterostichus tristis*, Sy.imp=*Synuchus impunctatus*, Tr.vul=*Trichotichnus vulpeculus.* See **Appendix III** for pitfall trap numbers.

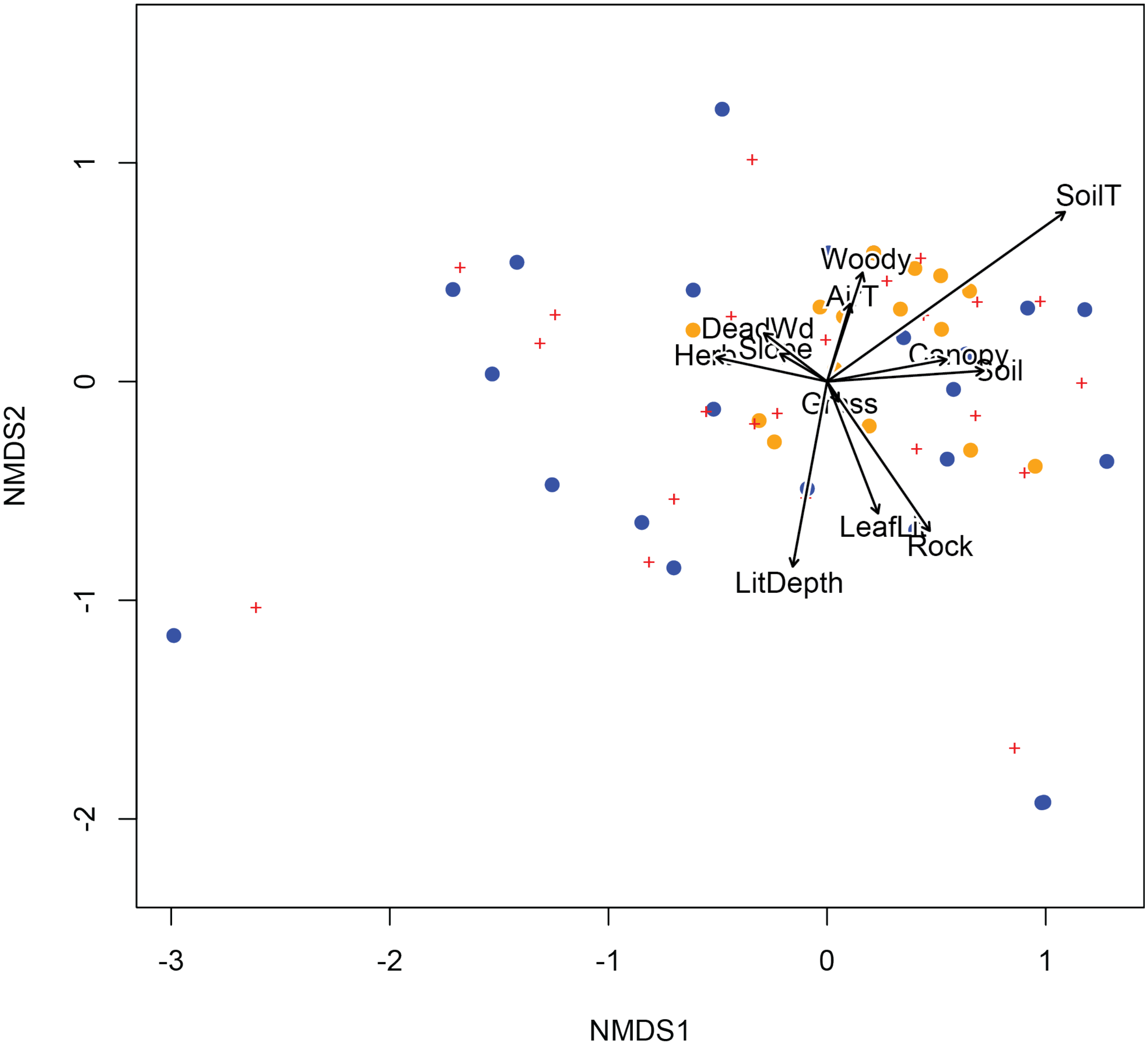

Figure 40. Environmental variables measured in association with each pitfall sample, overlaid on the ordination. Samples and species as in **Figure 39**.

