TERRESTRIAL GASTROPOD INVENTORY OF IGNEOUS OUTCROPS IN NORTHEASTERN MINNESOTA

Vertigo modesta modesta

Vertigo paradoxa

Vertigo cristata

Final Report:
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Jeffrey C. Nekola, Matthew Barthel,
Peter Massart, Eric North
Department of Natural and Applied Sciences
University of Wisconsin – Green Bay
Green Bay, Wisconsin 54311

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TABLE OF CONTENTS

INTRODUCTION

The terrestrial gastropod fauna of the Midwest includes a number of the rarest animal taxa in North America. This fact was recognized as early as the late 1800's when the Pleistocene Hendersonia occulta was discovered alive along the Upper Mississippi River valley (Pilsbry 1948). Since then, a number of Midwestern endemics or near endemics have been identified including *Catinella exile, Catinella gelida, Discus macclintockii, Hawaiia* n.sp., *Stenotrema hubrichti, Vertigo hubrichti, Vertigo 'iowaensis , Vertigo mermacensis*, and *Vertigo morsei* (Hubricht 1985, Frest 1990, Frest 1991).

Previous investigations into terrestrial gastropod biodiversity in the upper Midwest have been largely limited to the Paleozoic Plateau ('Driftless Area') and the Iowan Erosional Surface in northeastern Iowa, and the Black Hills of South Dakota (Frest 1981, 1982, 1983, 1984, 1985, 1986a, 19866, 1987, 1990, 1991, Frest and Johannes 1991). As these areas were beyond the limit of Wisconsin glaciation, they were presumed to be the only potential refuges for glacial relict taxa However, investigations made from 1995-1998 from eastern Wisconsin to southern Ontario documented that these relicts were not as geographically restricted as previously believed.

Four habitats were found to harbor the bulk of important land snail species in this area (Nekola et al. 1996; Nekola 19986). Carbonate cliffs support populations of at least seventeen rare Michigan and Wisconsin taxa, nine of which are likely glacial relicts. The fauna of these sites, while bearing marked similarity to algific talus slope and maderate cliff sites of the Paleozoic Plateau, are unique and support a higher frequency of northeastern species at (or beyond) their normal range limits (Nekola et al. 1996). Fens harbor the European disjunct *Euconulus alderi*, the presumed glacial relicts *Catinella exile, Vertigo elatior*, and *Vertigo morsel*, plus at least two undescribed endemic taxa (*Hawaiia* n.sp. and *Punctum* n.sp.; Frest 1990). Tamarack-sedge wetlands have also been found to harbor the critically endangered *Vertigo nylanderi* (last seen alive in 1949), plus *Euconulus alderi* and Vertigo elation Mafic or ultramafic igneous outcrops (basalts and serpentines) in northern Wisconsin and the Keweenaw Peninsula were found to support populations of *Vertigo cristata* and *Vertigo paradoxa*, both known from less than a U.S. dozen sites (Frest and Johannes 1991, Nekola 19986). A number of other regionally rare taxa, including *Planogyra asteriscus* and *Zoogenetes harpa* have also been found on these sites.

The conservation importance of these habitats transcends the rare species found within them. Approximately 1/3 of carbonate cliff sites in the western Great Lakes harbor 24 or more taxa (Nekola, *in press A),* a level of sympatry which has been identified as being of global importance for land snails (Tattersfield 1996). Algific talus slopes,

lakeshore carbonate ledges, and calcareous open meadows also commonly harbor faunas of 17 or more taxa (Nekola, *in press A).* Carbonate cliff sites in eastern Wisconsin are also among the richest reported land snail sites at small spatial scales, with up to 21 taxa coexisting within 400 cm2, and 34 taxa within 100 m2 samples (Nekola, *in press B).* Based on these analyses, carbonate cliffs and related habitats in the Great Lakes region warrant inclusion among the most important habitats for molluscan biodiversity on a global scale.

Unfortunately, land snail communities are among the most sensitive known to anthropogenic and other disturbances (Frest and Johannes *1995).* Even as the conservation importance of these taxa and sites are being realized, they are being lost from development, agriculture, forestry, and recreational pressures (Frest 1991, Nekola *et al.* 1996, Nekola *unpublished data).* Like taxa of the tropical rain forest, local terrestrial gastropod species and communities of the Upper Midwest may be lost before the full extent of their existence is recognized.

This is particularly true in northeastern Minnesota, where anthropogenic impacts from forestry, recreation, and development are high. Almost nothing is known about the faunas associated with the west shore of Lake Superior. Hubricht *(1985)* identifies Minnesota as one of the most poorly known regions in the eastern U.S. for land snails. No species had previously been reported from Cook County, and only six have ever been recorded in total from Lake and St. Louis counties.

A concentration of mafic igneous outcrops exist in northeastern Minnesota along the Pigeon River and the western Lake Superior shore (Coffin and Pfannmuller 1988*).* These sites are one of the most important refugia for disjunct arctic and western Cordilleran vascular plants in eastern North America (Fernald 1925, Butters and Abbe 1953, Given and Soper 1981). North facing basalt cliffs along the Pigeon River support at least 16 Minnesota DNR-listed taxa, while similar outcrops along the Lake Superior shore support populations of at least 11 additional listed taxa. Rare snails might also occur in these sites are they often coexist with plants given their similarly small minimum habitat requirements and effectively sessile nature at the landscape scale (Berry 1966, Frest and Johannes 1995).

This report summarizes the findings of a survey conducted during the summer of 1998 from igneous outcrops along the western Lake Superior shore in Cook, Lake, and St. Louis counties in northeastern Minnesota. Through this research, a better understanding of the nature of the terrestrial gastropods from this little known area is possible.

METHODS

Study Sites

A total of 39 areas were surveyed for terrestrial gastropods along the western Lake Superior shore (Figure 1; Appendix I). Sites were selected if they represented typical examples of their respective habitat type, and were undisturbed. Only one of these sites did not represent an igneous outcrop habitat. This site (Iceland Fen) was a rich tamarack wetland.

Field Sampling

Documentation of terrestrial gastropod communities was accomplished by hand collection of larger shells and litter sampling for smaller taxa from representative 100-1000 m2 regions within sites. Larger shells were stored in plastic snap-lid vials. Approximately 4 liters of soil litter was collected from each site. For igneous outcrop 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 cool air vents on the cliff face or in the associated talus. At Iceland Fen, collection was made of: (1) small blocks (ca. 125 cm3) of turf; and (2) loose soil and leaf litter accumulations under or adjacent to shrubs.

The location of each site was marked on USGS 7.5 or 15 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 (ca. 80-950 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 hand picked against a neutral

brown background using a binocular microscope and a small sable brush. All shells and shell fragments were removed. Rock fragments from each site were identified by Dr. Steven Dutch of the Department of Natural and Applied Sciences at the University of Wisconsin - Green Bay. These samples are being archived by him in University collections.

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 for sites sampled in the western Great Lakes region (349 total sites). Testing for statistical differences in the ratio of high vs. normal or low richness sites per state 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) equal or exceed the number of cells (14) by a factor of ten (Zar 1984).

The relationship between geographic position and richness was graphically represented by plotting the site richness vs. UTM N-S or UTM E-W coordinates for all habitats. The central tendency 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 conducted 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. Testing for such differences in response was 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.

RESULTS

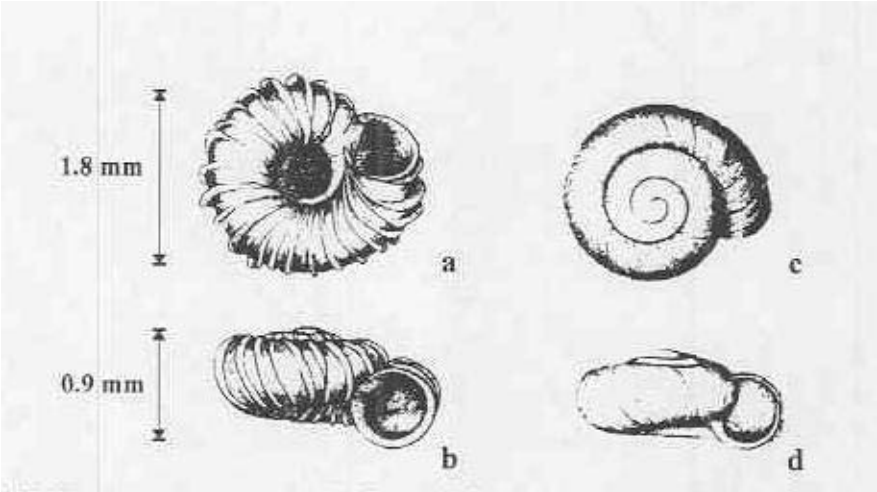
State and County Faunas

Previous to this study, 61 terrestrial gastropod taxa had been reported from Minnesota (Dawley 1955, Hubricht 1985, Ostlie 1991, Frest and Johannes 1991*)*. Only 6 of these had been identified from Lake and St. Louis counties. No taxa were previously reported from Cook County (Table 1). In the course of this research, 9 taxa were added to the Minnesota fauna, a *15%* increase (Table 2), while 25 were added to the northeastern Minnesota fauna, a more than 4-fold increase (Table 1).

Unique, Unusual or Rare Taxa.

Using TNC Heritage Program ranking rules for special species (S1 = Critically Endangered; S2 = Endangered; S3 = Threatened) in conjunction with previous and current distributional information, 6 of the taxa encountered in this survey appear to warrant Heritage Program ranking and/or Minnesota DNR listing for endangered species protection (Table 3). The rationale for the suggested rank and status of these taxa, combined with taxonomic information, ecological preferences, and observed distribution, follow. Taxa are arranged in alphabetical order.

Planogyra asteriscus (Morse, 1857)



Suggested Minnesota status: S1; Endangered

This spectacular species was previously unreported from the state, although it has been recently found at 9 sites in the Upper Peninsula (Nekola 19986) and at a single site in northeastern Wisconsin (Nekola 1998a). It is known from less than 25 counties in the northeastern U.S. Oughton (1948) indicates that it is sporadic and rare in Ontario. This taxon is currently ranked as 'SU' in both Michigan and Wisconsin, where it has Special Concern status.

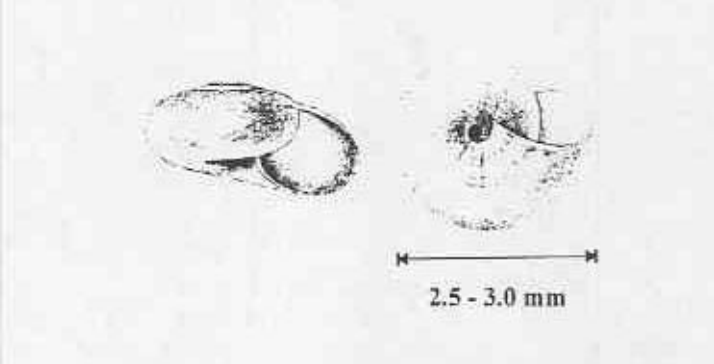
A total of 4 stations were located in northeastern Minnesota from mesic outcrops supporting White Cedar and from the single sampled Tamarack wetland.

The general lack of mesic Thuja-dominated forests with base-rich soils in Minnesota will likely limit this species to rather few sites, as is similar for this species in Ontario (Oughton 1948). It seems unlikely that the number of Minnesota populations will exceed 25. This expectation, combined with the limited range of this species in the U.S., suggests that P. asteriscus should be listed as Endangered in Minnesota.

Sites of occurrence:

Cook County: Cascade River Cedars, Cascade River Cliff, Iceland Fen, Temperance River Road

Striatum ferrea Morse, 1864



Suggested Minnesota status: S1; Endangered .

This species is primarily Appalachian in distribution, extending from Tennessee to Maine, with additional sites occurring westward through the Great Lakes into Michigan and northern Wisconsin. It is only known from 5 counties in Wisconsin, having been observed at.only 18 total sites. All but 5 of these are limited to the northern half of the Door Peninsula (Levi and Levi 1950, Nekola *et al.* 1996, Nekola *unpublished data).*

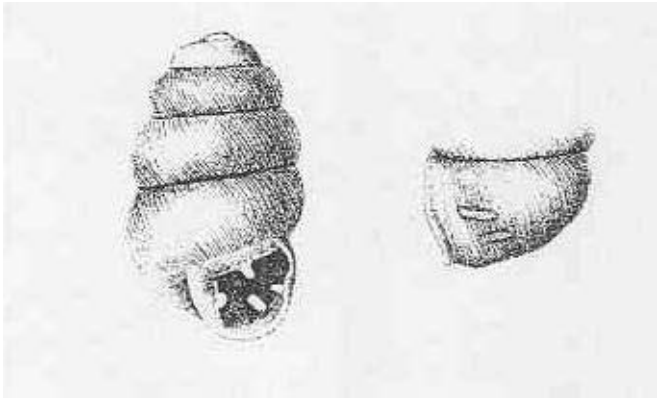
Striatura ferrea was located from a single site in the study area in the city of Duluth along Skyline Drive. This represents not only a state record, but also the western-most population yet observed. Like other sites in the western Great Lakes, this area has mesic and rich soils. This species and *Cochlicopa morseana* are the only land snails with Appalachian affinities located within the study region. Other such taxa (e.g., *Glyphyalinia rhoadsii, Glyphyalinia wheatleyi, Paravitrea multidenata)* have western range limits which terminate in the Porcupine Mountains of the Upper Peninsula.

It is likely that few additional populations will be found in the state, as the climate is likely too severe to the north, west, and south. Given the limitation of the only known population of this species to a site within the city of Duluth, Endangered status seems appropriate.

Site of occurrence:

St. Louis County: Skyline Drive West Talus

Vertigo cristata (Sterki, 1919)



Suggested Minnesota status: S3; Special Concern.

Vertigo cristata is a clearly marked and distinct species. Only it and *V. mermacensis* of the northern Ozarks and the Paleozoic Plateau *of* northeastern Iowa are between *1.8-2.2* mm in size and possess 4 apertural lamella which are arranged in cross-shaped pattern. It differs from *V. mermacensis* by possessing a strong crest in back *of* the aperture, and by its yellowish (rather than cinnamon-red) shell color. In the western Great Lakes, it is most similar to some *V. paradoxa* individuals, which possess a lower palatial lamella more deeply inserted than the upper, and to *V. modesta modesta,* which is > 2 $^{1}/_{4}$ mm in height.

In the study region, shells typically fell into two size classes, with one class ranging from 1.7-1.9 mm, and the other ranging from 2.1-2.2 mm. Although no shell measurements have yet been made, it appeared as though few intermediates exist. The larger shells were difficult to distinguish from *V. modesta modesta.* However, except for size, shells from both size classes appeared identical. As such, these two forms are considered for this report to constitute a single entity. It may be prudent at some future time to conduct morphometric and genetic analyses on these forms to help elucidate their true taxonomic status.

This species was not listed by Hubricht (1985) as being a member of the eastern U.S. land snail fauna. Its closest known approach was on the north shore of Lake Superior (Pilsbry 1948). Although Oughton (1948) reported it across all of Ontario, more recent work (Nekola 1998a) has demonstrated it to be limited to areas north from the northern tip of the Bruce Peninsula.

The first discovery of *V. cristata* from the U.S. was made from northeastern Wisconsin in 1996. Since then a total of 36 stations have been observed in 10 northern Wisconsin and Michigan Upper Peninsula counties. These populations are limited to

carbonate cliffs, lakeshore carbonate ledges, igneous outcrops, rocky woodlands, white cedar wetlands, and igneous shorelines.

A total of 34 sites were located for this species across all three counties of the study region. It was the most frequently encountered *Vertigo* in the study region. While some populations were large (such as at Mt. Josephine), for the great majority fewer than 5 adult shells were observed.

The very limited range of this species in the U.S. (with almost one-half of known sites being found in northeastern Minnesota), combined with its usually small population size, suggest that this species should be tracked by the Minnesota Heritage Program and listed as a species of special concern.

