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TERRESTRIAL GASTROPOD RICHNESS OF CARBONATE CLIFF AND ASSOCIATED HABITATS IN THE GREAT LAKES REGION OF NORTH AMERICA

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ABSTRACT

The richness of terrestrial gastropod communities in 19 different habitat types in a 1,300 × 1,000 km region in the Great Lakes region of North America was analyzed using 349 0.01–0.1 ha samples. Sites supporting high-richness faunas (24 or more taxa) were limited in the study region to areas south of 45°N. Only weakly significant longitudinal gradients in richness were observed, while a significant latitudinal gradient was present. When only wooded carbonate outcrops were analyzed, a significant negative correlation between richness and latitude was present only between 44°N and 45°N. Highly significant differences in richness between habitats were also observed. Carbonate cliffs harbored the richest faunas, possessing a mean greater than 20. Approximately 25% of these sites contained 24 or more taxa, with a maximum richness of 34 being recorded. Algific talus slopes and lakeshore carbonate ledges were also found to commonly harbor faunas of 17 or more taxa. All of these sites are characterized by shaded, vertical exposures of carbonate bedrock. Only two of the habitats (old fields and open dunes) were found to never support a dozen or more co-occurring taxa. Based on these analyses, carbonate cliffs and related habitats in the Great Lakes region should be included among the most important habitats on a global scale for molluscan biodiversity.

Key words: terrestrial gastropods, community ecology, biodiversity, conservation, North America, Niagaran Escarpment, cliff ecology.

INTRODUCTION

One of the more important components of community structure is richness or the number of co-occurring species (Peet, 1974). While Solem & Climo (1985) suggest that land snail community richness rarely exceeds 12, a number of other studies have documented much higher rates of sympatry. Tropical forest ecosystems have the highest reported richnesses at various sample grains, with up to 40 taxa being reported from individual sites in the Greater Antilles (Solem, 1984), 45 species from a 400 m^2 area in southwestern Cameroon (de Winter & Gittenberger, 1998), 50 species from a <4 ha site near Amboni Cave in eastern Tanzania (Emberton et al., 1997), 52 species from a 4 ha area near Manombo, Madagascar (Emberton, 1995), and 56 species from the 4.2 ha Waipipi Scenic Reserve in New Zealand (Solem et al., 1981). Communities with high land snail richness have also been reported from the temperate zone. Up to 24 species have been recorded from 0.01 ha areas in the Italian Alps (Bishop, 1980), 26 species 0.09 ha regions in British Columbia coniferous forests (Cameron, 1986), 27 species from 9.1 ha Ekholmen Island in Sweden (Nilsson et al., 1988), 39 species from approximately 1 ha samples in SW Sweden (Waldén, 1981), and 44 species from an approximately 4 ha site on Pine Mountain in Harlan County, Kentucky (Emberton, 1995). However, such sites are uncommon enough that Tattersfield (1996) concludes, based upon his review of the international literature, that sites with 24 or more sympatric terrestrial gastropod taxa in small to moderate sample sizes (approx. <10 ha) are of global conservation importance.

Reconnaissance of a dozen eastern Wisconsin limestone and dolomite cliff sites for glacial relict snails (Nekola et al., 1996) documented three sites that possessed 24 or more co-occurring species. Previous surveys made from similar habitats in northeastern Iowa (Frest, 1982, 1987; Frest & Fay, 1981) documented at least five additional sites that also equalled or exceeded this level of sympatry. If these surveys are reflective of such sites as a whole, carbonate cliffs and associated habitats in central North America could be consid-

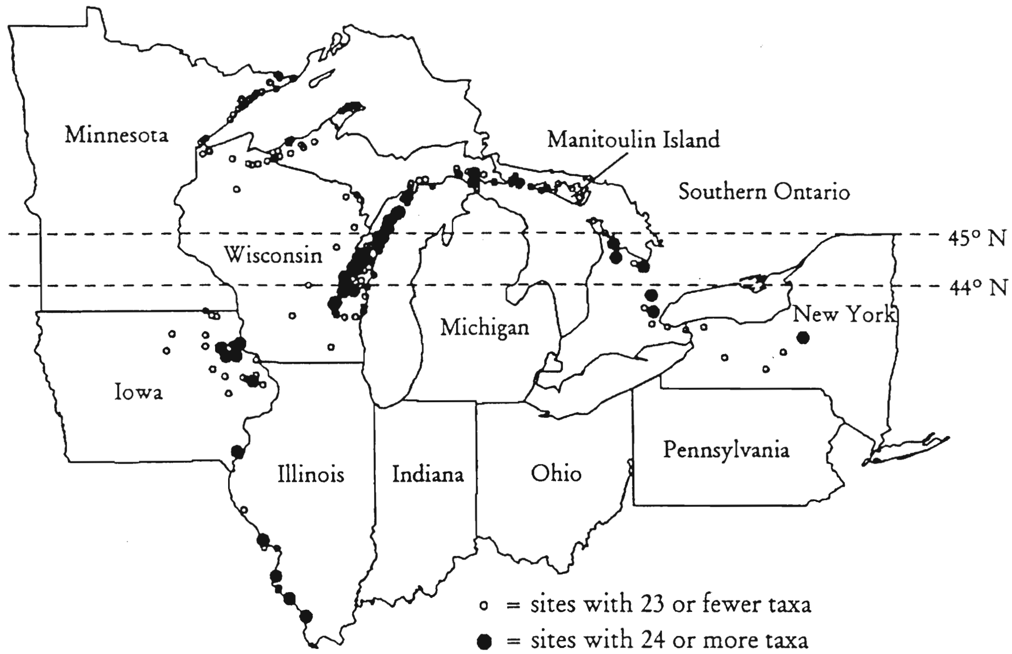

FIG. 1. Distribution of high-richness terrestrial gastropod communities within Great Lakes region.

ered among the richest global terrestrial gastropod communities, particularly at small scales. Unfortunately, given the preliminary nature of these investigations, it was not possible to determine whether these sites were simply outliers, or whether other habitats in this landscape harbored similarly high numbers of species.

The purpose of this paper is to investigate the terrestrial gastropod richness of carbonate cliffs and other habitats in a 1,300 × 1,000 km region centered on the North American Great Lakes. Through this it will be possible to better estimate the frequency of high diversity assemblages from various habitats, to identify potential geographic gradients in species richness over this extent, and to compare the richness of carbonate cliff habitats to others in this landscape.

MATERIALS AND METHODS

Study Sites

A total of 349 areas were surveyed for their terrestrial gastropod faunas (Fig. 1, Appendix I). Sites were chosen for survey if they represented typical examples of their respective habitat and (except for anthropogenic habitats) were undisturbed. They ranged from north-central Iowa through Wisconsin, the Upper Peninsula of Michigan, and southern Ontario (including Manitoulin Island and the Bruce Peninsula), to central New York State (an extent of approximately 1,300 km) and from northeastern Minnesota and the Keweenaw Peninsula in Michigan to southern Illinois (an extent of approximately 1,000 km). The bulk of collections were made along or adjacent to the Niagaran Escarpment, a narrow zone of exposed Silurian-age carbonates extending from Rochester, New York, to West Union, Iowa. Sampling was most intensive (252 sites) from Drummond Island, Michigan, through northeastern Iowa, where an effort was made to sample along the Escarpment from all areas supporting carbonate bedrock outcrops.

Collections were made from nineteen distinct habitat types: carbonate cliffs (114 sites), igneous cliffs (72), rocky woodlands (21), lakeshore carbonate ledges (19), fens (19), algific talus slopes (16), Tamarack wetlands (16), lakeshore alluvial banks (12), upland woods (8), lowland woods (8), White Ceder wetlands (8), calcareous meadows (7), cobble beaches (7), alvars (6), carbonate glades

(5), igneous shorelines (4), old fields (3), shale cliffs (3), and open dunes (1).

Carbonate cliffs represent 3–30 m tall, wooded limestone or dolomite outcrops that typically support moss or fern-covered ledges. Igneous cliffs are wooded, 2–20 m tall basalt, serpentine, or granite outcrops and associated open talus slopes located on the Precambrian Shield of northern Wisconsin, the Upper Peninsula of Michigan, and northeastern Minnesota. Rocky woodlands are upland tracts with abundant bedrock or glacial-erratic boulders. Lakeshore carbonate ledges are <3 m tall, wooded limestone or dolomite outcrops that are within 3 km of the Lake Michigan or Lake Huron shore. Fens are peatland areas formed at locations of groundwater discharge that maintain higher soil moisture and a cooler soil temperatures than is otherwise found in the surrounding landscape (Nekola, 1994). Sampling was only conducted from sites in which *Sphagnum* mosses were either uncommon or lacking. Algific talus slopes are associated with mechanical karst systems harboring year-round ice reservoirs. Air and water drainage from these ice caves through loose carbonate talus has created an unique buffered microclimate where soil temperatures rarely range lower than −10°C in winter or exceed 10°C in the summer, and have a more constant soil moisture as compared to surrounding forest soils. Such sites have been shown (Frest, 1991) to support populations of the glacial relict snails *Catinella gelida* (F. C. Baker, 1927), *Discus macclintockii* (F. C. Baker, 1928), *Hendersonia occulta* (Say, 1831), and *Vertigo hubrichti* Pilsbry, 1934. Tamarack wetlands represent almost pure *Larix laricina* (DuRoi) K. Koch. stands that are open and support abundant *Alnus rugosa* (DuRoi) Spreng. and *Carex* growth. Collections were limited to areas that lacked *Sphagnum* cover. Such sites appear restricted to regions with thin soils over carbonate bedrock. Lakeshore alluvial banks represent steep wooded banks along the Lake Michigan shore that are developed into unconsolidated lacustrine material. Upland woods represent wooded tracts developed on soils lacking large rocky debris. Lowland woods represent deciduous forests found in floodplains or depressions. White Cedar wetlands represent forested peatlands, dominated by *Thuja occidentalis* L., that are associated with groundwater seepage. Surficial soil chemistry can vary from acidic (where *Sphagnum* moss is abundant) to neutral or alkaline (where *Sphagnum* is largely absent). Litter collections were limited to the latter class of sites. Calcareous meadows are open or very sparsely forested wet meadows found on carbonate-rich mineral (rather than organic) substrate. Cobble beaches are constantly wet shoreline grassland habitats developed on flat limestone or dolomite pavement with little or no soil development except in bedrock fracture planes. Alvars are similar to cobble beaches except that they are found in upland locations and become xeric by midsummer. Carbonate glades are xeric grassland communities with thin soils overlying limestone, dolomite, or calcareous shales. Igneous shoreline sites occur along the Lake Superior coast in the Keewenaw Peninsula where basalts or basalt-derived conglomerate sequences are exposed. They are largely treeless, have only limited soil development, and support a number of western and arctic disjunct vascular plants. Old fields represent early successional grasslands that develop following agricultural abandonment. Shale cliffs represent wooded cliffs or banks developed into shale exposures that are often kept wet through constant groundwater seepage. Open dunes are xeric grasslands found in sandy soils along the Great Lakes shore.