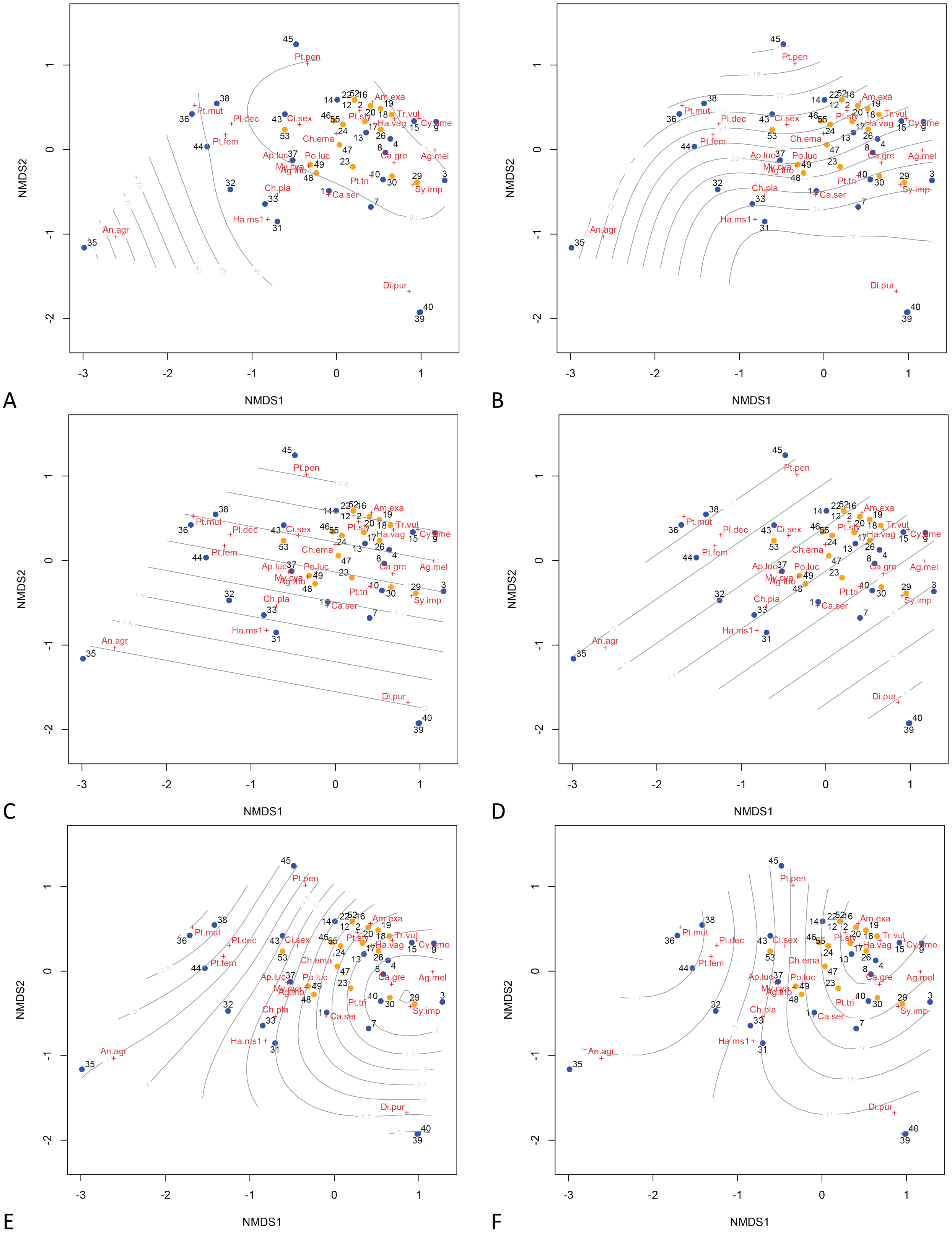

Figure 41. Select environmental variables displayed as a Gaussian surface on the ordination. A-Canopy Cover; B-Leaf Litter Cover; C-Leaf Litter Depth; D-Rock Cover; E-Soil Cover; F-Soil Temperature. Other data as in **Figure 39**.