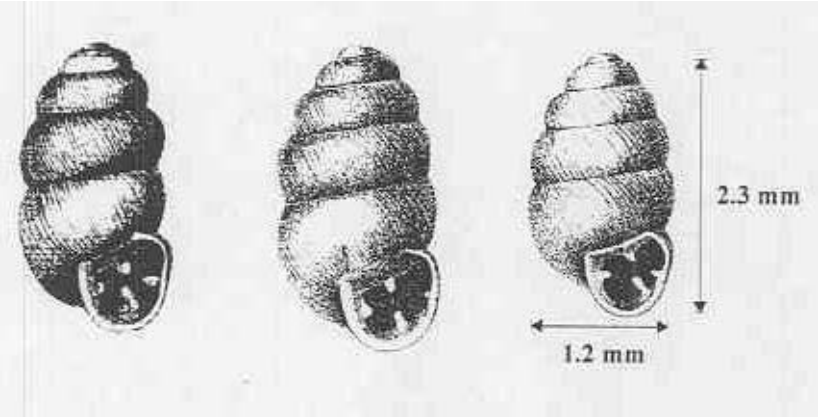
Sites of occurrence:

Cook County: Caribou Lake East, Caribou Lake North, Carlton Peak, Cascade River Cedars, Cascade River Cliff, Iceland Fen, John Lake, Lutsen Mountains, McFarland Lake Cliff, McFarland Lake Talus, Moose Mountain, Mt. Josephine Cliff, Mt. Josephine Talus, Oberg Mountain, Pine Lake, Pine River Road, Poplar River, Port of Entry Cliff, Port of Entry Talus, Portage Brook, Sawbill Road, South Fowl Lake, Sugarloaf Cove, Temperance River Upland, Timber Creek

Lake County: Day Hill, Finland Forest, Goldeneye Lake Cliff, Goldeneye Lake Talus, Manitou River Falls, Sawmill Creek

St. Louis County: Chester Bowl Park, Skyline Drive West Cliff, Skyline Drive West Talus

Vertigo modesta modesta (Say, 1824)



Suggested Minnesota status: S1; Endangered

This is the largest woodland Vertigo in eastern North America, with a height exceeding 2.3 mm. While characteristic of the Rocky Mountains and boreal forest (Oughton 1948, Pilsbry 1948), it was known in the eastern U.S. only from Pleistocene fossils (Hubricht 1985). In such deposits (ranging from the central Plains to southern Indiana), it is found with *Catinella gelida, Columella columella alticola, Hendersonia occulta, Oreohelix strigosa cooperi*, and *Vallonia gracilicosta albula* (Frest and Rhodes 1981). Hubricht (1985) considered the reports in Pilsbry (1948) of this species from the New England states to be based on Pleistocene material. This species has been found to be an extremely rare element in the western Great Lakes fauna, with extant populations being reported from the north shore of Lake Superior (Oughton 1948), Manitoulin Island, Owens Sound region in southern Ontario (Nekola 1998a), and from two sites at the northern tip of the Keweenaw Peninsula (Nekola 1998b). These latter colonies represent the first verifiable modern records of this species from the eastern U.S.

This taxon was located from 3 sites in the northern half of the study region, where they typically co-occurred with *V. cristata* and *V. paradoxa*. As in the Keweenaw Peninsula, populations appeared absent from open cliff faces and xeric sites.

Vertigo modesta modesta populations in Minnesota appear to be few in number, limited to extremely fragile sites, and susceptible to anthropogenic disturbances. Given the extremely limited range of this taxon in both the state and eastern U.S., immediate 10

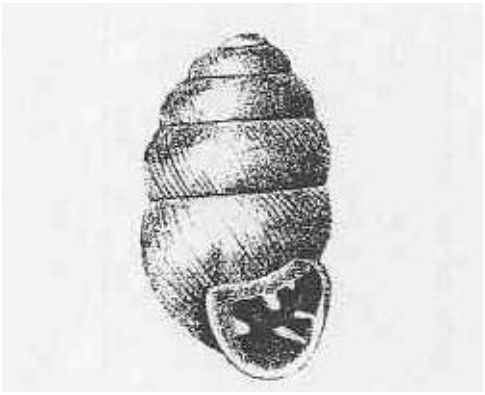
listing as a state endangered species is warranted, as are efforts to protect its sites of known occurrence.

Sites of occurrence:

Cook County: Cascade River Cliff, Mt. Josephine Talus

Lake County: Manitou River Falls

Vertigo modesta parietalis (Ancey, 1887)



Suggested Minnesota status: S1; Endangered

A number of races of *Vertigo modesta* with slightly different shell morphologies occur in the western U.S., including *V. m. parietalis,* which differs from the nominate subspecies by possessing a distinct angular lamella. While Hubricht (1985) does not map this entity from the eastern U.S. Pleistocene record, Frest and Dickson (1986) do. Based on observations of material in the collections of the Field Museum of Natural History, it appears that this form is present (though quite rare) in central and eastern Canada. However, it is much more frequent in Rocky Mountain sites. This race was located from single sites in the western Great Lakes region in the Keweenaw Peninsula and in southern Ontario (Nekola 1998a, 1998b). At both of these sites it is intermixed with V. *m. modesta.*

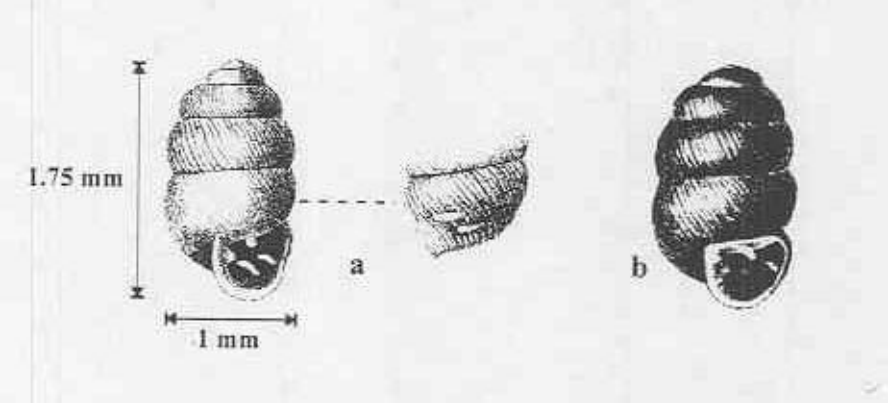
This taxon was located at two of the three Minnesota stations, doubling the number of extant sites known in the Great Lakes region. Being much more uncommon on these sites than the nominate subspecies, it is undoubtedly one of the rarest land snails in the state, and warrants immediate listing as a state endangered species.

Site of occurrence:

Cook County: Mt. Josephine Talus

Lake County: Manitou River Falls

Vertigo paradoxa (Sterki, 1900)



Suggested Minnesota status: S2; Threatened

Vertigo paradoxa is closely allied to a number of described and undescribed midwestern *Vertigo* taxa, including *V. hubrichti, V. 'iowaensis'* and *V. brierensis*. Frest and Johannes (1991) state that *V. paradoxa* differs from the former two taxa by having a shallow depression over the lower palatial lamella, and shorter palatial lamella which do not deeply enter into the aperture. Based on descriptions in Frest (1991) *Vertigo paradoxa* seems to be very similar to *V. brierensis,* and may differ only by having a taller columellar lamella. It seems likely that morphometric analysis of these entities will demonstrate that they are not specifically distinct.

Vertigo paradoxa is known in Canada from far northwestern Ontario to James Bay and Lake Ontario (Oughton 1948) to Newfoundland (Pilsbry 1948). It was previously reported in the eastern U.S. from only two counties in eastern Maine, one county in the Lower Peninsula of Michigan, and from 5 sites in the Black Hills (Frest and Johannes 1991). More recent investigations have uncovered it from 9 stations in northern Wisconsin, 14 sites along the Niagaran Escarpment in southern Ontario (Nekola 1998a), and 30 sites in the Upper Peninsula of Michigan. It is known from numerous Pleistocene deposits in northwestern Kansas (Franzen and Leonard 1947).

All material collected in the region have been assigned to *V. paradoxa* based upon their short and shallowly inserted palatial lamella, and relatively weak external depression over the lower palatial. However, some individuals appeared intermediate to V. *hubrichti* as they possessed a small basal lamella and had a relatively deep depression over the palatials.

Vertigo paradoxa was located from 20 stations in all three counties. Because the bulk of reported populations for this species in the U.S. occur in the western Great Lakes region and that populations are generally limited to fragile rock outcrop communities, and that few additional sites are expected in the state, tracking of this species as S2 and listing as Threatened would seem warranted. Frest and Johannes (1991) recommended, based on its limited U.S. distribution, that *V. paradoxa* be Federally listed as endangered.

Sites of occurrence:

Cook County: Caribou Lake East, Cascade River Cedars, Cascade River Cliff, John Lake, McFarland Lake Cliff, Mt. Josephine Cliff, Mt. Josephine Talus, Pine Lake, Poplar River,. Port of Entry Cliff, Port of Entry Talus, Portage Brook, Sawbill Road, South Fowl' Lake, Sugarloaf Cove, Temperance River Upland

Lake County: Manitou River Falls

St. Louis County: Hawk Ridge Sanctuary, Skyline Drive West Cliff, Skyline Drive West Talus

Terrestrial Gastropod Faunas.

1. Igneous Outcrop. These habitats represent wooded, 2-30 meter tall basalt, rhyolite, or *anorthosite outcrops* associated with Keweenawan Rift deposits along the western Lake Superior shoreline. Also included are open talus slopes under cliffs. The bottom fringe of such talus slopes often possess cooler and moister microclimates than immediately upslope due to air seepage. A total of 38 sites were sampled.

29 terrestrial gastropod taxa were located on these sites (Table 4), including all 6 rare species. 10 species were found on at least 50% of sites, with the most common (> 80% of surveyed sites) being *Zonitoides arboreus, Discus catskillensis, Vertigo cristata,* and *Nesovitrea binneyana.*

2. Tamarack Wetland. The single sites sampled represented an almost pure *Larix laricina* grove which was open and supported a thick *Carex* turf. *Sphagnum* mosses were essentially absent, while *Alnus rugosa* was a common shrub. Such sites appear to be quite uncommon in the region, as most *Larix* sites support dense *Sphagnum* growth and are thus not appropriate for land snails.

11 terrestrial gastropod taxa were identified from The Iceland Fen station (Table 5), including *Planogyra asteriscus* and *Vertigo cristata.*

Species Richness Patterns.

The land snail faunas of northeastern Minnesota igneous cliffs were found to be among the most impoverished in the western Great Lakes region. While up to 44% of sites in other states harbored 24 or more taxa (Table 6), no sites in northeastern Minnesota approached this level of sympatry with maximum site richness values being 14 (observed at Cascade River Cedars, Mt. Josephine Talus, and Skyline Drive West Talus; see Appendix I). However, these values are comparable to igneous outcrops observed in adjacent Wisconsin and Michigan (Nekola 1998a, 1998b). It is interesting to note that the total number of taxa encountered over all sites (31) is equaled or exceeded in 100 m^2 sampling regions at 4 individual carbonate cliff sites in Iowa, Ontario, and Wisconsin (Nekola, *in press).*

Regression analysis of species richness vs. geographic position (Figure 2) demonstrates that a weakly significant E-W gradient in richness is present (p=0.031) across the entire Great Lakes region, accounting for a very small percentage of total variation (r^2=0.013). However, a much stronger latitudinal trend is present (p<0.0005, r^2=0.188). Inspection of the locally weighted scatterplot smoothing for this relationship suggests, that the decrease

of richness is not constant with increasing latitude. From 4100 km north (370 N) to approximately 5000 km north (450 N), only 6.3% of variation is accounted for by latitudinal location. However, over 41h times the variance in richness is accounted for by this variable north of this position.

DISCUSSION

Documentation of the Minnesota Terrestrial Gastropod Fauna.

Given the lack of previous research on land snails in northeastern Minnesota; it should not be surprizing that the regional land snail fauna was increased over 4-fold in this study. What is surprizing, however, is that more northern or western disjunct taxa were not located (such as *Columella columella alticola, Vertigo alpestris oughtoni, Vertigo binneyana, Vertigo concinnula),* particularly given the number of vascular plants from these same habitats which demonstrate similar biogeographic patterns. Except for *Vertigo modesta,* none of the observed taxa range into arctic or alpine zones. While it is possible that some taxa were simply not encountered, the constancy of the faunas observed on these sites suggests that nearly the total universe of regional taxa may have been encountered.

Distribution of Rare Terrestrial Gastropod Taxa

The rare taxa encountered in this study fall into three basic geographic categories. *Planogyra asteriscus, Vertigo modesta modesta* and *Vertigo modesta parietalis* are all limited to the northern half of the study region. *Striatura ferrea is* limited to the southernmost area, while *Vertigo paradoxa* and *V. cristata* are found throughout. These distributions follow closely patterns previously observed in the western Upper Peninsula and northwestern Wisconsin (Appendix II).

Diversity Patterns in Terrestrial Gastropod Communities

Like igneous outcrops observed elsewhere in the western Lake Superior basin, sites in northeastern Minnesota were found to harbor a relatively limited fauna, with a maximum richness of 14 taxa being observed. The overlap between sites was also found to be very high, so that only 31 total taxa were encountered, a level of sympatry is equaled or exceeded for some single carbonate cliff sites. These low richness levels are reflected in analysis of the frequency of high-richness (>24 sympatric taxa) sites across the Upper

Midwest, with northeastern Minnesota having no sites which came within 10 taxa of this level.

The reasons for such low levels of site and regional biodiversity are likely many-fold. First, while containing more calcium than other igneous rocks, the bedrock of these sites has far less of this limiting resource than carbonate outcrops or other lime rich habitats. However, this does not help explain the low level of compositional turnover between site faunas. It seems likely that additional contemporaneous or historical factors must be operating which limit regional richness levels. For instance, the majority of sites have been subjected to relatively recent timbering and/or forest fires (the latter events being indicated by occurrence of charcoal in soil litter samples). Both of these disturbances are known to have highly negative impacts on land snail populations and community diversity (Frest and Johannes 1995). It seems possible that the commonness of these events in the region may have decreased diversity with only the most tolerant forms surviving, leading to the curiously low regional diversity levels.

Conservation Priorities

At least 6 of the taxa located in this study should be listed as Endangered, Threatened, or Special Concern species by the Minnesota Endangered Species Act. Of these, the most imperiled appear to be *Planogyra asteriscus, Striatura ferrea, Vertigo modesta modesta,* and *Vertigo modesta parietalis*, given the few number of populations combined with site fragility and potential threats.

From these data, identification of the most important land snail sites in the region is possible, based on the number of rare taxa plus overall species richness.

Five sites were found to harbor 3 or more rare taxa (Cascade River Cliff, Manitou River Falls, Mt. Josephine Talus, Cascade River Cedars, and Skyline Drive West Talus). These sites also harbored among the richest species assemblages, with 12, 11, 12, 14, and 14 taxa, respectively. Other sites with locally high richness levels (but fewer rare taxa) include Mt. Josephine Cliff (14 taxa, 2 rare), Temperance River Upland (14, 2), Poplar River (13, 2), Iceland Fen (11, 2), and South Fowl Lake (11, 2). These sites should be afforded protection to ensure survival of the igneous outcrop land snail fauna.

CONCLUSIONS AND RECOMMENDATIONS

Through this study a total of 70 terrestrial gastropod taxa are now known from the state, with 32 of these being reported from Cook, Lake, and St. Louis counties. Of these, 6 warrant ranking by the Minnesota Heritage Program, and listing for protection by the Minnesota Endangered Species Act. For some of these taxa *(Vertigo cristata, Vertigo modesta)* approximately half of known stations in the eastern U.S. are found in this region.