Field Sampling

Documentation of the terrestrial gastropod communities from each site was accomplished by hand collection of larger shells and litter sampling for smaller taxa from representative 100–1,000 m^2 regions within sites. As suggested by Emberton et al. (1996), sample collection was concentrated at places of high micro-mollusc density, with a constant volume of soil litter (approximately 4 liters) being collected from each site. For woodland sites, litter collection was concentrated: (1) at places with an abundance of larger shells; (2) along the base of rocks or trees; (3) on soil covered ledges; and/or (4) at cold air vents on the cliff face or in the associated talus. For open sites, collections consisted of: (1) small blocks (approx. 125 cm^3) of turf; and/or (2) loose soil and leaf litter accumulations under or adjacent to shrubs, cobbles and/or boulders.

The location of each sample was marked on USGS (or equivalent) 7.5 minute topographic maps. The latitude-longitude coordinates for each was then determined through digitization of these maps using the ATLAS DRAW software package. Conversion of locations into UTM Zone 16 coordinates was completed using ARCINFO.

Laboratory Procedures

Samples were slowly and completely dried in either a low-temperature soil oven (approx. 80–95°C) or in full sun in a greenhouse. Dried samples were then soaked in water for 3–24 hours, and subjected to careful but vigorous water disaggregation through a standard sieve series (ASTME 3/8" (9.5 mm), 10 (2.0 mm), 20 (0.85), and 40 (0.425 mm) mesh screens). Sieved sample fractions were then dried and passed again through the same sieve series. These dry, resorted fractions were then hand picked against a neutral-brown background. All shells and shell fragments were removed.

All recovered, identifiable shells were assigned to species (or subspecies) using the author's reference collection and the Hubricht Collection at the Field Museum of Natural History. From this, the total number of taxa per site was determined. All specimens have been catalogued and are housed in collections maintained at the University of Wisconsin-Green Bay.

Statistical Analyses

The frequency of high richness (24 or more taxa) sites was calculated across all habitats, and for wooded carbonate outcrops (carbonate cliffs, algific talus slopes, lakeshore carbonate ledges) only, within each of the included states or provinces (Illinois, Iowa, Minnesota, Michigan, southern Ontario, and New York). Testing for statistical differences in the ratio of high vs. normal or low richness sites was conducted via the Pearson Chi-Square and Likelihood Ratio tests. The Likelihood Ratio test was calculated as some of the predicted values were sparse (< 5), complicating interpretation of Pearson's Chi-square statistic. The asymptotic distribution of the Likelihood Ratio test, however, is trustworthy when the number of observations (349 and 149, respectively) equal or exceed the number of cells (14) by a factor of ten (Zar, 1984). Based on apparent differences in the ratio of high-diversity sites between northern and southern sections of the study area, these tests were repeated following exclusion of sites from Minnesota, Michigan and Manitoulin Island.

The relationship between geographic position and richness was graphically represented by plotting site richness vs. UTM N-S or UTM E-W coordinates for (1) all habitats, and (2) for wooded carbonate outcrop (carbonate cliff, algific slope, and carbonate lakeshore ledge) sites only. The central tendencies in these relationships were indicated though locally weighted scatterplot smoothing (Cleveland, 1979). The statistical significance of these relationships, and amount of variance in richness accounted for by geographic position, was estimated using least-squares regression. Cartesian UTM coordinates were analyzed to preclude biases originating from use of polar-coordinate latitude and longitude coordinates.

For the N-S relationships, locally weighted scatterplot smoothing indicated that the response of richness might not be constant. Tests for such differences in response were conducted by splitting the data sets into different N-S position regions, and repeating regression analyses separately for each. The p-values and r^2 for each of these models were recorded.

The central tendency in site richness among habitat types was graphically represented via a box plot with habitats being sorted along the horizontal axis from the highest to lowest means. In box plots the central line represents the median of the sample, the margins of the box represent the interquartile distances, and the fences represent 1.5 times the interquartile distances. For data having a Gaussian distribution, approximately 99.3% of the data will fall inside of the fences (Velleman & Hoaglin, 1981). Outliers falling outside of the fences are shown with asterisks. Testing for significant differences in the average richness between habitats was conducted using ANOVA.

RESULTS

Regional Patterns

Forty of 349 sites harbored 24 or more terrestrial gastropod taxa within 0.01–0.1 ha samples (Fig. 1). Seven sites (4 Iowa, 1 Illinois, 1 Ontario, 1 Wisconsin) harbored 30 or more taxa, with a maximum richness of 34 being observed from a Brown County, Wisconsin, site. Eighty-five percent of high richness sites were found on carbonate cliff habitats. The only non-carbonate cliff habitats that possessed high terrestrial gastropod richness were three algific talus slopes (all with imbedded carbonate cliffs) and single White Cedar

TABLE 1. Ratio of high richness (24 or more taxa) to medium and low richness (23 or fewer taxa) sites in states and provinces within study region.

	All sites		Wooded carbonate outcrops	
State or Province	# high	# medium-low	# high	# medium-low
Illinois	4	5	4	5
Iowa	8	25	7	16
Michigan	1	74	1	18
Minnesota	0	39	0	0
New York	1	5	1	2
Ontario	5	17	5	14
Wisconsin	21	144	19	57

	All states and provinces	
	All sites	Wooded carbonate outcrops
Pearson Statistic	30.763	6.2791
p-value	< 0.00005	0.2800
Likelihood Ratio Statistic	34.2086	7.3618
p-value	< 0.00005	0.1951

Minnesota, Michigan and Manitoulin Island sites excluded	
	All sites
Pearson Statistic	12.2529
p-value:	0.0156
Likelihood Ratio Statistic	10.4536
p-value:	0.0334

wetland, Tamarack wetland, and Rocky woodland sites.

Approximately 11% of all sampled sites had 24 or more taxa (Table 1). The frequency of these high richness sites in the seven states or provinces varied between 0% and 44% of all sites. These differences were significant (Pearson chi-square and Likelihood Ratio $p < 0.00005$). It appeared possible that this difference may be attributed to the much lower frequency of high-richness sites in Minnesota, Upper Peninsula of Michigan, and Manitoulin Island. However, differences in the frequency of high-richness sites was found to remain marginally significant (Pearson chi-square $p = 0.0156$; Likelihood Ratio $p = 0.0334$), even after removal of the most northern regions from analysis. This marginal significance is apparently related to a lowered frequency of high-richness sites in Wisconsin.

Approximately 25% of all wooded carbonate outcrop sites harbored high richness communities. The frequency of these in the five states or provinces ranged between 5% and 44% (Table 1), and occurred over the entire extent of the sample region (Fig. 1). While carbonate cliff sites of high-richness appeared scarce in the Upper Peninsula of Michigan and Manitoulin Island, Pearson's chi-square ($p = 0.2800$) and the Likelihood Ratio ($p = 0.1951$) tests demonstrated that at the state or province scale, these differences were non-significant.

Geographic Gradients

Only a marginally significant (Fig. 2; $p = 0.031$) and weak ($r^2 = 0.013$) trend was found between richness and E-W UTM position across all habitats. This relationship was found to not be significant when only wooded carbonate outcrops were analyzed (Fig. 3; $p = 0.106$). The relationship between richness and N-S UTM location, however, was found to be stronger and more significant both for all habitats ($p < 0.0005$; $r^2 = 0.188$) as well as for wooded carbonate outcrop sites only ($p = 0.003$; $r^2 = 0.059$), with northerly sites possessing lower richness than southerly sites.

