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# The Plant Tension Zone in Michigan

Margaret Thompson McCann

# THE PLANT TENSION ZONE IN MICHIGAN

by

Margaret Thompson McCann

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Margaret Thompson McCann

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# CHAPTER I

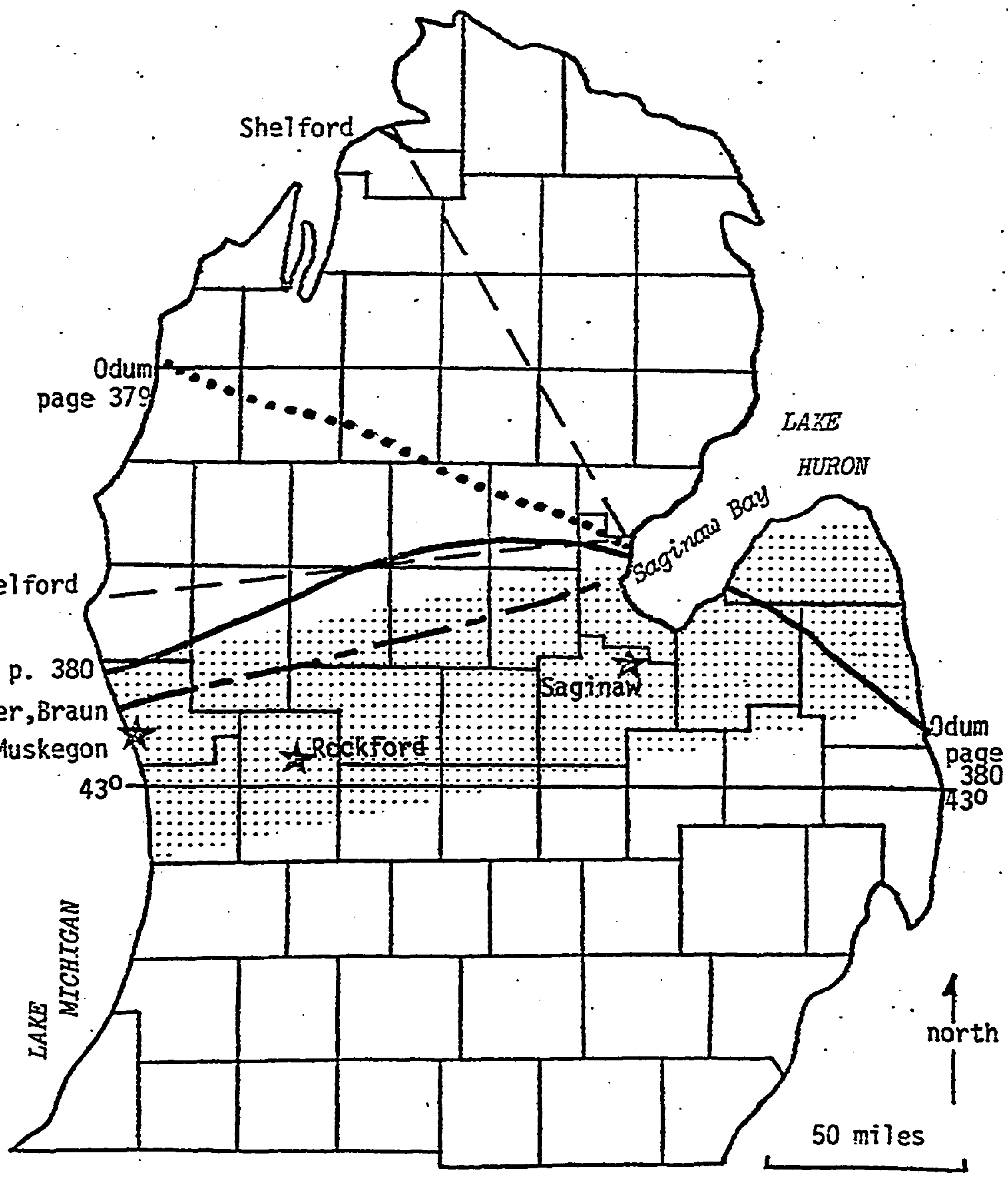
## INTRODUCTION

The vegetation of the northern part of Michigan's Lower Peninsula is markedly different from that of the southern portion. On maps of vegetation of the world or of North America, the northern Lower Peninsula is called the Northern Hardwoods Ecotone with Boreal Forest or generalized into the Northern Coniferous Forest (Odum, 1971; Brewer, 1979). The southern part is mapped as Temperate Deciduous Forest. Braun's (1950) subdivisions of the Eastern Deciduous Forest include the Hemlock-White Pine-Northern Hardwood Forest in the northern Lower Peninsula and the Beech-Maple Forest in the southern Lower Peninsula. Shelford (1963) called the northern Lower Peninsula Maple-Beech-Hemlock (with Coniferous Forest in the northeastern third) and the southern Lower Peninsula Maple-Beech. The names are not important here; what is striking is that even on highly generalized vegetation maps there is a line midway across the Lower Peninsula (Figure 1).

In Michigan, Livingston (1903a) noted the north-south division in Kent County plant societies, with pines mixed with hardwoods in the north but not southward. He referred to a "'zone of tension'" (page 96) along an east-west line passing through Rockford. Beal, in his Michigan Flora (1904), discussed the two zones in the Lower Peninsula and divided the hardwoods (south) from the pine country (north) at about 43$^{o}$ north latitude (Figure 1).

The tension zone, though often a line on a map, is an area where there is much change in vegetation in a comparatively narrow zone. Potzger (1946) suggested it is about 60 miles wide and goes from

Figure 1. The Lower Peninsula of Michigan with vegetation boundaries marked, after Braun (1950), Shelford (1963), Odum (1971), and Brewer (1979). The shaded area indicates the 60-mile wide tension zone of Potzgar (1946). 43° north latitude divided the forests of Beal (1904).



about Muskegon to Saginaw (the shaded band in Figure 1). In Wisconsin, Curtis (1959) mapped the vegetation tension zone using the range limits (southern or northern) of 182 species. These range limits were most concentrated in a band he called the tension zone. North of here the vegetation was different from the southern vegetation. The 182 species were not chosen to show vegetation differences; they weren't necessarily representative of southern or northern communities but were all the Wisconsin members of a family or genus. This showed that the vegetation tension zone in Wisconsin was also where many individual plant species reached their range limits, and suggested that herbarium records of the distribution of plants in Michigan would likewise show the Michigan vegetation tension zone.

My objectives were to (1) locate the tension zone in Michigan as shown by the range lines of many individual plant species, and (2) give a reasonable ecological or physiological explanation for it.

Geographical correlations with the tension zone have been made (Potzger, 1946; Curtis, 1959), but correlation alone is not evidence of cause. That the tension zone happens to match the isoline for some average summer temperature means no more than the correlations with institutions of higher learning, percent of population over 65, or any of the items in Table 1. Because mere correlation does not show cause, I used another approach. I chose factors which have been shown to determine plant ranges or which reasonably could be ecologically or physiologically limiting, then made hypotheses as to the sort of tension zone each would shape and attempted to disprove these hypotheses. Although different species

Table 1. Some factors which correlate with the vegetation zones in the Lower Peninsula of Michigan. Counties north of and including the Oceana to Huron row are counted as northern; Muskegon to Sanilac counties and southward are counted as southern. Data from Senninger (1970).

| Feature | Northern | Southern |
|---|---|---|
| Number of counties with: | | |
| 1967 retail trade over $100,000,000 | 1 | 15 |
| Fewer than 50 persons per square mile | 29 | 1 |
| At least 50 persons per square mile | 5 | 33 |
| Under 10% of the population 65 years of age or older | 5 | 21 |
| At least 13% of the population 65 years of age or older | 9 | 0 |
| 1964 death rate of 11 per 1000 and higher | 23 | 4 |
| 1964 death rate under 11 per 1000 | 11 | 30 |
| 25% or more of the families with incomes under $3,000 in 1960 | 27 | 3 |
| At least 1,000 employed in construction | 2 | 24 |
| Number of institutions of higher learning | 11 | 65 |
| Number of flour mills, breweries, and wineries | 4 | 31 |
| Number of motor vehicle assembly and parts plants in 1969 | 2 | 100 |

might be limited by different factors, there may be a general explanation for many of the range boundaries and thus for the tension zone. It was such a general factor I hoped to find.

## CHAPTER II

## METHODS

### Data Collection

County distribution records of 649 species of vascular plants having a range boundary in the Lower Peninsula of Michigan were the data base (Appendices 1 and 2). Michigan occurrences by county for lower vascular plants (Billington, 1952) and for gymnosperms and monocots (Voss, 1972) have been published. For a few dicots, suitable Michigan distribution maps have been published; where boundaries occurred in the Lower Peninsula, I used these (noted in Appendix 1). For the rest of the dicots, I made a list of about 600 species likely to have a range boundary in the Lower Peninsula based on the range given by Gleason and Cronquist (1963) or Beal (1904, 1908). I then recorded herbarium records by county at the following herbaria: Western Michigan University (WMU), University of Michigan (UM), and Michigan State University (MSC). Specimens were not carefully verified; a few obvious mislabellings were not used, and difficult genera were used only if the specimens were noted as verified. Local flora lists (Cole, 1901; Beal, 1904, 1908; Hanes and Hanes, 1947; Swink, 1969; Mustard, 1979) were used as supplements. Appendix 1 includes the county distribution maps for the 317 dicot species with a range boundary in the Lower Peninsula. Appendix 2 lists the lower vascular plants, gymnosperms, and monocots used.

A species was considered to have a range boundary in the Lower Peninsula (and thus included in the data set) if it was found in no more than three Lower Peninsula counties outside the bulk of the

county records. Floras of Indiana (Deam, 1940) and Ohio (Braun, 1967) were checked for the occurrence of northern plants which may have had a range boundary close to the Michigan state line, because Michigan data alone would show these as occurring throughout the state.

Life forms were determined for the flowering plants after Ennis (1928) and McDonald (1937). Where these sources disagreed and for species not listed, Gleason and Cronquist's (1963) description was used. A few plants were listed as annual or biennial; these were counted as annual, as that would be the case in the coldest winters.

Manipulation of Data

The distribution data were used in two ways: for range lines and for calculation of a zone index value for each county. Range lines were drawn for the species where ranges were reasonably unambiguous. I allowed three disjunct county records, and drew the lines to the centers of the counties (see Appendix 1 for individual range lines). For purposes of clarity in illustrations which included many range lines, they are not all drawn to the centers as this would result in too much overlap. Secondly, for each county a zone index was calculated as $\frac{\frac{S_c}{3} - N_c}{\frac{S_c}{3} + N_c}$ where $S_c$ and $N_c$ are the number of southern and northern species collected per county. The division by three adjusts for the three times greater number of southern species so that where all the southern and all the northern species are found the

index value is 0. With only southern species, the zone index equals +1; with only northern species, -1.

Uses of Range Lines and Index Values

A problem with distribution data is that it is not known whether a species is actually missing from an area (here, a county) or if it simply has not been collected and included in the data set. The problem is worse where collecting effort is uneven, as in Michigan (Voss, 1972). Figure 2 shows the number of southern plus the number of northern species recorded per county; it is difficult to believe that Sanilac County actually has under one-eighth the species of St. Clair County, and Presque Isle County half that of Cheboygan and Ogemaw half that of Presque Isle. Range lines fill out the data, bridging gaps in the distribution: if a county has no record of species A but it is found in adjacent counties, the range will include that county. Because they can give the appearance of data where there is no data, range lines were not drawn for species with few and scattered records. Index values have the advantage of using all the data and only the data; no subjectivity is involved. Proportional undercollecting is not a problem.

However, range lines have an important use: they show trends of individual species ranges which are lost with indexes. For example, if the number of southern plants collected per county was as in Figure 3 A and the number of northern plants was as in B, index values would be as in C. The index values are calculated on the basis of the total number of northern and southern plants collected per county, no matter what odd combination of ranges produced that

Figure 2. Names of counties, and the number of northern plus the number of southern species of plants collected.

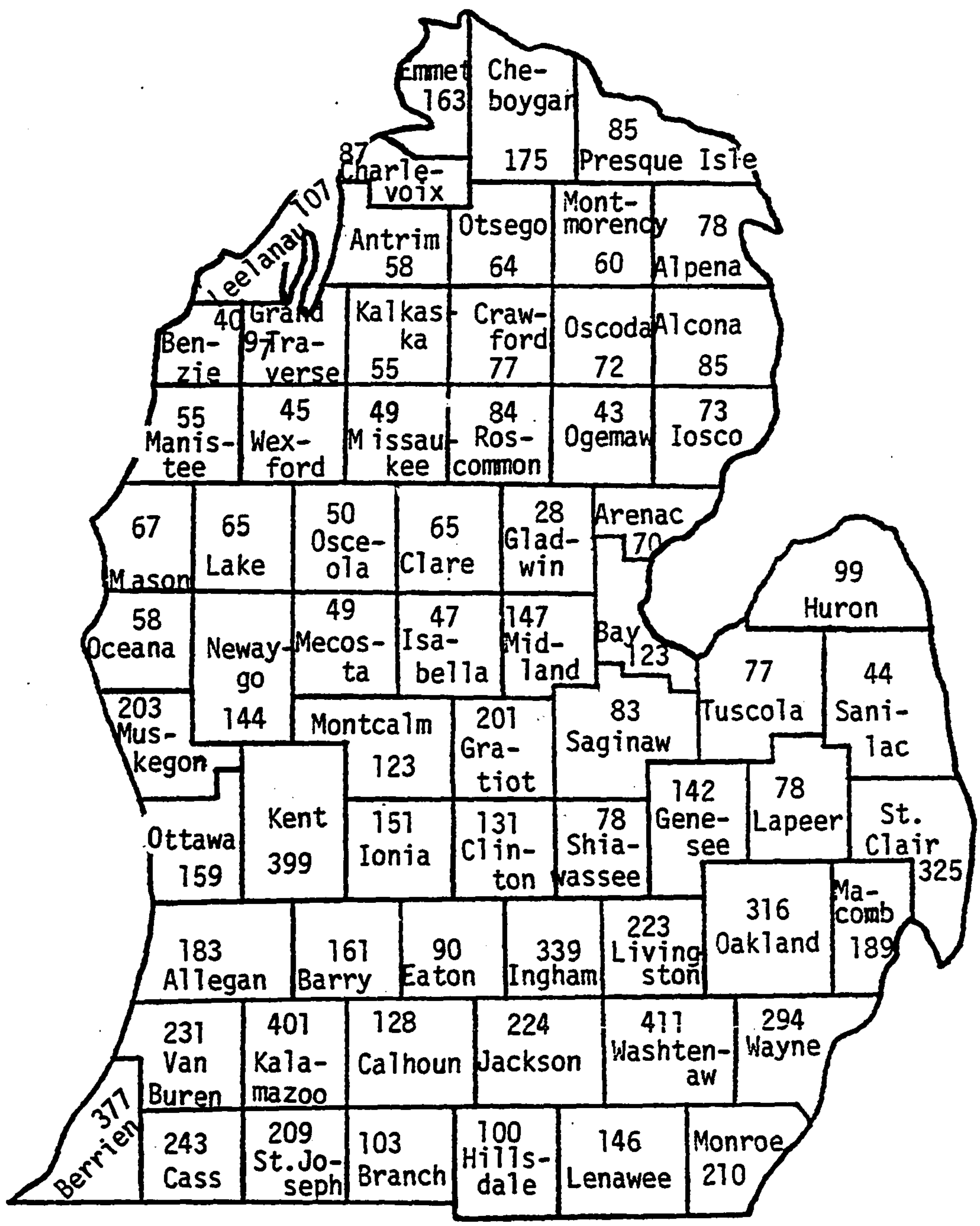


Figure 3. Several distributions which will produce the same zone index values and tension zone.

| | | | |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 15 | 15 | 15 | 15 |
| 15 | 15 | 15 | 15 |

A
number of southern plants per county

| | | | |
|---|---|---|---|
| 15 | 15 | 15 | 15 |
| 15 | 15 | 15 | 15 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |

B
number of northern plants per county

→

| | | | | |
|---|---|---|---|---|
| -1 | -1 | -1 | -1 | |
| -1 | -1 | -1 | -1 | tz |
| +1 | +1 | +1 | +1 | |
| +1 | +1 | +1 | +1 | |

C
zone index values per county; tension zone at "tz"

| | | | |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 15 | 15 | 0 | 0 |
| 15 | 15 | 0 | 0 |

D

| | | | |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 15 | 15 |
| 0 | 0 | 15 | 15 |

E

With southern plants as either D+E or F+G, the total number of southern plants is A.

| | | | |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 8 | 7 | 8 | 7 |
| 7 | 8 | 7 | 8 |

F

| | | | |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 7 | 8 | 7 | 8 |
| 8 | 7 | 8 | 7 |

G

| | | | |
|---|---|---|---|
| 50 | 50 | 50 | 50 |
| 1 | 1 | 1 | 1 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |

H
number of northern plants per county

With northern plants as either H or B, and southern plants as A, the zone index values and tension zone are as in C.

total. For example, the southern plants could have been comprised of two groups with exclusive ranges (D and E) or two groups with overlapping ranges (F and G). The number of plants collected per county would be identical with A, so the zone index values and tension zone (C) would be identical with either set. Likewise, index values treat northern and southern species together, so that different trends of northern and southern species are not shown. For example, different northern distributions---B and H---would give the same zone index values and tension zone.

The distribution of range lines was tested by $X^2$ (Cox, 1976). A line was drawn along $85^o$ west longitude and divided into ten 20-minute segments of latitude from $42^o$ to $45^o20'$ north latitude. The distribution of range lines across this line was tested. The null hypothesis was that, on the average, range lines would be distributed evenly among these 10 segments of 20 minutes of latitude. A significant difference would indicate a concentration of range lines into a tension zone.

## CHAPTER III

## FLORISTIC EVIDENCE FOR A TENSION ZONE

A floristic tension zone is a concentration of range lines of many species; a vegetation tension zone reflects a change in the abundance of the dominant species (such as trees). To test the hypothesis that the tension zone is a floristic tension zone, not only a vegetation tension zone, range lines were used.

A map of the southern limits of northern species (Figure 4) shows no concentration of range lines in the middle, where a tension zone would be ($\alpha > .925$, not significantly different from an even distribution). The northern flora, then, does not show a tension zone. This is not surprising, because many of the stations are probably relicts of a more extensive distribution during postglacial times. Herbarium data, such as used here, would not reflect any scarcity of northern plants in the south; on the contrary, rarity would make them sought after by collectors. As many northern species have been collected in some southern counties (Oakland, 47; Washtenaw, 34) as in several northern counties (Ogemaw, 21; Manistee, 31; Antrim, 45) (Figure 5).

The northern range lines of southern plants, however, do form a tension zone ($\alpha < .005$, a significant difference) (Figure 6). The range lines are concentrated in a broad band from Muskegon to Bay to St. Clair County. Fewer than 9% of the 494 southern species have been collected in any one county north of the band (Figure 7).

The trends of the range lines of southern plants are clearer if divided into groups. Range lines which run fairly straight

Figure 4. Southern range limits of northern plants in the Lower Peninsula of Michigan.

Figure 5. The number of northern plants collected per county.