These findings also suggest additional lines of research which should be addressed to help ensure the protection of these communities and the rare species found in them:

1. Surveys conducted elsewhere in the western Great Lakes have shown that the richest land snail assemblages are confined to sites with high levels of available soil calcium (Nekola, *in press B).* The lack of such habitats in the study region makes it impossible to assess the composition and diversity pattern for such habitats in Minnesota. There are a number of calcium-rich habitats throughout the state which warrant more thorough investigation. Target habitats for such additional surveys should include:

(a) rich fens in southeastern Minnesota, as sites in adjacent Iowa have been shown to support a diverse land snail assemblage which includes a number of rare and endemic taxa including *Catinella exile, Euconulus alderi, Hawaiia* n.sp., *Punctum* n.sp., *Vertigo elatior,* and *Vertigo morsei* (Frest 1990).

(b) calcareous wooded peatlands in northwestern Minnesota. Similar sites in the Upper Peninsula and northeastern Wisconsin have been shown to harbor an important fauna which includes the critically endangered *Vertigo nylanderi,* currently known from only 8 extant global sites. Before these discoveries, the last known collection of this taxon was made in 1949 from Lake Itasca, and it is likely that appropriate habitat will be found from there north to the Canadian border. It is also possible that such sites may serve as refugia for some of the arctic-alpine or disjunct taxa which were originally expected in northeastern Minnesota.

(c) calcareous aspen parkland in far northwestern Minnesota has been reported to harbor at least one population of *Vertigo arthuri,* which is otherwise limited to less than 2 dozen sites in the Black Hills (Frest and Johannes *1991).* Based on reports on Oughton (1948) and Hubricht (1995), other western *Vertigo* taxa, such as *V binneyana* and *V. concinnula,* may also be found in these habitats.

(d) calcareous glades in the Paleozoic Plateau in Wisconsin (Theler 1997) and Iowa (Nekola, *in press B)* support diverse land snail communities harboring a number of western and southern taxa at their range limits. Similar sites in Minnesota are currently unsurveyed.

2. Morphometric, anatomical and genetic analysis should be conducted on the populations of *Vertigo cristata* and *Succinea ovalis (sensu latu)* encountered in the study region. Individuals of this latter taxon appeared smaller than 'normal' material. They also differed by having more heavily calcified shells and by occurring on dry rock outcrops. These populations could well represent a new species. However, races in this group are notoriously plastic, making it unclear as to what the rules for distinction between species should be. Enlisting of a specialist in these groups to assess the phylogenetic status of these populations should be considered.

3. Surveys of additional igneous outcrop sites need to be conducted to better assess the Minnesota range of both *Vertigo modesta* subspecies.

4. Long-term monitoring of the effect of various recreational and forestry management practices on terrestrial gastropods diversity should be conducted. Preliminary observations seems to indicate that these activities (especially rock climbing and clear cutting) is detrimental to faunas. Additionally, it will be vital to know how much buffer is required to ensure adequate protection of terrestrial gastropod faunas, and to assess the impact of fire on community structure and diversity.

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TABLE 1. Terrestrial gastropod taxa of Minnesota with previous and new records from 3 counties in study region. In this table a * demarcated a previous report of the taxon from a given county while a + represents a county record confirmed via this study. Total represents the total number of stations encounterd for each taxon within the study area. Previous county distributions are based on Hubricht (1985), while the state fauna list is based on Dawley (1955), Hubricht (1985), Ostlie (1991), and Frest & Johannes (1991).

Taxon	Cook	Lake	St. Louis	Total
Allogonia profunda (Say, 1821)				
Anguispira alternata (Say, 1817)	+	+	+	12
Carychium exiguum (Say, 1822)	+			1
Carychium exile H.C.Lea, 1842	+	+	+	6
Catinella avara (Say, 1824)				
Cochlicopa lubrica (Müller, 1774)	+		+	4
Cochlicopa lubricella (Porro, 1838)	+			1
Cochlicopa morseana (Doherty, 1878)			+	2
Cochlicopa nitens (Gallenstein, 1848)				
Columella simplex (Gould, 1841)	+		+	8
Deroceras laeve (Müller, 1774)				
Discus catskillensis (Pilsbry, 1898)	+	+	+	34
Discus cronkhitei (Newcomb, 1865)	+			11
Euconulus fulvus (Müller, 1774)	+	+	*	20
Gastrocopta abbreviata (Sterki, 1909)				
Gastrocopta armifera (Say, 1821)				
Gastrocopta contracta (Say, 1822)				
Gastrocopta corticaria (Say, 1816)				
Gastrocopta holzingeri (Sterki, 1889)				
Gastrocopta pentodon (Say, 1821)	+			1
Gastrocopta similis (Sterki, 1909)				
Gastrocopta tappaniana (C.B. Adams, 1842)	+			1
Glyphyalinia indentata (Say, 1823)				
Hawaiia miniscula (A. Binney, 1840)				
Helicodiscus parallelus (Say, 1817)	+			1
Helicodiscus shimeki Hubricht, 1962			+	2
Hendersonia occulta (Say, 1831)				
Mesodon clausus clausus (Say, 1821)				
Mesodon thyroidus (Say, 1816)				
Nesovitrea binneyana (Morse, 1864)	+	+	+	32
Nesovitrea electrina (Gould, 1841)	+	+	+	8
Oxyloma retusa (I. Lea, 1834)				
Planogyra asteriscus (Morse, 1857)	+			4
Pomatiopsis lapidaria (Say, 1817)				
Punctum minutissimum (I.Lea, 1841)	+	+	+	18

TABLE 1. – cont.

Taxon	Cook	Lake	St. Louis	Total
Punctum vitreum H.B. Baker, 1930				
Stenotrema barbatum (Clapp, 1904)				
Stenotrema fraternum fraternum (Say, 1824)				
Stenotrema leai leai (A. Binney)				
Striatura exigua (Stimpson, 1847)	+	+	+	16
Striatura ferrea Morse, 1864			+	1
Striatura milium (Morse, 1859)	+	+	+	21
Strobilops affinis Pilsbry, 1893				
Strobilops labyrinthica (Say, 1817)	+	+	+	5
Succinea n.sp. Minnesota A				
Succinea n.sp. Minnesota B				
Succinea ovalis Say, 1817	+	*	+	9
Triodopsis alleni (Wetherby in Sampson, 1883)				
Triodopsis multilineata (Say, 1821)				
Vallonia costata (Müller, 1774)				
Vallonia gracilicosta Reinhardt, 1883				
Vallonia perspectiva Sterki, 1892				
Vallonia pulchella (Müller, 1774)				
Vertigo bollesiana (Morse, 1865)				
Vertigo arthuri von Martens, 1884				
Vertigo cristata (Sterki, 1919)	+	+	+	34
Vertigo gouldi (A. Binney, 1843)		+		1
Vertigo hubrichti (Pilsbry, 1934)				
Vertigo 'iowaensis' (*sensu* Frest 1991)				
Vertigo mermacensis Van Devender, 1979				
Vertigo modesta modesta (Say, 1824)	+	+		3
Vertigo modesta parietalis (Ancey)	+	+		2
Vertigo morsei Sterki, 1894				
Vertigo nylanderi Sterki, 1909				
Vertigo ovata Say, 1822				
Vertigo paradoxa Sterki, 1900	+	+	+	20
Vitrina limpida Gould, 1850	+	*	+	3
Zonitoides arboreus (Say, 1816)	+	*	+	36
Zonitoides nitidus (Müller, 1774)		*		
Zoogenetes harpa (Say, 1824)	+	+	*	22
Total Richness	27	20	20	
County Records	27	16	18	
% Increase in Fauna	-	400	500	

TABLE 2. Terrestrial gastropod taxa added to the Minnesota fauna

Nesovitrea binneyana
Planogyra asteriscus
Punctum minutissimum
Striatura exigua
Striatura ferrea
Vertigo cristata
Vertigo modesta modesta
Vertigo modesta parietalis
Vertigo paradoxa

TABLE 3. Rare Minnesota terrestrial gastropods encountered in this study, with recommended state rank and status.

Taxon	# Occurrences	Rank	Status
Striatura ferrea	1	S1	END
Vertigo modesta modesta	2	S1	END
Vertigo modesta parietalis	3	S1	END
Planogyra asteriscus	4	S1	END
Vertigo paradoxa	20	S2	THR
Vertigo cristata	34	S3	SC

TABLE 4. Frequency of terrestrial gastropod taxa from 38 northeastern Minnesota igneous outcrop site. Rare species are designated with **bold** type.

Taxon	# sites	% frequency
Zonitoides arboreus (Say, 1816)	36	94.7
Discus catskillensis (Pilsbry, 1898)	33	86.8
Vertigo cristata (Sterki, 1919)	33	86.8
Nesovitrea binneyana (Morse, 1864)	32	84.2
Zoogenetes harpa (Say, 1824)	22	57.9
Striatura milium (Morse, 1859)	20	55.3
Vertigo paradoxa Sterki, 1900	20	52.6
Euconulus fulvus (Müller, 1774)	19	50.0
Punctum minutissimum (I.Lea, 1841)	17	44.7
Striatura exigua (Stimpson, 1847)	15	39.5
Anguispira alternata (Say, 1817)	12	31.6
Discus cronkhitei (Newcomb, 1865)	10	26.3
Succinea ovalis Say, 1817	9	23.7
Columella simplex (Gould, 1841)	8	21.1
Nesovitrea electrina (Gould, 1841)	7	18.4
Carychium exile H.C.Lea, 1842	6	15.8
Strobilops labyrinthica (Say, 1817)	5	13.2
Cochlicopa lubrica (Müller, 1774)	4	10.5
Planogyra asteriscus (Morse, 1857)	3	7.9
Vertigo modesta modesta (Say, 1824)	3	7.9
Vitrina limpida Gould, 1850	3	7.9
Cochlicopa morseana (Doherty, 1878)	2	5.3
Helicodiscus shimeki Hubricht, 1962	2	5.3
Vertigo modesta parietalis (Ancey)	2	5.3
Cochlicopa lubricella (Porro, 1838)	1	2.6
Gastrocopta pentodon (Say, 1821)	1	2.6
Helicodiscus parallelus (Say, 1817)	1	2.6
Striatura ferrea Morse, 1864	1	2.6
Vertigo gouldi (A. Binney, 1843)	1	2.6

TABLE 5. Terrestrial gastropod taxa from 1 northeastern Minnesota tamarack wetland. Rare species are designated with **bold** type.

Carychium exiguum
Discus catskillensis
Discus cronkhitei
Euconulus fulvus
Gastrocopta tappaniana
Nesovitrea electrina
Planogyra asteriscus
Punctum minutissimum
Striatura exigua
Straitura milium
Vertigo cristata

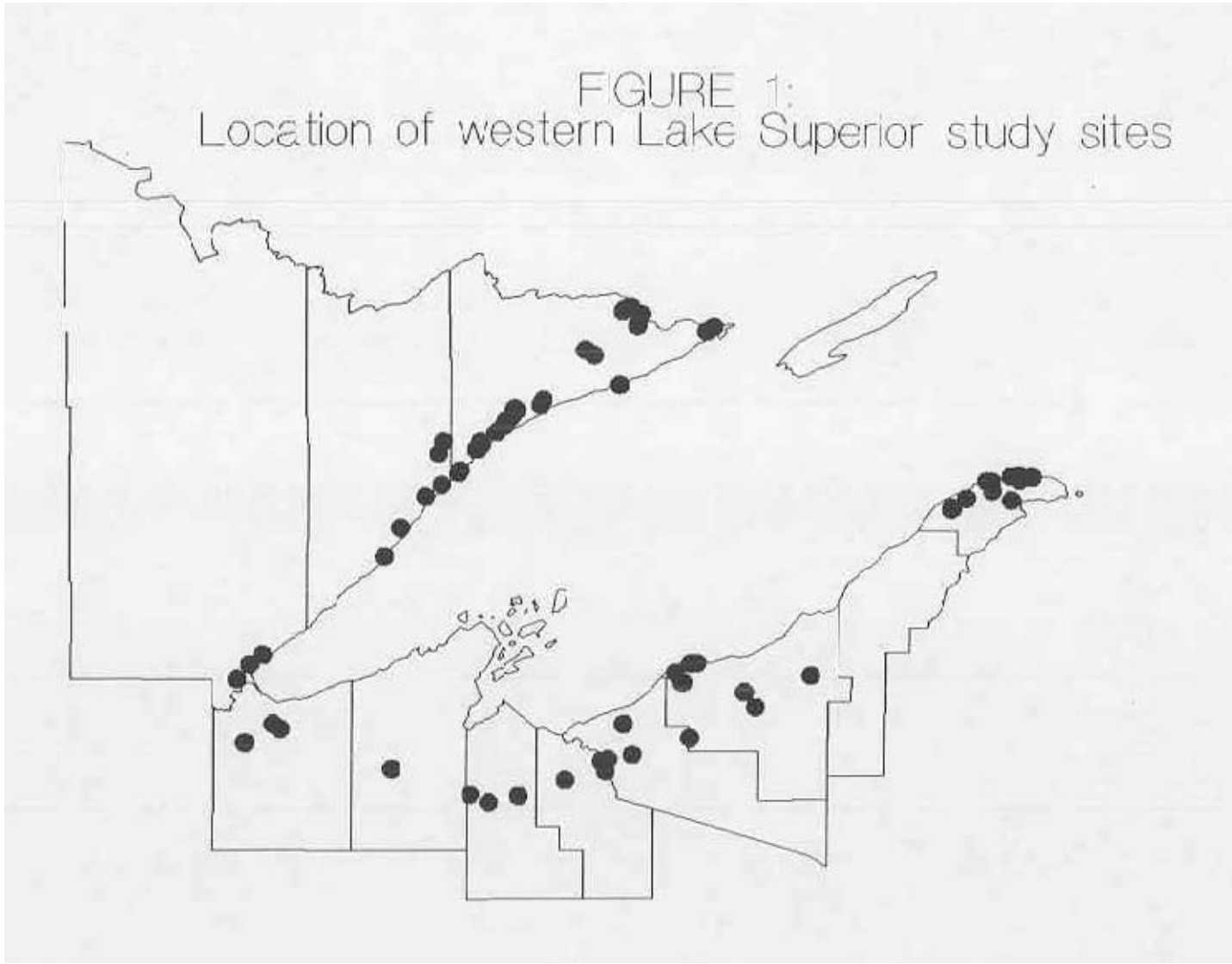
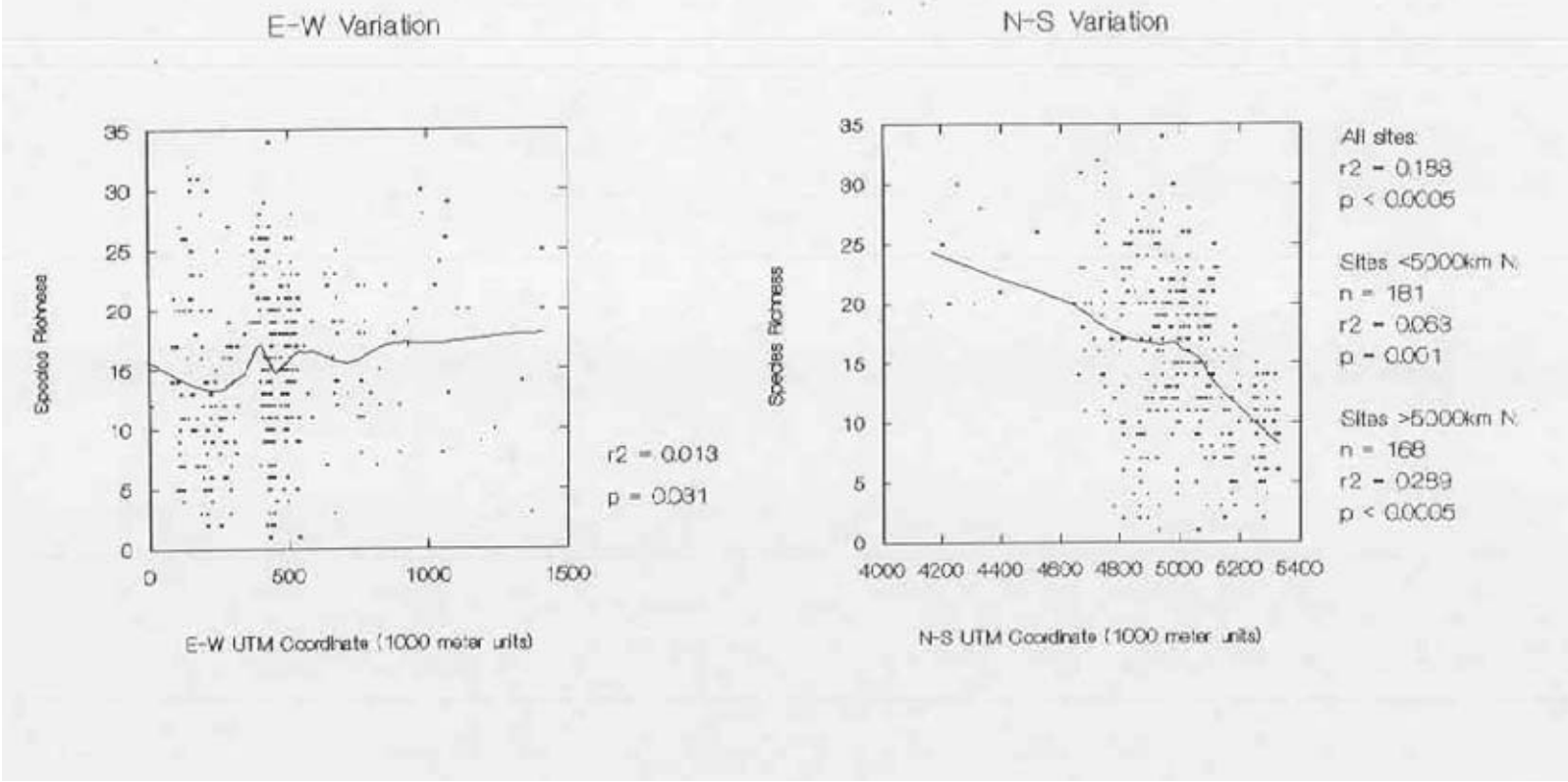


FIGURE 1:
Location of western Lake Superior study sites

FIGURE 2: Geographic Patterns in Terrestrial Gastropod Community Richness



APPENDIX I: Site Descriptions

Each site surveyed for terrestrial gastropods are listed below. The list is arranged alphabetically within each county. The legal location and USGS 7.5 minute quad name which contains each site is listed, as is the topography of the site. All encountered terrestrial gastropod taxa are listed, followed by their accession number in the primary author's reference collection. Species in **bold** type represent taxa recommended for state listing.