The shape of the locally weighted scatterplot smoothing lines for the N-S relationships, in conjunction with additional regression analyses, demonstrate that this pattern is not constant over the study region. Across all habitats, only a weak ($r^2 = 0.063$) but statistically significant ($p = 0.001$) relationship was observed south of 5,000 km while north of this position this same relationship was more significant ($p < 0.0005$) and over 4½ times stronger ($r^2 = 0.289$; Fig. 2). When only

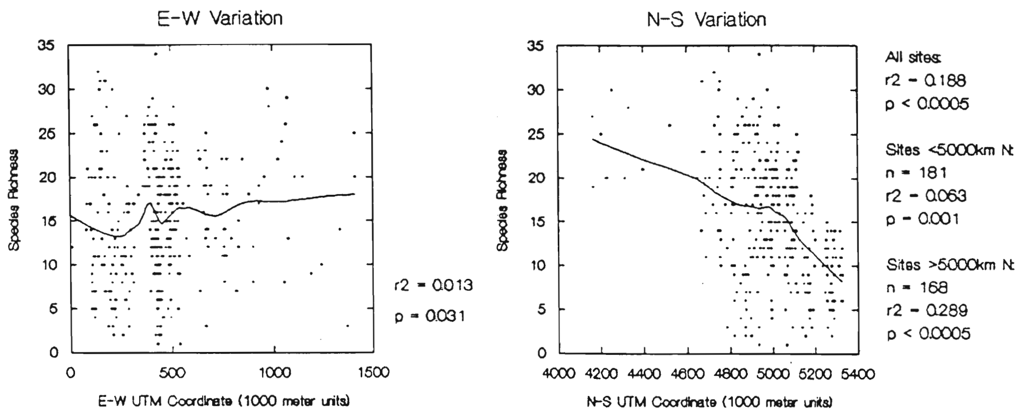

FIG. 2. Relationship of terrestrial gastropod richness to E-W and N-S UTM location across all 19 habitat types. A locally weighted scatterplot smoothing line has been fitted to each relationship.

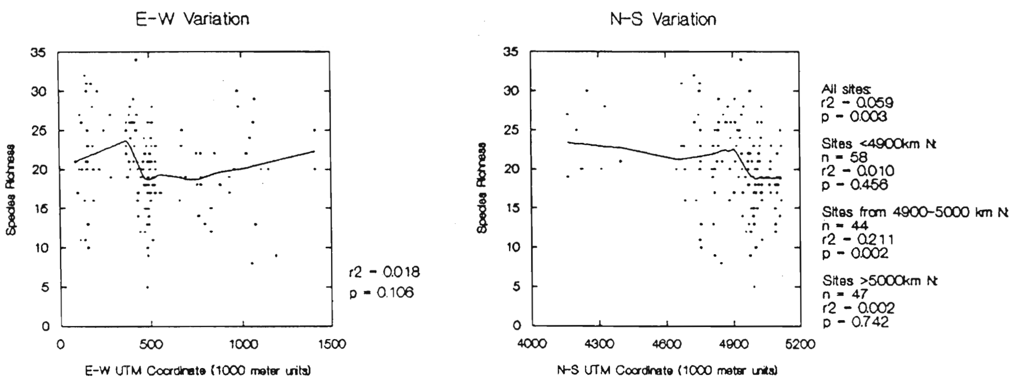

FIG. 3. Relationship of terrestrial gastropod richness to E-W and N-S UTM location for wooded carbonate outcrop sites (carbonate cliffs, algific talus slopes, and lakeshore carbonate ledges). A locally weighted scatterplot smoothing line has been fitted to each relationship.

wooded carbonate outcrops were considered, no relationship was apparent south of 4900 km (roughly 44° N; $p = 0.456$) and north of 5,000 km (approx. 45° N; $p = 0.742$). However, a significant ($p = 0.002$) and moderately strong ($r^2 = 0.221$) relationship was apparent between 4,900 and 5,000 km (Fig. 3).

Habitat Patterns

Comparison of site richness values demonstrate striking differences among the 19 sampled habitat types (Fig. 4). Carbonate cliffs were the richest habitats sampled, possessing a mean score approaching 21. Algific talus slopes and lakeshore carbonate ledges followed, having mean richness scores exceeding 17. Both carbonate cliffs and algific slopes had upper data fences that exceeded 30 species per site. Rocky woodlands, carbonate glades, calcareous meadows, White Cedar wetlands and fens had mean richness scores ranging from 15.3 to 13.9. Igneous shorelines, Tamarack wetlands, lakeshore alluvial banks, lowland woods and cobble beaches had mean richness scores ranging from 12 to 10.6. Igneous cliffs, alvars, shale cliffs, upland woods, old fields, and open dunes all had mean richness scores of less than 10. ANOVA showed these differences to be highly significant ($p < 0.0005$), with almost 50% of observed variance in richness being accounted for by habitat type.

DISCUSSION

Regional Species Richness Patterns

Although Solem & Climo (1985) stated that land snail community richness rarely exceeds

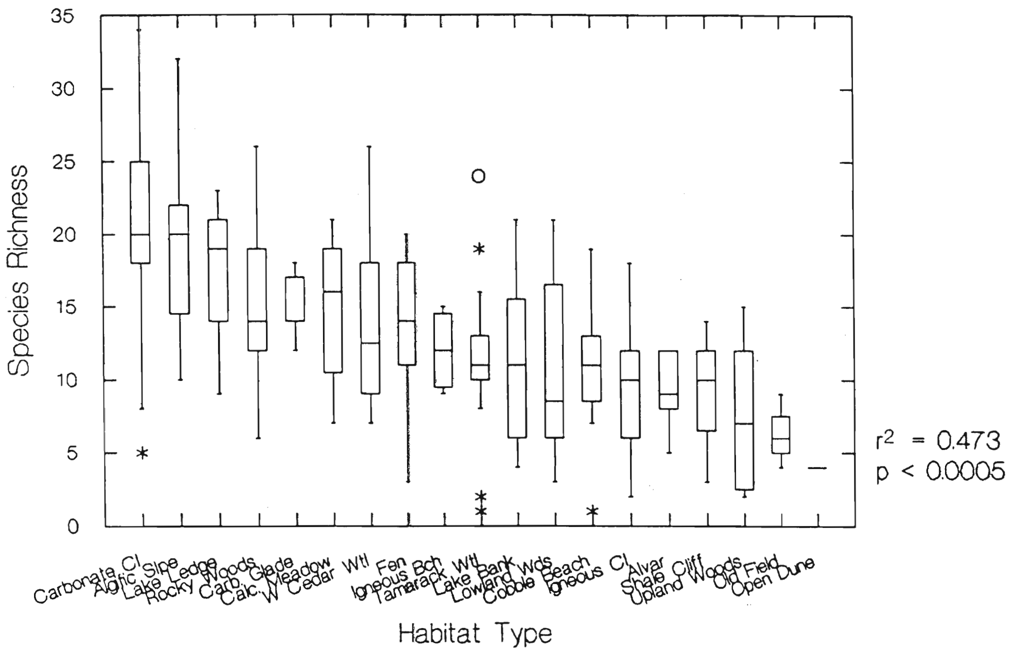

FIG. 4. Box-plot diagrams of terrestrial gastropod richness across 19 habitat types. Habitats are sorted along the horizontal axis from highest to lowest mean scores.

12 taxa, fully 232 of the sites inventoried (66% of the total) equalled or exceeded this level. Sites with 12 or more taxa were found in 17 of the 19 sampled habitats. Only old field and open dune habitats never equalled or exceeded this richness level. It is not clear whether Solem & Climo were unnecessarily pessimistic about terrestrial gastropod community richness, or if the Niagaran Escarpment in the Great Lakes region possesses uniquely rich community assemblages. While it seems likely that the former is true, it should be mentioned that sites with a dozen or more co-occurring terrestrial gastropod taxa may be less frequent in other landscapes. For example, in this study only 34% of northern Wisconsin, western Upper Peninsula and northeastern Minnesota sites had 12 or more co-occurring taxa. Burch (1956) reported maximum mean richness of nine taxa per site in the eastern piedmont and coastal plain of Virginia. Clarke et al. (1968) found no more than nine co-occurring taxa in New Brunswick forests. In their survey of 189 sites (many with carbonate substrates) in the Black Hills of South Dakota, Frest & Johannes (1993) report only seven (less than 4%) that harbor a dozen or more taxa. Cowie et al. (1995) found that no more than 12 taxa coexisted within approximately 100 m^2 samples on Hawaiian vegetated lava flows. It will be necessary to expand these analyses to additional landscapes with a greater diversity of geological substrates and ecological histories to determine whether the terrestrial gastropod communities of the Great Lakes are uniquely rich, or if our definition of what constitutes a species-rich community must be expanded.

Little or no variation in richness was recorded over most of the region. Only a very weak longitudinal trends were identified, and only north of UTM 5,000 were strong latitudinal trends observed. When only wooded carbonate outcrops (carbonate cliffs, algific talus slopes, and lakeshore carbonate ledges) were considered, the significant latitudinal trend in richness was restricted to sites falling between UTM 4,900 and 5,000 km N (or roughly 44° N to 45° N). Similarly, the occurrence frequency of high richness sites (using Tattersfield's criteria of 24 or more taxa) was found to only weakly differ between Illinois, Iowa, southern Ontario, New York, and Wisconsin. However, in Minnesota, the Upper Peninsula of Michigan, and Manitoulin Island this ratio was over ten times lower across all habitats, and at least five times lower on wooded carbonate outcrops.

A number of factors could be responsible for the significantly lower richness levels observed in the northern reaches of the study area. At least some of this decrease in richness may be due to lower-Ca and pH soils associated with igneous (rather than carbonate) bedrock on northern sites. However, this can not explain the significant reductions in richness observed on the northern-most wooded carbonate outcrop sites in the Upper Peninsula and Manitoulin Island. Perhaps the low richness values are related to the greater isolation of these sites, because they are separated from other carbonate outcrops the waters of Green Bay and Georgian Bay as well as the acidic soils of the Precambrian Shield. Additional research will be necessary to tease apart the differential roles played by contemporaneous and historical processes in determining regional terrestrial gastropod richness patterns.