Table 4. Permutation Test of fit of environmental variables to the ordination plot. P values based on 999 permutations.

Environmental Variable	**NMDS1**	**NMDS2**	**r^2**	**Pr(>r)**	**Significance**
Soil Temperature	0.814186	0.580604	0.288	0.001	***
Litter Depth	-0.182583	-0.98319	0.1195	0.08	+
Rock Cover	0.566582	-0.824005	0.1109	0.107	
Soil Cover	0.997654	0.068459	0.0829	0.183	
Leaf Litter Cover	0.360449	-0.932779	0.0674	0.264	
Canopy Cover	0.98349	0.180961	0.0498	0.373	
Herbaceous Cover	-0.977517	0.210855	0.0432	0.405	
Woody Cover	0.30979	0.950805	0.0442	0.427	
Dead Wood	-0.794668	0.607044	0.0213	0.612	
Air Temperature	0.284788	0.958591	0.0221	0.646	
Slope	-0.860837	0.50888	0.01	0.791	
Grass Cover	0.494954	-0.868919	0.0018	0.959	

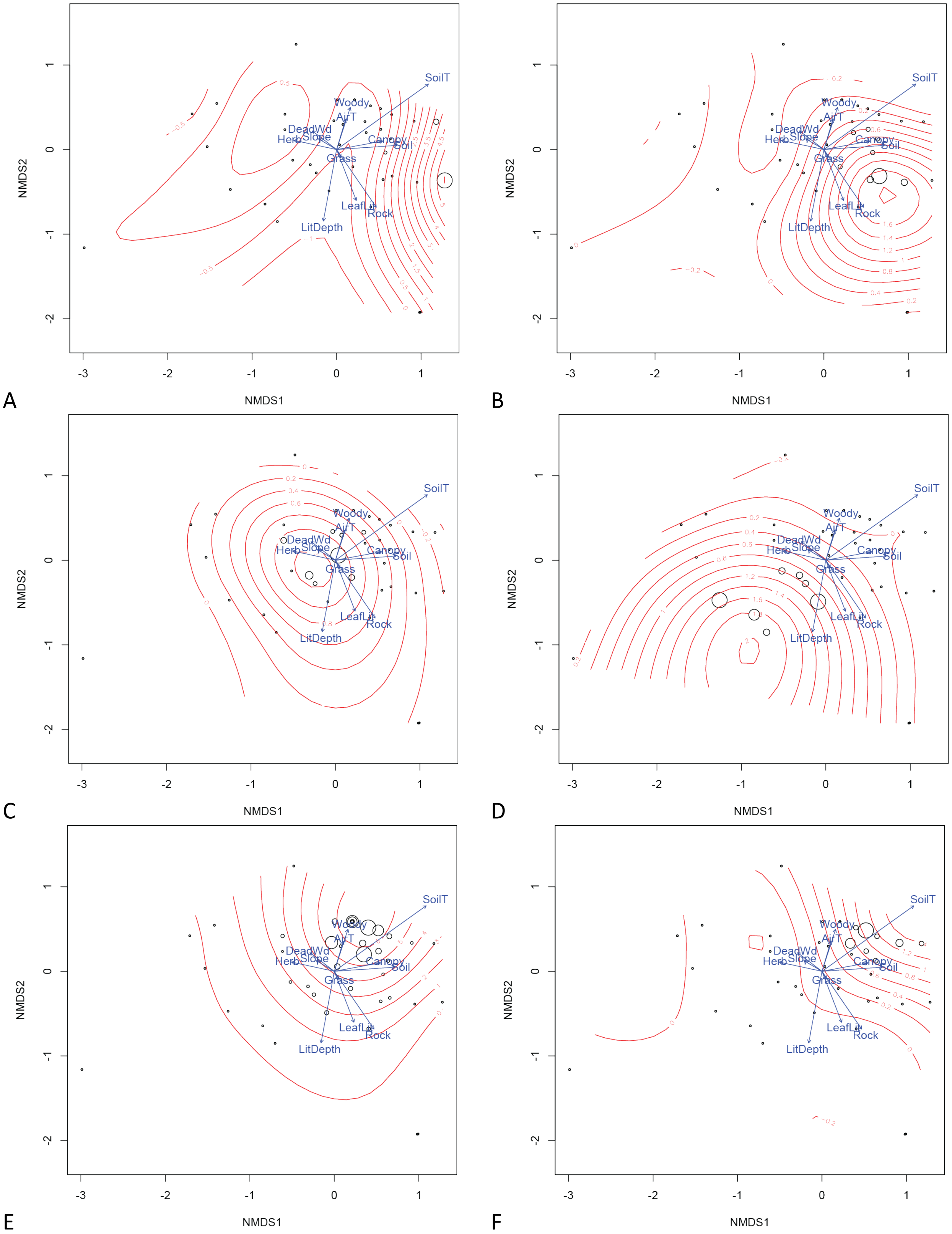

Figure 42. Six most abundant species (A-*Agonum melanarium*; B-*Calathus gregarious*; C-*Chlaenius emarginatus*; D-*Chlaenius platyderus*; E-*Pterostichus stygicus*; F-*Trichotichnus vulpeculus*), relative abundance in pitfall traps (circle size) and relative abundance expressed as a Gaussian surface on the ordination. Refer to **Figure 39** for sample numbers.