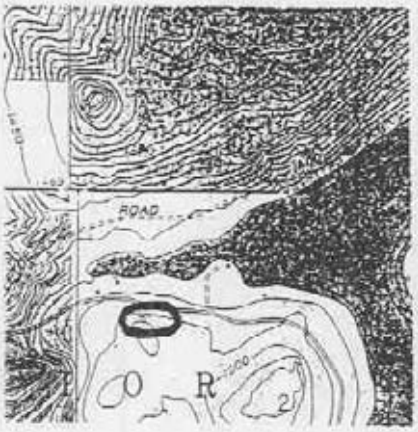
COOK COUNTY

Caribou Lake East. W½ NE¼ SW¼ SE¼ Sec. 2, T. 60 N., R. 3 W. (Lutsen quad)

This site represents a group of 2-3 meter east facing diabase ledges, in an area dominated by medium age *Thuja occidentalis*. This heavily shaded area also has smaller numbers of *Abies balsamea* and *Betula papyifera*. *Polypodium* and mosses are found growing on and around the ledges and nearby boulders.

Discus catskillensis	(4699)	***Vertigo cristata***	(4704)
Euconulus fulvus	(4700)	***Vertigo paradoxa***	(4705)
Nesovitrea binneyana	(4701)	*Zonitoides arboreus*	(4706)
Nesovitrea electrina	(4702)	*Zoogenetes harpa*	(4707)
Striatura milium	(4703)		

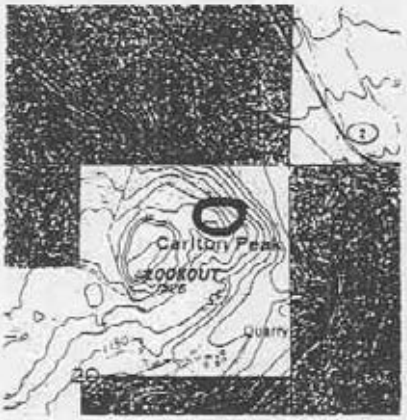
Caribou Lake North. NE¼ SW¼ NW¼ Sec. 2, T. 60 N., R. 3 W. (Lutsen quad)



This site represents a north facing 50 meter long talus slope of medium to large diabase boulders. *Thuja occidentalis, Picea abies, Betula papyifera*, and *Tsuga canadensis* are present.

Discus catskillensis	(4732)	*Striatura milium*	(4735)
Nesovitrea binneyana	(4733)	*Vertigo cristata*	(4736)
Striatura exigua	(4734)	*Zonitoides arboreus*	(4737)

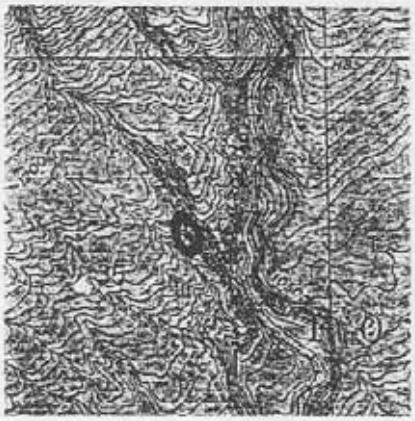
Carlton Peak. NE¼ SW¼ NE¼ NE¼ Sec. 20, T. 59 N., R. 4 W. (Tofte quad)



This site represents a north facing 3-5 meter cliff of anorthosite, near the top of Carlton Peak. *Thuja occidentalis* and *Picea glauca* were the dominate trees, while *Betula papyifera*, *Pinus strobus*, and *Pinus resinosa* were also found nearby. This locality was one of the most disturbed sites surveyed. The Superior Hiking Trail follows up this hill, and several different trails are found near the peak which is a popular overlook area (about 50 were seen during time of sample collection alonee). Besides the influence of numerous hikers, rock climbers are also known to frequent this locality. Charred wood in the soil indicates evidence of a fire history for this locality.

Vertigo cristata	(4750)	*Zoogenetes harpa*	(4751)

Cascade River Cliff. NE¼ SW¼ NE¼ Sec. 35, T. 61 N., R. 2 W. (Deer Yard Lake quad)



This locality is found on a 5-15 meter north facing rhyolite cliff along a branch of the Cascade River near the Superior Hiking Trail in an area of old growth *Pinus strobus*, *Thuja occidentalis* and some *Picea glauca*. There is apparently an old flooded mine shaft near by, and there is some evidence of mine tailings. *Polypodium*, *Woodsia* and mosses are found in abundance a shorter section of the cliff among younger trees of *Betula papyifera* and *Picea glauca* near a point of spring water seepage.

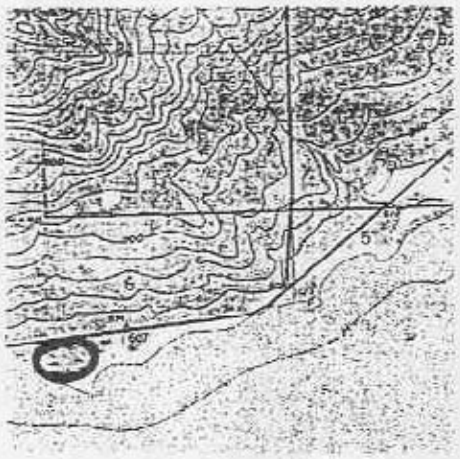
Carychium exile	(4687)	*Striatura exigua*	(4693)
Discus catskillensis	(4688)	*Striatura milium*	(4694)
Gastrocopta pentodon	(4689)	*Vertigo cristata*	(4695)
Nesovitrea binneyana	(4690)	*Vertigo modesta modesta*	(4696)
Planogyra asteriscus	(4691)	*Vertigo paradoxa*	(4697)
Punctum minutissimum	(4692)	*Zonitoides arboreus*	(4698)

Cascade River Cedars. S½ NW¼ NE¼ NW¼ Sec. 25, T. 61 N., R. 2 W. (Deer Yard Lake quad)

This site represents a rocky slope of rhyolite and diabase adjacent to the river among medium age *Thuja occidentalis* and young *Betula papyifera*. This locality is found along the Superior Hiking Trail. Further south of this site along the river is an expansive area of old growth *Thuja occidentalis* and *Tsuga canadensis*. These trees seem to be of an age that predates logging of the northwoods and should be protected from logging.

Anguispira alternata	(4618)	*Punctum minutissimum*	(4625)
Carychium exile	(4619)	*Striatura milium*	(4626)
Cochlicopa lubrica	(4620)	*Vertigo cristata*	(4627)
Discus catskillensis	(4621)	*Vertigo paradoxa*	(4628)
Discus cronkhitei	(4622)	*Zonitoides arboreus*	(4629)
Nesovitrea binneyana	(4623)	*Zoogenetes harpa*	(4630)
Planogyra asteriscus	(4624)		

Iceland Coastal Fen. SW¼ SE¼ NW¼ Sec. 6, T. 61 N., R. 3 E. (Marr Island quad)



This open *Larix laricina* swamp containing *Potentilla fruticosa* and *Carex* turf is tightly located between Highway 61 and Lake Superior. Young *Larix* predominate with some older *Larix, Picea mariana*, and *Thuja occidentalis*. Common bog plants were found in open areas and thick stands of *Alnus rugosa* follow along the pebble beach. Frequent disturbance in the area is evident from various trails going through the fen from the beach, along with parking, and camping sites near by.

Carychium exiguum	(4607)	*Planogyra asteriscus*	(4613)
Discus catskillensis	(4608)	*Punctum minutissimum*	(4614)
Discus cronkhitei	(4609)	*Striatura exigua*	(4615)
Euconulus fulvus	(4610)	*Striatura milium*	(4616)
Gastrocopta tappaniana	(4611)	*Vertigo cristata*	(4617)
Nesovitrea electrina	(4612)		

John Lake. S½ NE¼ SE¼ SE¼ Sec. 33, T. 65 N., R. 3 E. (Pine Lake East quad)

This site represents a 3-5 meter northeast facing basalt cliff on top of a 75 meter tall hill. Old growth *Pinus strobus*, *Thuja occidentalis*, *Tsuga canadensis*, and *Acer saccharum* dominate the hill with a sparse understory of *Acer spicatum* and *Rubus parviflorus*. *Polypodium*, *Woodsia* and moss where abundant adjacent to the cliff. Cold air drafts were located in rock outcrops near the base of the hill.

Anguispira alternata	(4541)	*Striatura milium*	(4546)
Discus catskillensis	(4542)	*Vertigo cristata*	(4547)
Euconulus fulvus	(4543)	*Vertigo paradoxa*	(4548)
Nesovitrea binneyana	(4544)	*Zonitoides arboreus*	(4549)
Punctum minutissimum	(4545)		

Lake Cliff. SE¼ SE¼ NW¼ Sec. 21, T. 58 N., R. 5 W. (Little Marais quad)

This site consists of a west facing U-shaped 10-15 meter rhyolite cliff on the Lake Superior shore. *Thuja occidentalis* is growing all along the north facing side of the cliff, and several of them could be very old. Moss is abundant on the cliff which receive wave spray up to 5 meters high. The area above the cliff is sparsely covered by *Betula papyrifera*. Based on several electric boxes recently placed along a dead end road, the area above the cliff appears ready for development.

Discus catskillensis	(4745)	*Vitrina limpida*	(4748)
Helicodiscus parallelus	(4746)	*Zonitoides arboreus*	(4749)
Nesovitrea binneyana	(4747)		

Lutsen Mountains. NW¼ NW¼ SW¼ Sec. 15, T. 60 N., R. 3 W. (Lutsen quad)

This site consist of a 10-15 meter north facing diabase cliff and associated talus. Talus boulders harbored *Woodsia*, *Polypodium*, and thick moss growth. The talus weak cold air vents were present near the base. A medium age forest of *Picea glauca*, *Abies balsamea*, and *Betula papyrifera* dominate the area.

Discus catskillensis	(4738)	*Vertigo cristata*	(4740)
Nesovitrea binneyana	(4739)	*Zoogenetes harpa*	(4741)

McFarland Lake Cliff. S½ NW¼ SW¼ NE¼ Sec. 5, T. 64 N., R. 3 E. (Pine Lake East quad)

This is a 10-15 meter north facing basalt cliff on a 75 meter tall hill along the lake shore in the State Forest. Cottages were located on the opposite shore but this area seems to be undisturbed with sections of old growth *Pinus strobus*, *Thuja occidentalis*, and *Picea glauca*. The cliff face also had some stunted *Thuja occidentalis* that could be several hundred years old. Young *Betula papyifera* and *Thuja occidentalis* are also found immediately below the cliff on an open talus. Evidence of a fire history is found by fire scars on the trees, and burnt wood in the leaf litter.

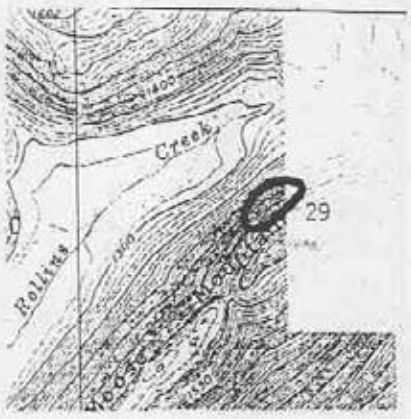
Discus catskillensis	(4674)	*Vertigo paradoxa*	(4677)
Nesovitrea binneyana	(4675)	*Zonitoides arboreus*	(4678)
Vertigo cristata	(4676)	*Zoogenetes harpa*	(4679)

McFarland Lake Talus. S½ NW¼ SW¼ NE¼ Sec. 5, T. 64 N., R. 3 E. (Pine Lake East quad)

The site is located directly below McFarland Lake Cliff on a 75 meter long talus slope with medium to large boulders covered with *Polypodium*, *Woodsia* and thick moss. Young *Acer saccharum*, *Betula papyrifera*, *Thuja occidentalis* and *Acer spicatum* are present. Water and cool air seepage is present near the talus base along the lake. This site has evidence of a fire history from burnt wood found in leaf litter.

Discus catskillensis	(4708)	*Nesovitrea binneyana*	(4711)
Discus cronkhitei	(4709)	*Vertigo cristata*	(4712)
Euconulus fulvus	(4710)	*Zonitoides arboreus*	(4713)

Moose Mountain. E½ SE¼ SE¼ NW¼ Sec. 29, T. 60 N., R. 3 W. (Lutsen quad)



This northwest facing 30-40 meter diabase cliff with associated 20 meter long lichen covered talus had the largest population of *Polypodium* that the collector (Eric North) had ever seen. The cliff face and lower talus was shaded by *Thuja occidentalis*. There was a considerable amount of deteriorated burnt wood in the leaf litter indicating recent fire event(s) for this location.

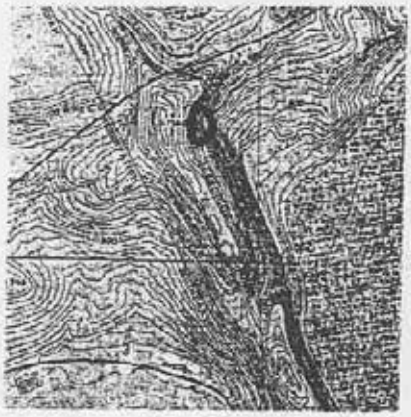
Anguispira alternata	(4849)	*Striatura exigua*	(4855)
Cochlicopa lubrica	(4850)	*Striatura milium*	(4856)
Discus catskillensis	(4851)	*Succinea ovalis*	(4857)
Discus cronkhitei	(4852)	*Vertigo cristata*	(4858)
Euconulus fulvus	(4853)	*Zonitoides arboreus*	(4859)
Nesovitrea binneyana	(4854)		

Mt. Josephine Cliff. SW¼ SE¼ NE¼ Sec. 34, T. 64 N., R. 6 E. (Grand Portage quad)

This site consists of a 10-20 meter northeast facing diabase cliff located near a parking overlook. Old growth of *Pinus strobus*, *Picea glauca*, and *Thuja occidentalis* shade sections of this cliff that lack exposed talus. *Polypodium* and *Woodsia* are found on small ledges on the cliff base. This site is probably the best example of undisturbed cliff habitat adjacent to the Lake Superior shore line in Minnesota, and should be afforded some type of protection.