Habitat-specific Species Richness Patterns

Significant differences were observed among the 16 sampled habitats, with carbonate cliffs possessing the highest average number of taxa per site. Over one-half of such sites harbored 21 or more species. Other habitats found to harbor rich assemblages of species included algific talus slopes, lakeshore carbonate ledges, rocky woodlands, carbonate glades, calcareous open meadows, White Cedar wetlands, and fens. All of these habitats are associated with calcareous substrata, either in the form of exposed bedrock, boulders, talus, wet marl, calcareous alluvium or nutrient-rich peat. The lowest richness habitats were, in general, associated with more acidic substrata such as igneous outcrops, sand dunes, or exposed alluvium. However, this pattern is not without exception as low-richness cobble beach and alvar faunas are developed on carbonate outcrops.

Carbonate Cliffs as Terrestrial Gastropod Diversity Hot Spots

Wooded carbonate cliffs, on average, support the highest number of terrestrial gastropod taxa within any habitat in the study region. The richest 5% of these support 29 or more taxa, with a maximum of 34 taxa being recorded. Such sites appear to be among the richest reported globally from 1 ha or smaller quadrats. Waldén (1981) observed up to 39 taxa from 1 ha quadrats in wooded talus slopes in Sweden, while Tattersfield (1996) identified up to 33 taxa per one-sixth hectare samples from Kenyan rain forest. Other published reports of terrestrial gastropod richness from 0.1 ha or less quadrats (e.g., Schmid, 1966; Bishop, 1980; Nilsson et al., 1988; Getz & Uetz, 1994; Cowie et al., 1995; de Winter & Gittenberger, 1998) have reported no more than 45 co-occurring taxa. Maximum richness in Great Lakes carbonate cliff sites is also within 25% of the richest known North American site (at Pine Mountain, Kentucky; Emberton, 1995).

Further research will be necessary to determine if the richness levels of carbonate cliffs in the Great Lakes region are unique, or if similar levels are present in other landscapes. Research from other regions (e.g., New South Wales, Australia: Stanisic, 1997; Germany: Schmid, 1966; Scotland: Cameron & Greenwood, 1991; Sweden: Waldén 1981) indicates that maximum terrestrial gastropod richness frequently occurs on wooded carbonate outcrops. Based on this current and previous research it seems likely that carbonate cliffs will be found to be among the most important habitats for molluscan biodiversity on a global scale.

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APPENDIX I

Name, location, habitat type, and terrestrial gastropod richness of sample sites

Site Name	Location	Habitat Type	Richness
	ILLINOIS		
Calhoun County			
Franklin Hill	90°36′38″W, 39°3′57″N	Carbonate Cliff	28
Jackson County			
Kings Ferry Bluff Base	89°26′16″W, 37°36′36″N	Carbonate Cliff	27
Kings Ferry Bluff Crest	89°26′15″W, 37°36′36″N	Carbonate Cliff	19
Madison County			
Cliffton Terrace	90°13′36″W, 38°54′51″N	Carbonate Cliff	20
Monroe County			
Fults Reserve	90°11′15″W, 38°9′19″N	Carbonate Cliff	20
Fountain Gap	90°15′33″W, 38°22′36″N	Carbonate Cliff	30
Pike County			
Shewhart Bluff	91°6′48″W, 39°39′N	Carbonate Cliff	21
Randolph County			
Prairie du Rocher	90°11′56″W, 38°6′28″N	Carbonate Cliff	20
Chester	89°53′6″W, 37°56′42″N	Carbonate Cliff	25
	IOWA		
Bremer County			
Brayton-Horsley	92°6′28″W, 42°48′35″N	Fen	14
Buchanan County			
Rowley West	91°54′39″W, 42°22′15″N	Fen	20
Chickasaw County			
Stapelton Church	92°6′14″W, 43°1′35″N	Fen	17
Clayton County			
Bixby East	91°23′56″W, 42°40′28″N	Algific Talus Slope	16
Buck Creek 4	91°11′23″W, 42°51′35″N	Algific Talus Slope	13
Buck Creek Tributary 1	91°10′55″W, 42°51′47″N	Algific Talus Slope	21
Buck Creek Tributary 2	91°10′55″W, 42° 51′56″N	Algific Talus Slope	10
Buck Creek Tributary 3	91°10′55″W, 42°52′5″N	Algific Talus Slope	25
Buck Creek Tributary 4	91°10′58″W, 42°52′1″N	Algific Talus Slope	31
Buck Creek Tributary 5	91°11′2″W, 42°51′52″N	Algific Talus Slope	23
Elkader South	91°23′45″W, 42°50′23″N	Algific Talus Slope	11
South Cedar 2	91°14′38″W, 42°49′58″N	Algific Talus Slope	20
South Cedar 3	91°14′23″W, 42°49′51″N	Carbonate Cliff	30
Delaware County			
Backbone West	91°33′43″W, 42°37′5″N	Carbonate Cliff	26
Elk River East	91°17′27″W, 42°37′42″N	Algific Talus Slope	32
Des Moines County			
Iowa Ammunition Plant	91°17′16″W, 40°46′27″N	Rocky Woods	26
Dubuque County			
Roosevelt Road	90°44′30″W, 42°32′55″N	Carbonate Glade	17

Fayette County			
Brush Creek Canyon 1	91°41′27″W, 42°47′2″N	Algific Talus Slope	11
Brush Creek Canyon 2	91°41′20″W, 42°46′46″N	Carbonate Cliff	27
Floyd County			
Juniper Hill Shale Glade	92°59′2″W, 43°3′10″N	Carbonate Glade	12
Franklin County			
Hampton East Glade	93°8′13″W, 42°43′41″N	Carbonate Glade	14
Howard County			
Larkin Bridge East	92°5′8″W, 43°29′32″N	Algific Talus Slope	21
Jackson County			
Hamilton Glade	90°34′8″W, 42°4′23″N	Carbonate Glade	14
Lytle Creek 6	90°45′21″W, 42°15′34″N	Algific Talus Slope	20
Lytle Creek 16	90°45′28″W, 42°15′40″N	Algific Talus Slope	16
Maquoketa Caves	90°46′22″W, 42°7′3″N	Carbonate Cliff	23
Pine Creek	90°50′41″W, 42°8′27″N	Carbonate Cliff	31
Jones County			
Canton Glade	90°59′52″W, 42°10′46″N	Carbonate Glade	18
Pictured Rocks	91°6′18″W, 42°12′28″N	Carbonate Cliff	23
Linn County			
Dark Hollow	91°30′W, 41°53′54″N	Carbonate Cliff	20
Paris Fen	91°35′41″W, 42°13′39″N	Fen	11
Winneshiek County			
Bluffton West 2	91°55′16″W, 43°24′10″N	Algific Talus Slope	17
Heritage Farm	91°47′59″W, 43°22′55″N	Algific Talus Slope	20

MICHIGAN

Chippewa County			
Bass Cove Cobble Beach	83°32′45″W, 45°55′10″N	Cobble Beach	11
Bass Cove Upland	83°32′46″W, 45°55′24″N	Rocky Woods	11
Hill Lake East	84°30′51″W, 46°7′48″N	Carbonate Cliff	19
Huron Bay	83°45′17″W, 45°57′12″N	Cobble Beach	11
Maple Hill	84°46′55″W, 46°9′34″N	Carbonate Cliff	25
Marble Head Center	83°28′28″W, 45°59′3″N	Carbonate Cliff	18
Marble Head North	83°28′30″W, 45°59′17″N	Carbonate Cliff	19
Marble Head South	83°28′35″W, 45°58′46″N	Carbonate Cliff	22
Maxton Plains Center 1	83°39′48″W, 46°4′26″N	Alvar	8
Maxton Plains Center 2	83°39′24″W, 46°4′44″N	Tamarack Wetland	8
Poe Point	83°38′30″W, 46°6′10″N	Lakeshore Carbonate Ledge	14
Prentiss Bay	84°13′49″W, 45°59′25″N	Tamarack Wetland	13
Scott Bay	83°40′1″W, 46°3′31″N	Fen	12
Scott Quarry	84°50′4″W, 46°10′43″N	Carbonate Cliff	23
Seastone Point	83°45′34″W, 46°1′21″N	Carbonate Cliff	22
Spencers Mountain Lower	84°56′39″W, 46°11′33″N	Rocky Woods	19
Spencers Mountain Upper	84°56′43″W, 46°11′29″N	Carbonate Cliff	16
Tourist Road	83°43′48″W, 46°1′44″N	Carbonate Cliff	18
Delta County			
Ansel's Point	86°34′26″W, 45°48′12″N	Carbonate Cliff	23
Burnt Bluff	86°42′39″W, 45°41′11″N	Carbonate Cliff	19
Cooks Ridge	86°29′27″W, 45°57′59″N	Rocky Woods	20
Fayette St. Park	86°39′46″W, 45°43′40″N	Carbonate Cliff	18
Garden Bluff	86°37′48″W, 45°46′47″N	Carbonate Cliff	17
Garden Corners	86°32′4″W, 45°53′23″N	Tamarack Wetland	11
Garden Peninsula Alvar	86°38′38″W, 45°39′48″N	Alvar	5
Goully Harbor	86°36′47″W, 45°46′42″N	Carbonate Cliff	21