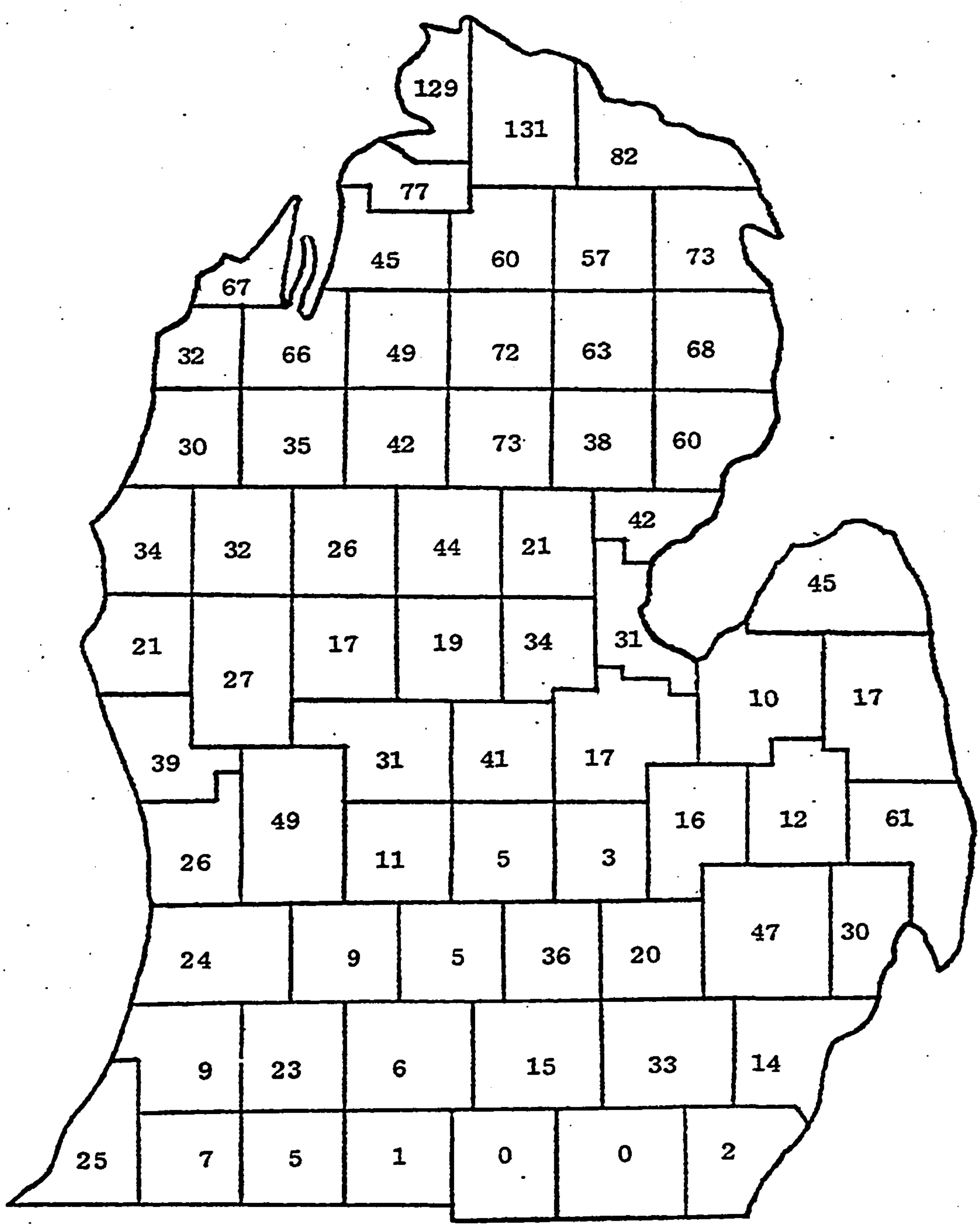


Figure 6. Northern range limits of southern plants in the Lower Peninsula of Michigan.

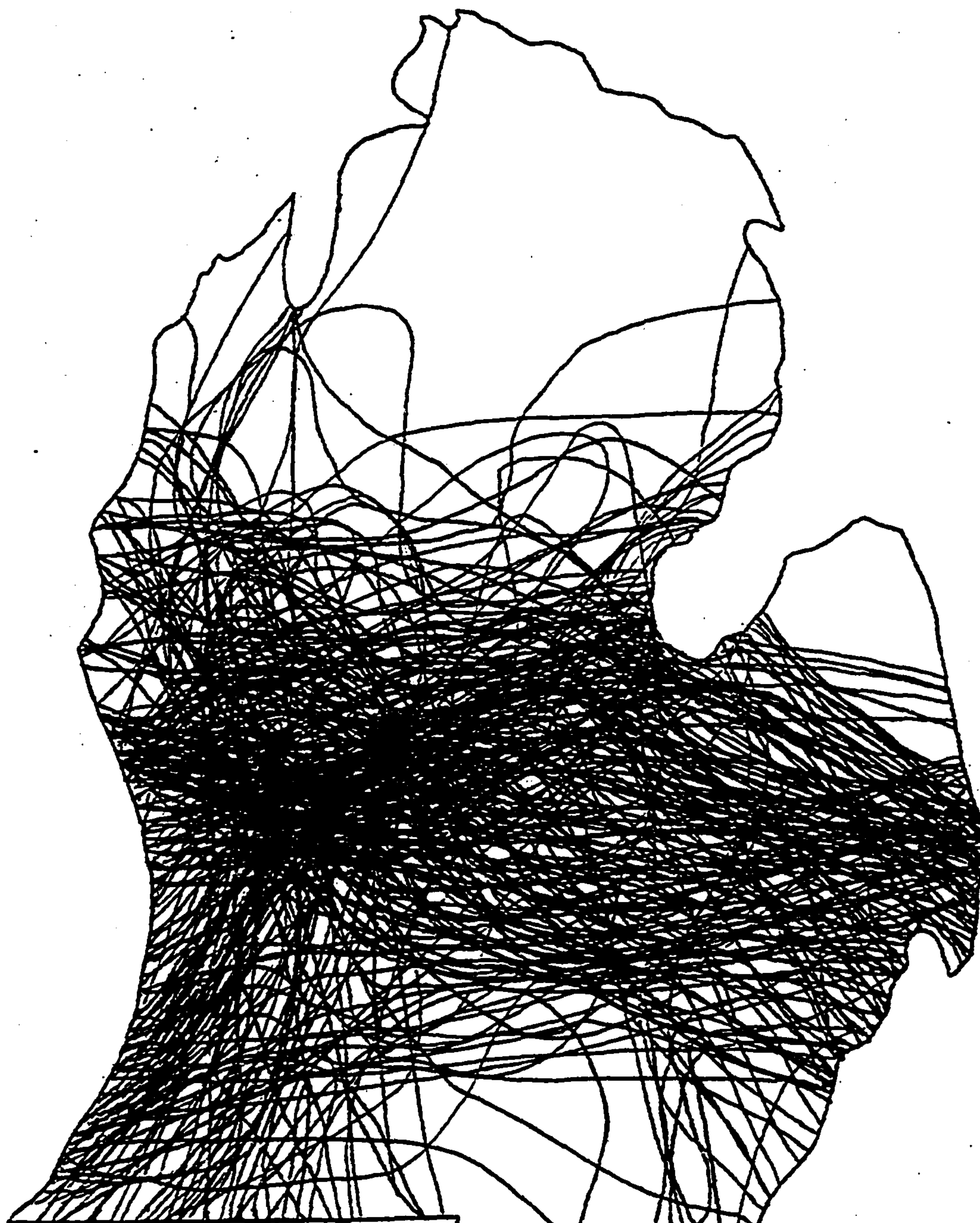
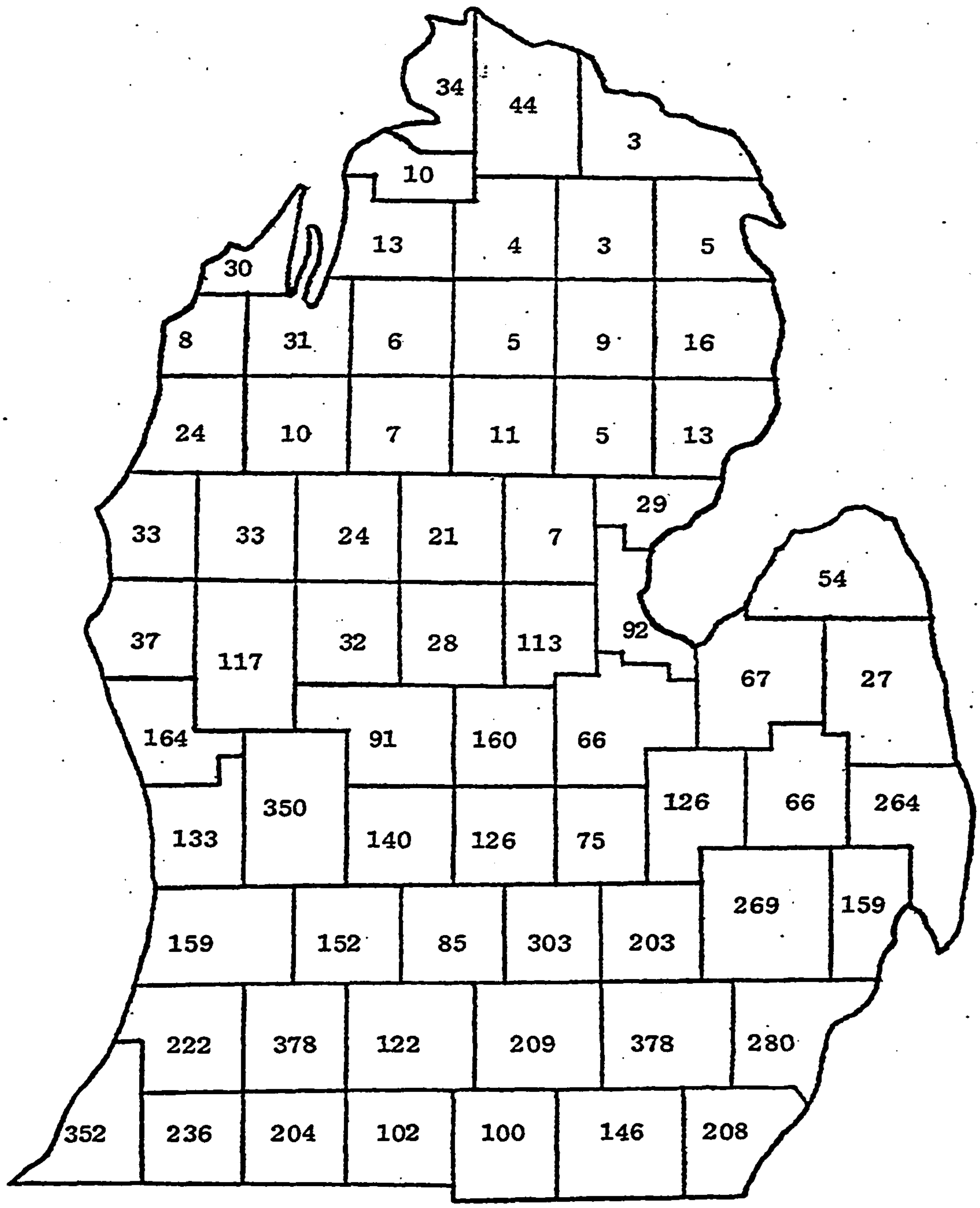


Figure 7. The number of southern plants collected per county.



east-west are mostly in the middle of the peninsula (Figure 8). Range lines which turn north at Lake Michigan are mostly north of here (Figure 9). In the south, they bend south at Lake Michigan (Figure 10). There is also a southward dip around Oakland and Macomb counties, and a southern turn in the thumb.

The isolines of the zone index values show similar trends (Figure 11). The zero value---the center of the tension zone shown by this method---is from Muskegon to Bay to northern St. Clair County, like the band shown by the northern limits of southern plants. The most negative (north) values are in the northeast, showing that the southern influence is stronger along Lake Michigan. In the south, the isolines are widely-spaced, reflecting the northern species found in the south. The lines turn south at Lake Michigan and around Oakland and Macomb counties, as fewer southern (or more northern) plants are found there than in the center of the south.

Figure 8. Northern range limits of southern plants which are fairly straight east-west.

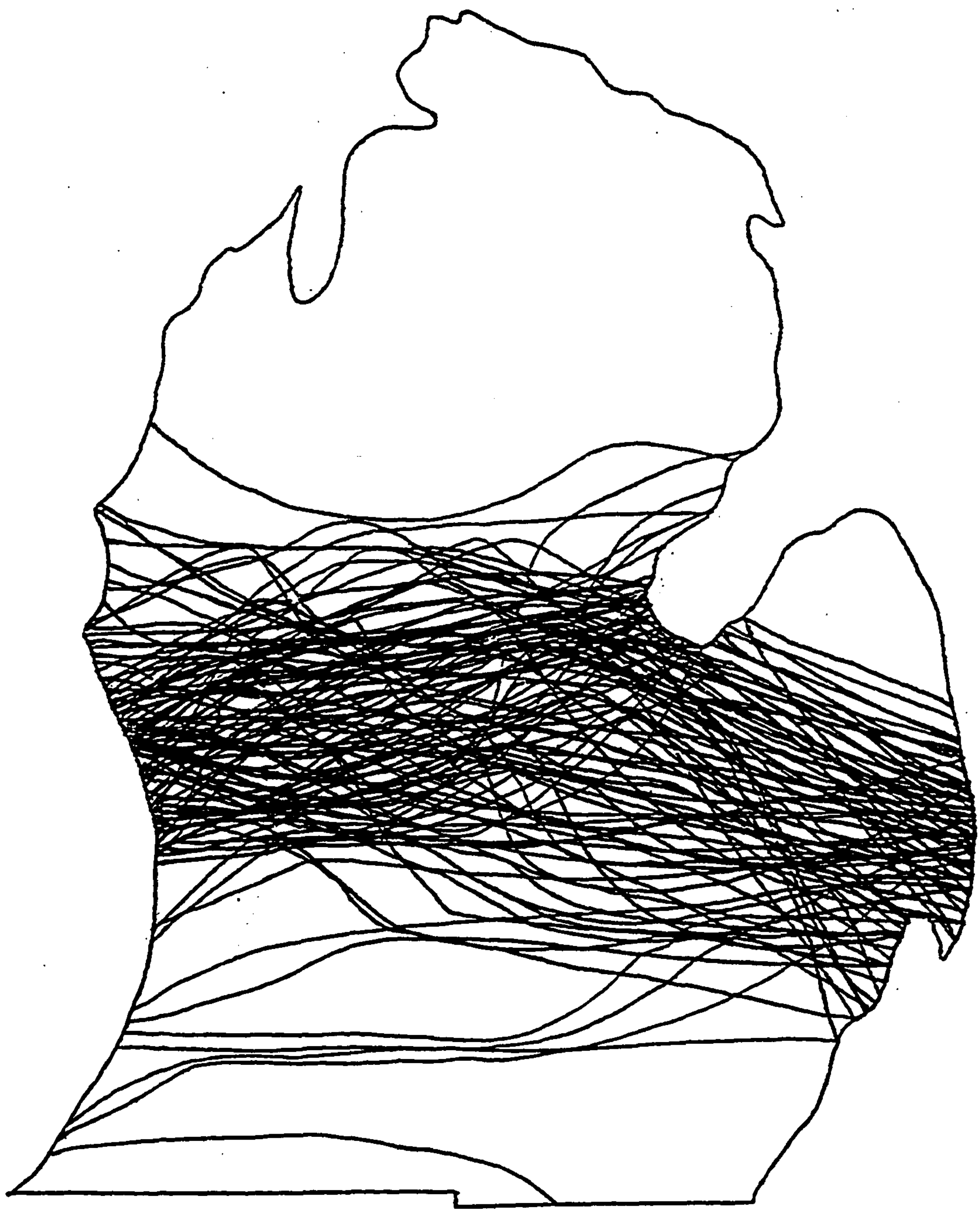


Figure 9. Northern range limits for southern plants which are found farther north along Lake Michigan than in the center of the peninsula.

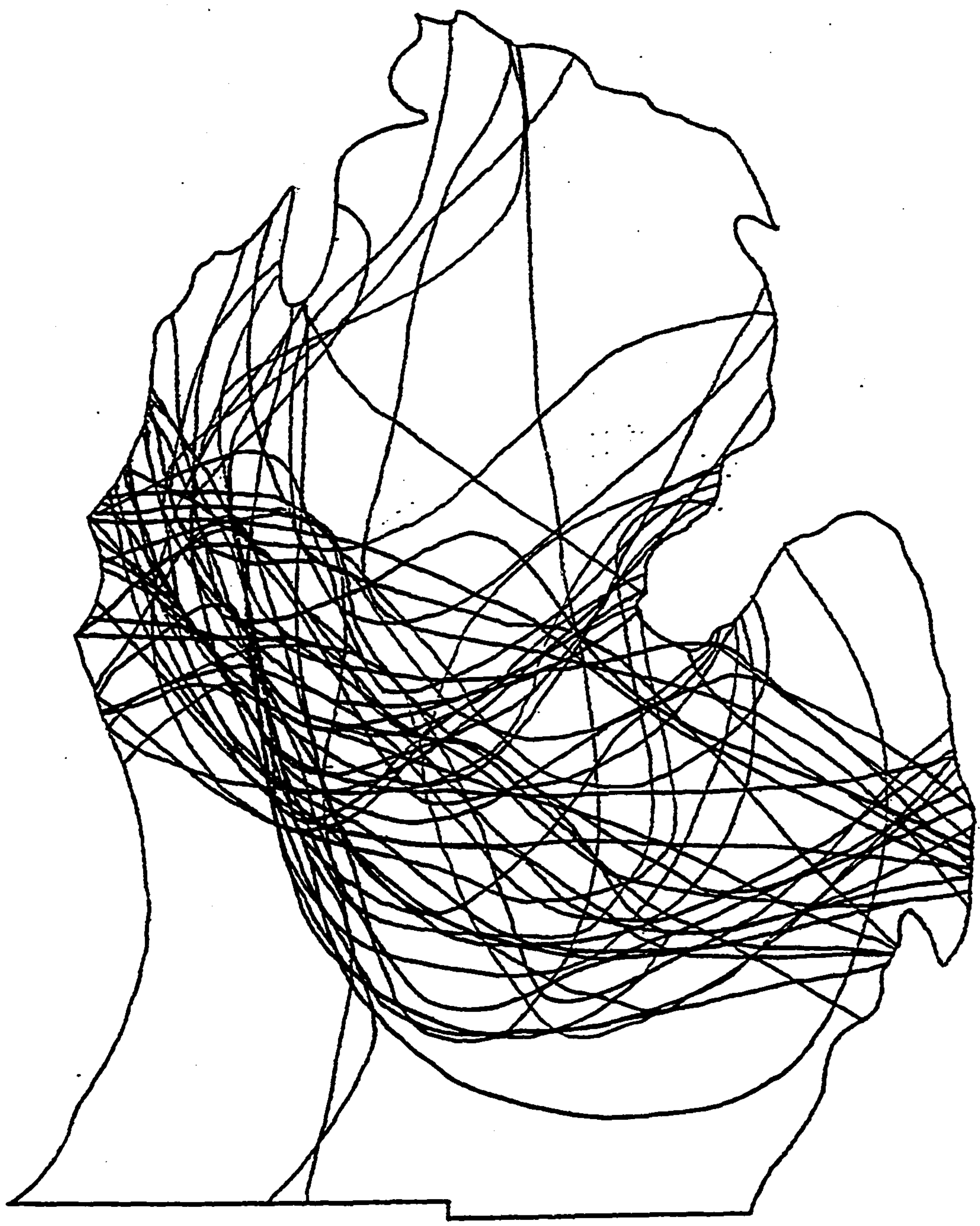
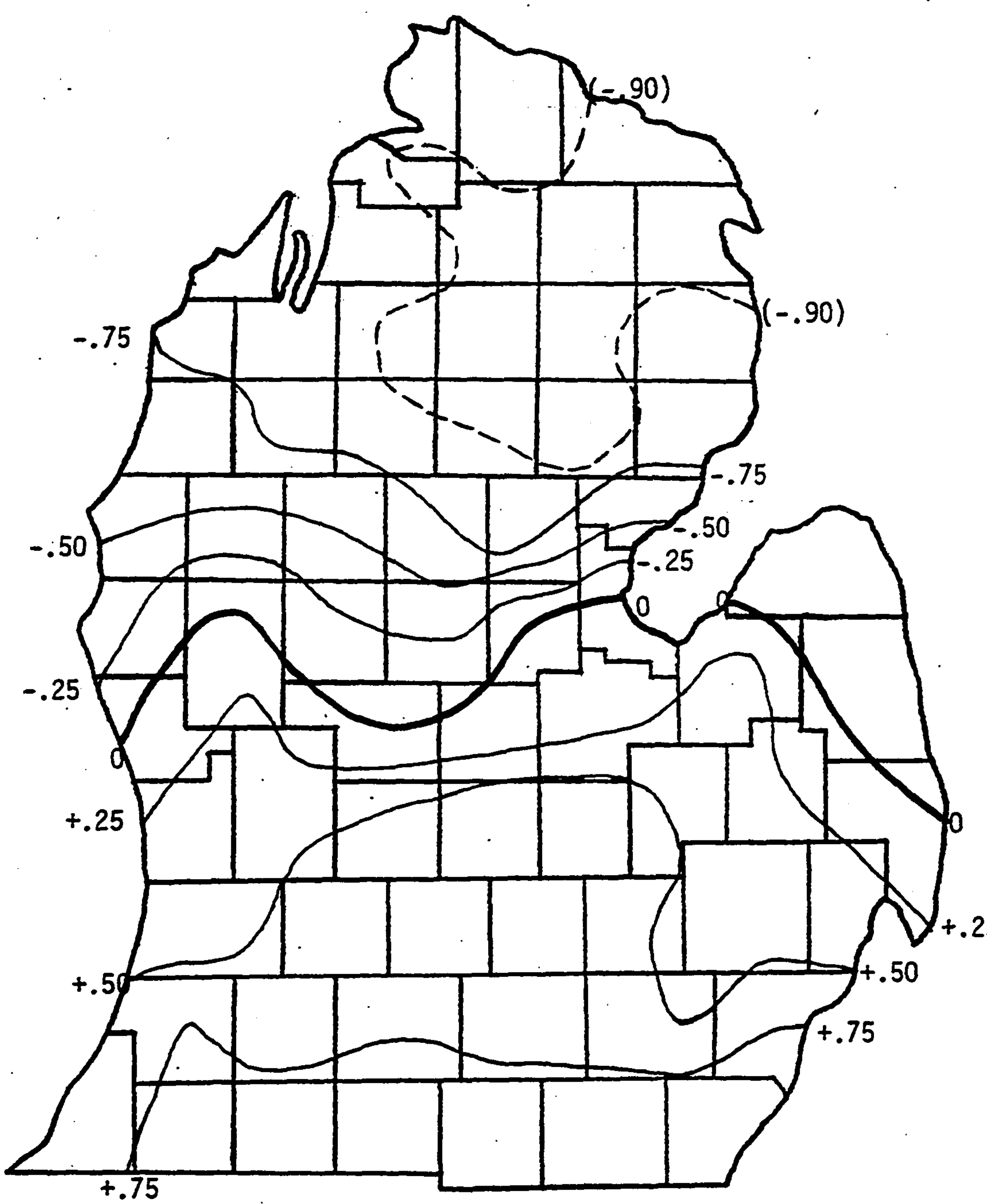