Anguispira alternata	(4550)	*Striatura exigua*	(4557)
Columella simplex	(4551)	*Striatura milium*	(4558)
Discus catskillensis	(4552)	*Vertigo cristata*	(4559)
Discus cronkhitei	(4553)	*Vertigo paradoxa*	(4560)
Euconulus fulvus	(4554)	*Zonitoides arboreus*	(4561)
Nesovitrea binneyana	(4555)	*Zoogenetes harpa*	(4562)
Punctum minutissimum	(4556)		

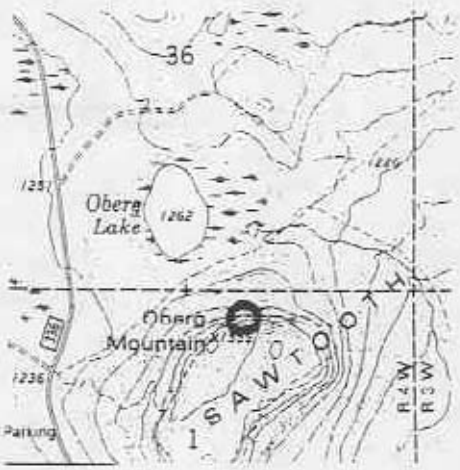
Mt. Josephine Talus. SW¼ SE¼ NE¼ Sec. 34, T. 64 N., R. 6 E. (Grand Portage quad)



This site is located on a 75 meter long talus adjacent to the Mt. Josephine Overlook Cliff site. Diabase boulders of medium to large size are covered with lichens at the top and and moss in lower third of the slope. The bottom third of the talus has an old growth canopy of *Pinus strobus*, *Picea glauca*, and *Thuja occidentalis*. Some *Betula papyrifera*, *Populus tremuloides*, and *Acer spicatum* are also present.

Carychium exile	(4563)	*Vertigo cristata*	(4569)
Discus catskillensis	(4564)	*Vertigo modesta modesta*	(4570)
Discus cronkhitei	(4565)	*Vertigo modesta parietalis*	(4571)
Nesovitrea binneyana	(4566)	*Vertigo paradoxa*	(4572)
Punctum minutissimum	(4567)	*Zonitoides arboreus*	(4573)
Striatura exigua	(4568)		

Oberg Mountain. NW¼ NW¼ NE¼ Sec. 1, T. 59 N., R. 4 W. (Honeymoon Mt. quad)



This is a 3-5 meter north facing diabase cliff located along the Superior Hiking Trail. The cliff is shaded by medium age *Acer saccharum*, *Abies balsamifera*, and *Acer spicatum*. *Thuja occidentalis*, *Betula papyifera*, and *Sorbus americana* are also present.

Discus cronkhitei	(4821)	*Vertigo cristata*	(4824)
Euconulus fulvus	(4822)	*Zonitoides arboreus*	(4825)
Nesovitrea binneyana	(4823)		

Pine Lake. W½ SE¼ SE¼ SE¼ Sec. 6, T. 64 N., R. 3 E. (Pine Lake East quad)

This consists of a 3-5 meter north facing basalt cliff located on top of very steep 100 meter tall hill above Pine Lake. The hill below the cliff has old growth *Pinus strobus*, *Tsuga canadensis*, and some *Acer saccharum*, with a sparse understory of *Acer spicatum*, and *Rubus parviflorus*. The area above the cliff was recently cut, and allows sunlight to penetrate causing a dense understory growth near the cliff face. Some of the *Vertigo cristata* individuals from this site appear transitional with *V. gouldi*, and may represent a different taxon.

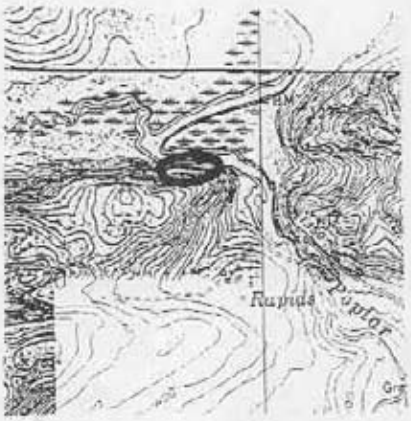
Anguispira alternata	(4772)	*Succinea ovalis*	(4778)
Discus catskillensis	(4773)	*Vertigo cristata*	(4779)
Euconulus fulvus	(4774)	*Vertigo paradoxa*	(4780)
Nesovitrea binneyana	(4775)	*Zonitoides arboreus*	(4781)
Punctum minutissimum	(4776)	*Zoogenetes harpa*	(4782)
Striatura milium	(4777)		

Pine River Road. E½ SW¼ SE¼ SE¼ Sec. 22, T. 63 N., R. 1 E. (Pine Mountain quad)

This site represents a north facing slope of rhyolite covered in moss and shaded by *Tsuga canadensis*. Scatterd *Acer saccharum*, *Betula papyifera*, and *Thuja occidentalis* are found nearby. There is evidence of recent cutting west of this site.

Columella simplex	(4870)	*Striatura milium*	(4875)
Discus catskillensis	(4871)	*Succinea ovalis*	(4876)
Nesovitrea binneyana	(4872)	*Vertigo cristata*	(4877)
Punctum minutissimum	(4873)	*Zonitoides arboreus*	(4878)
Striatura exigua	(4874)	*Zoogenetes harpa*	(4879)

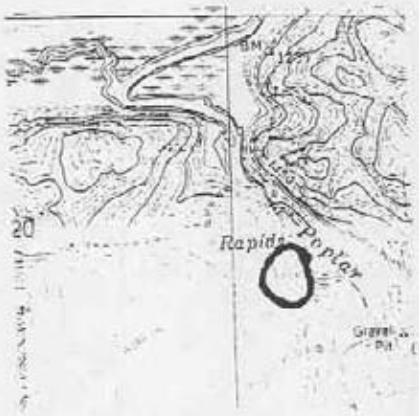
Poplar River Overlook. S½ SW¼ NE¼ NE¼ Sec. 20, T. 60 N., R. 3 W. (Lutsen quad)



This site represents a 15 meter north facing basalt cliff near a bend of the Poplar River. The cliff face was exposed except for some scattered moss covered ledges having *Thuja occidentalis* and *Polypodium*. *Betula papyifera*, and *Picea glauca* are present on a xeric talus of large boulders that follows from the cliff in to the river.

Columella simplex	(4766)	*Nesovitrea binneyana*	(4769)
Discus catskillensis	(4767)	*Nesovitrea electrina*	(4770)
Euconulus fulvus	(4768)	*Zonitoides arboreus*	(4771)

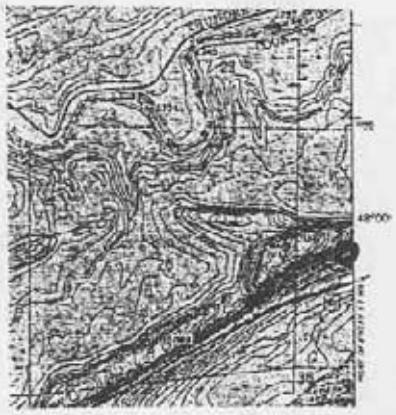
Poplar River Rapids. SE¼ NW¼ SW¼ Sec. 21, T. 60 N., R. 3 W. (Lutsen quad)



This site consisted of a 3-meter northeast-facing ledge of basalt along the Poplar River. *Betula papyrifera, Acer saccharum,* and *Thuja occidentalis* provide a partial canopy to some *Polypodium* ferns. Burnt wood present in the leaf litter indicates a fire history for this locality.

Discus catskillensis	(4836)	*Striatura milium*	(4843)
Discus cronkhitei	(4837)	*Succinea ovalis*	(4844)
Euconulus fulvus	(4838)	*Vertigo cristata*	(4845)
Nesovitrea binneyana	(4839)	*Vertigo paradoxa*	(4846)
Nesovitrea electrina	(4840)	*Zonitoides arboreus*	(4847)
Punctum minutissimum	(4841)	*Zoogenetes harpa*	(4848)
Striatura exigua	(4842)		

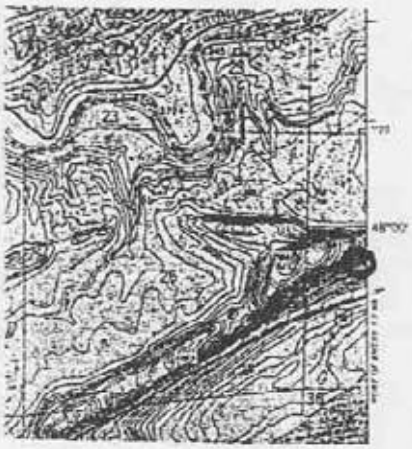
Port of Entry Cliff. SE¼ SE¼ NW¼ Sec. 25, T. 64 N., R. 6 E. (Grand Portage quad)



This 5-10 meter southeast facing diabase or basalt cliff is located on top of a 75 meter tall hill. Young *Betula papyrifera, Thuja occidentalis,* and *Picea glauca* grow along the top base. The cliff faceand uplands seem to have been recently disturbed by fire and logging.

Anguispira alternata	(4723)	*Succinea ovalis*	(4728)
Discus catskillensis	(4724)	*Vertigo cristata*	(4729)
Discus cronkhitei	(4725)	*Vertigo paradoxa*	(4730)
Euconulus fulvus	(4726)	*Zonitoides arboreus*	(4731)
Nesovitrea binneyana	(4727)		

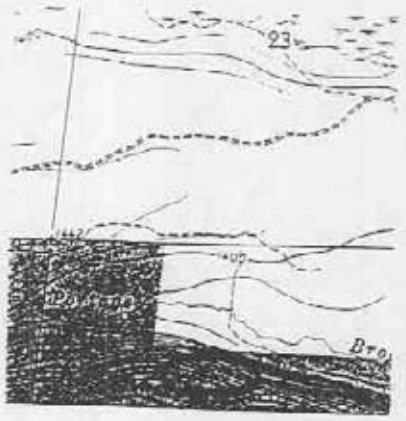
Port of Entry Talus. SE¼ SE¼ NW¼ Sec. 25, T. 64 N., R. 6 E. (Grand Portage quad)



This site is located below the Port of Entry Cliff, and consists of a 50 meter long talus consisting of lichen and moss covered boulders. The lower half of the talus is in a canopy of older *Pinus strobus, Pinus resinosa, Picea glauca, Thuja occidentalis* and *Acer spicatum*. Some of the older trees may have fire scars.

Anguispira alternata	(4714)	*Vertigo cristata*	(4719)
Discus catskillensis	(4715)	*Vertigo paradoxa*	(4720)
Discus cronkhitei	(4716)	*Vitrina limpida*	(4721)
Nesovitrea binneyana	(4717)	*Zonitoides arboreus*	(4722)
Succinea ovalis	(4718)		

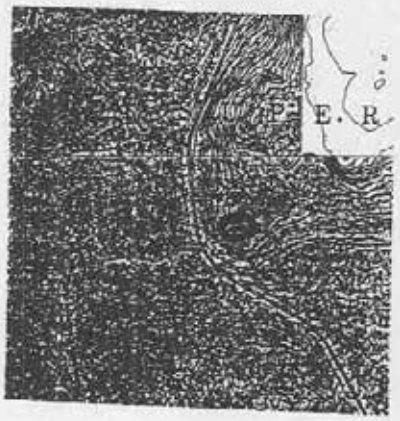
Portage Brook. N½ SE¼ NW¼ Sec. 26, T. 64 N., R. 3 E. (Pine Lake East quad)



This site consists of several 1-2 meter ledges on top of a 20-30 meter tall north-facing basalt cliff. The cliff top and bottom had been recently cut (ca. 1-2 years). A fern population including *Polypodium*, *Woodsia*, *Asplenium*, and *Camptosorus rhizophyllus* is still afforded some protected by young *Betula papyrifera*, *Thuja occidentalis*, and *Picea sp.* This rich fern population has an uncertain future as vegetational succession occurs.

Discus catskillensis	(4760)	*Vertigo cristata*	(4763)
Discus cronkhitei	(4761)	*Vertigo paradoxa*	(4764)
Euconulus fulvus	(4762)	*Zonitoides arboreus*	(4765)

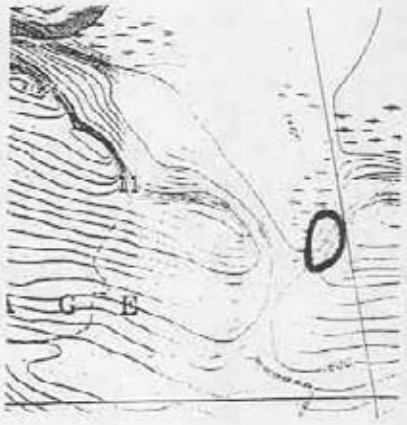
Sawbill Road. SE¼ NW¼ NE¼ Sec. 17, T. 59 N., R. 4 W. (Tofte quad)



This site consists of a north-facing 3 meter cliff of anorthosite near the top of a sandy hill. The trees of this locality consist of *Abies balsamea, Betula papyrifera, Thuja occidentalis,* and *Picea abies.* Burnt wood was present in the leaf litter, indicating a fire history for this locality.

Discus catskillensis	(4793)	*Succinea ovalis*	(4798)
Euconulus fulvus	(4794)	*Vertigo cristata*	(4799)
Nesovitrea binneyana	(4795)	*Vertigo paradoxa*	(4800)
Punctum minutissimum	(4796)	*Zonitoides arboreus*	(4801)
Striatura milium	(4797)	*Zoogenetes harpa*	(4802)

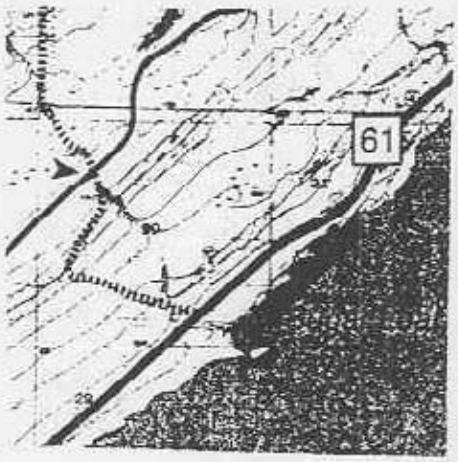
South Fowl Lake. SE¼ NE¼ SE¼ Sec. 11, T. 64 N., R. 3 E. (Pine Lake East quad)



This site represents a 3-5 meter northwest facing dark basalt cliff in an upland woods of medium age *Picea glauca, Thuja occidentalis,* and *Acer saccharum* forest. An understory of *Polypodium, Woodsia, Rubus parviflorus* and *Acer spicatum* are present near the cliff face. The area surrounding this site has been clear cut while this site remains for the most part undamaged. A heavily used ATV trail is adjacent to cliff.