Jacks Bluff	86°31′33″W, 45°51′10″N	Lakeshore Alluvial Bank	21
Kregg Bay Northwest 1	86°32′10″W, 45°43′13″N	Alvar	9
Kregg Bay Northwest 2	86°31′59″W, 45°42′39″N	Cobble Beach	1
O16 West	86°43′1″W, 45°40′17″N	Rocky Woods	14
Pt. Detour 1	86°37′47″W, 45°38′3″N	Alvar	9
Pt. Detour 2	86°36′21″W, 45°36′25″N	Cobble Beach	15
Pt. Detour 3	86°36′25″W, 45°36′16″N	Lakeshore Carbonate Ledge	19
South River Bay	86°37′19″W, 45°45′22″N	Carbonate Cliff	20
Gogebic County			
Bessemer NE	90°2′24″W, 46°29′31″N	Igneous Cliff	16
Copper Mountain	90°5′16″W, 46°36′5″N	Igneous Cliff	11
Mt. Zion Park	90°10′8″W, 46°28′37″N	Igneous Cliff	2
Keewenaw County			
Agate Point	88°1′4″W, 47°28′38″N	Igneous Lakeshore	14
Brockway Mountain	87°58′15″W, 47°27′48″N	Igneous Cliff	6
Cliff Range North 1	88°15′11″W, 47°23′55″N	Igneous Cliff	11
Cliff Range North 2	88°15′9″W, 47°23′55″N	Igneous Cliff	13
Cliff Range South	88°19′50″W, 47°21′36″N	Igneous Cliff	12
Cliffton	88°19′23″W, 47°21′54″N	White Cedar Wetland	12
Copper Harbor Shore	87°54′15″W, 47°28′36″N	Igneous Lakeshore	10
Copper Harbor Marina	87°54′14″W, 47°28′19″N	White Cedar Wetland	11
Dans Point	87°58′37″W, 47°28′47″N	Igneous Lakeshore	15
Delaware Gap	88°6′57″W, 47°25′29″N	Igneous Cliff	13
Eagle Harbor	88°8′54″W, 47°27′39″N	Igneous Lakeshore	9
Grand Marais Harbor	88°7′9″W, 47°27′37″N	Igneous Cliff	15
Mt. Bohemia	88°0′51″W, 47°23′34″N	Igneous Cliff	12
Luce County			
McLeod Hill	85°15′37″W, 46°15′17″N	Rocky Woods	23
Mackinac County			
Dinkey Line Road	85°14′16″W, 46°10′49″N	White Cedar Wetland	7
Gamble Road	84°45′W, 46°7′42″N	Rocky Woods	21
Greene Cedar	84°51′51″W, 46°1′41″N	White Cedar Wetland	14
Kenneth Road	84°50′34″W, 46°5′50″N	Carbonate Cliff	19
Martineau Creek	84°43′11″W, 45°59′8″N	Fen	14
McCann High School	84°43′36″W, 45°51′48″N	Rocky Woods	12
Point St. Ignace	84°42′34″W, 45°57′8″N	Rocky Woods	18
Round Lake 1	84°52′31″W, 45°57′18″N	Fen	3
Round Lake 2	84°52′31″W, 45°57′11″N	White Cedar Wetland	13
Summerby Swamp	84°47′43″W, 45°58′15″N	Fen	19
Townhall Road	85°10′28″W, 46°8′19″N	White Cedar Wetland	22
Ontonagon County			
Adventure Mountain	89°4′51″W, 46°46′17″N	Igneous Cliff	18
Cloud Peak	89°43′58″W, 46°48′51″N	Igneous Cliff	16
Cranberry River Hill	89°26′28″W, 46°42′47″N	Igneous Cliff	8
Cuyahoga Peak	89°41′59″W, 46°48′56″N	Igneous Cliff	17
Miscowawbic Peak	89°48′47″W, 46°47′N	Igneous Cliff	16
Norwich Mountain	89°22′54″W, 46°39′37″N	Igneous Cliff	12
Rodgers Cedar Swamp	89°44′3″W, 46°33′7″N	White Cedar Wetland	7
Summit Peak Lower	89°46′27″W, 46°44′55″N	Igneous Cliff	3
Summit Peak Upper	89°46′25″W, 46°44′48″N	Igneous Cliff	5
School Craft County			
Manistique North	86°16′W, 46°1′37″N	Carbonate Cliff	17
Merwin Creek	86°5′40″W, 46°2′30″N	Rocky Woods	13
Seul Choix Point 1	85°54′50″W, 45°55′12″N	Cobble Beach	19
Seul Choix Point 2	85°54′53″W, 45°55′14″N	Rocky Woods	11

MINNESOTA

Cook County			
Caribou Lake E	90°40′1″W, 47°42′23″N	Igneous Cliff	9
Caribou Lake N	90°40′40″W, 47°42′46″N	Igneous Cliff	6
Carlton Peak	90°51′22″W, 47°35′9″N	Igneous Cliff	2
Cascade River Cedars	90°31′32″W, 47°44′36″N	Igneous Cliff	14
Cascade River Cliff	90°32′15″W, 47°43′28″N	Igneous Cliff	12
Iceland Fen	90°7′3″W, 47°47′44″N	Tamarack Wetland	11
John Lake	90°3′29″W, 48°3′56″N	Igneous Cliff	9
Lake Cliff	90°58′23″W, 47°29′40″N	Igneous Cliff	5
Lutsen Mountains	90°41′54″W, 47°40′49″N	Igneous Cliff	4
McFarland Lake Cliff	90°5′25″W, 48°3′34″N	Igneous Cliff	6
McFarland Lake Talus	90°5′18″W, 48°3′36″N	Igneous Cliff	6
Moose Mt. Cliff	90°44′9″W, 47°39′7″N	Igneous Cliff	11
Mt. Josephine Cliff	89°39′14″W, 47°58′58″N	Igneous Cliff	14
Mt. Josephine Talus	89°39′14″W, 47°58′50″N	Igneous Cliff	11
Oberg Mountain	90°46′38″W, 47°37′44″N	Igneous Cliff	5
Pine Lake	90°6′7″W, 48°3′3″N	Igneous Cliff	12
Pine River Road	90°18′4″W, 47°54′59″N	Igneous Cliff	10
Poplar River	90°43′15″W, 47°39′55″N	Igneous Cliff	13
Poplar River Overlook	90°43′34″W, 47°40′13″N	Igneous Cliff	6
Port of Entry Cliff	89°37′12″W, 47°59′51″N	Igneous Cliff	9
Port of Entry Talus	89°37′6″W, 47°59′47″N	Igneous Cliff	9
Portage Brook	90°1′24″W, 48°0′2″N	Igneous Cliff	6
Sawbill Road N Cliff	90°51′37″W, 47°35′50″N	Igneous Cliff	10
South Fowl Lake	90°0′28″W, 48°2′27″N	Igneous Cliff	11
Sugarloaf Cove	90°58′50″W, 47°29′12″N	Igneous Cliff	7
Temperance River Road	90°53′3″W, 47°34′6″N	Igneous Cliff	8
Temperance River Upland	90°52′22″W, 47°34′22″N	Igneous Cliff	14
Timber Creek	90°15′19″W, 47°53′53″N	Igneous Cliff	10
Lake County			
Day Hill	91°22′59″W, 47°11′36″N	Igneous Cliff	10
Finland Forest	91°5′25″W, 47°33′13″N	Igneous Cliff	7
Goldeneye Lake Cliff	91°3′55″W, 47°35′53″N	Igneous Cliff	6
Goldeneye Lake Talus	91°3′48″W, 47°35′50″N	Igneous Cliff	7
Manitou River Falls	91°4′27″W, 47°26′44″N	Igneous Cliff	12
Sawmill Creek	91°9′43″W, 47°24′15″N	Igneous Cliff	3
Water Tanks	91°17′45″W, 47°17′42″N	Igneous Cliff	7
St. Louis County			
Chester Bowl	92°5′55″W, 46°48′48″N	Igneous Cliff	10
Hawk Ridge Sanctuary	92°1′55″W, 46°50′49″N	Igneous Cliff	13
Skyline Drive West Cliff	92°10′6″W, 46°45′47″N	Igneous Cliff	5
Skyline Drive West Talus	92°10′6″W, 46°45′43″N	Igneous Cliff	14

NEW YORK

Cayuga County			
Fillmore Glen State Park	76°23′52″W, 42°41′45″N	Shale Cliff	3
Madison County			
Cazenova Gorge 1	75°50′41″W, 42°58′49″N	Carbonate Cliff	25
Cazenova Gorge 2	75°50′49″W, 42°58′49″N	Carbonate Cliff	20
Niagara County			
Gasport Ravine	78°35′2″W, 43°10′52″N	Carbonate Cliff	9
Schuyler County			
Watkins Glen State Park	76°53′24″W, 42°22′16″N	Shale Cliff	14