Figure 10. Northern range limits of southern plants which are found farther north in the center of the peninsula than at Lake Michigan.

Figure 11. Isolines of zone index values. The zero line is the center of the tension zone shown by this method.



# CHAPTER IV

## POSSIBLE CAUSES OF THE TENSION ZONE

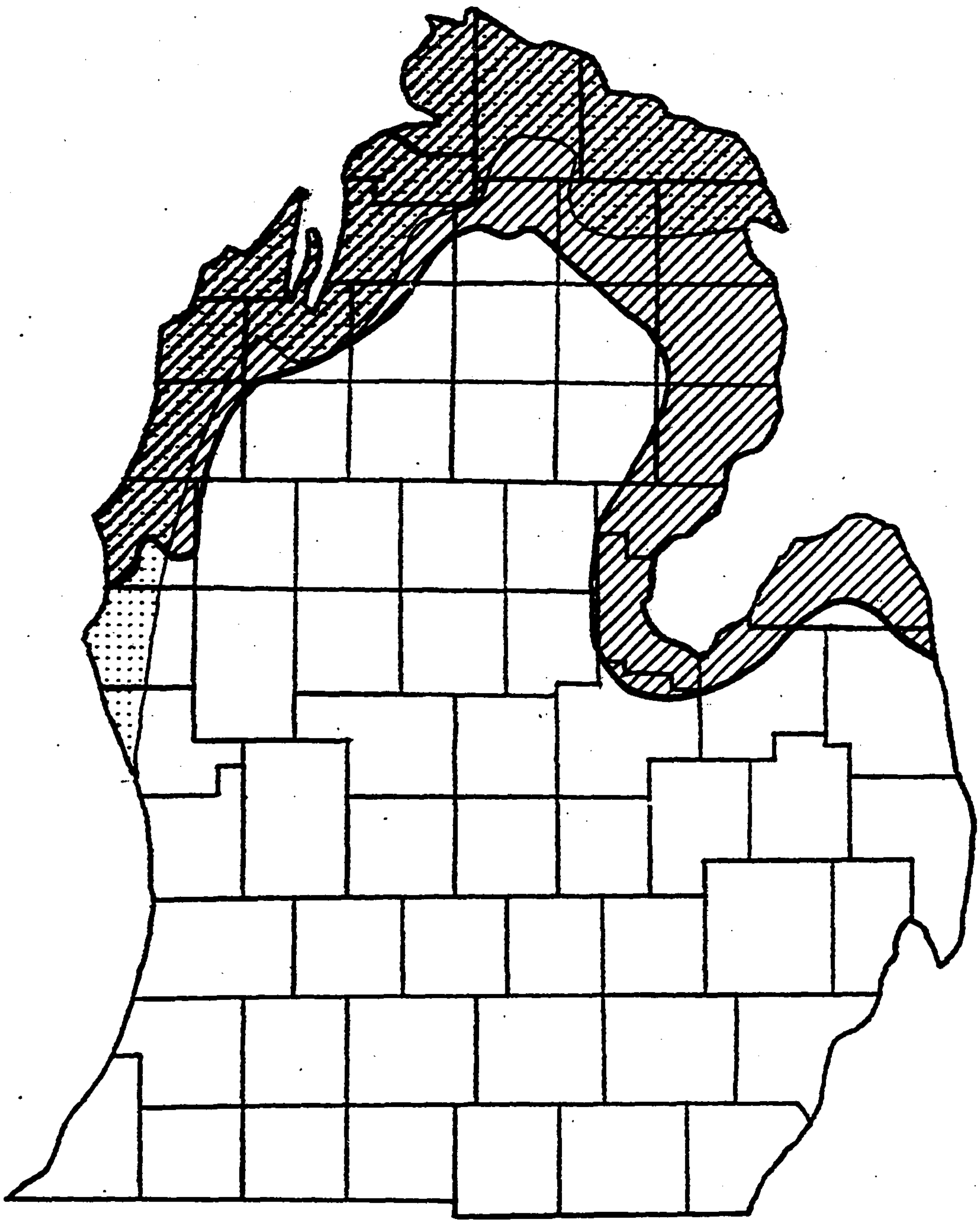
### Soils

Since the tension zone was probably established as a zone of marked vegetation change since some 10,000 years ago (Potzger, 1946; Curtis, 1959), if soil differences caused the tension zone they would have had to be present then, and thus due to differences in parent material or effects of climate rather than differences in the effects of vegetation on soils. The persistence, not the establishment, of the tension zone may be encouraged by soil differences caused by vegetation.

Michigan's soil parent material is glacial drift; there are ground and end moraines, outwash plains, and lake sediments (Dorr and Eschman, 1970). Plant communities do vary with soil origins (Livingston, 1903b; Brubaker, 1975) but all these are found throughout the Lower Peninsula. However, the origins of this parent material may be different. For instance, the Valders readvance carried red silt and clay from Lake Superior and the western Upper Peninsula to some of the northern Lower Peninsula and the Lake Michigan shoreline north of Muskegon (Dorr and Eschman, 1970) and the Cary readvance carried less fertile soil (Spurr, 1962). If plant boundaries were determined by different soil parent material, they would occur at the boundaries of drift carried by each glacial lobe, or something like Figure 12. This is not the case.

The present soil differences are probably the result of vegetation and climate rather than causing the vegetation difference.

Figure 12. The Cary readvance carried material to the striped area, the Valders to the shaded area. After Farrand and Eschman (1974).

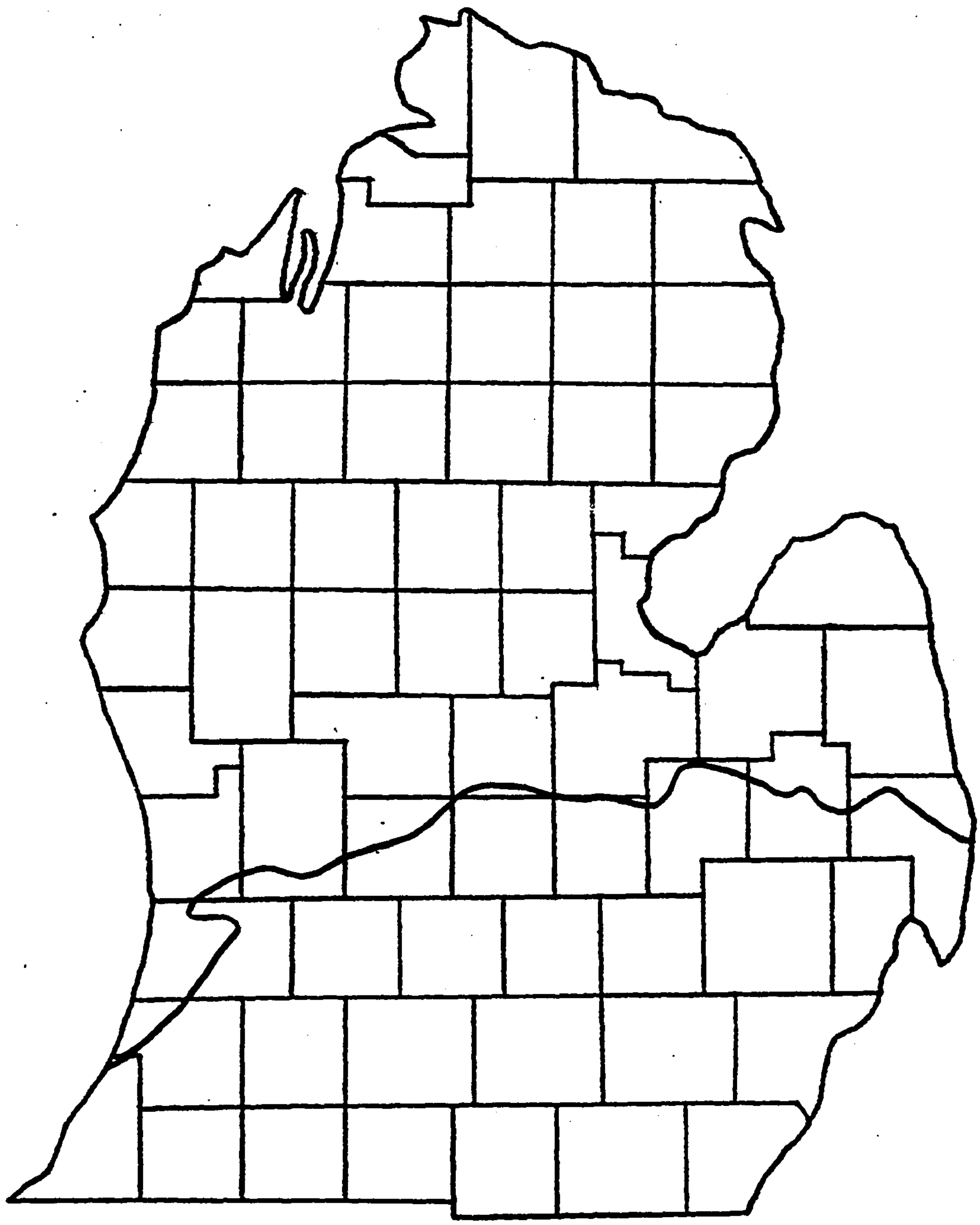


Podzols, as in the northern Lower Peninsula (Figure 13), are formed in a climate where evaporation is low so that water (carrying dissolved mineral nutrients) moves mostly downward through the soil. Coniferous vegetation adds to this process: they take very little from the subsoil or parent material and cycle very little to their needles and thus to the soil surface (Curtis, 1959; Eyre, 1968). The southern soils are Gray-Brown Podzolic (Forest) Soils, a hybrid group between Podzols and Brown Forest Soils. Broad-leaved trees counteract previous podzolization by moving nutrients from the root zone to leaves to the soil surface, and higher evaporation helps by slowing the downward movement of water (Curtis, 1959). It is likely that podzols were formed first, under the postglacial coniferous forests, and depodzolization occurred later with the warming climate and the invasion of broad-leaved trees. Currently the Podzol/Gray-Brown Podzolic (Forest) Soil boundary is south of the vegetation boundary, evidence for the lag time between vegetation change and resultant soil change.

## Topographical Barriers

Topographical barriers, such as mountain ridges or large bodies of water, can block the migration of plants and thereby make range boundaries. Northern plants have managed to migrate into the northern Lower Peninsula, so if there is or was some barrier causing the tension zone it must either be selective, so that only northern species can pass it, or it could be that northern species migrated into the north before a barrier was established at the tension zone.

Figure 13. Generalized soils of Michigan, after Whiteside et al. (1956). Gray-Brown Podzolic (Forest) Soils are in the south and Podzols are in the north.



An east-west mountain ridge, inhospitable to many plants in its alpine heights, and without passes, could keep southern plants south of it until they migrated around the Great Lakes and into the northern Lower Peninsula from the north. However, there is no such east-west mountain ridge in Michigan; even the belts of hills the glaciers left are mostly north-south (Dorr and Eschman, 1970).

The Grand River valley is at about the right location for a tension-zone-causing barrier. However, only at about 12,500 years ago, when it was the Ubly outlet channel of Glacial Lake Whittlesey, would it have been a formidable barrier though swampland persisting there could have been an obstacle to migration for a longer time (Fitting, 1975). For the last several thousand years it has been unimportant as a barrier to plant migration (Davis, 1976; Kapp, 1977) and cannot account for the tension zone.

## Climate

Several authors (Potzger, 1946; Curtis, 1959) have suggested that the tension zone is caused by some aspect of climate. Potzger (1946:172) pointed out that several climatic factors had "important dividing lines" there. He does not state, however, why (for example) 40 inches of frost penetration for January would be more important than 39 or 41 inches. Any area can be described by a set of climatic values, but it is unlikely that the same set is important for many plants. Only in two ways could climatic factors determine a tension zone: (1) A single value for a climatic variable could be more important than higher or lower values; where that value occurred would be many range boundaries. A few such values exist; for instance,

many organisms have an upper lethal temperature of around 45° to 50° C. (Levitt, 1972). Where temperatures reached 45° to 50° there would be more range boundaries than where temperatures reached 35° to 40° or 55° to 60°. However, there are no such values clearly limiting species in Michigan. (2) A limiting climatic factor which changes more rapidly in a certain region could create a tension zone there. It is more likely that climate would account for the tension zone in this second manner.

Precipitation

Inadequate. Plant range limits may be caused by inadequate precipitation (Klages, 1942). This could reasonably limit southern or northern plants. If the tension zone were caused by precipitation inadequate for plants on one side of it, we would expect the tension zone to be oriented north-south, since the eastern side of the Lower Peninsula is drier than the western side (Figure 14). The zone would be very broad, as the isohyets of mean annual precipitation are not more closely spaced in one area than in another. This is not the case.

Seasonal. It is more likely that precipitation during a particular period of the year, perhaps just before and during the growing season, could be critical (Klages, 1942). There are seasonal differences in the distribution of precipitation in the Lower Peninsula (Brunnschweiler, 1962); if the tension zone is caused by inadequate spring rainfall limiting southern plants, we would expect range lines to look like the isohyets of spring precipitation (Figure 15): there would be a minor concentration of range lines across from Ottawa to Shiawassee County, with some plants found only in

Figure 14. Mean annual precipitation in inches, 1931-1952, from Brunnschweiler (1962).