Anguispira alternata	(4631)	*Striatura milium*	(4637)
Columella simplex	(4632)	*Vertigo cristata*	(4638)
Discus catskillensis	(4633)	*Vertigo paradoxa*	(4639)
Euconulus fulvus	(4634)	*Zonitoides arboreus*	(4640)
Nesovitrea binneyana	(4635)	*Zoogenetes harpa*	(4641)
Striatura exigua	(4636)		

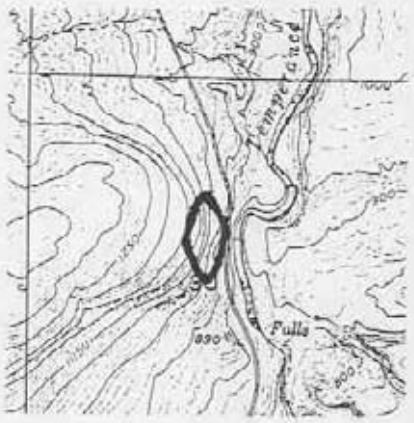
Sugarloaf Cove Point. NE¼ NE¼ NE¼ Sec. 29, T. 58 N., R. 5 W. (Little Marais quad)



This site is a 3-5 meter, west and north facing rhyolite ledge located on the island point of Sugarloaf Cove State Natural Area. A sparse but rich fern, sedge, grass, and moss population was present on the open cliff face. The area above the cliff had very thick growth of *Picea glauca*, and some *Betula papyrifera*. This site had a dozen different groups of people climbing around and causing considerable damage to some of the primroses and other plants growing in the area. The inviting sign along the highway advertising this state natural area may defeat the purpose of it being a designated a natural area due to the large number of tourists attracted by the sign.

Cochlicopa lubrica	(4667)	*Vertigo paradoxa*	(4671)
Cochlicopa lubricella	(4668)	*Zonitoides arboreus*	(4672)
Nesovitrea binneyana	(4669)	*Zoogenetes harpa*	(4673)
Vertigo cristata	(4670)		

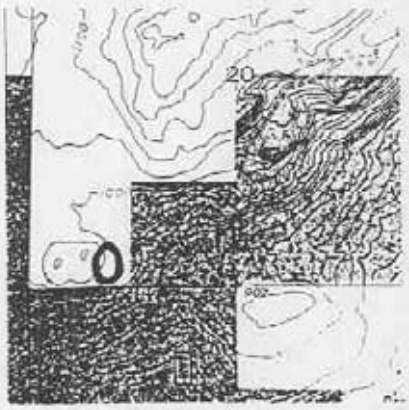
Temperance River Road. E½ SE¼ NW¼ Sec.30, T. 59 N., R. 4 W. (Schroeder quad)



This site represent a north facing rocky slope and short ledge of diabase. *Equisetum arvense* was present in an area near a moist crevice. *Abies balsamea*, *Betula papyrifera* and *Thuja occidentalis* shaded the sampling area.

Carychium exile	(4752)	*Planogyra asteriscus*	(4756)
Columella simplex	(4753)	*Punctum minutissimum*	(4757)
Discus catskillensis	(4754)	*Zonitoides arboreus*	(4758)
Nesovitrea binneyana	(4755)	*Zoogenetes harpa*	(4759)

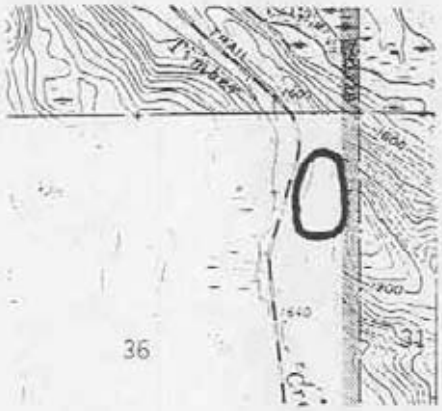
Temperance River Upland. SE¼ SW¼ SW¼ Sec. 20, T. 59 N., R. 4 W. (Tofte quad)



This site represents 1-2 meter tall, moss covered ledges and rocks of anorthosite and basalt. This site is found in upland woods near a section of the Superior Hiking Trail. Early successional *Betula papyrifera* and *Acer saccharum* serve as a canopy to *Woodsia, Polypodium, Camptosorus rhizophyllus* and a rich population of mosses. This area has a history of fire, and some larger *Pinus strobus* further down the trail show fire scars.

Anguispira alternata	(4594)	*Strobilops labyrinthica*	(4601)
Columella simplex	(4595)	*Succinea ovalis*	(4602)
Discus catskillensis	(4596)	*Vertigo cristata*	(4603)
Nesovitrea binneyana	(4597)	*Vertigo paradoxa*	(4604)
Punctum minutissimum	(4598)	*Zonitoides arboreus*	(4605)
Striatura exigua	(4599)	*Zoogenetes harpa*	(4606)
Striatura milium	(4600)		

Timber Creek. SE¼ NE¼ NE¼ Sec. 36, T. 63 N., R. 1 E. (Pine Mountain quad)



This site consists of short 1 meter ledges of rhyolite or basalt on top of a large hill. The dominate trees include *Abies balsamea, Betula papyifera,* and *Pinus strobus.* There is evidence of fire history for this site from burnt wood found in the leaf litter.

Discus catskillensis	(4783)	*Striatura exigua*	(4788)
Euconulus fulvus	(4784)	*Striatura milium*	(4789)
Nesovitrea binneyana	(4785)	*Vertigo cristata*	(4790)
Nesovitrea electrina	(4786)	*Zonitoides arboreus*	(4791)
Punctum minutissimum	(4787)	*Zoogenetes harpa*	(4792)

LAKE COUNTY

Day Hill. E½ NE¼ SW¼ NW¼ Sec. 5, T. 54 N., R. 8 W. (Split Rock quad)

This site consists of 1-2 meter tall outcrops of anorthosite. An understory of *Polypodium* and *Cornus canadensis* is heavily shaded by thick stands of *Betula papyrifera*.

Anguispira alternata	(4860)	*Striatura exigua*	(4865)
Discus catskillensis	(4861)	*Striatura milium*	(4866)
Euconulus fulvus	(4862)	*Vertigo cristata*	(4867)
Nesovitrea binneyana	(4863)	*Zonitoides arboreus*	(4868)
Nesovitrea electrina	(4864)	*Zoogenetes harpa*	(4869)

Goldeneye Lake Cliff. NW¼ SW¼ NW¼ Sec. 14, T. 59 N., R. 5 W. (Cramer quad)

This site consists of a north-facing 3-meter cliff. *Thuja occidentalis* was found on ledges on the cliff. A young forest of *Acer saccharum*, *Abies balsamea*, *Thuja occidentalis*, and *Betula papyifera* is surround this site. There is evidence of fire history for this site from burnt wood found in the leaf litter.

Discus catskillensis	(4574)	*Vertigo cristata*	(4577)
Nesovitrea binneyana	(4575)	*Zonitoides arboreus*	(4578)
Striatura exigua	(4576)	*Zoogenetes harpa*	(4579)

Goldeneye Lake Talus. NW¼ SW¼ NW¼ Sec. 14, T. 59 N., R. 5 W. (Cramer quad)

This site consists of a north facing talus slope of medium sized boulders below Goldeneye Lake Cliff.

Discus catskillensis	(4580)	*Vertigo cristata*	(4584)
Nesovitrea binneyana	(4581)	*Zonitoides arboreus*	(4585)
Striatura exigua	(4582)	*Zoogenetes harpa*	(4586)
Striatura milium	(4583)		

Finland Forest. E½ NW¼ SE¼ NE¼ Sec. 33, T. 59 N., R. 5 W. (Cramer quad)

This site represents a 2-3 meter cliff of dark basalt, in a forest dominated by *Betula papyifera* with some *Abies balsamea* and *Acer saccharum*.

Discus catskillensis	(4680)	*Vertigo cristata*	(4684)
Nesovitrea binneyana	(4681)	*Zonitoides arboreus*	(4685)
Punctum minutissimum	(4682)	*Zoogenetes harpa*	(4686)
Striatura milium	(4683)		

Manitou River Falls. NE¼ SW¼ SE¼ Sec. 3, T. 57 N., R. 6 W. (Little Marais quad)

This site represents a 30-40 meter north facing basalt cliff located next to an abandoned part of old highway 61. Medium age to near old growth *Pinus strobus, Thuja occidentalis, and Picea glauca* serve as a canopy to *Acer spicatum* and *Rubus parviflorus*. The cliff area supports a diverse population of ferns including *Woodsia*, *Polypodium*, *Asplenium*, and *Camptosorus rhizophyllus*. The entire height of the cliff was shaded by trees on the cliff face. Mosses and lichens are found everywhere on the cliff face. This site is in a very rugged and narrow river valley that would require climbing gear for a safe return. An accessible steep grassy opening on a section of the cliff should be surveyed for additional species.

Carychium exile	(4655)	*Vertigo cristata*	(4661)
Discus catskillensis	(4656)	*Vertigo modesta modesta*	(4662)
Euconulus fulvus	(4657)	*Vertigo modesta parietalis*	(4663)
Nesovitrea binneyana	(4658)	*Vertigo paradoxa*	(4664)
Punctum minutissimum	(4659)	*Zonitoides arboreus*	(4665)
Striatura milium	(4660)	*Zoogenetes harpa*	(4666)

Sawmill Creek. NE¼ SE¼ SW¼ Sec. 24, T. 57 N., R. 7 W. (Finland quad)

This relatively open north-facing 20-30 meter cliff of anorthosite is located in an area considered to be "a climbing hot spot." *Acer saccharum* and *Sorbus americana* are present on the talus. *Thuja occidentalis, Betula papyifera are* present on top of the cliff. The Superior Hiking Trail is located on top of the cliff, and flow channels that scour and wash soil away during rain are present from both rock climbing and hiker activity. Trampling of *Polypodium* and mosses near the cliff base is also prevalent.

Discus catskillensis	(4742)	*Zonitoides arboreus*	(4744)
Vertigo cristata	(4743)		

Water Tanks. S½ N½ SE¼ NW¼ Sec. 36, T. 56 N., R. 8 W. (Silver Bay quad)

This site is located on a 10-15 meter northwest facing basalt cliff. *Betula papyrifera*, *Sorbus americana*, and *Thuja occidentalis* shade an understory of *Polypodium* and *Woodsia*. This site has been heavily modified as it now boasts huge water storage tanks 5 meters from the cliff edge, and numerous rusty buckets and paint cans littering the area. Burnt wood was also found in the leaf litter, indicating a fire history.

Discus catskillensis	(4587)	*Strobilops labyrinthica*	(4591)
Euconulus fulvus	(4588)	*Vertigo gouldi*	(4592)
Nesovitrea binneyana	(4589)	*Zonitoides arboreus*	(4593)
Punctum minutissimum	(4590)		

ST. LOUIS COUNTY

Hawk Ridge Sanctuary. SE¼ SW¼ NE¼ Sec. 6, T. 50 N., R. 13 W. (Duluth quad)

This site represents a 40-50 meter south facing diabase cliff with an adjacent north-facing shaded outcrop of 3-5 meters in height. *Betula papyrifera* and *Acer saccharum* shade the outcrop with sparse *Polypodium* growth among the rocks.

Cochlicopa morseana	(4803)	*Striatura milium*	(4810)
Columella simplex	(4804)	*Strobilops labyrinthica*	(4811)
Euconulus fulvus	(4805)	*Vertigo paradoxa*	(4812)
Nesovitrea binneyana	(4806)	*Vitrina limpida*	(4813)
Nesovitrea electrina	(4807)	*Zonitoides arboreus*	(4814)
Punctum minutissimum	(4808)	*Zoogenetes harpa*	(4815)
Striatura exigua	(4809)		

Chester Bowl Park. NE¼ SW¼ NW¼ SE¼ Sec. 15, T. 50 N., R. 14 W. (Duluth quad)

This site represents a small diabase outcrop of 1-2 meters on a north facing hill near a hiking trail. *Acer saccharum*, *Thuja occidentalis*, and *Sorbus americana* shade some *Polypodium*. Burnt wood in the leaf litter indicates a fire history for this locality.

Anguispira alternata	(4826)	*Striatura milium*	(4831)
Cochlicopa lubrica	(4827)	*Succinea ovalis*	(4832)
Discus catskillensis	(4828)	*Vertigo cristata*	(4833)
Helicodiscus shimeki	(4829)	*Zonitoides arboreus*	(4834)
Nesovitrea electrina	(4830)	*Zoogenetes harpa*	(4835)

Skyline Drive West Cliff. S½ SW¼ NE¼ NW¼ Sec. 6, T. 50 N., R. 14 W. (Duluth Heights quad)

This exposed northeast-facing 20-30 meter basalt cliff has ledges covered with *Polypodium*, *Woodsia*, and moss. An immediately adjacent southwest facing cliff forms a valley that seems to act as a cold air funnel from the upland down to the lake. *Acer saccharum* is present nearby.

Euconulus fulvus	(4816)	*Vertigo paradoxa*	(4819)
Strobilops labyrinthica	(4817)	*Zonitoides arboreus*	(4820)
Vertigo cristata	(4818)		

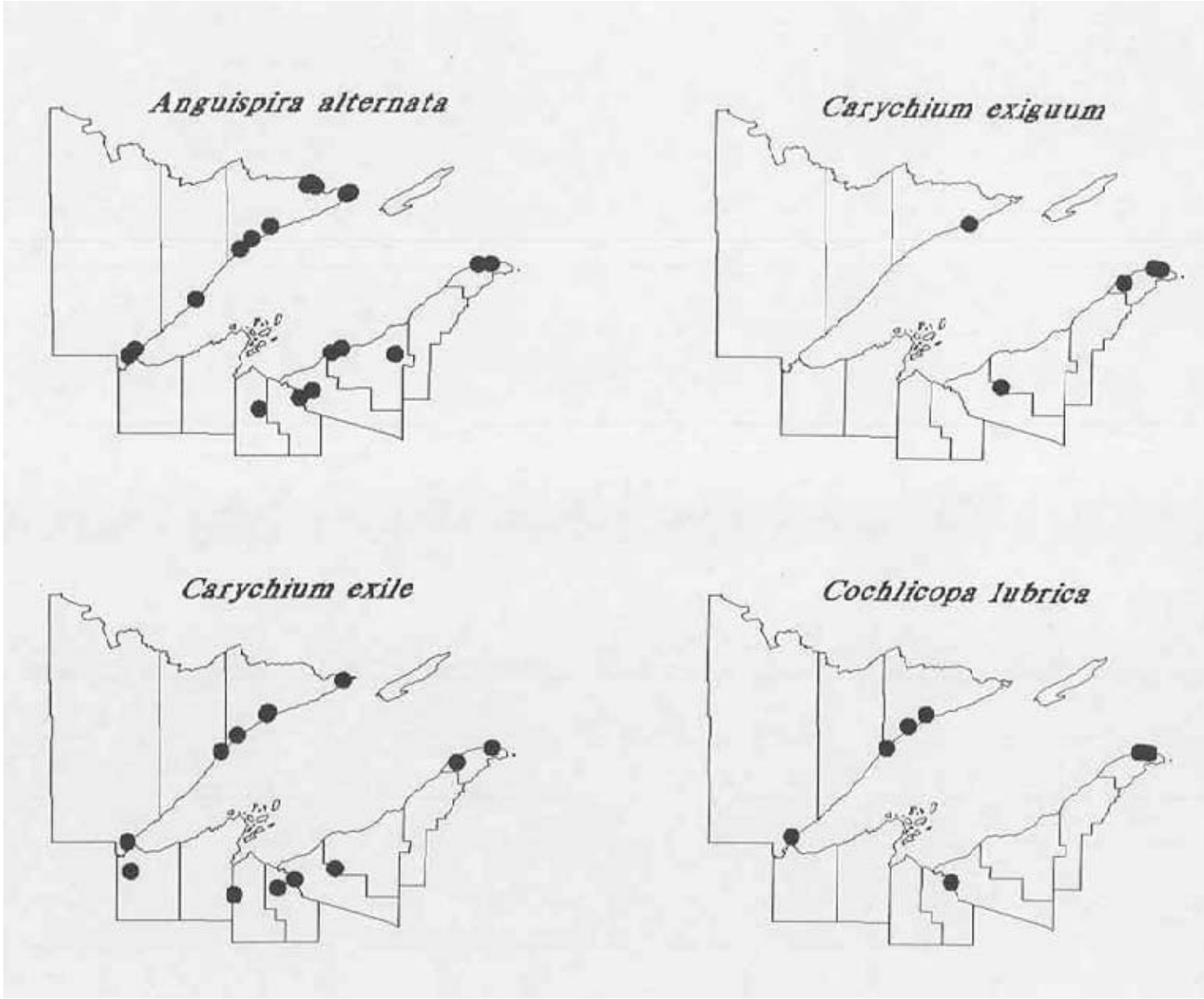
Skyline Drive West Talus. S½ SW¼ NE¼ NW¼ Sec. 6, T. 50 N., R. 14 W. (Duluth Heights quad)