Wyoming County			
Letchworth State Park	78°1′26″W, 42°35′41″N	Shale Cliff	10

ONTARIO

Bruce County			
Grotto Trail	81°31′19″W, 45°14′38″N	Carbonate Cliff	19
Lions Head	81°13′4″W, 45°0′28″N	Carbonate Cliff	20
Overhanging Point	81°31′51″W, 45°14′40″N	Carbonate Cliff	17
Grey County			
Inglis Falls	80°56′2″W, 44°31′50″N	Carbonate Cliff	28
Metcalfe Rock	80°26′31″W, 44°25′3″N	Carbonate Cliff	22
Skinners Bluff	80°59′31″W, 44°47′36″N	Carbonate Cliff	30
Halton County			
Crawford Lake	79°56′27″W, 43°28′27″N	Carbonate Cliff	29
Royal Municipality of Hamilton-Wentworth			
Dundas Park	79°58′48″W, 43°14′18″N	Carbonate Cliff	13
Manitoulin District			
Burnt Island	82°56′9″W, 45°49′26″N	Cobble Beach	7
Cooks Dock Lower	82°47′20″W, 45°52′50″N	Carbonate Cliff	12
Cooks Dock Upper	82°47′20″W, 45°52′48″N	Carbonate Cliff	15
Cup & Saucer East	82°6′10″W, 45°51′21″N	Carbonate Cliff	18
Cup & Saucer North	82°5′59″W, 45°51′9″N	Carbonate Cliff	18
Janet Head	82°29′16″W, 45°56′43″N	Carbonate Cliff	22
McLean Park Lowland	81°54′28″W, 45°41′31″N	Lowland Woods	8
McLean Park Upland	81°54′25″W, 45°41′44″N	Rocky Woods	12
Mississagi Lighthouse	83°13′19″W, 45°53′36″N	Lakeshore Carbonate Ledge	13
Niagara County			
Beamers Falls	79°34′1″W, 43°11′16″N	Carbonate Cliff	20
Niagara Whorlpool	79°4′1″W, 43°7′24″N	Carbonate Cliff	20
Peel County			
Devils Pulpit	79°59′27″W, 43°48′4″N	Carbonate Cliff	26
Simcoe County			
Glen Huron	80°11′41″W, 44°21′1″N	Carbonate Cliff	24
Wellington County			
Guelph Jail	80°10′44″W, 43°32′51″N	Carbonate Cliff	8

WISCONSIN

Ashland County			
Beaverdam Lake	90°48′33″W, 46°19′26″N	Igneous Cliff	3
Loon Lake Bluff	90°38′49″W, 46°20′52″N	Igneous Cliff	12
St. Peter's Dome	90°54′39″W, 46°21′5″N	Igneous Cliff	9
Bayfield County			
Rainbow Lake Wilderness	91°20′13″W, 46°26′35″N	Upland Woods	7
Brown County			
Bayshore Park	87°47′59″W, 44°38′12″N	Carbonate Cliff	17
Benderville Wayside	87°50′31″W, 44°36′47″N	Carbonate Cliff	27
Blueberry Marsh	87°53′35″W, 44°31′46″N	Tamarack Wetland	1
Celtis Site	87°50′52″W, 44°36′35″N	Carbonate Cliff	34
Edgewater Villas	87°49′8″W, 44°37′42″N	Carbonate Cliff	14
Escarpment Glade	87°49′4″W, 44°37′9″N	Alvar	12
Fonferik Glen	87°58′15″W, 44°25′34″N	Carbonate Cliff	25
Gibson Alvar	87°50′52″W, 44°35′26″N	Alvar	12

Gravel Pit Road	87°47′59″W, 44°36′7″N	Calcareous Meadow	19
Greenleaf Cliff	88°4′1″W, 44°20′20″N	Carbonate Cliff	29
Greenleaf Talus	88°4′4″W, 44°20′16″N	Carbonate Cliff	21
Hilly Haven	88°2′43″W, 44°20′59″N	Carbonate Cliff	26
Iron Fence Wayside	87°49′40″W, 44°37′14″N	Carbonate Cliff	20
Lily Lake County Park 1	87°51′3″W, 44°25′19″N	Tamarack Wetland	13
Lily Lake County Park 2	87°51′3″W, 44°25′22″N	Lowland Woods	20
Neshota County Park 1	87°48′22″W, 44°24′5″N	Fen	20
Neshota County Park 2	87°48′17″W, 44°24′6″N	Rocky Woods	18
Scray's Hill	88°1′37″W, 44°23′N	Carbonate Cliff	23
UWGB Upland Woods	87°55′22″W, 44°31′33″N	Upland Woods	3
UWGB Cedar Swamp	87°55′29″W, 44°31′33″N	White Cedar Wetland	26
UWGB Escarpment	87°54′21″W, 44°31′48″N	Carbonate Cliff	25
Calumet County			
Calumet County Park	88°19′11″W, 44°6′45″N	Carbonate Cliff	20
Charlesburg Ledge	88°12′3″W, 43°58′10″N	Carbonate Cliff	26
East River Road	88°3′42″W, 44°8′21″N	Tamarack Wetland	12
High Cliff State Park 1	88°17′56″W, 44°9′11″N	Carbonate Cliff	24
High Cliff State Park 2	88°16′44″W, 44°10′13″N	Carbonate Cliff	26
High Cliff State Park 3	88°17′52″W, 44°9′18″N	Rocky Woods	14
High Cliff State Park 4	88°17′49″W, 44°9′14″N	Upland Woods	7
Kiel Marsh	88°3′34″W, 43°53′52″N	Tamarack Wetland	24
Stockbridge	88°17′17″W, 44°3′10″N	Carbonate Cliff	28
Dodge County			
Ledge County Park	88°35′2″W, 43°28′11″N	Carbonate Cliff	22
Mayville South	88°32′24″W, 43°27′27″N	Carbonate Cliff	23
Messner Ledge South	88°35′41″W, 43°37′55″N	Carbonate Cliff	25
Neda Mine	88°32′5″W, 43°25′23″N	Carbonate Cliff	19
Door County			
Bjorklunden	87°7′58″W, 45°1′54″N	Lakeshore Carbonate Ledge	21
Boyer Bluff 1	86°56′2″W, 45°25′10″N	Carbonate Cliff	17
Boyer Bluff 2	86°55′55″W, 45°25′6″N	Carbonate Cliff	16
Brussels Hill North	87°35′45″W, 44°46′13″N	Carbonate Cliff	20
Brussels Hill Radio Tower	87°35′27″W, 44°44′47″N	Carbonate Cliff	19
Carlsville Road	87°22′1″W, 44°57′4″N	Carbonate Cliff	12
Cave Point Shore	87°10′33″W, 44°55′38″N	Lakeshore Carbonate Ledge	9
Cave Point Uplands	87°10′44″W, 44°55′51″N	Rocky Woods	12
Cherry Escarpment	87°9′25″W, 45°11′11″N	Carbonate Cliff	17
Door Bluff Park	87°3′53″W, 45°17′48″N	Carbonate Cliff	18
Ellison Bay Park	87°5′38″W, 45°15′20″N	Carbonate Cliff	26
Fifield Tract	87°3′36″W, 45°6′N	Lakeshore Carbonate Ledge	17
Frey Tract	87°3′45″W, 45°14′34″N	Lakeshore Carbonate Ledge	15
Glidden Drive	87°12′36″W, 44°52′53″N	Lakeshore Carbonate Ledge	13
Hemlock Road 1	86°52′12″W, 45°20′50″N	Lakeshore Carbonate Ledge	23
Hemlock Road 2	86°52′4″W, 45°20′42″N	Rocky Woods	20
Hutter Tract	87°22′55″W, 44°56′5″N	Carbonate Cliff	24
Kangaroo Lake	87°10′4″W, 45°3′12″N	Rocky Woods	13
Kuchar Fen	87°10′51″W, 45°5′12″N	Fen	11
LaSalle Park	87°21′50″W, 44°41′23″N	Lakeshore Alluvial Bank	15
Little Harbor	87°24′7″W, 44°54′45″N	Carbonate Cliff	18

McKnight Escarpment	87°19′47″W, 45°0′43″N	Carbonate Cliff	15
Meridian Park	87°9′57″W, 45°0′22″N	Lakeshore Carbonate Ledge	15
Monument Point South	87°21′35″W, 44°58′35″N	Carbonate Cliff	15
Moonlight Bay	87°4′1″W, 45°4′54″N	Lakeshore Alluvial Bank	4
Mountain Park	86°54′10″W, 45°23′16″N	Carbonate Cliff	24
Mud Lake	87°4′44″W, 45°5′44″N	Lakeshore Carbonate Ledge	13
Newport State Park 1	86°59′13″W, 45°14′52″N	Lakeshore Carbonate Ledge	20
Newport State Park 2	86°59′23″W, 45°15′3″N	Lakeshore Carbonate Ledge	21
Newport State Park 3	86°59′49″W, 45°15′13″N	Lakeshore Carbonate Ledge	21
Peninsula State Park 1	87°13′8″W, 45°9′42″N	Carbonate Cliff	18
Peninsula State Park 2	87°12′7″W, 45°9′45″N	Carbonate Cliff	10
Port de Mort	86°59′31″W, 45°17′50″N	Carbonate Cliff	22
Potawatomie State Park 1	87°25′29″W, 44°52′38″N	Carbonate Cliff	20
Potawatomie State Park 2	87°24′46″W, 44°51′40″N	Carbonate Cliff	18
Potawatomie SW	87°26′31″W, 44°51′45″N	Carbonate Cliff	21
Red River Bluff	87°41′6″W, 44°45′43″N	Carbonate Cliff	12
Ridges Sand Swale	87°7′8″W, 45°4′12″N	Calcareous Meadow	10
Rock Island 1	86°49′44″W, 45°25′20″N	Carbonate Cliff	26
Rock Island 2	86°49′40″W, 45°24′53″N	Upland Woods	15
Rock Island 3	86°49′4″W, 45°25′37″N	Carbonate Cliff	19
Rock Island 4	86°49′8″W, 45°25′31″N	Carbonate Cliff	18
Rock Island 5	86°49′37″W, 45°25′19″N	Carbonate Cliff	28
Rock Island 6	86°49′44″W, 45°25′6″N	Carbonate Cliff	11
Rocky Point	87°19′11″W, 44°46′23″N	Lakeshore Alluvial Bank	13
Sand Dune Park	86°53′52″W, 45°20′14″N	Lakeshore Alluvial Bank	14
Shivering Sands	87°15′57″W, 44°52′30″N	Lakeshore Carbonate Ledge	22
Ski Slope, E-facing	87°14′5″W, 45°6′10″N	Carbonate Cliff	23
Ski Slope, N-facing	87°14′16″W, 45°6′18″N	Carbonate Cliff	15
South Shore Road	86°53′6″W, 45°20′10″N	Lakeshore Carbonate Ledge	21
Standish	87°21′57″W, 45°57′36″N	Carbonate Cliff	22
Thorpe Pond	87°13′40″W, 45°4′20″N	Fen	10
Toft Point 1	87°5′20″W, 45°3′23″N	Upland Woods	13
Toft Point 2	87°6′3″W, 45°4′50″N	Fen	12
Toft Point 3	87°5′52″W, 45°4′43″N	Tamarack Wetland	11
Toft Point 4	87°5′59″W, 45°4′58″N	Lowland Woods	13
Toft Point 5	87°5′52″W, 45°4′22″N	Lakeshore Carbonate Ledge	14
Toft Point 6	87°5′5″W, 45°4′40″N	Lakeshore Carbonate Ledge	19
Toft Point 7	87°5′2″W, 45°3′59″N	Cobble Beach	10
Toft Point 8	87°5′45″W, 45°4′14″N	Rocky Woods	6
Ulman Woods	87°32′3″W, 44°44′58″N	Rocky Woods	11
Werkheiser Escarpment	87°20′27″W, 44°59′39″N	Carbonate Cliff	15
Wilson Escarpment	87°15′43″W, 45°5′3″N	Carbonate Cliff	5
Douglas County			
Flanagan Lookout 1	91°56′9″W, 46°35′8″N	Igneous Cliff	5
Flanagan Lookout 2	91°56′6″W, 46°35′7″N	Igneous Cliff	7