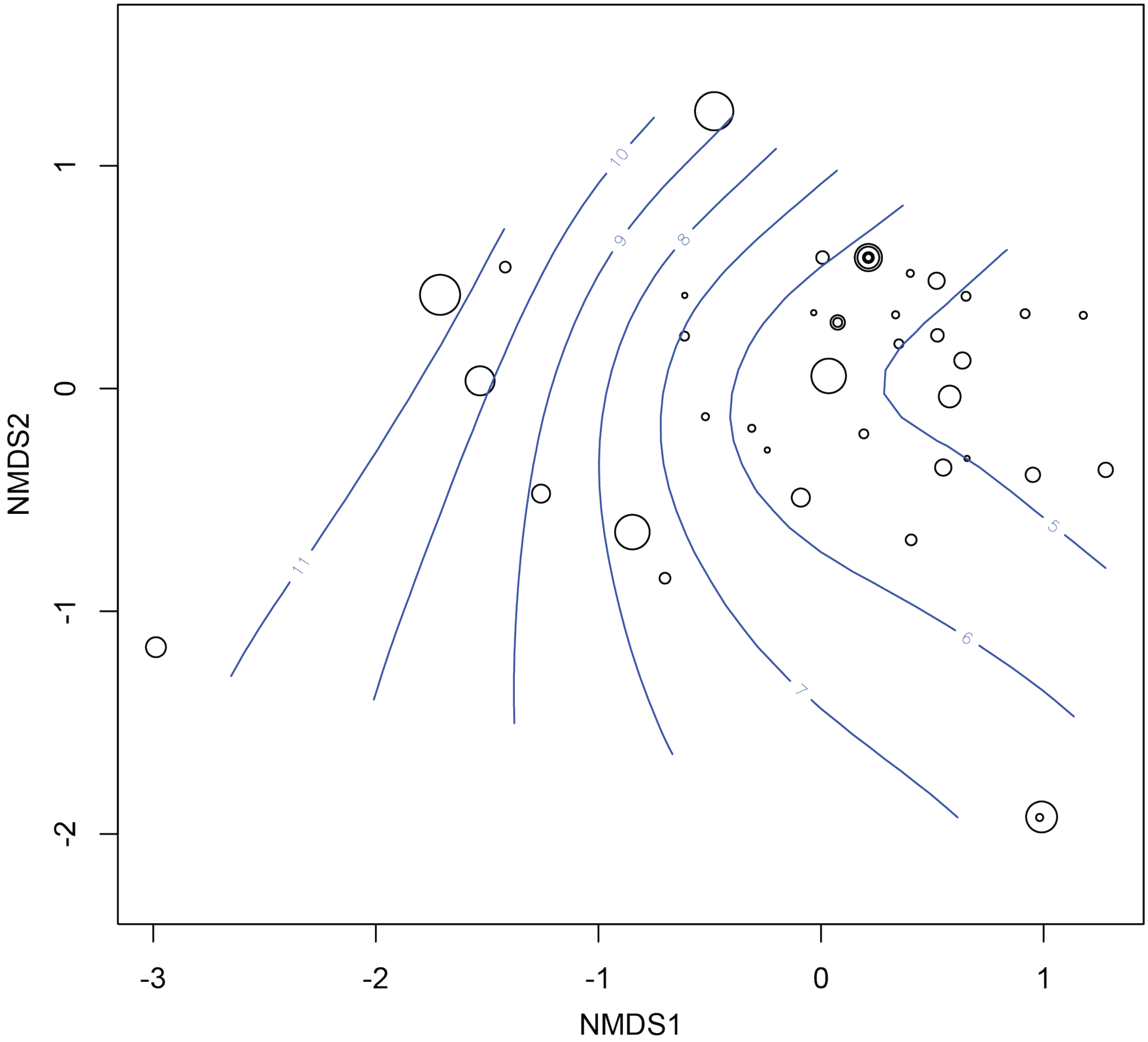

Figure 43. Species richness per pitfall sample expressed as a Gaussian surface on the ordination, with circle size proportional to species richness. Refer to **Figure 39** for sample numbers.

Discussion

Soil temperature was an important factor in explaining the abundance and composition of ground beetles in our pitfall trap samples (Table 4). The algific sites had greater richness than the non-algific sites. Non-algific samples tended to be more similar to one another than did the algific samples, which were more variable in composition. Leaf litter depth may also be an important variable in explaining the abundance and composition of ground beetles when comparing algific versus non-algific sites.

None of the species recorded in our study are particularly rare in North America, with many having broad distributions. There were insufficient data to determine the conservation status of these species in the state of Illinois, though none were new records for Illinois. Samples were dominated by the beetle *Pterostichus stygicus*, and few individual samples contained more than two species. The algific sites also showed greater richness and diversity of ground beetle species than did the non-algific sites. Using a simple greedy algorithm, carefully selecting only half of the sites for focused conservation and management would provide some protection for more than 87% of the 24 species.

Our study underscores the uniqueness and high diversity of life at Illinois' algific slopes. All records of ground beetles from this study appear to be new records for the sites at which they were recorded – highlighting the fact that we know virtually nothing about the invertebrate fauna of Illinois' algific slopes beyond one snail (and now, a single family of beetles). More informed management would greatly benefit from further study of this imperiled habitat type.

Acknowledgements

Christopher J. Kirkpatrick and Randy Nyboer provided valuable assistance in identifying and contacting landowners. We thank Barbara Woodford, Nancy and Adlai Stevenson, and Lu Bleveans for access to the sites on private land, and the Illinois Department of Natural Resources and the Illinois Nature Preserves Commission for access to Hanover Bluff Nature Preserve.