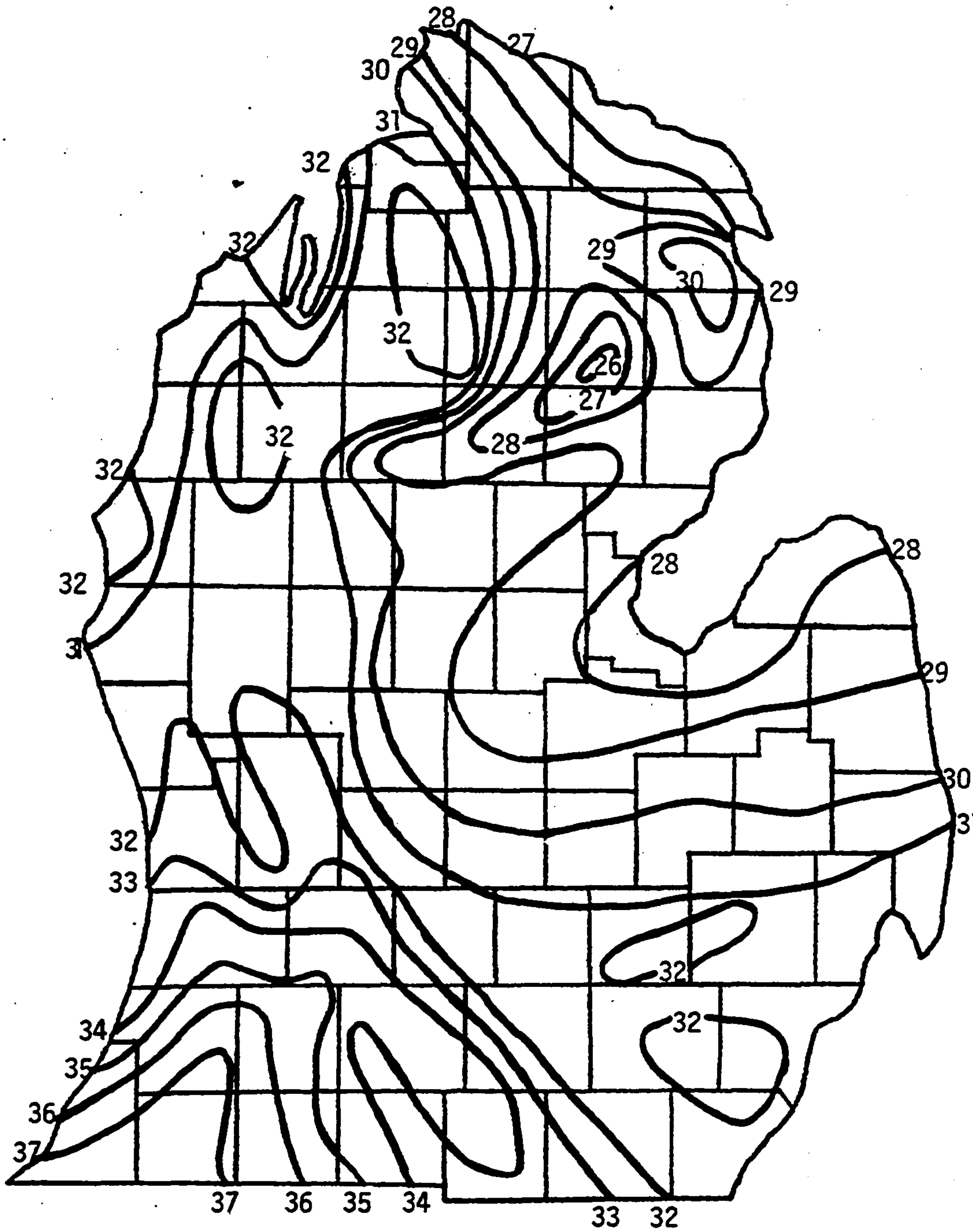
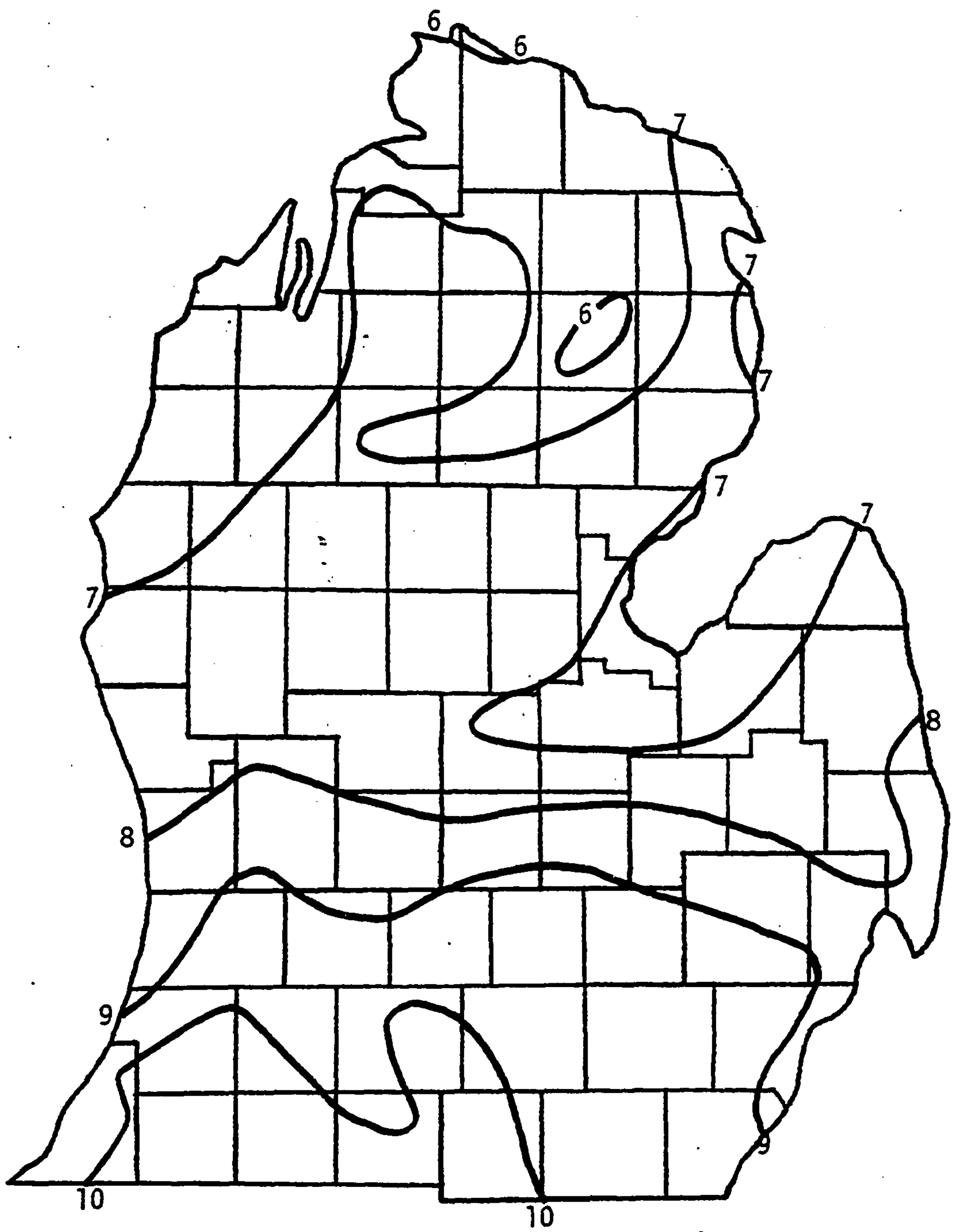


Figure 15. Spring precipitation in inches, after Brunnschweiler (1962).



Branch, Hillsdale, St. Joseph, or Cass counties but not in the extreme southwest or southeast. The actual range lines (Figures 4 and 6) do not look like that, so inadequate spring precipitation does not cause the tension zone. If summer precipitation were critical, we would expect some plants to be limited to the wetter areas of the southwest and the central northern counties (Figure 16). Again, this is not the case.

Variability. Perhaps some other facet of precipitation, such as variability, causes the tension zone. Dry seasons which occur regularly are not a problem, but unseasonable droughts kill plants (Meineke, 1925; Daubenmire, 1974). If the tension zone is caused by variable precipitation, we would see range boundaries densest northwest of Saginaw Bay where the changes in precipitation variability are greatest. Range lines would run northeast to southwest like the isolines of variability (Figure 17). The plant range lines are not like that. Another way of expressing precipitation variability is the number of days with precipitation (Figure 18). If this were important in determining range limits, there would be no tension zone; range lines would be fairly evenly distributed across the Lower Peninsula and generally run north-south, not east-west as they do.

Glaze. There are some other, less obvious, aspects of precipitation which limit at least some plants. Glaze storms, for instance, damage trees (Lemon, 1961); they could determine range limits. There are more days with glaze in the western Lower Peninsula than in the east (Figure 19), but there is not the north-south division of the tension zone.

Figure 16. Summer precipitation in inches, after Brunnschweiler (1962).

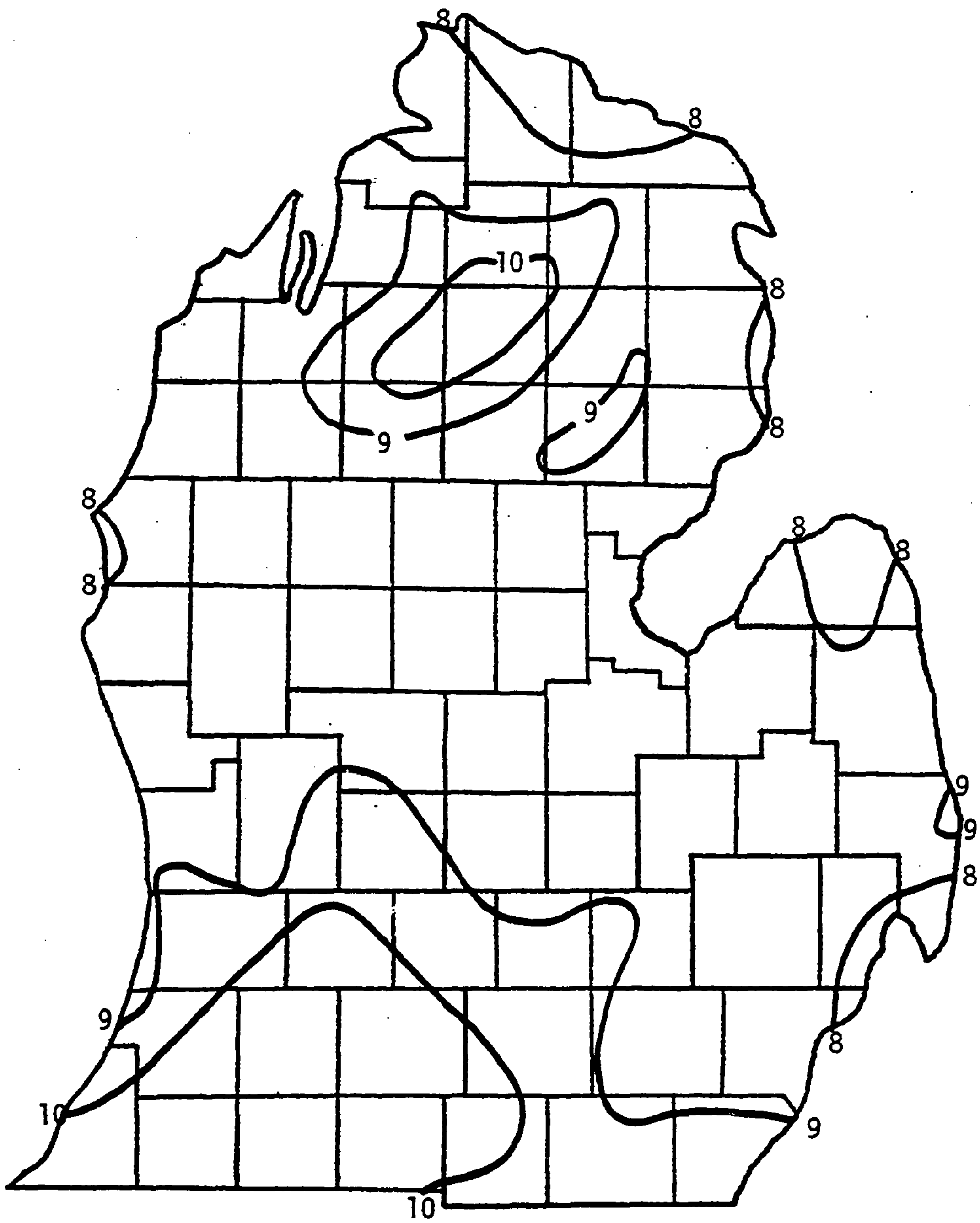


Figure 17. Percentage coefficient of variation of mean annual precipitation, after Niedringhaus (1966).

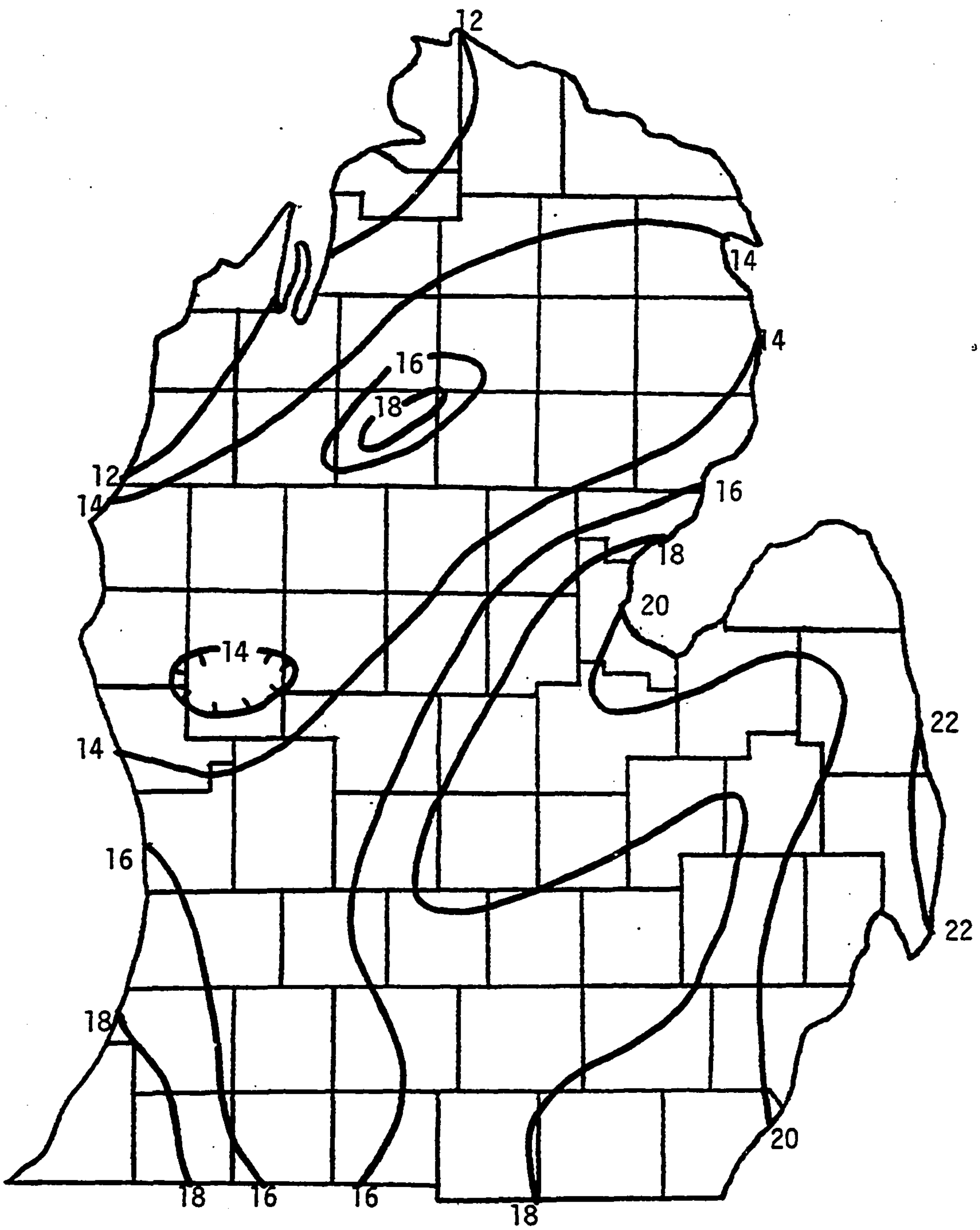


Figure 18. Mean number of days with at least .1 inch of precipitation, after Niedringhaus (1966).

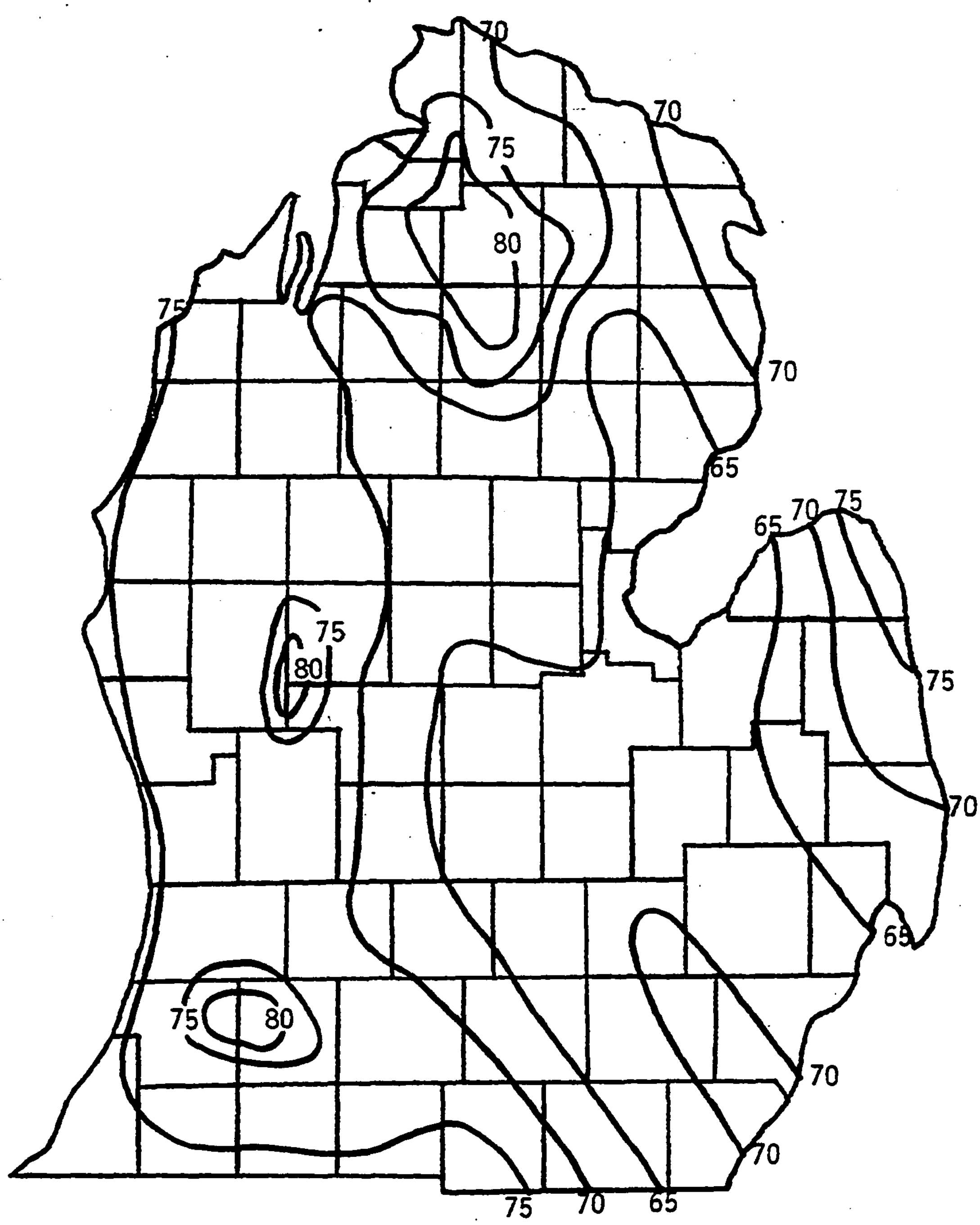
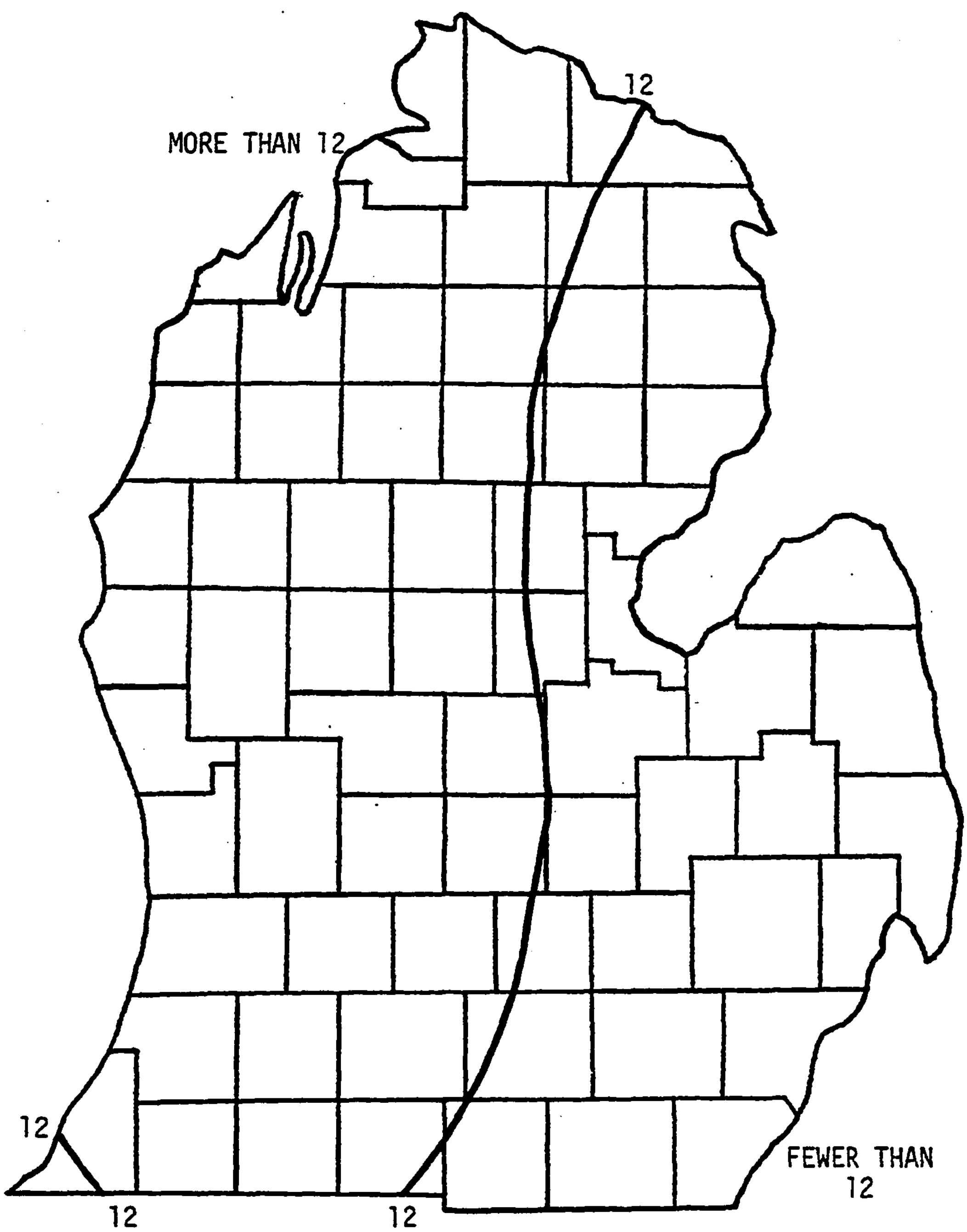


Figure 19. Average annual number of days with glaze, after Merz (1978).