Pattison State Park 1	92°7′26″W, 46°32′14″N	Igneous Cliff	9
Pattison State Park 2	92°7′26″W, 46°32′15″N	Igneous Cliff	8
Pattison State Park 3	92°7′26″W, 46°32′16″N	Igneous Cliff	7
South Range	91°58′26″W, 46°36′15″N	Old Field	4
Fond du Lac County			
Ledge Bar	88°21′3″W, 43°52′4″N	Carbonate Cliff	27
Messner Ledge	88°35′31″W, 43°38′13″N	Carbonate Cliff	23
Messner Ledge North	88°35′24″W, 43°38′25″N	Carbonate Cliff	23
Oakfield Brick Yard	88°33′10″W, 43°40′27″N	Carbonate Cliff	26
Oakfield Ledge	88°34′55″W, 43°38′55″N	Carbonate Cliff	23
Peebles	88°22′40″W, 43°48′32″N	Carbonate Cliff	21
Shley Pond	88°33′39″W, 43°40′8″N	Carbonate Cliff	25
Iron County			
Hurley Visitor Center	90°12′14″W, 46°28′13″N	Igneous Cliff	11
Lake Lavina Bluff 1	90°10′55″W, 46°26′6″N	Igneous Cliff	11
Lake Lavina Bluff 2	90°10′55″W, 46°26′6″N	Igneous Cliff	8
Whitecap Mountain	90°23′49″W, 46°24′15″N	Igneous Cliff	15
Kewaunee County			
Kewaunee Fish Hatchery	87°33′50″W, 44°28′45″N	Lakeshore Carbonate Ledge	19
Lipsky Swamp 1	87°37′15″W, 44°28′57″N	Tamarack Wetland	11
Lipsky Swamp 2	87°37′13″W, 44°28′50″N	Lowland Woods	7
Little Scarboro Creek 1	87°37′26″W, 44°30′39″N	Rocky Woods	18
Little Scarboro Creek 2	87°37′22″W, 44°30′45″N	Cacareous Meadow	16
Mud Lake	87°39′45″W, 44°39′37″N	Tamarack Wetland	19
Stony Creek Woods	87°22′51″W, 44°39′51″N	Lakeshore Alluvial Bank	16
Thiry Daems	87°42′14″W, 44°36′8″N	Calcareous Meadow	19
Tisch Mills	87°38′21″W, 44°20′50″N	Tamarack Wetland	12
Manitowoc County			
Cato Falls County Park 1	87°50′34″W, 44°5′31″N	Carbonate Cliff	16
Cato Falls County Park 2	87°50′49″W, 44°5′29″N	Lakeshore Alluvial Bank	9
Cooperstown Swamp	87°53′12″W, 44°16′16″N	Tamarack Wetland	11
Frelich Road Swamp	87°52′8″W, 44°17′40″N	Lowland Woods	21
Kingfisher Farm 1	87°42′3″W, 43°57′43″N	Lakeshore Alluvial Bank	20
Kingfisher Farm 2	87°42′17″W, 43°57′47″N	Lakeshore Alluvial Bank	6
Kingfisher Farm 3	87°42′3″W, 43°57′51″N	Lakeshore Alluvial Bank	6
Kingfisher Farm 4	87°42′14″W, 43°57′46″N	Upland Woods	2
Kingfisher Farm 5	87°42′10″W, 43°57′51″N	Lowland Woods	3
Kingfisher Farm 6	87°42′21″W, 43°57′48″N	Lowland Woods	9
Kingfisher Farm 7	87°42′25″W, 43°57′49″N	Fen	10
Maribel Caves	87°46′11″W, 44°17′9″N	Carbonate Cliff	17
Point Beach 1	87°31′11″W, 44°12′5″N	Upland Woods	11
Point Beach 2	87°30′39″W, 44°11′52″N	Open Dune	4
SLC Bog 1	87°54′5″W, 43°59′31″N	Calcareous Meadow	7
SLC Bog 2	87°54′3″W, 43°59′21″N	Lowland Woods	5
SLC Bog 3	87°53′50″W, 43°59′31″N	Old Field	9
Tamarack Road	88°0′55″W, 44°12′12″N	Tamarack Wetland	2
Marinette County			
Kimlark Lake	87°50′56″W, 45°39′37″N	Calcareous Meadow	11
Niagara East Bluff 1	87°56′41″W, 45°45′24″N	Igneous Cliff	10
Niagara East Bluff 2	87°56′41″W, 45°45′23″N	Igneous Cliff	15
Pound Roadside	88°1′1″W, 45°7′29″N	Calcareous Meadow	21

Spur Lake 1	88°14′5″W, 45°43′5″N	Fen	15
Spur Lake 2	88°13′58″W, 45°42′59″N	Fen	12
Ozaukee County			
Cedarburg Bog 1	88°0′34″W, 43°23′9″N	Fen	10
Cedarburg Bog 2	88°1′4″W, 43°22′59″N	Tamarack Wetland	16
Harrington Beach 1	87°48′10″W, 43°29′26″N	Old Field	6
Harrington Beach 2	87°47′56″W, 43°29′16″N	Upland Woods	2
Harrington Beach 3	87°47′41″W, 43°29′42″N	Lakeshore Carbonate Ledge	10
Sauk County			
Devils Lake	89°43′57″W, 43°24′30″N	Igneous Cliff	17
Sawyer County			
Pipestone Falls	91°14′12″W, 45°51′19″N	Igneous Cliff	11
Shawano County			
Porter Road	88°30′10″W, 44°44′16″N	Carbonate Cliff	19
Sheboygan County			
Evergreen Park	87°44′29″W, 43°46′56″N	Lakeshore Alluvial Bank	4
Waters Edge	87°46′46″W, 43°34′53″N	Lakeshore Alluvial Bank	7
Mehles Springs	88°1′16″W, 43°51′38″N	Tamarack Wetland	9
Walworth County			
Bluff Creek Fen	88°40′54″W, 42°48′2″N	Fen	19
Washington County			
Allenton Fen	88°18′25″W, 43°22′41″N	Fen	19
Waushara County			
Bass Lake	89°16′58″W, 44°0′15″N	Fen	17

APPENDIX II

Species occurance within 19 habitat types

Species	Habitat Type 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Total
Allogonia profunda (Say, 1821)	20		5			3	1								5					34
Anguispira alternata (Say, 1817)	106	23	11		1	15	7					4			14		1	2		184
Anguispira kochi (Pfeiffer, 1845)	1																			1
Carychium exiguum (Say, 1822)	5			16	5			1	1	4			4		1	1	14	7	1	60
Carychium exile (H. C. Lea, 1842)	71	12	16	3		8	7	3		1	1	2	4		10		1	5		144
Carychium nannodes (Clapp, 1905)	1																			1
Catinella aff. *"vermeta"* (Say)								1	2											3
Catinella avara (Say, 1824)	2				2			4		3							3			14
Catinella exile (Leonard, 1972)				7	3															10
Catinella gelida (F. C. Baker, 1927)	17		3																	20
Cepaea nemoralis (Linné, 1798)	1																			1
Cochlicopa lubrica (Müller, 1774)	27	5	1	2	2	3	7	2		2	1	4			11		2	3	2	74
Cochlicopa lubricella (Porro, 1838)	14	5		3		2	1	1		4		1			5					36
Cochlicopa morseana (Doherty, 1878)	12	6	4			2	2								5		1			32
Columella simplex (Gould, 1841)	74	26	12	5	4	17	11	2		1		2	3		13	1	3	6	3	183
Deroceras laeve (Müller, 1774)	56	1	4	8	2	1	1		2	3		1	2		2	2	4	2		91
Discus catskillensis (Pilsbry, 1898)	88	58	1	1	2	18	4			1	1	2	3		15	1	2	4	4	205
Discus cronkhitei (Newcomb, 1865)	16	12	1	4	2	1	1			3					2		3	1	1	47
Discus macclintockii (F. C. Baker, 1928)	1		5																	6
Discus patulus (Deshayes, 1830)			1																	1
Euconulus alderi (Gray, 1840)				14	1					2			2				11	4		34
Euconulus dentatus (Sterki, 1893)	1																			1
Euconulus fulvus (Müller, 1774)	65	35	1	3	1	14	5	1	1	3		3	2	1	9		2	1	1	148
Euconulus polygyratus (Pilsbry, 1899)	38	5	10	1		8	2				1	2	1		13	2		2		85
Euconulus trochulus (Reinhardt, 1883)	2																			2
Gastrocopta armifera (Say, 1821)	17		1				1	1	2						1					23
Gastrocopta contracta (Say, 1822)	76	2	12	9	1	7	1	1	4	4			2		6	1	4	1		131
Gastrocopta corticaria (Say, 1816)	44		5			1			2						1					53
Gastrocopta holzingeri (Sterki, 1889)	53	1	11			2	1	1	5				2	1	1					78
Gastrocopta mcclungi (Hanna & Johnson, 1913)	4																			4
Gastrocopta pentodon (Say, 1821)	84	9	11	1	1	7	1	2	4		1	1	3		6		1		1	133
Gastrocopta procera (Gould, 1840)	8								3											11
Gastrocopta similis (Sterki, 1909)	6								5											14