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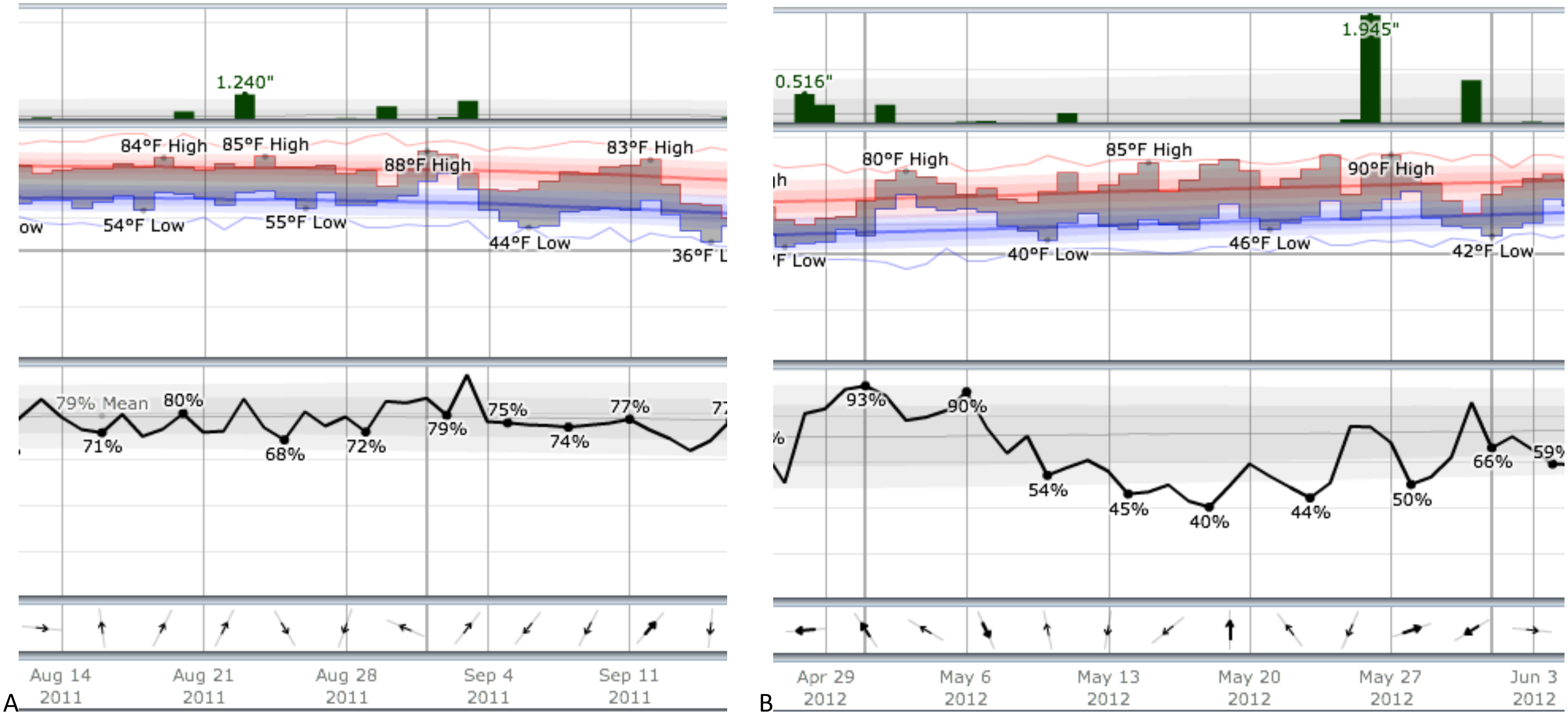
Appendix I. Summary of sample site characteristics.

Site	Aspect (degrees)	Aspect Direction	Average Slope (degrees)	Average Canopy Cover (percent)	Average Herbaceous Cover (percent)	Average Leaf litter depth (mm)	Average Air Temperature (C)	Average Soil Temperature (C)
AS1	280	WNW	15.8	86.7	39.1	34.5	21.03	14.51
AS2	340	NNW	23.8	91.7	49.5	39.2	21.07	14.29
PM1	330	NW	23.0	78.3	87.8	9.4	22.21	13.71
HB1	80	ENE	13.2	93.9	62.1	18.5	20.07	17.98
HB2	120	ESE	9.0	82.2	8.0	28.1	21.15	17.84
STV	170	SSE	15.0	92.3	39.4	39.9	22.24	17.52

Appendix II. Weather history for study area.