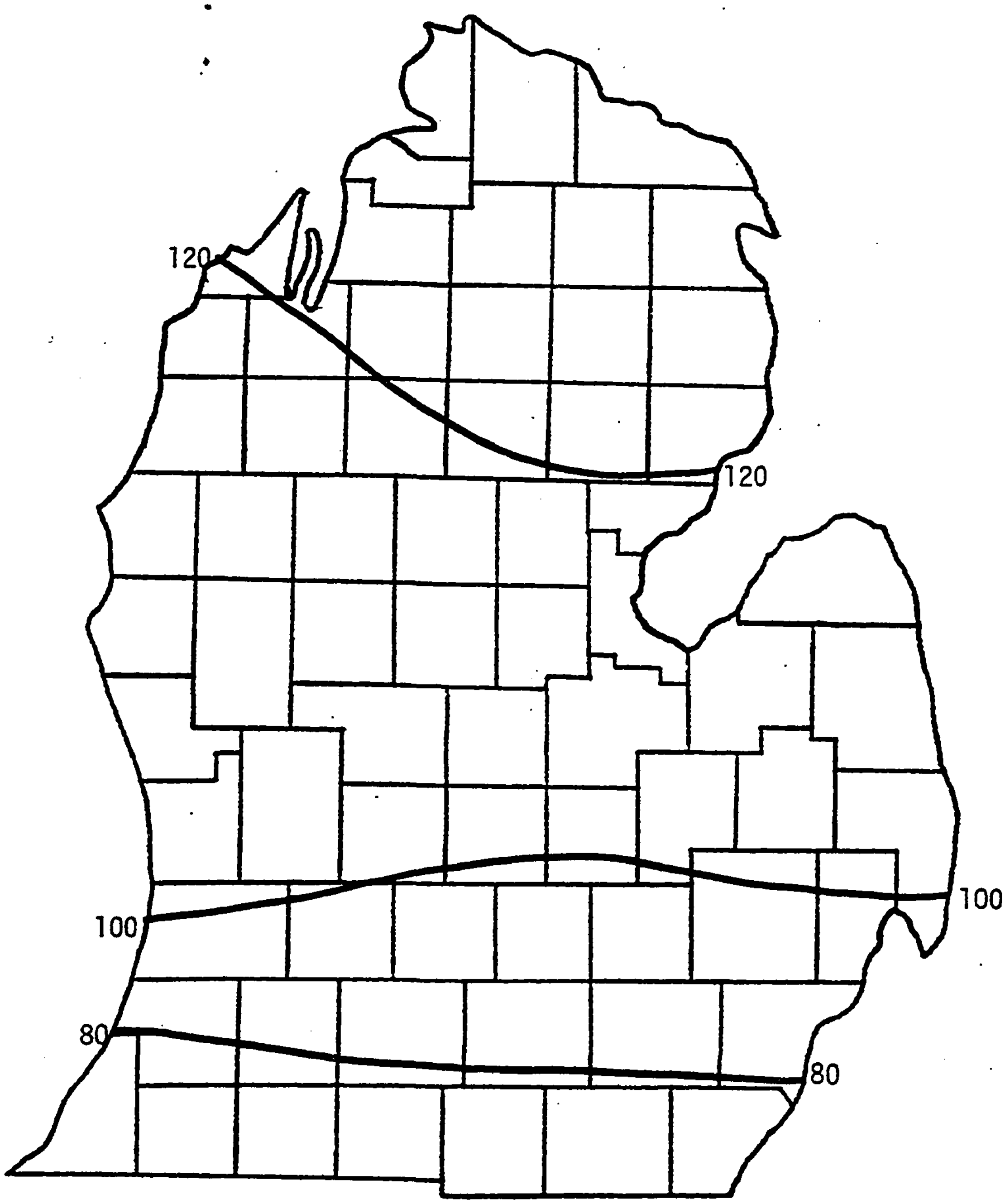


Snow. Snow cover insulates and thereby lessens freeze-thaw cycles and the heaving that disturbs roots (Klages, 1942; Daubenmire, 1974); in the fall, snow cover retards freezing so soil moisture is available longer (Klages, 1942). Deep snow also reduces transpiration, thus reducing damage by winter drought (Denisen, 1958) which can set poleward limits (Klages, 1942). In the spring, snow retards thawing so late frosts are not so damaging (Diebold, 1938). Snow cover also provides conditions suitable for snow molding, which injures young trees (Korstian, 1923). Some plants are restricted to snow patch habitats, while others need a longer snow-free period (Daubenmire, 1974). Snow cover (not snow fall) could, then, limit southern plants at their northern boundary, and northern plants at their southern border. If a steep gradient in the number of days with snow cover caused the tension zone, it would be across the southernmost three tiers of counties (Figure 20); if snow accumulation was critical, the snowbelts of Kalamazoo-Bloomington-Allegan in the southwest and Vanderbilt-Fife Lake in the central north (Niedringhaus, 1966) would be reflected in plant boundaries. The tension zone is not there, so it is not caused by snow cover differences.

Heavy snow fall can break branches, but damage is mostly limited to evergreens (Curtis, 1936).

Evaporation. It is apparent that precipitation alone does not cause many ranges to end at the tension zone. However, the amount of water a plant requires depends largely on how much it is losing by transpiration. This will be greater when the air around it is dry, which can be measured as potential evaporation. Measures of just

Figure 20. Average annual number of days with snow cover, after Merz (1978).



precipitation, without regard to temperature, wind, and humidity, are less meaningful ecologically. If high evaporation limited northern plants at their southern borders, they would show a tension zone from Mason County across to Sanilac County, as the evaporation gradient is steep there (Figure 21). They would also be found less in the driest area, shaded in Figure 21, than in the extreme southwest. The northern plants do not show these patterns (Figures 4 and 5). Even when the northern plants typically found in humid microclimates such as swamps and bogs are excluded, the remaining northern plants neither show a tension zone nor are they found less in the driest area (Figures 22 and 23).

I conclude that none of these aspects of precipitation accounts for the tension zone.

Temperature

Extreme cold. Extreme cold temperatures could limit southern plants. Cold injures some plants (Caprio, 1966) and can be fatal (Turnage and Hinckley, 1938; Wagener, 1957). The extent of this depends on previous hardening of the individual plants and on the duration of the cold (Shreve, 1914). I have five weather maps which show some aspect of cold which may limit southern plants (Figures 24-28); the trends are similar enough to test as a group. If the tension zone as shown by southern plants were determined by extreme cold, their northern boundaries would be U-shaped: they would be found farther north along Lake Michigan and Lake Huron than in the center of the state, and species would drop out of the flora mostly

Figure 21. Potential evaporation (percent by which evaporation exceeds precipitation) during the growing season, after Sommers (1977). The shaded area has the highest potential evaporation.

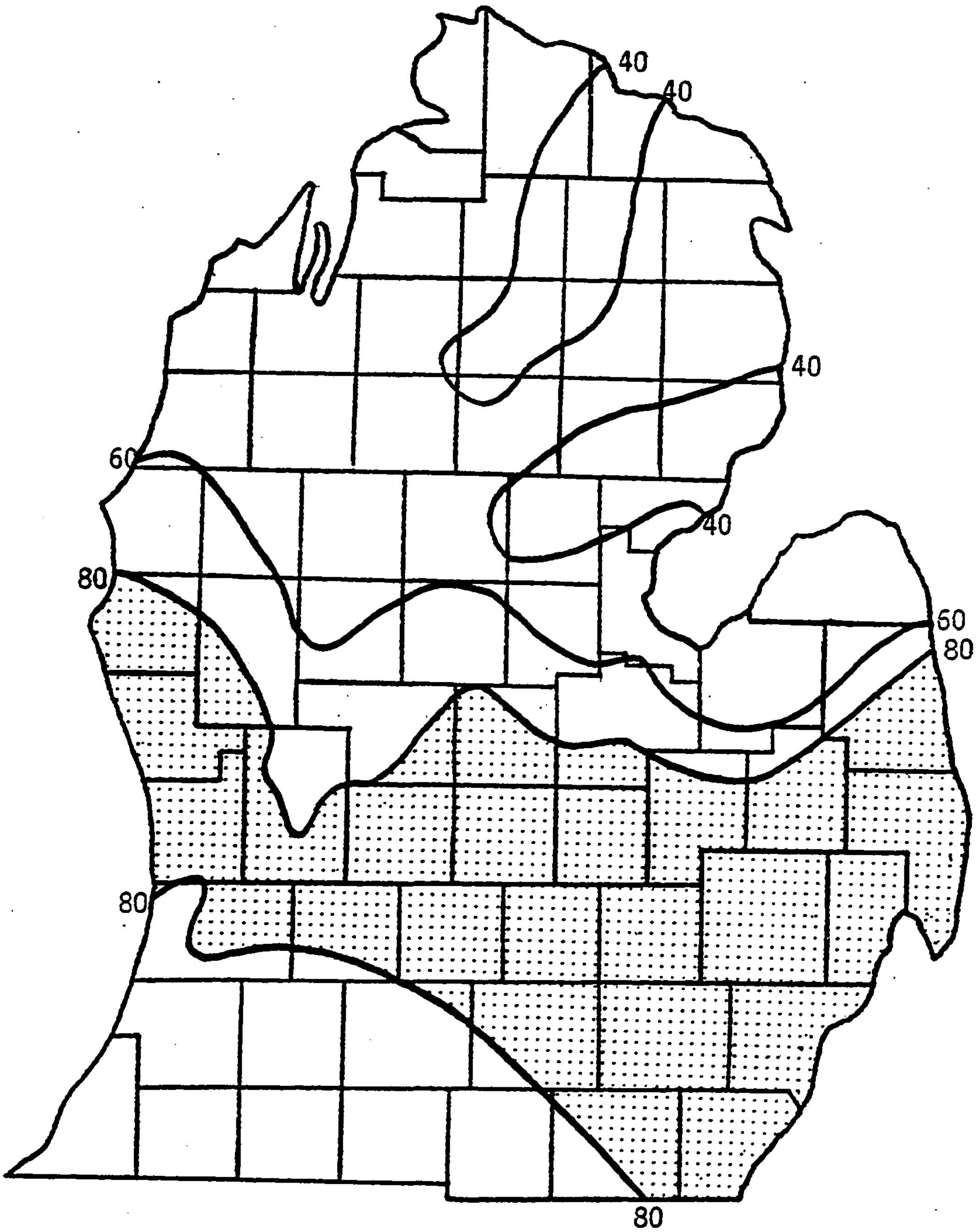


Figure 22. Southern range limits of northern plants not typically found in wet habitats.

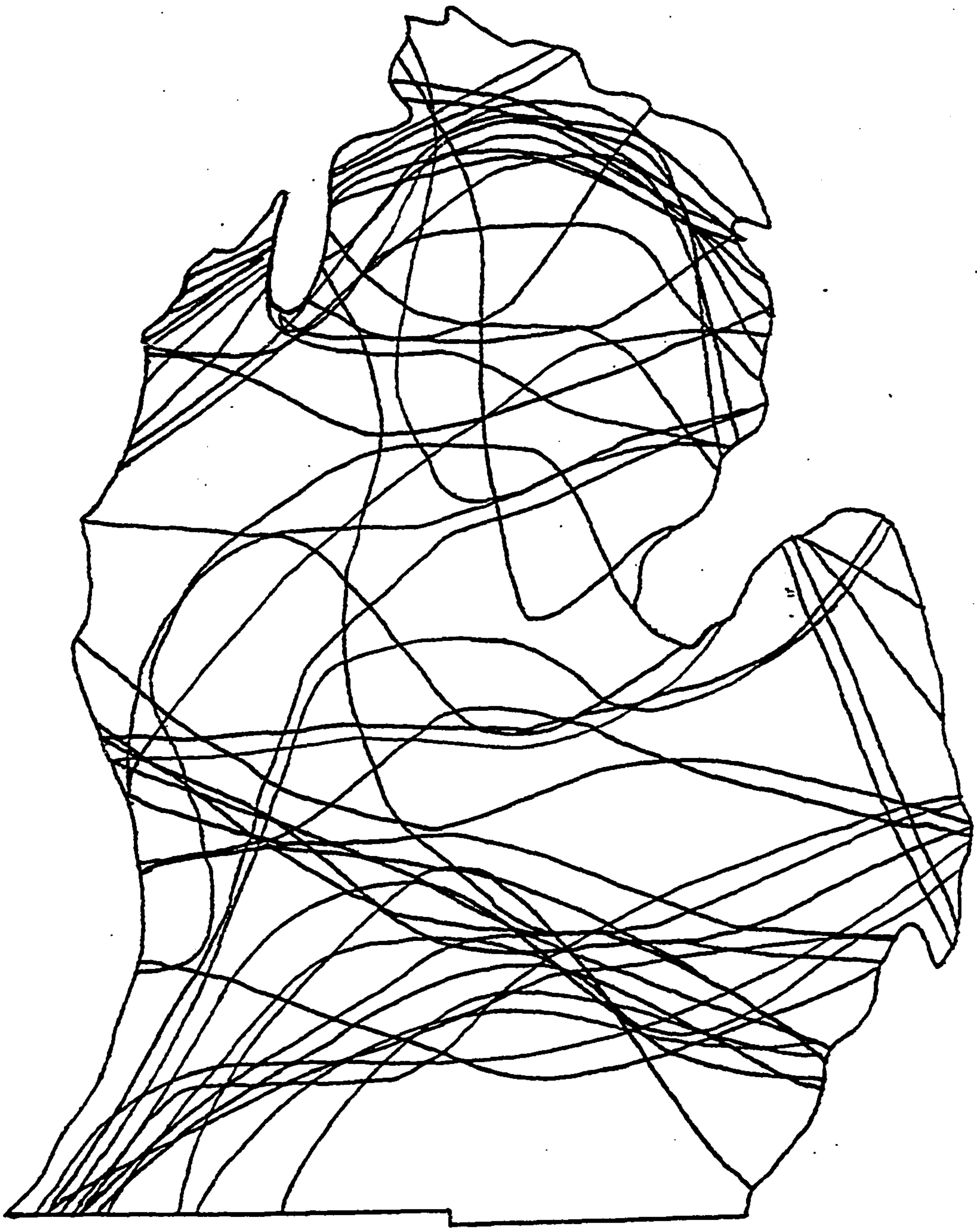


Figure 23. The number of northern plants not typically found in wet habitats in each county.

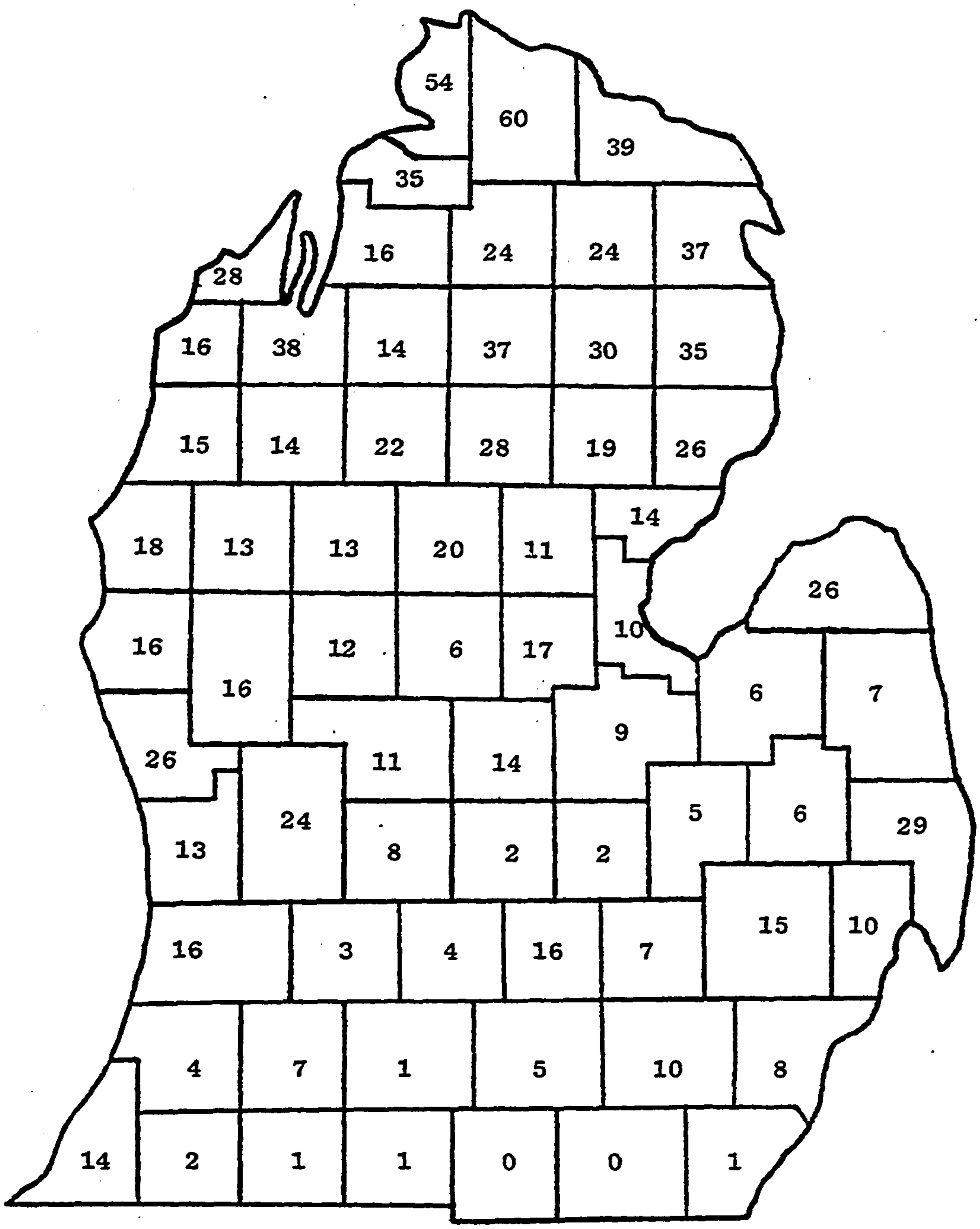


Figure 24. Absolute minimum temperature, ° F., after Niedringhaus (1966).