Species	Habitat Type 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Total
Gastrocopta tappaniana (C. B. Adams, 1842)	2			15	4		1	5		6			2		2	1	14	2	1	55
Glyphyalinia indentata (Say, 1823)	51	6	4	2	1	7	1	2	3	1	1	1			9		1	1		91
Glyphyalinia rhoadsi (Pilsbry, 1899)	15	1				1	1								4					22
Glyphyalinia wheatleyi (Bland, 1883)	5					1									1					7
Guppya sterkii (Dall, 1888)	16		2												2					20
Haplotrema concavum (Say, 1821)	11		7										2		1	1				22
Hawaiia miniscula (A. Binney, 1840)	52		10	5	4		2	1	5	3			1		4		2	1		90
Hawaiia n. sp. (*sensu* Frest, 1990)				4																4
Helicodiscus inermis (H. B. Baker, 1929)	4								1											5
Helicodiscus n. sp. (*sensu* Frest, 1990)				3																3
Helicodiscus notius (Hubricht, 1962)	7																			7
Helicodiscus parallelus (Say, 1817)	34	7	3	4		3		2	3	1					9		6	1	4	77
Helicodiscus shimeki (Hubricht, 1962)	73	19	8	2	1	15	6	2	1	1		5	2		14	1	1	3		154
Helicodiscus singleyanus (Pilsbry, 1890)	7		1												1					9
Hendersonia occulta (Say, 1831)	27	2	16	1		3	9						3		3					64
Mesodon clausus clausus (Say, 1821)	2		2												1					5
Mesodon inflectus (Say, 1821)	3																			3
Mesodon pennsylvanicus (Green, 1827)															1					1
Mesodon thyroidus (Say, 1816)	9		2			1														12
Mesodon zaletus (A. Binney, 1837)	3																			3
Mesomphix cupreus (Rafinesque, 1831)	2															1				3
Mesomphix friabilis (W. G. Binney, 1857)	6																			6
Mesomphix inornatus (Say, 1821)	4															1				5
Nesovitrea binneyana (Morse, 1864)	42	52	7	1	1	9	1	1			2	2	1		4			4	2	129
Nesovitrea electrina (Gould, 1841)	5	9	1	15	2	3	1	3	3	3			4			1	14	5	2	71
Oxychylus cellarius (Müller, 1774)	1																			1
Oxyloma peoriensis (Wolf, in Walker, 1892)				1																1
Oxyloma retusa (I. Lea, 1834)	1		1	8	3			1		5			1					1		21
Paravitrea multidentata (A. Binney, 1840)	53	7				12	1					1			11					85
Paravitrea significans (Bland, 1866)	6																			6
Planogyra asteriscus (Morse, 1857)		4		1		2	1								1		1	5		15
Polygyra dorfeuilliana (I. Lea, 1838)	2																			2
Pomatiopsis lapidaria (Say, 1817)	1			2									1							4
Punctum minutissimum (I. Lea, 1841)	68	37		4	5	18	6	4		3		4	3		17	3	5	5	4	186

Punctum n. sp. (*sensu* Frest, 1990)				8						1							2			11
Punctum vitreum (H. B. Baker, 1930)	41	1	16	1		1	5		5				3		3		1			77
Pupilla muscorum (Linné, 1758)	3														1			1		5
Pupoides albilabris (C. B. Adams, 1821)	10		1				4	1												16
Rabdotus dealbatus (Say, 1821)	1																			1
Stenotrema barbatum (Clapp, 1904)	5		6	2													1			14
Stenotrema fraternum fraternum (Say, 1824)	57	3	6			7							1		6			1		81
Stenotrema hubrichti (Pilsbry, 1940)	2																			2
Stenotrema leai leai (A. Binney)	1			8	4			1	4	3			2				3	1		27
Striatura exigua (Stimpson, 1847)	20	30		6		8	2					3	3		9	1	8	7	2	99
Striatura ferrea (Morse, 1864)	15	7		1		7	2						3		7	1	1	3		47
Striatura meridionalis (Pilsbry & Ferriss, 1906)	7																			7
Striatura milium (Morse, 1859)	45	47	11	8		17	5	1		1	1	4	6		14	1	11	6	4	182
Strobilops aenea (Pilsbry, 1926)	2		2																	4
Strobilops affinis (Pilsbry, 1893)				9				1		3			1				2			16
Strobilops labyrinthica (Say, 1817)	95	28	10	8	4	18	6	3	1	3	2	4	4	1	14		7	7	3	218
Succinea ovalis (Say, 1817)	27	9		2		5	5			3		4	1		7		2	1		42
Succinea aff. *pleistocenica* (F. C. Baker) (?)	5																			5
Triodopsis albolabris (Say, 1816)	6	1				2						2			3					14
Triodopsis alleni (Wetherby in Sampson, 1883)	3		2												1					6
Triodopsis denotata (Férussac, 1821)	2																			2
Triodopsis discoidea (Pilsbry, 1904)	1																			1
Triodopsis fosteri (F. C. Baker, 1932)	8														1					9
Triodopsis multilineata (Say, 1821)	3			3											2					8
Triodopsis tridentata (Say, 1816)	11															1				12
Vallonia costata (Müller, 1774)	20			2	1	1	1	1		5	2				1		1	1		36
Vallonia excentrica (Sterki, 1893)	1		1								1									3
Vallonia gracilicosta (Reinhardt, 1883)	41		3																	44
Vallonia parvula (Sterki, 1892)	3								5											8
Vallonia perspectiva (Sterki, 1892)	23		6						1						1					31
Vallonia pulchella (Müller, 1774)	10			6			1	1		6	1								1	26
Ventridens ligera (Say, 1821)	1																			1
Vertigo bollesiana (Morse, 1865)	47	14	9			16	4				1				2	2	1	1		97
Vertigo cristata (Sterki, 1919)	13	48				6									2		1	2	2	74
Vertigo elatior (Sterki, 1894)				17	4		1	2		3		1	2		1	1	11	2		45
Vertigo gouldi (A. Binney, 1843)	103	12	13			15	2					1	3		11		1	1		162
Vertigo hubrichti (Pilsbry, 1934)	53	1	10			10	2	1							1					78

Species	Habitat Type 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Total
Vertigo "iowaensis" (*sensu* Frest, 1991)	32		5			4														41
Vertigo mermacensis (Van Devender, 1979)	6		2																	8
Vertigo milium (Gould, 1840)	19		1	8						3	1				1		1	1		35
Vertigo modesta modesta (Say, 1824)	2	5																		7
Vertigo modesta parietalis (Ancey, 18)	1	3																		4
Vertigo morsei (Sterki, 1894)				5																5
Vertigo nylanderi (Sterki, 1909)													1				8	1		10
Vertigo ovata (Say, 1822)				4	4					6							2			16
Vertigo paradoxa (Sterki, 1900)	23	33			1	1									2		1		3	64
Vertigo pygmaea (Draparnaud, 1801)	14			3			2	1		6	1	1			1					29
Vertigo tridentata (Wolf, 1870)	11		6						3											20
Vitrina limpida (Gould, 1850)	10	3			1		2	2			1				5			1	3	28
Zonitoides arboreus (Say, 1816)	100	63	6	7	3	18	5	1	4	4		3	5	1	16	1	12	6		255
Zonitoides limatulus (W. G. Binney, 1840)	1																			1
Zonitoides nitidus (Müller, 1774)	5			2	2	1	3			1							4	1		19
Zoogenetes harpa (Say, 1824)	7	35				1									3				4	50
Total sites sampled per habitat	114	72	16	19	7	19	12	6	5	7	3	8	8	1	21	3	16	8	4	349

Habitat Legend:

Habitat	Number	Habitat	Number
Carbonate Cliff	1	Old Field	11
Igneous Cliff	2	Upland Woods	12
Algific Talus Slope	3	Lowland Woods	13
Fen	4	Open Dune	14
Cobble Beach	5	Rocky Woodland	15
Lakeshore Carbonate Ledge	6	Shale Cliff	16
Lakeshore Alluvial Bank	7	Tamarack Wetland	17
Alvar	8	White Cedar Wetland	18
Carbonate Glade	9	Igneous Shoreline	19
Calcareous Meadow	10		