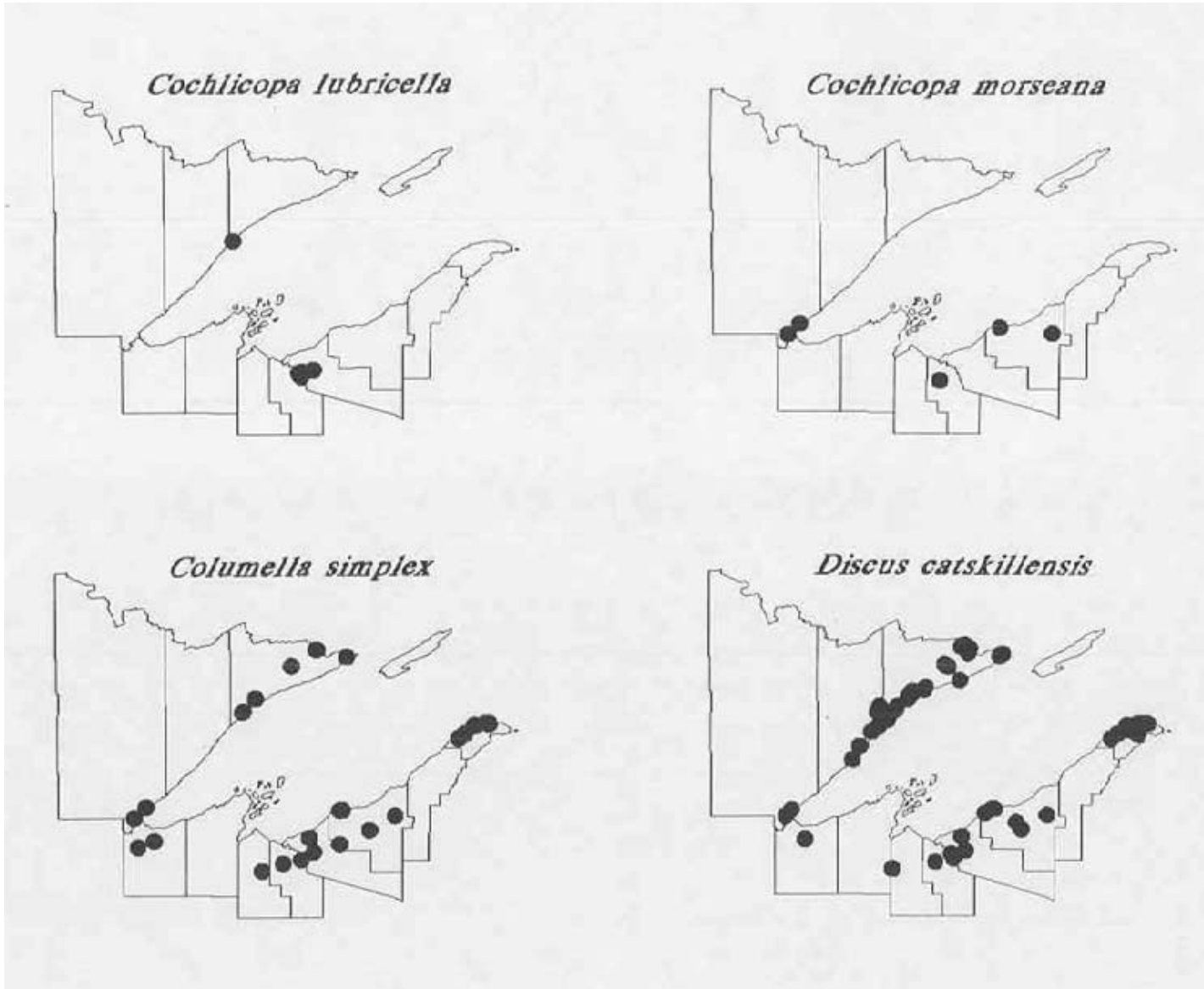
This talus is directly below the Skyline Drive West Cliff. It is very well shaded by a canopy of *Acer saccharum*. *Polypodium* and mosses are present on the talus rocks.

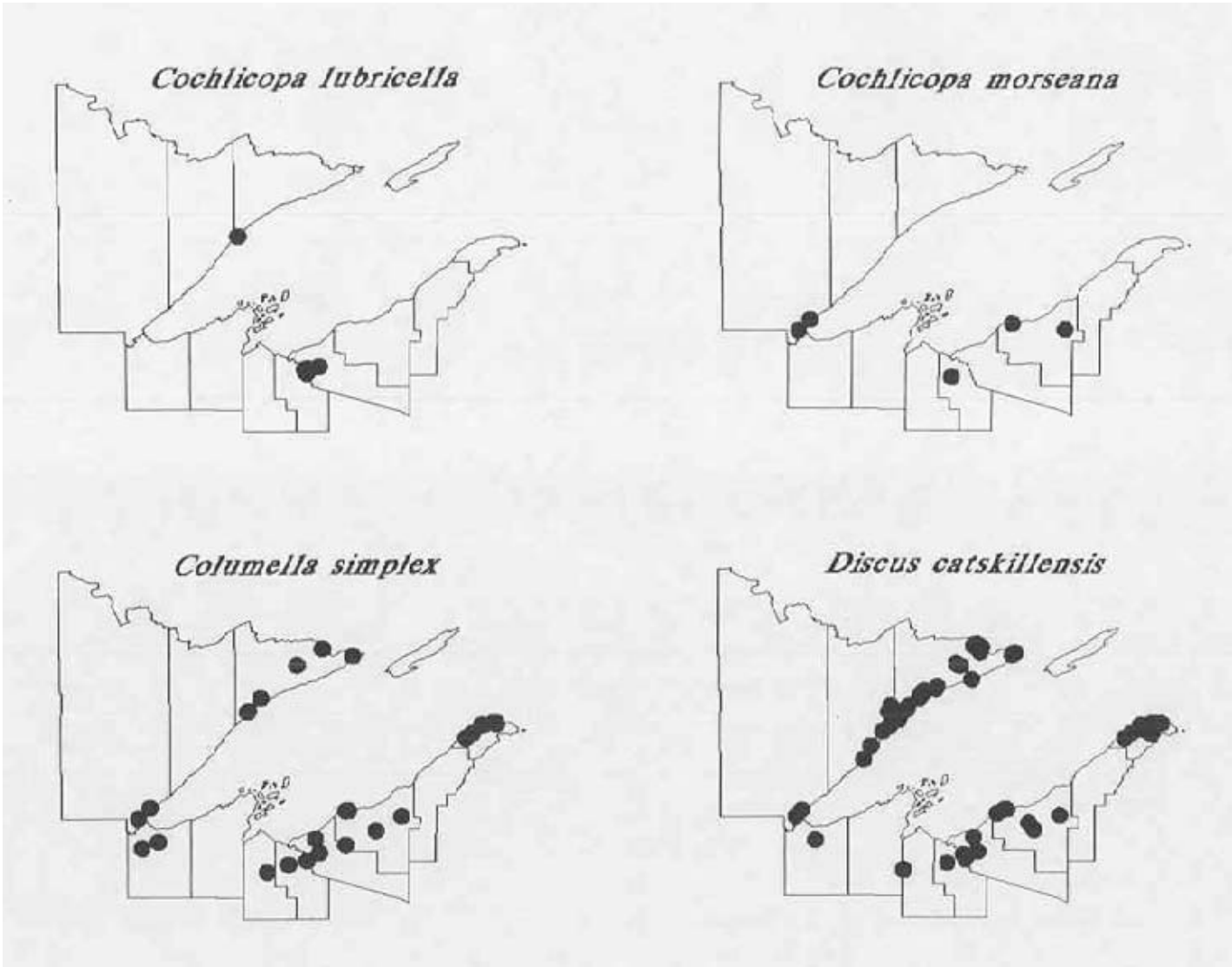
Anguispira alternata	(4642)	*Striatura exigua*	(4649)
Carychium exile	(4643)	*Striatura ferrea*	(4650)
Cochlicopa morseana	(4644)	*Strobilops labyrinthica*	(4651)
Columella simplex	(4645)	*Vertigo cristata*	(4652)
Discus catskillensis	(4646)	*Vertigo paradoxa*	(4653)
Helicodiscus shimeki	(4647)	*Zonitoides arboreus*	(4654)
Punctum minutissimum	(4648)		

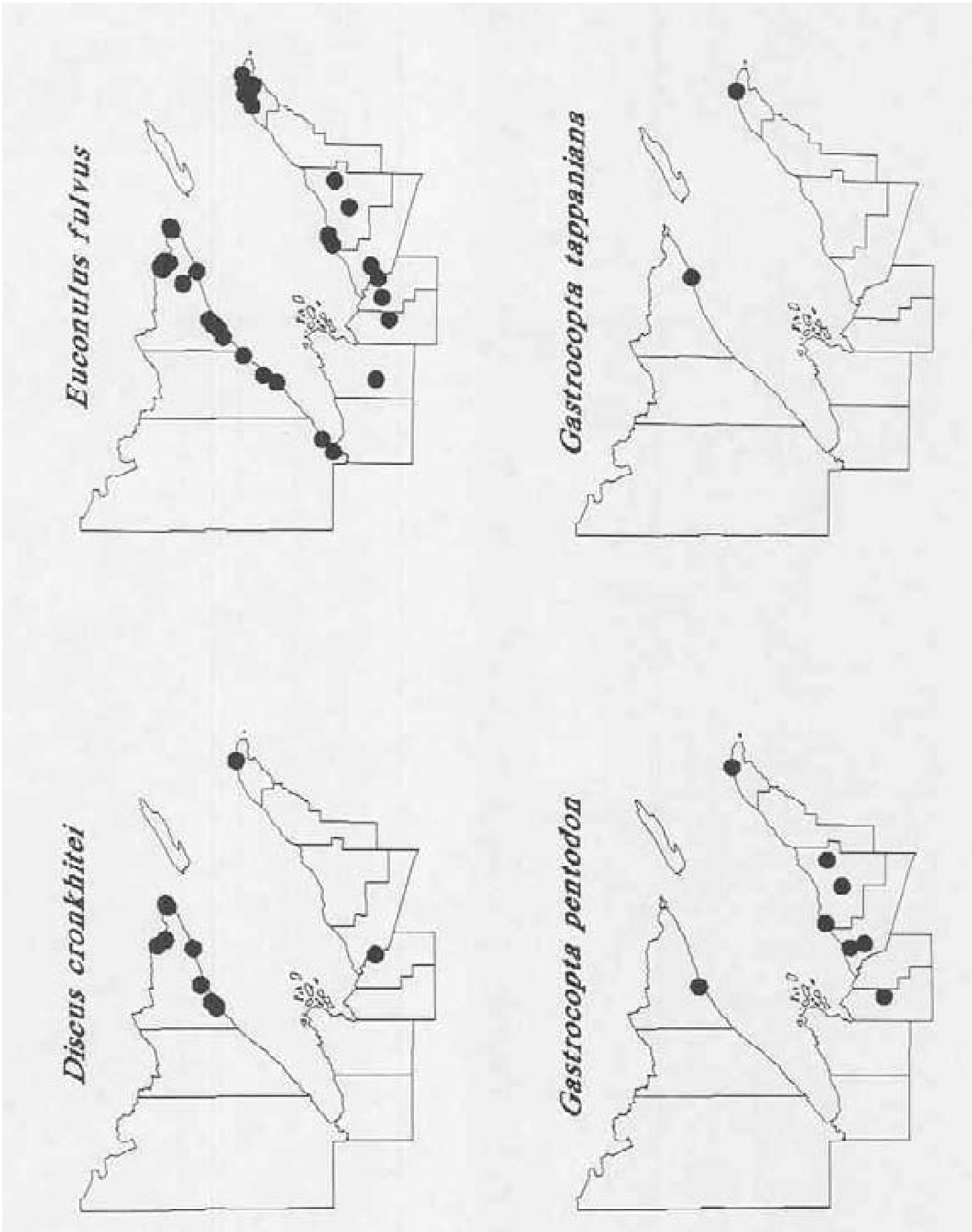
APPENDIX II.

Western Great Lakes distribution maps for terrestrial gastropod taxa encountered during this study