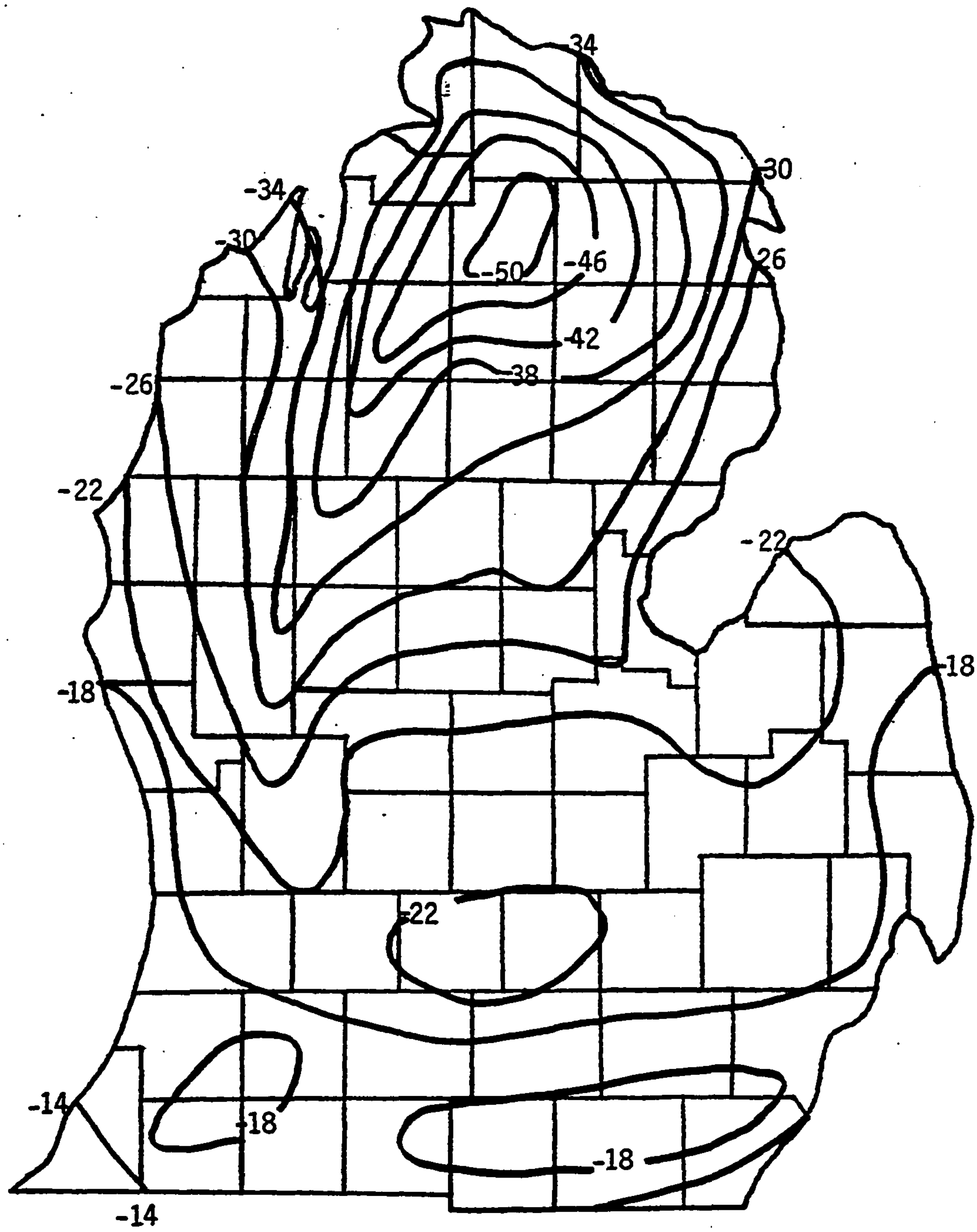


Figure 25. Mean minimun temperature, $^{\circ}$ F., after Niedringhaus (1966).

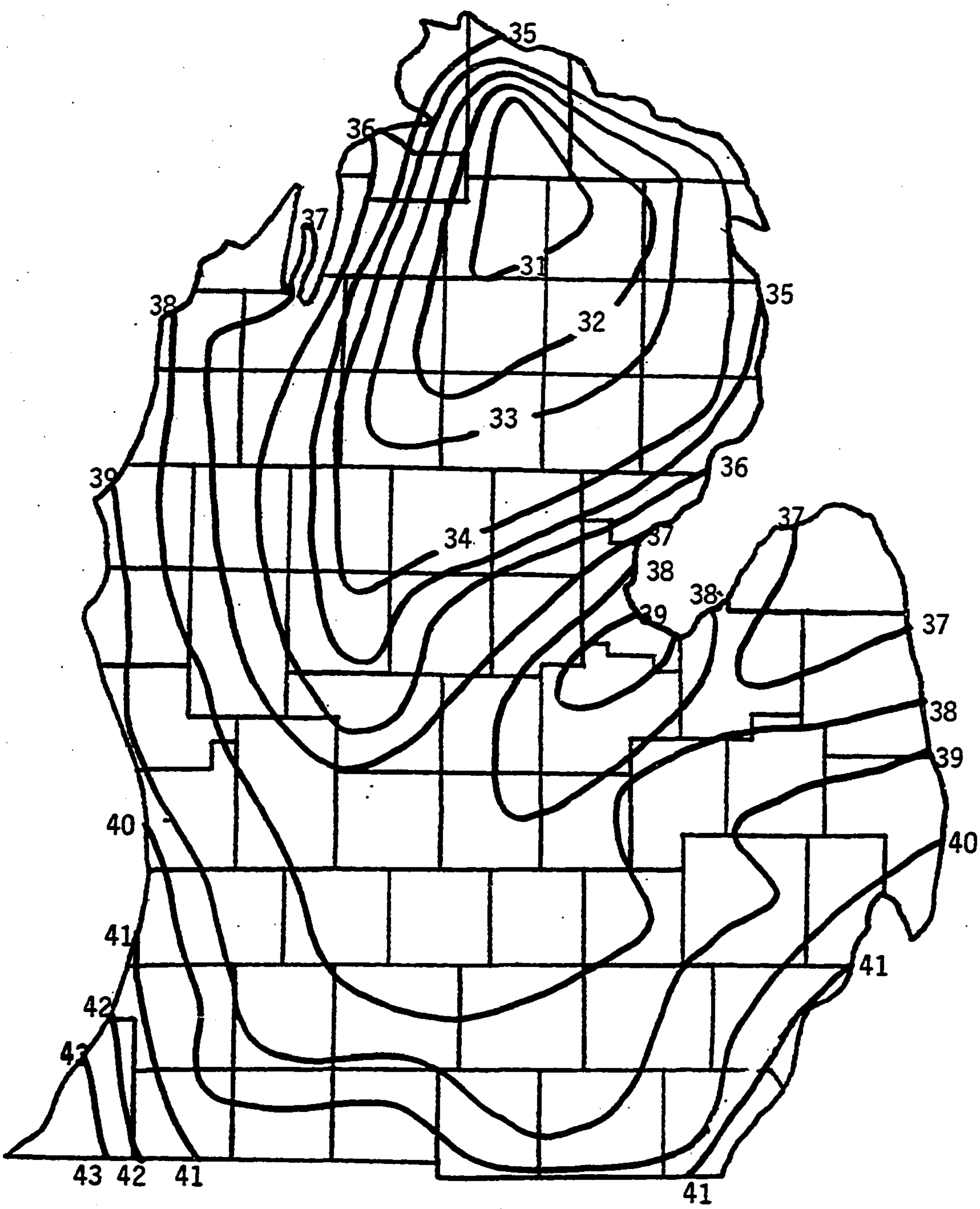


Figure 26. Mean number of days with minimum temperature 32$^{0}$ F. or below, after Niedringhaus (1966).

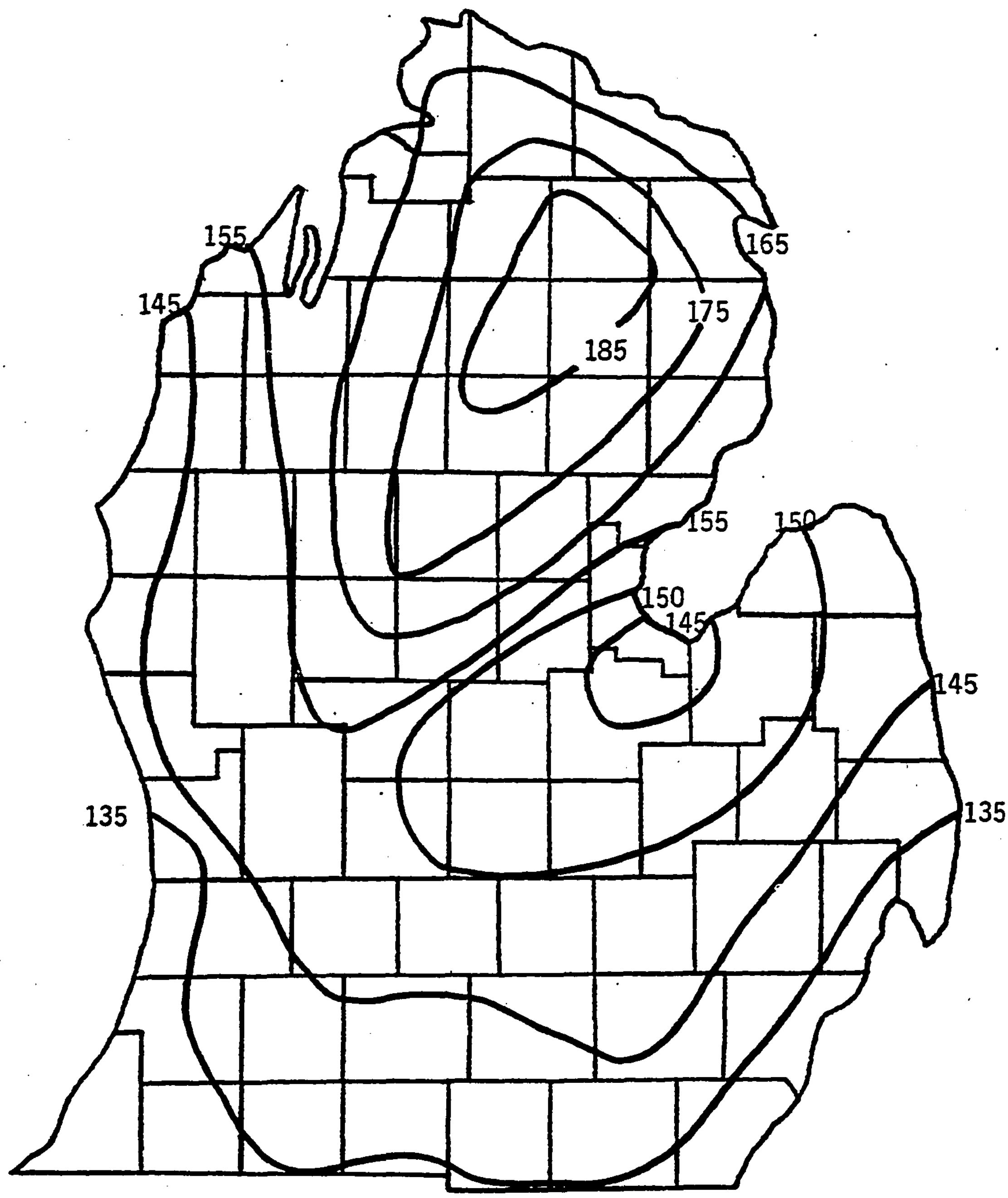


Figure 27. Mean number of days with maximum temperature $32^{o}$ F. or below, after Niedringhaus (1966).

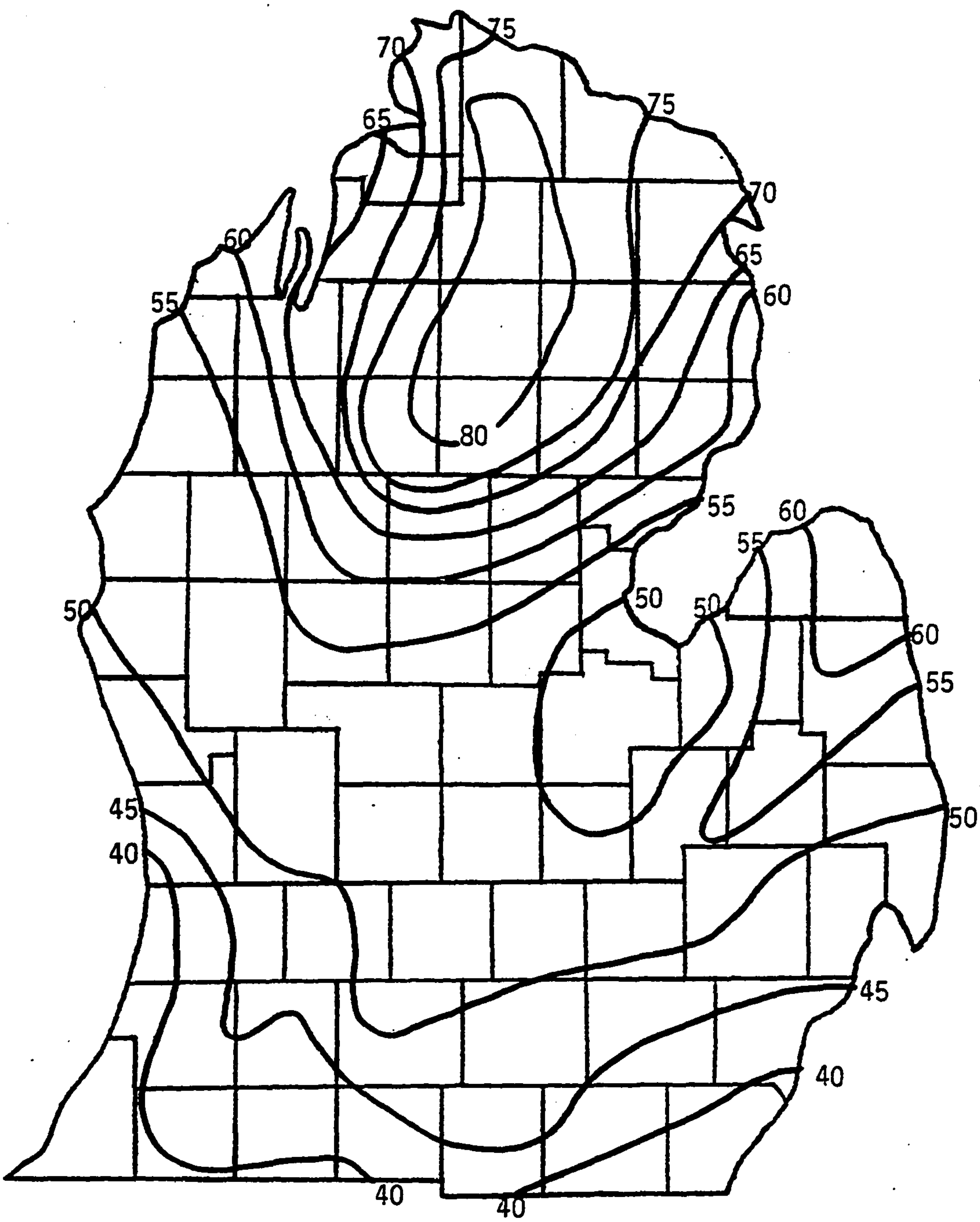
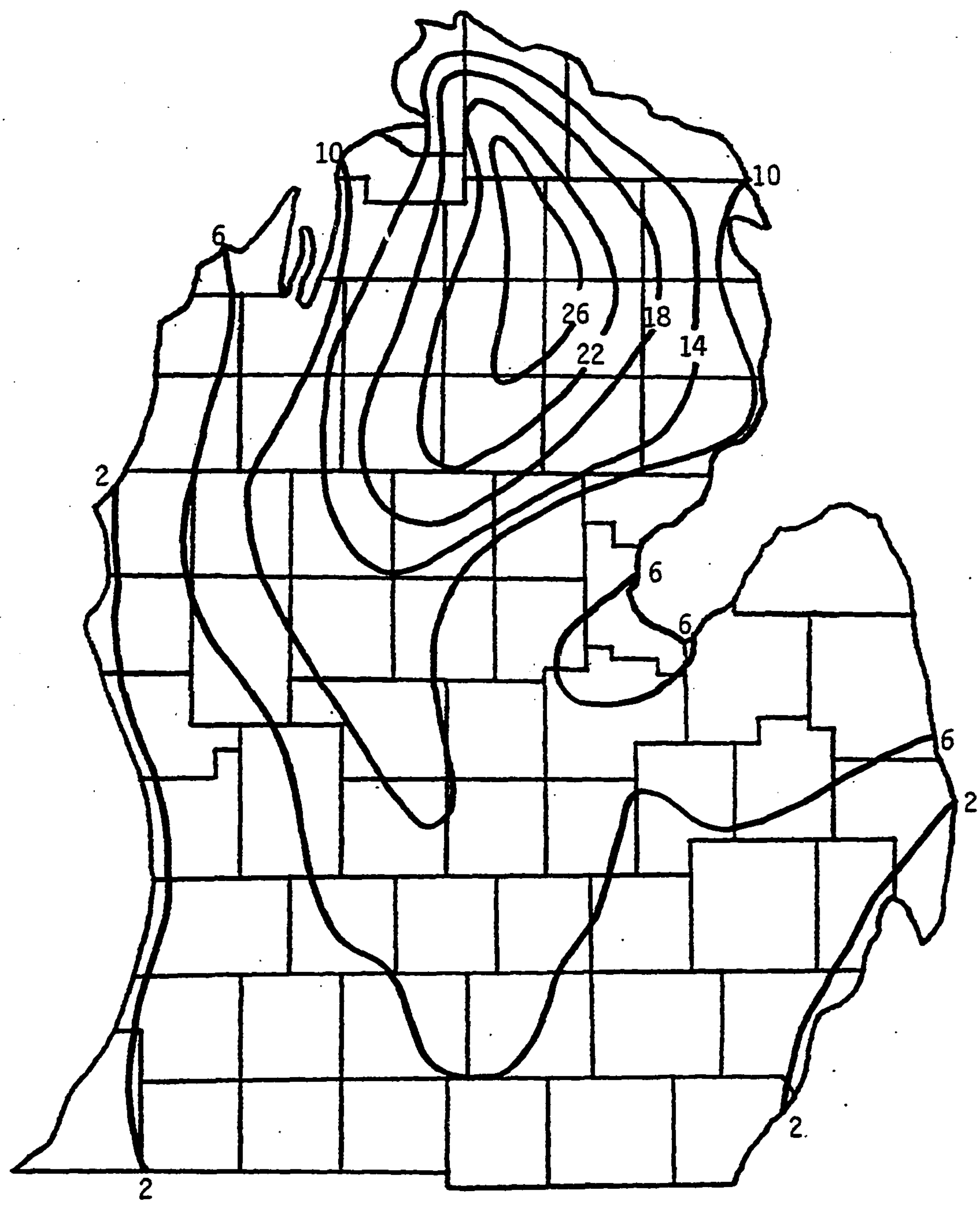


Figure 28. Mean number of days with minimum temperature $0^{o}$ F. or below, after Niedringhaus (1966).



where the isolines are closely spaced. This is not the case, so cold temperatures do not cause the concentration of range limits at the tension zone.

Extreme heat. Northern plants could be limited by hot summer temperatures. The optimal temperature for photosynthesis is usually lower than that for respiration, so high temperatures cause the photosynthesis:respiration ratio to become unfavorable (Daubenmire, 1974). High temperatures can also repress flowering (Post, 1937; Thompson, 1939; Samish, 1954), be detrimental to seeds (Daubenmire, 1974) or inhibit germination (Toole et al., 1956). If high temperatures determined the southern limits of northern plants, range lines would occur in a pattern similar to the isolines of mean or absolute maximum temperatures or isolines of the duration of hot weather (Figures 29-31). A single tension zone would not be predicted, as the isolines show rapid changes in several places. A feature common to those maps of high temperature is that the lines extend sharply south along Lake Michigan. Only eight of the northern species' ranges do this (Figure 4), so, in general, high temperatures do not set the southern boundaries of northern plants in Michigan.