(42.2720°N, 90.3381°W)

Source: http://weatherspark.com/#!graphs;loc=42.2720,-90.3381   (accessed 22 December 2012)



A. Fall sample period: August-September 2011

B. Spring sample period: May 2012

Appendix III. Carabidae recovered from pitfall traps, by site, trap, and sample period

Pitfall Trap Number	Season (F-Fall, S-Spring)	Site Type (A-Algific, N-Non	Site	Pitfall Replicate	*Agonoleptus thoracicus*	*Agonum melanarium*	*Amara exarata*	*Anisodactylus agricola*	*Apenes lucidula*	*Calathus gregarius*	*Carabus serratus*	*Chlaenius emarginatus*	*Chlaenius platyderus*	*Cicindela sexguttata*	*Cymindis americana*	*Dicaelus purpuratus*	*Harpalus* morphospecies 1	*Harpalus vagans*	*Myas cyanescens*	*Platynus decentis*	*Poecilus lucublandus*	*Pterostichus femoralis*	*Pterostichus mutus*	*Pterostichus pensylvanicus*	*Pterostichus stygicus*	*Pterostichus tristis*	*Synuchus impunctatus*	*Trichotichnus vulpeculus*
1	F	A	AS1	1	0	0	0	0	0	0	1	0	3	0	0	0	0	0	0	0	0	0	0	0	3	0	2	0
2	F	A	AS1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
3	F	A	AS1	3	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
4	F	A	AS1	4	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1
5	F	A	AS1	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	F	A	AS2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	F	A	AS2	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2	0	0	0
8	F	A	AS2	3	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
9	F	A	AS2	4	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
10	F	A	AS2	5	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
12	F	A	PM1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0
13	F	A	PM1	3	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	0	0	0
14	F	A	PM1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	5	0	0	0
15	F	A	PM1	5	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	2
16	F	N	HB1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0
17	F	N	HB1	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	3
18	F	N	HB1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	4	0	0	1
19	F	N	HB1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	5
20	F	N	HB1	5	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	0	0	1
21	F	N	HB2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	F	N	HB2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0

23	F	N	HB2	3	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0	0
24	F	N	HB2	4	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
25	F	N	HB2	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	F	N	STV	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	1
29	F	N	STV	4	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
30	F	N	STV	5	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
31	S	A	AS1	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
32	S	A	AS1	2	0	0	0	1	0	0	0	0	3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
33	S	A	AS1	3	0	0	0	0	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
34	S	A	AS1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	S	A	AS1	5	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	S	A	AS2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0
37	S	A	AS2	2	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0
38	S	A	AS2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0
39	S	A	AS2	4	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
40	S	A	AS2	5	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
41	S	A	PM1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
42	S	A	PM1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
43	S	A	PM1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	1	0	1	2	0	0	0
44	S	A	PM1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
45	S	A	PM1	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
46	S	N	HB1	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0	0	0	14	0	0	0
47	S	N	HB1	2	0	0	0	0	0	0	0	7	0	0	0	0	0	1	0	0	0	0	0	0	5	0	0	0
48	S	N	HB1	3	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	2	0	0	0	2	0	0	0
49	S	N	HB1	4	1	0	0	0	0	0	0	3	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0
50	S	N	HB1	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51	S	N	HB2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
52	S	N	HB2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
53	S	N	HB2	3	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
54	S	N	HB2	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
55	S	N	HB2	5	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0

Appendix IV. Global & State Conservation Status Ranks

A. Global Conservation Status Rank

definitions from NatureServe Explorer (http://www.natureserve.org/explorer/granks.ht
accessed 31 Oct 2012)

Rank	Definition
GX	**Presumed Extinct** (species)— Not located despite intensive searches and virtually no likeli rediscovery. **Eliminated** (ecological communities)—Eliminated throughout its range, with no restoratio potential due to extinction of dominant or characteristic species.
GH	**Possibly Extinct** (species)— Missing; known from only historical occurrences but still some rediscovery. **Presumed Eliminated**— (Historic, ecological communities)-Presumed eliminated through range, with no or virtually no likelihood that it will be rediscovered, but with the potential restoration, for example, American Chestnut (Forest).
G1	**Critically Imperiled**—At very high risk of extinction due to extreme rarity (often 5 or fewe populations), very steep declines, or other factors.
G2	**Imperiled**—At high risk of extinction due to very restricted range, very few populations (or fewer), steep declines, or other factors.
G3	**Vulnerable**—At moderate risk of extinction due to a restricted range, relatively few popul (often 80 or fewer), recent and widespread declines, or other factors.
G4	**Apparently Secure**—Uncommon but not rare; some cause for long-term concern due to d or other factors.
G5	**Secure**—Common; widespread and abundant.