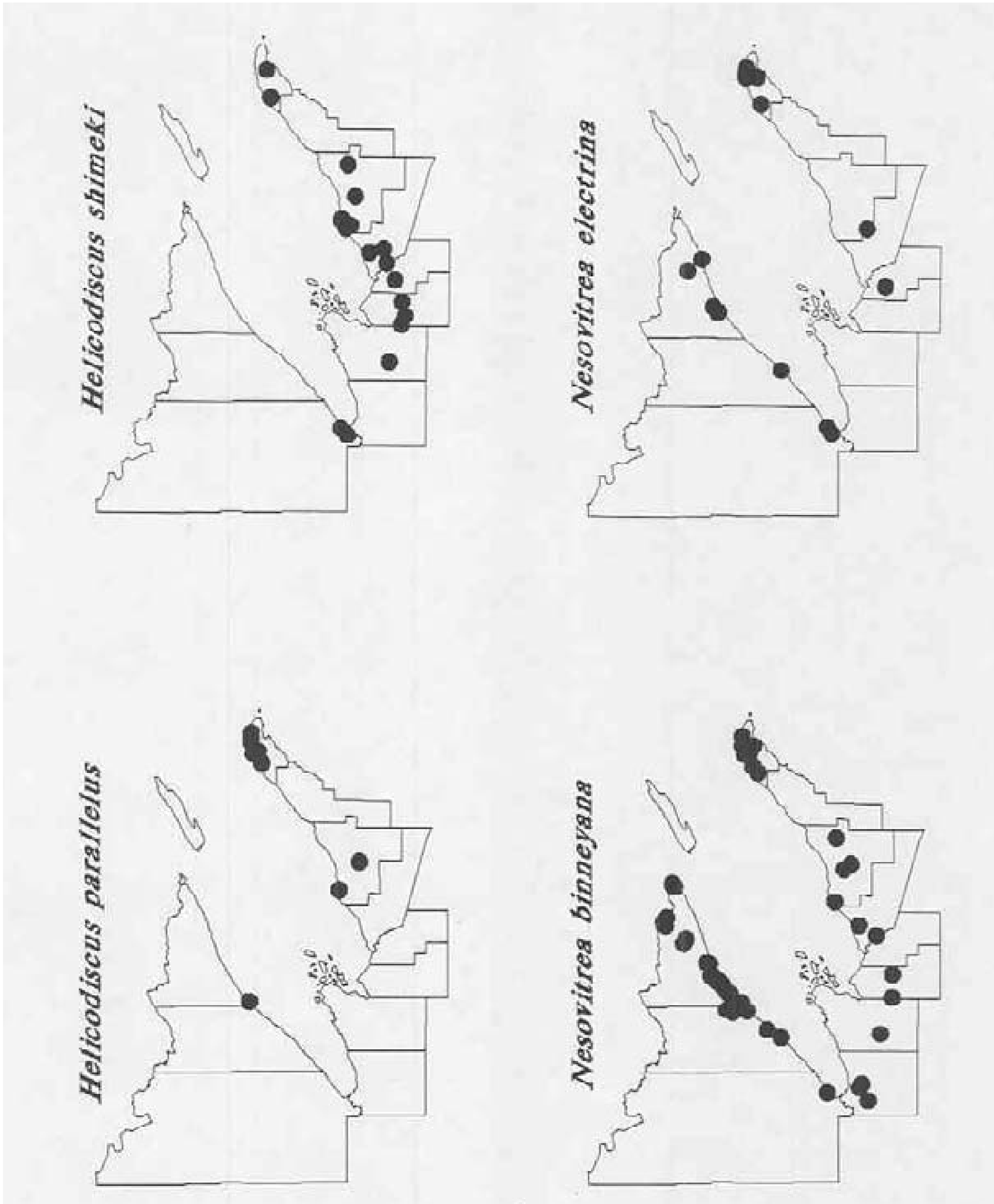

Anguispira alternata
Carychium exiguum
Carychium exile
Cochlicopa lubrica

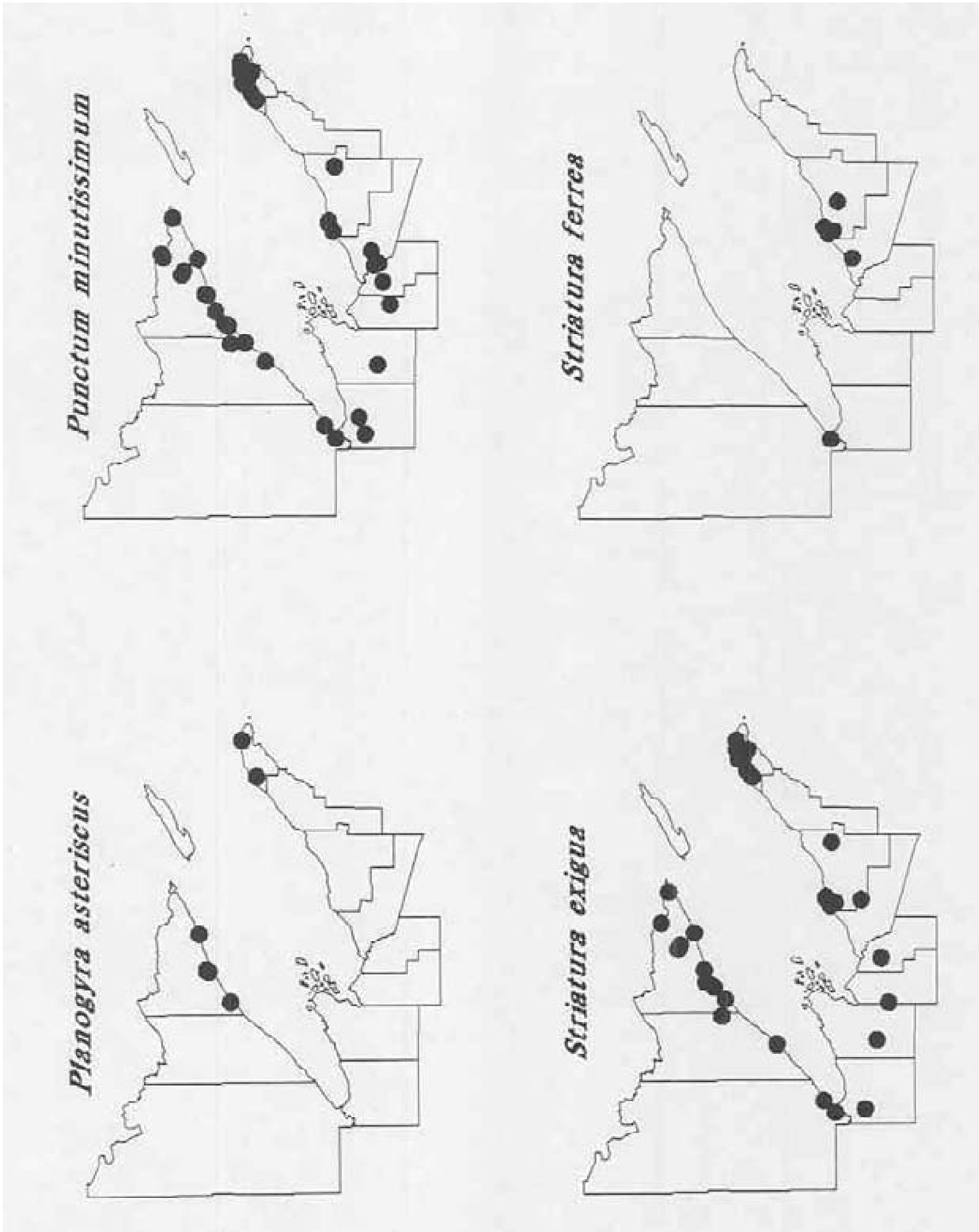

Cochlicopa lubricella
Cochlicopa morseana
Columella simplex
Discus catskillensis

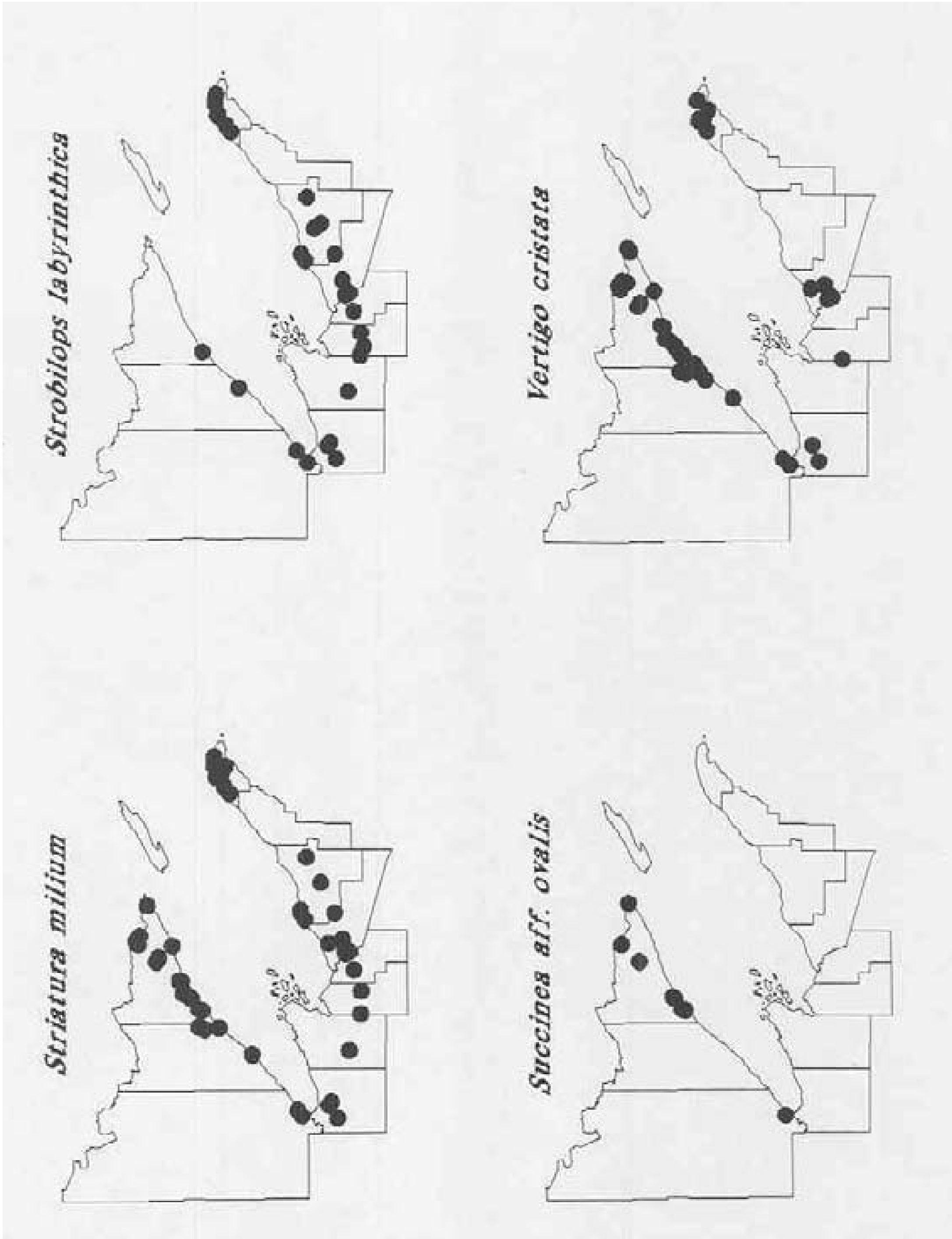

Cochlicopa lubricella
Cochlicopa morseana
Columella simplex
Discus catskillensis

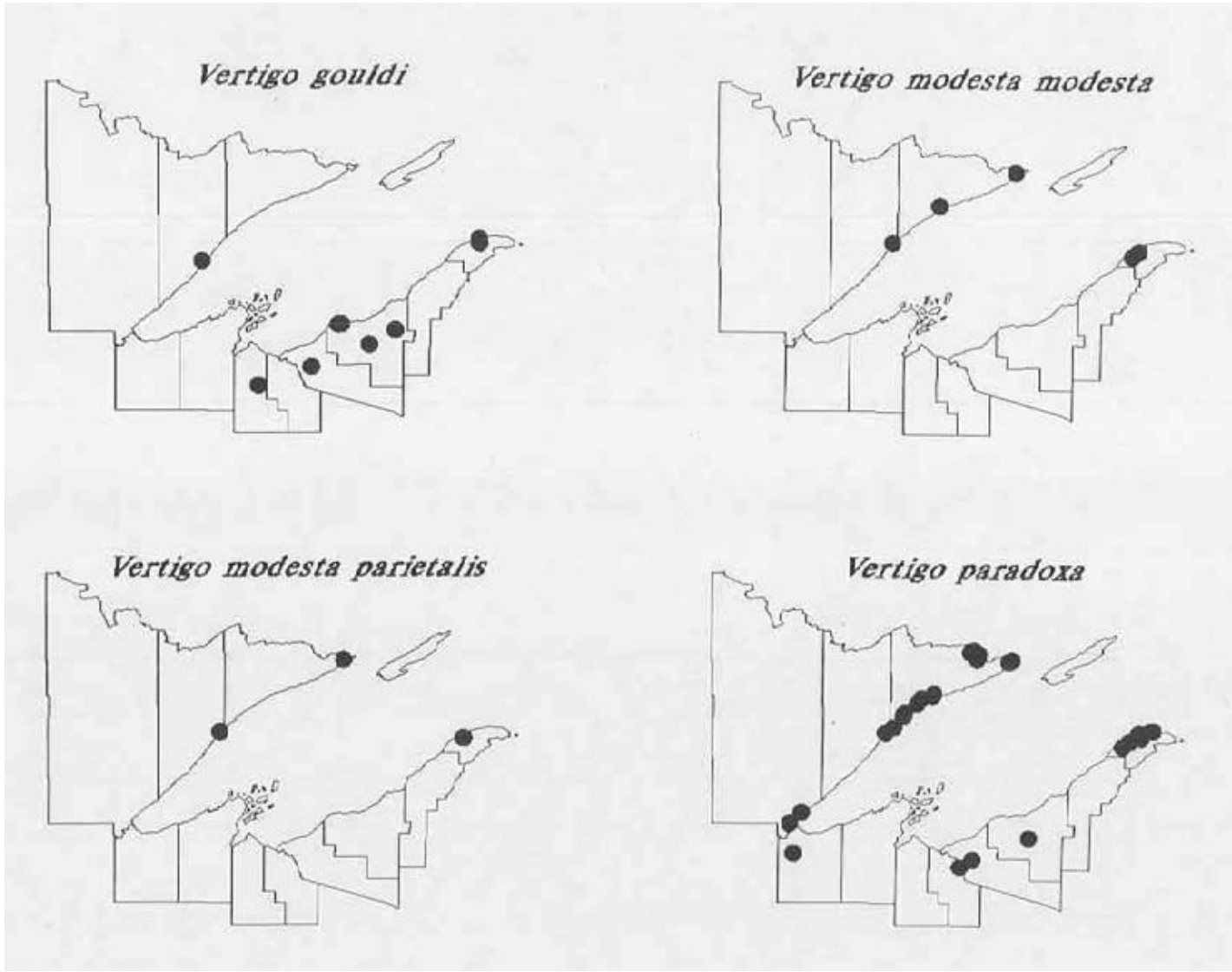


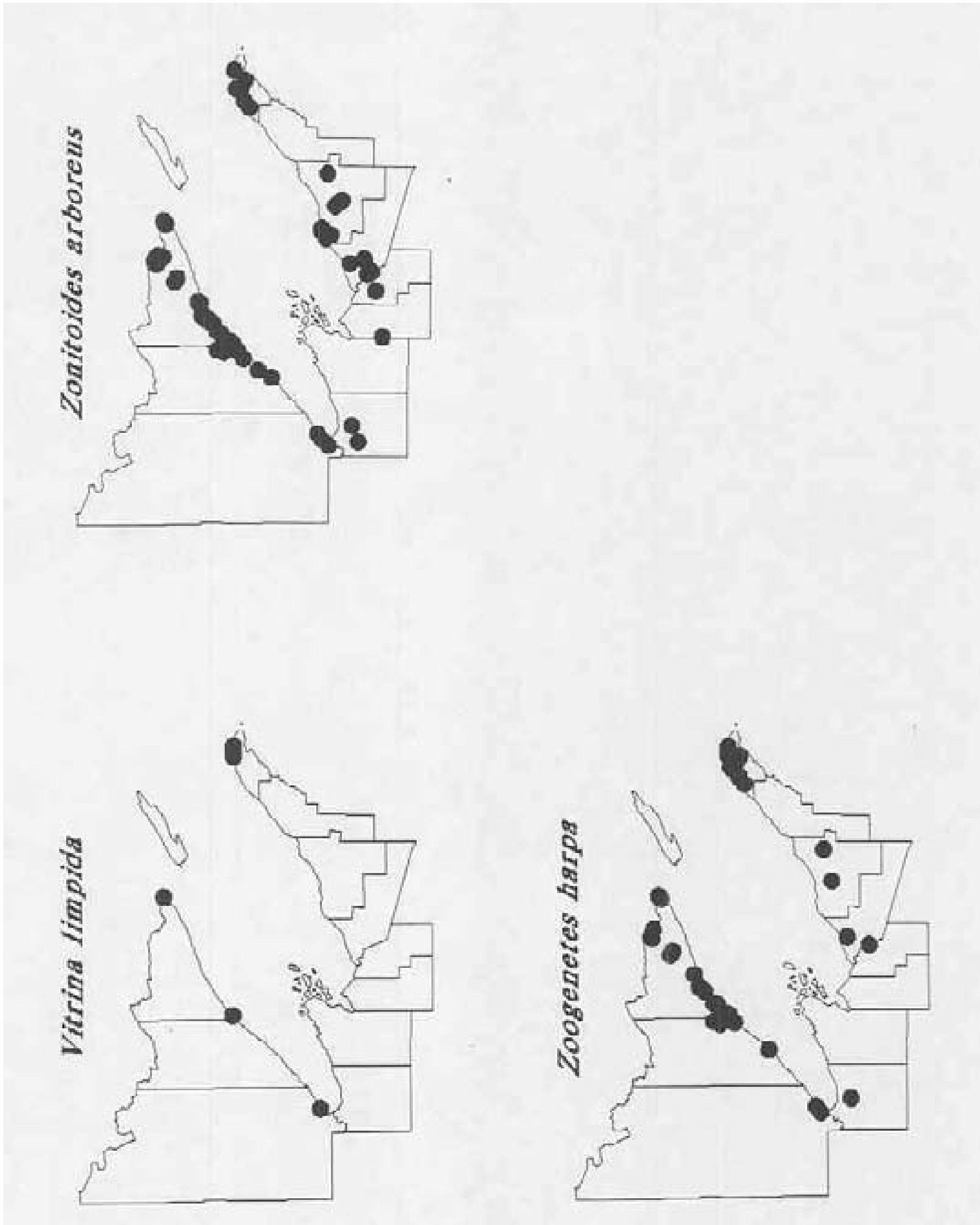
Euconulus fulvus
Discus cronkhitei
Gastrocopta tappaniana
Gastrocopta pentodon


Helicodiscus parallelus
Helicodiscus shimeki
Nesovitres binneyana
Nesovitres electrina


Punctum minutissimum
Striatura ferrea
Planogyra asteriscus
Striatura exigua


Strobilops labyrinthica
Striatura milium
Vertigo cristata
Succinea aff. ovalis


Vertigo gouldi
Vertigo modesta modesta
Vertigo modesta parietalis
Vertigo paradoxa


Zonitoides arboreus
Vitrina limpida
Zoogenetes harpa