High temperatures could also be important in setting the northern boundaries of southern plants. Some require high temperatures to induce flowering (Thompson, 1939; Daubenmire, 1960). If lack of sufficient hot weather limited southern plants, they would not be found along Lake Michigan as far north as in the center of the state, except for those of the southernmost counties. There would be slight concentrations of range lines in the southwest and near

Figure 29. Mean maximum temperature, ° F. After Niedringhaus (1966).

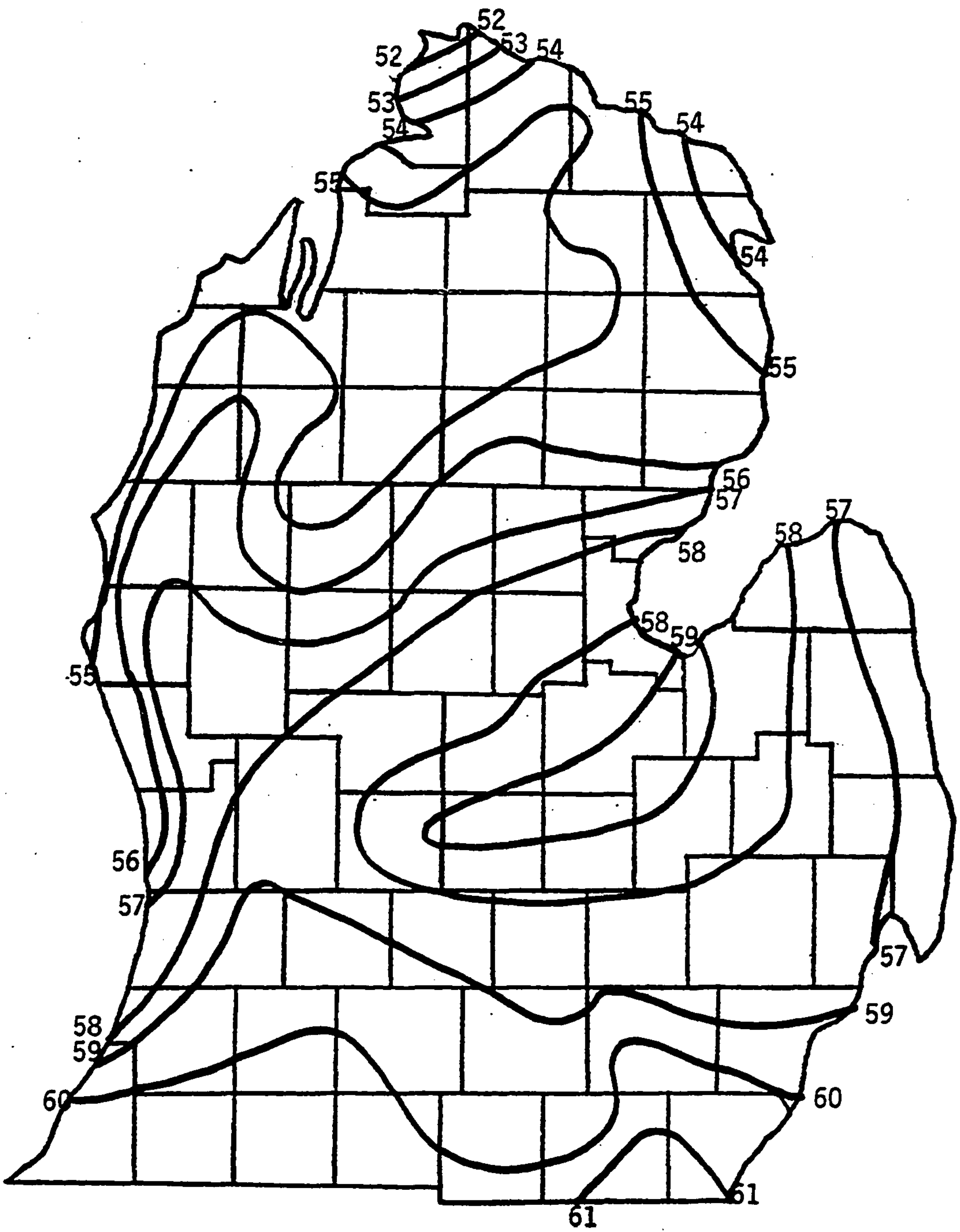


Figure 30. Absolute maximum temperature, ° F. After Niedringhaus (1966).

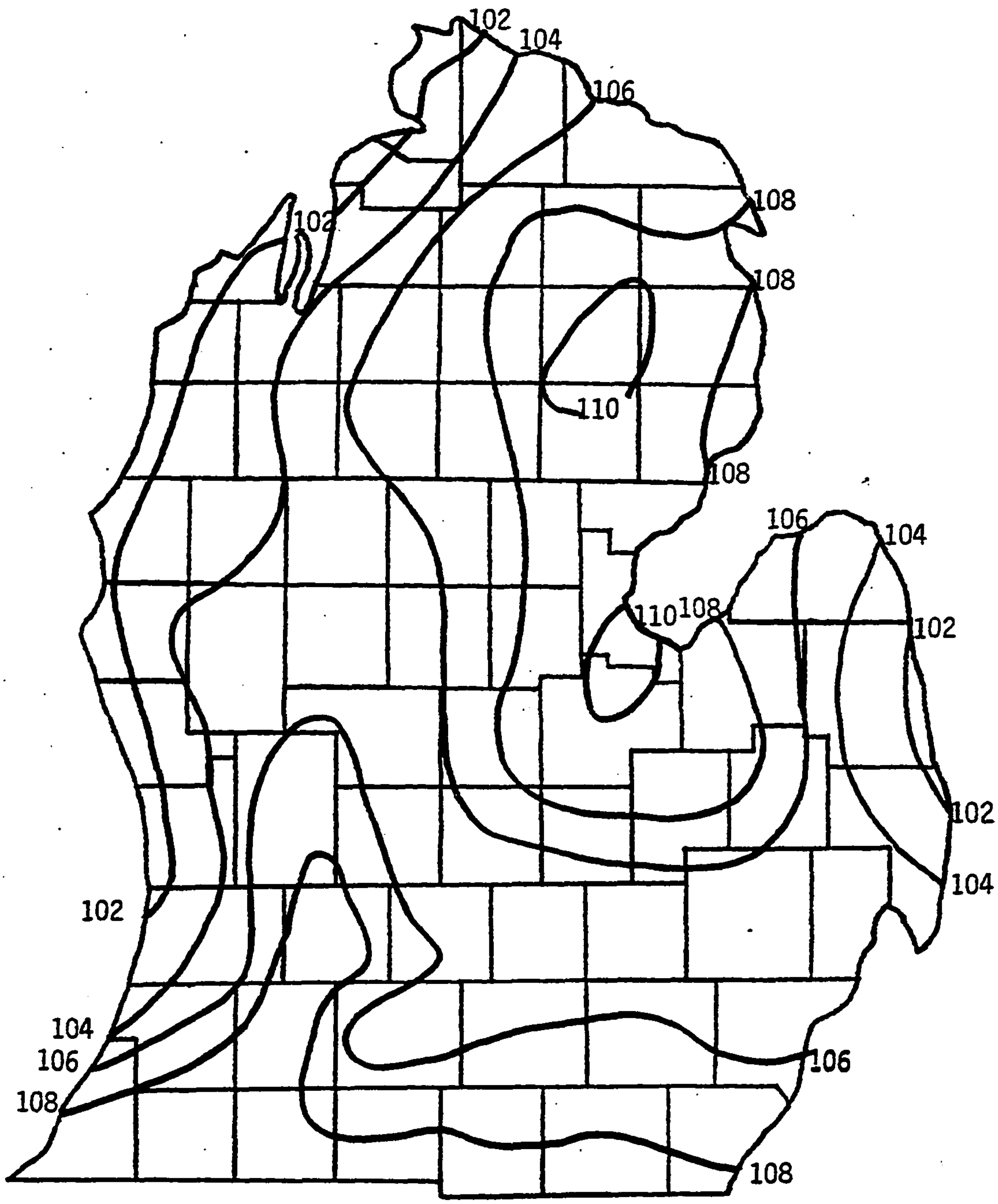
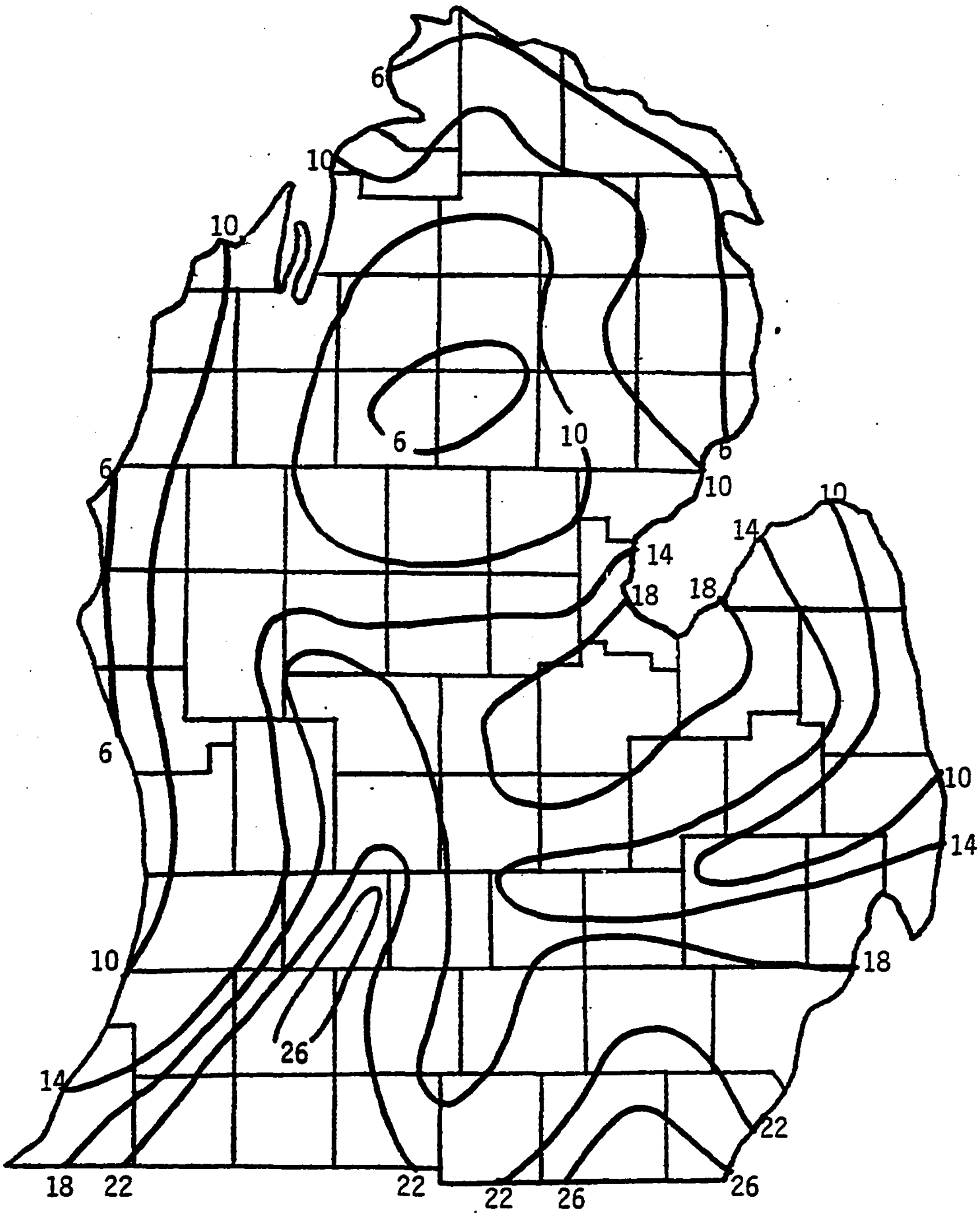


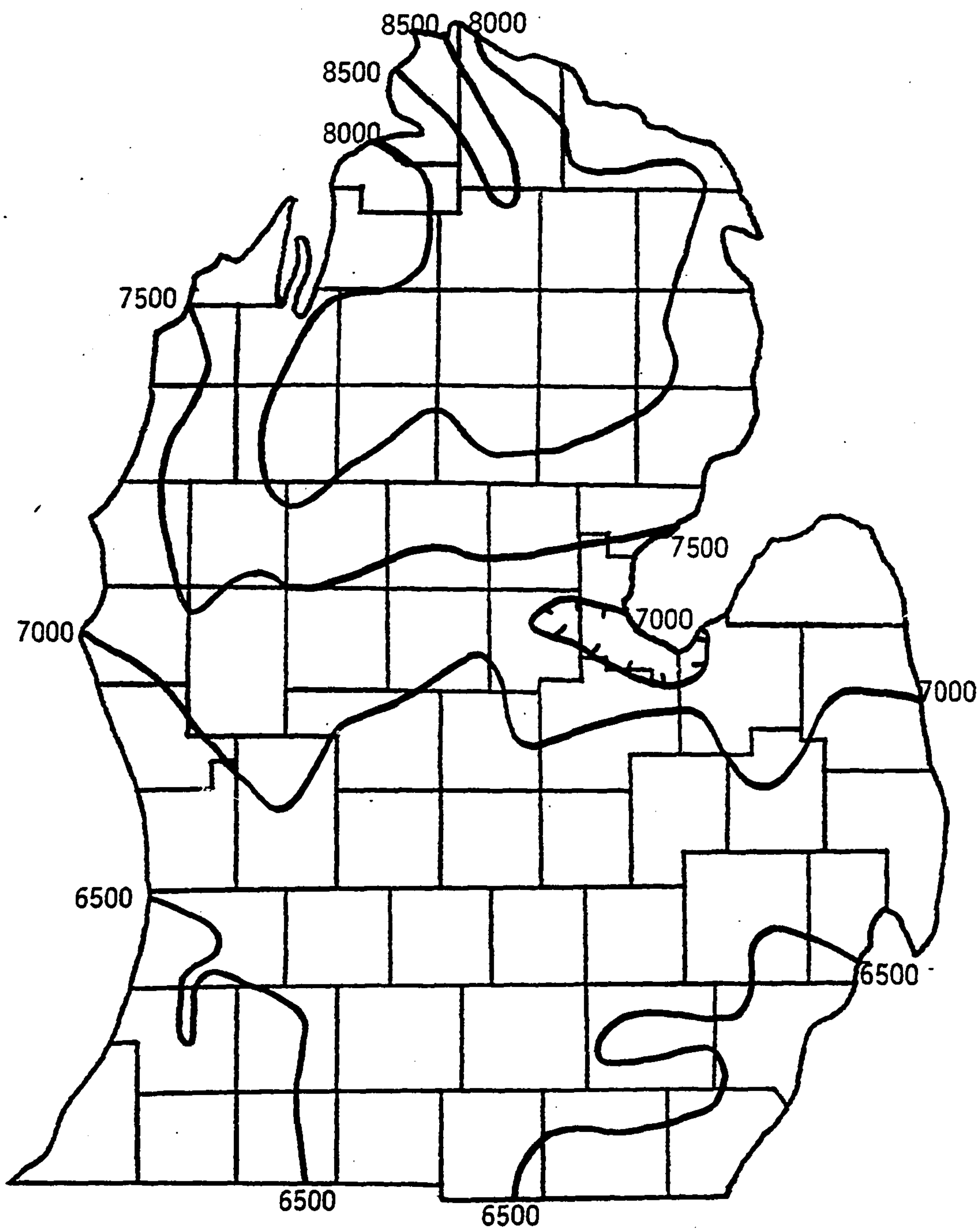
Figure 31. Mean number of days with maximum temperature 90$^{0}$ F. or above, after Niedringhaus (1966).



Saginaw Bay (Figures 29-31). This is partly upheld: many southern plants do avoid the Lake Michigan shoreline and have many boundary lines in the southwest and by Saginaw Bay (Figure 10). However, another large group of southern plants, which includes those farthest north, are found along Lake Michigan farther north than in the center (Figure 9). High temperatures do not account for the tension zone clearly shown by the southern plants.

Amount of cold. Many plants require a period of chilling to break dormancy (Darrow, 1942; Samish, 1954; Caprio, 1966), for the initiation of flowering (Post, 1937; Thompson, 1939; Downs and Hellmers, 1975), or for good germination (Busse, 1930; Toole et al., 1956). Northern plants could be limited at their southern boundaries, then, by insufficient winter cold. This chilling requirement is a combination of temperature and duration; the best available measure of that is heating degree days, the number of days below $65^{0}$ F. times the number of degrees below $65^{0}$ on those days. (Although $65^{0}$ F. may not be the most appropriate base, figures using other bases are not readily available; the isolines are probably similar.) If a requirement for some amount of cold (Figure 32) limited northern plant ranges we would find northern plants dropping out fairly evenly throughout, not showing a tension zone, and they would extend farthest south in the center of the state with as many found in Branch and Hillsdale counties as in Eaton and Calhoun. The warmer counties in the southwest and southeast would have fewer northern species. Although the northern species do not show a tension zone, in agree-

Figure 32. Heating degree days, base 65° F. Map constructed from data in Michigan Weather Service (1971).



ment with this hypothesis, the details do not match. The south-central counties have only a few northern species while counties in the southeast and particularly the southwest have many more (Figure 5).

Fluctuation. Some seeds require fluctuating temperatures (even beyond day-night differences) for germination (Busse, 1930; Warington, 1936). If the tension zone was caused by such a need by one group of plants and not the other, we would find a division between the central north, where temperatures are most variable, and the Lake Michigan shoreline, where there is least variation (Niedringhaus, 1966). The tension zone does not divide the Lower Peninsula this way, so temperature variation does not account for it.

Damaging spring frosts. Southern plants could be limited by late spring frosts which occur at a critical stage in their development. Many fruit trees, for instance, are sensitive to this and so are grown where there is a low likelihood of late frosts or where dormancy is broken so late that the plants are not vulnerable to the late spring frosts (Thomas, 1911). If the ranges of southern plants at the tension zone were limited by this, we would expect them to follow the pattern shown by the isolines of last frost (Figure 33) or by fruit production (Figure 34); they would be found farther north along Lake Michigan, and probably on the east, than in the center of the peninsula. This is not the case.

Frost-free season. Southern plants could require a minimum time without frost (Caprio, 1966; Daubenmire, 1974). If the bulk of southern plants were limited by this, they would not show a tension

Figure 33. Mean date of last temperature of 32° F. or lower in the spring, after Bujnowski and Twardzik (1971).