(Appendix IV concludes on following page)

Appendix IV. Concluded.

B. State Conservation Status Rank

definitions from NatureServe Explorer
(http://www.natureserve.org/explorer/ranking.htm accessed 31 Oct 2012)

Status	**Definition**
SX	**Presumed Extirpated**—Species or ecosystem is believed to be extirpated from the jurisdiction (i.e., nation or state/province). Not located despite intensive searches of historical sites and other appropriate habitat, and virtually no likelihood that it will be rediscovered.
SH	**Possibly Extirpated**— Known from only historical records but still some hope of rediscovery. There is evidence that the species or ecosystem may no longer be present in the jurisdiction, but not enough to state this with certainty. Examples of such evidence include (1) that a species has not been documented in approximately 20-40 years despite some searching or some evidence of significant habitat loss or degradation; (2) that a species or ecosystem has been searched for unsuccessfully, but not thoroughly enough to presume that it is no longer present in the jurisdiction.
S1	**Critically Imperiled**—Critically imperiled in the jurisdiction because of extreme rarity or because of some factor(s) such as very steep declines making it especially vulnerable to extirpation from the jurisdiction.
S2	**Imperiled**—Imperiled in the jurisdiction because of rarity due to very restricted range, very few populations, steep declines, or other factors making it very vulnerable to extirpation from jurisdiction.
S3	**Vulnerable**—Vulnerable in the jurisdiction due to a restricted range, relatively few populations, recent and widespread declines, or other factors making it vulnerable to extirpation.
S4	**Apparently Secure**—Uncommon but not rare; some cause for long-term concern due to declines or other factors.
S5	**Secure**—Common, widespread, and abundant in the jurisdiction.

Appendix V. Criteria for Selecting Illinois Species in Greatest need of Conservation

From Illinois Comprehensive Wildlife Conservation Plan & Strategy (IDNR 2005, pg. 294).

1. All species listed as threatened or endangered in Illinois, including federally listed species that occur within the State.

2. Species with a global conservation rank indicator of G1, G2, or G3.

3. Species is rare (small or low population size, density or range) or has significantly declined in abundance or distribution from historical levels.

4. Species is dependent upon a rare or vulnerable habitat for one or more life history needs (breeding, migration, wintering).

5. Species is endemic to Illinois, or the Illinois population is disjunct from the rest of the species' range.

6. Illinois' population of a species represents a significant proportion of the species' global population.

7. Species is representative of broad array of other species found in a particular habitat.

8. Species' status is poorly known, but available evidence suggests conservation concern.

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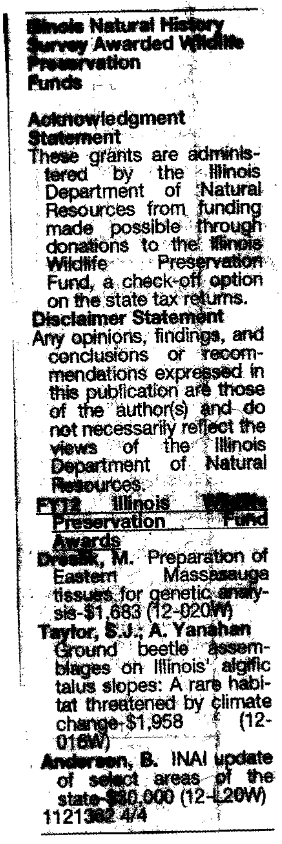

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Dreslik, M. Preparation of Eastern Massasauga tissues for genetic analysis-$1,683 (12-020W)

Taylor, S.J.; A. Yanahan Ground beetle assemblages on Illinois' algific talus slopes: A rare habitat threatened by climate change-$1,958 (12-016W)

Andersen, B. INAI update of select areas of the state-$[illegible]0,000 (12-L20W)

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