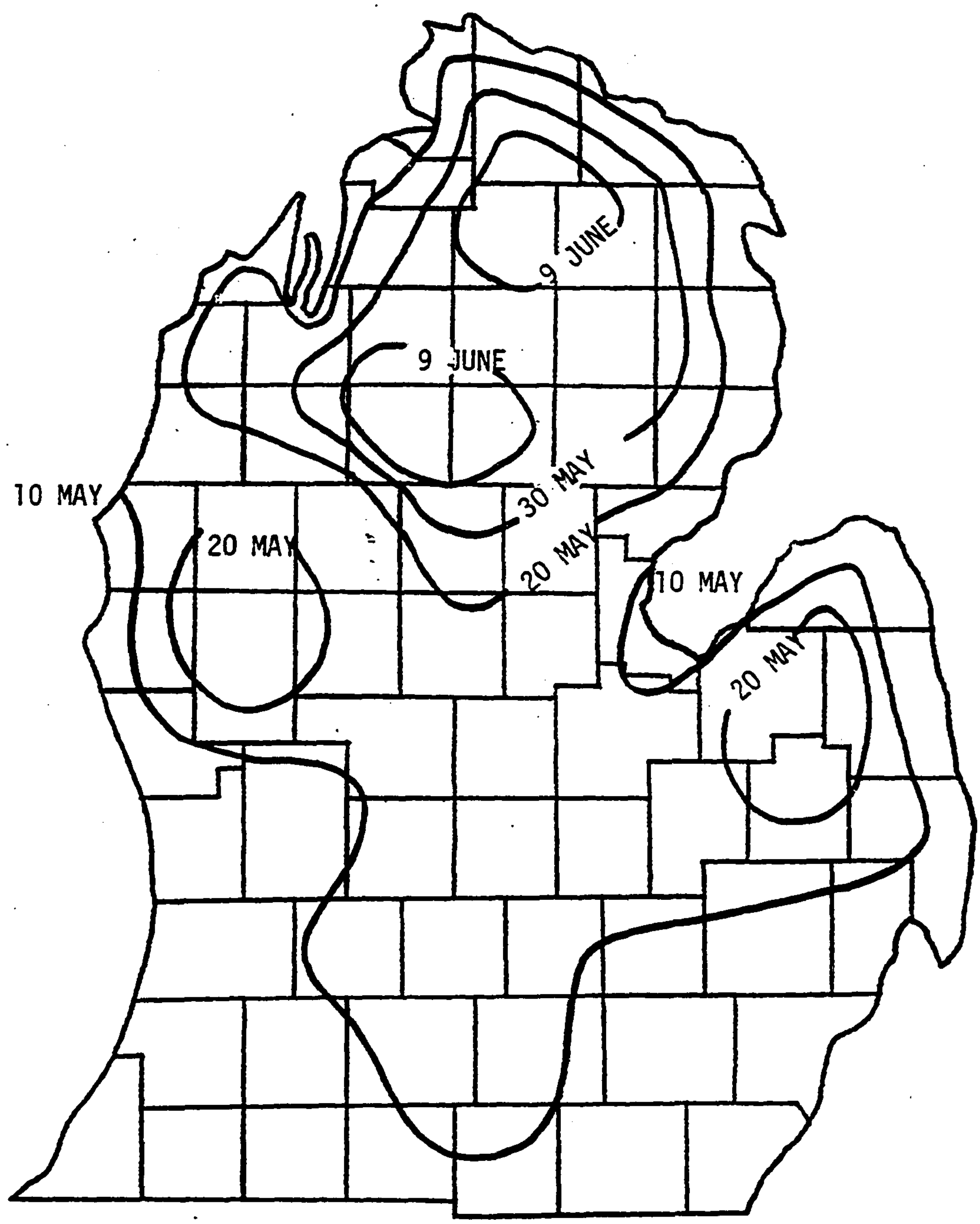
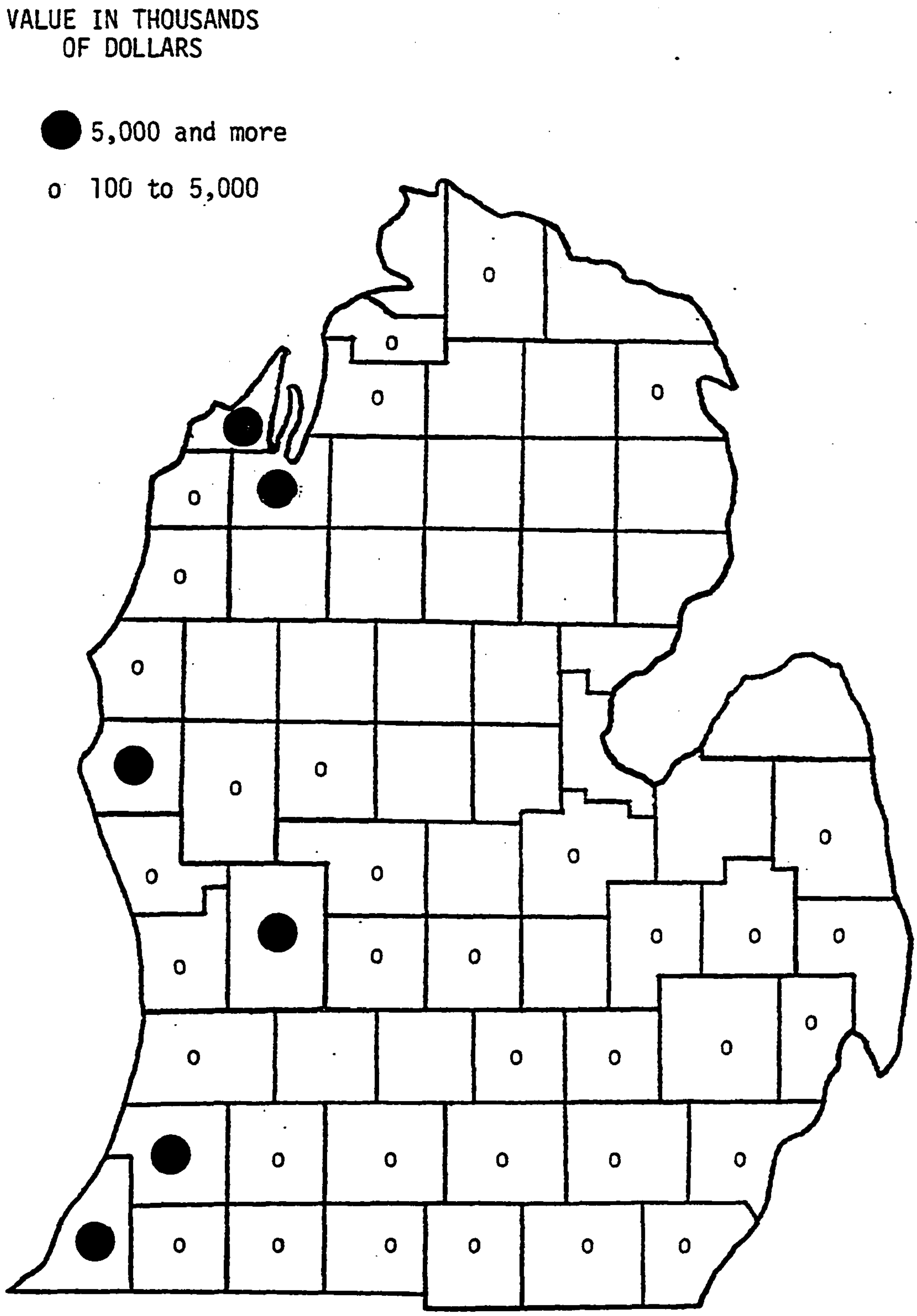


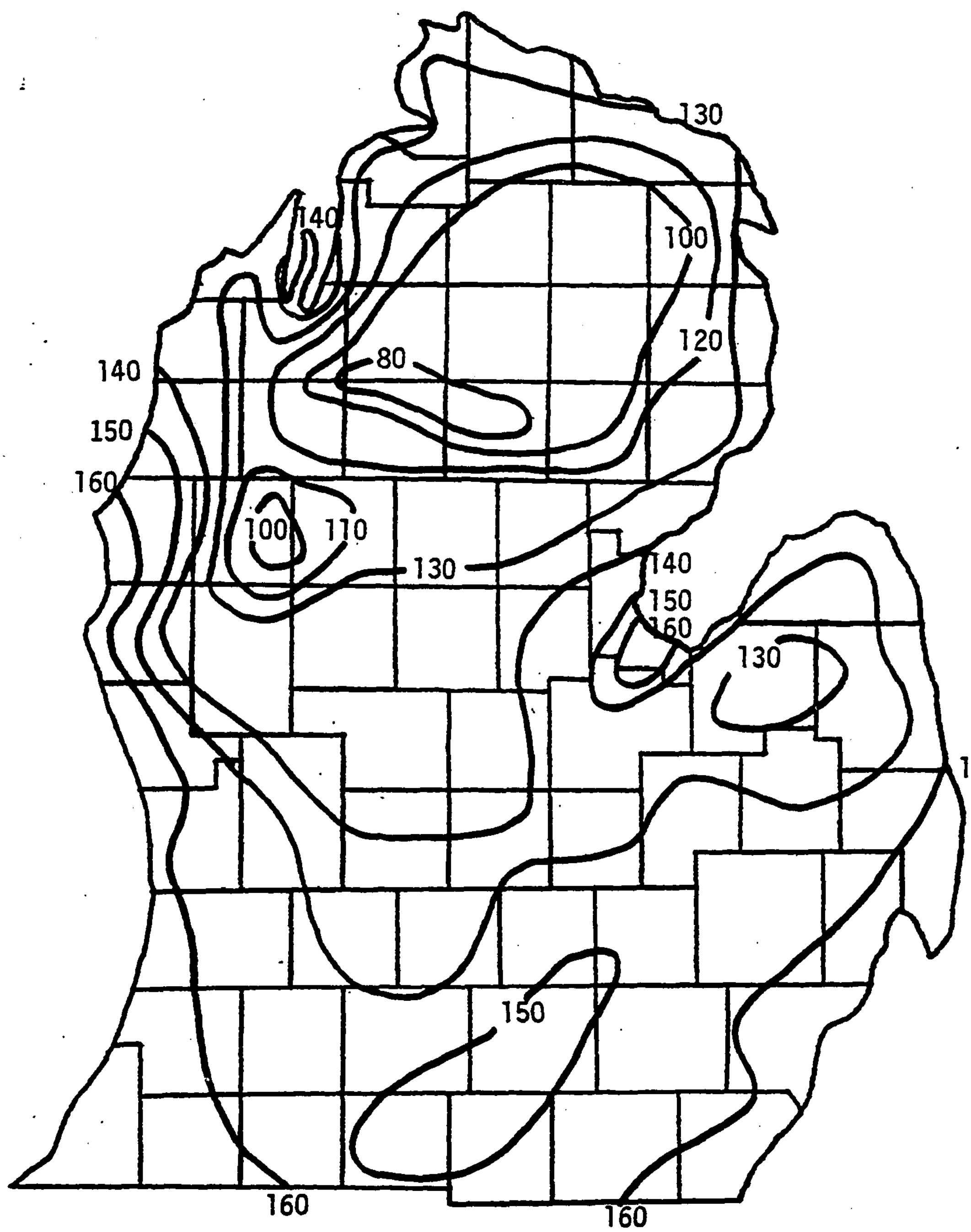
Figure 34. Fruit production in Michigan, after Senninger (1970).



zone, as the number of frost-free days decreases quite evenly north to south across the Lower Peninsula (Figure 35). Boundaries would be U-shaped; southern plants would not be found in the center as far north as in the east or west. A portion of the southern plant range boundaries, especially those found farthest north (Figure 9), fit this hypothesis; however, the tension zone is shown by the southern plants as a group and it would not be so if the frost-free period was the main cause of their boundaries.

Amount of heat. Southern plants could be limited by too little heat during the growing season, as it is widely recognized that speed of development is related to temperature (for a theoretical discussion, see Andrewartha and Birch, 1954). The relationship is not simple, as one degree of additional heat at, say, $3^{o}$ C. does not necessarily have the same effect as one additional degree at $30^{o}$. The plant's utilization of additional heat also depends on such things as its previous temperature regime (Daubenmire, 1974). At very high temperatures, as mentioned above, more heat can slow development or do harm. Up to those temperatures, however, and given that the plant is not dormant, the speed of development is related to heat and its duration. Heat sums, the product of the degrees above a base temperature and the time involved, are commonly expressed as growing degree days. Various bases may be used; Van Den Brink et al. (1971) show growing degree days for Michigan using base $40^{o}$, $45^{o}$, $50^{o}$, and $55^{o}$ F. The positions of the isolines are similar (although the values are different); since position is what is important only one, the base $40^{o}$ F. map, is included here (Figure

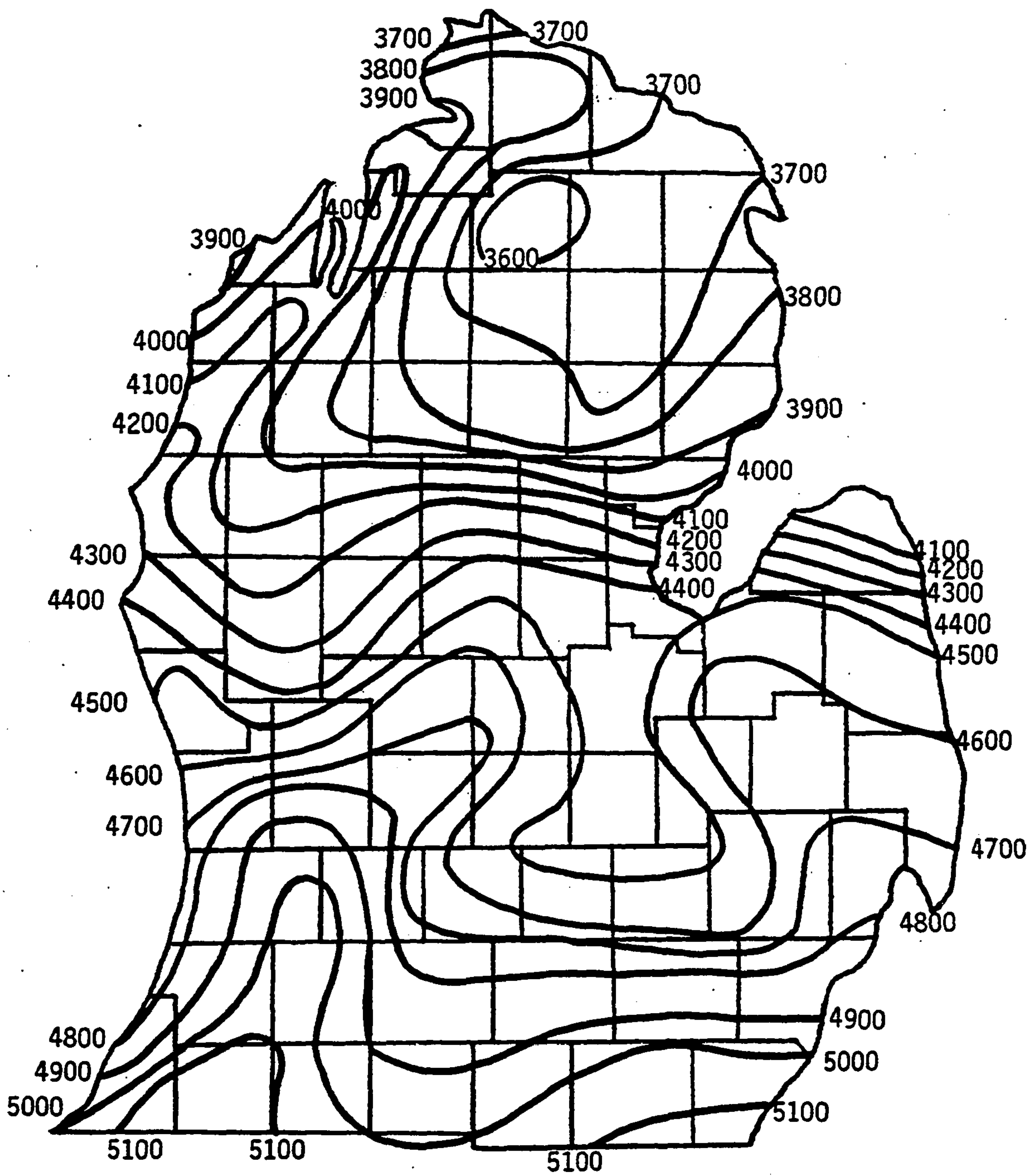
Figure 35. Mean annual frost-free period in days, 1931-1960, after Senninger (1970).



36). If fewer than needed growing degree days limit the southern plants at their northern borders, we would expect a rapid change through the center of the state with the tension zone most distinct at Bay County where the isolines are closest together. The southern range lines would be fairly straight east-west across the center; the ranges of the northernmost southern plants would extend farthest north along Lake Michigan while the boundary lines of the more southerly southern plants would turn south at Lake Michigan. Some plants, which require the most heat, would be found only in the extreme southwest and southeast corners of the state and not in Branch or Hillsdale counties. We might also see a dip in range lines: some plants would not be found in about Shiawassee County but found east and west of there. These trends are shown quite strongly by the range lines of southern plants (Figures 6-10), so this hypothesis is not falsified.

That insufficient heat limits southern plants and thereby causes and determines the location of the tension zone is the only hypothesis I have been unable to disprove wholly or in part. I conclude that, although some individual plants may be limited by other factors, insufficient heat limits enough species to account for the tension zone.

Figure 36. Average cumulative growing degree days in Michigan, 1 March to 31 October, after Van Den Brink et al. (1971). Base is $40^{0}$ F.



# CHAPTER V

# DISCUSSION

## Life Forms

Additional support for the hypothesis that insufficient heat is important in limiting the ranges of plants in Michigan comes from a comparison of life-form data for the southern and northern plants. If such a heat sum is important in range limitation, annuals would show this strongly as they must complete an entire life cycle in a single year. It is not sufficient, for example, to have conditions good enough for flowering and seed production only once in five years. Annuals which are able to live in the north would not be limited southward. These predictions are fulfilled. An unusually high percentage of southern plants which reach their northern limits in Michigan are annuals (14% versus 9.2% for Michigan as a whole (from Thieret, 1977), $P<.005$ tested by $X^2$) and there are no annuals among northern plants which have their southern limits in Michigan (Table 2).

## The Tension Zone in Wisconsin and Ontario

A further test of the hypothesis that insufficient heat accounts for the tension zone comes from Wisconsin and southern Ontario. Are the tension zones there located where predicted by growing degree day isolines?

In Wisconsin, growing degree days show the greatest change in a band which runs from the northwest to the center of the state and turns slightly north as it goes east to Lake Michigan then turns

Table 2. Life forms of groups of plants in Michigan. Data for the flora of Michigan, Berrien County, and Keweenaw County (Upper Peninsula) from Thieret (1977). Figures are per-cent of total number of species.

| | Annuals (Therophytes) | Buds below surface (Cryptophytes) | Buds at surface (Hemi-cryptophytes) | Buds between surface and 25 cm above (Chamaephytes) | Trees and shrubs, buds above 25 cm (Phanerophytes) |
|---|---|---|---|---|---|
| Michigan, 1608 species | 9.2 | 22.1 | 51.6 | 2.2 | 14.2 |
| Southern plants which have their northern limits in the Lower Peninsula, 487 species* | 14 | 24 | 50 | 1 | 11 |
| Northern plants which have their southern limits in the Lower Peninsula, 147 species | 0 | 31 | 43 | 5 | 22 |
| Berrien County, entire flora, 1030 species | 11.2 | 21.3 | 50.4 | 1.9 | 15.1 |
| Keweenaw County, entire flora, 667 species | 4.8 | 25.5 | 49.3 | 2.7 | 17.5 |

*When only native species are included, the total is 451 and the percentages are 11-25-51-1-12.

sharply south very close to the lake (Figure 37). If the tension zone in Wisconsin is caused by insufficient heat, as shown by growing degree day data, it would follow those trends. Curtis (1959) has mapped the range boundaries (either northern or southern) of 182 species and puts the tension zone as shown in Figure 38. This is as predicted by growing degree days.

In Ontario, growing degree days isolines are fairly evenly distributed (Figure 39). The tension zone thus predic would be poorly defined and range lines would lie about west to east-northeast, following the isoline trends. Thaler and Plowright's (1973) contour map of transition coefficients from distribution data (about like my zone index) shows a "weakly developed tension zone" (page 1773) which lies at about the same orientation as the growing degree days isolines (Figure 40).

## The Southern Boundary of Northern Plants

In Michigan, the northern plants do not have ranges concentrated in a tension zone. The case could be the same in Wisconsin and Ontario but the data are not presented in such a way that the southern and northern plants can be separated (Curtis, 1959; Thaler and Plowright, 1973). Unquestionably, though, there is a southern boundary to the northern vegetation which is (of course) mapped as matching the northern boundary of the southern vegetation which is also the northern limit of many southern species. The question, then, is what causes the northern plants to be found in the south but uncommon---not part of the vegetation?

Figure 37. Growing degree days in Wisconsin. The broken lines and italic numbers are base 42° F. and were available for only part of the state (after Phillips and McCulloch, 1972). The solid lines are to base 50° F., after Mitchell (1979).

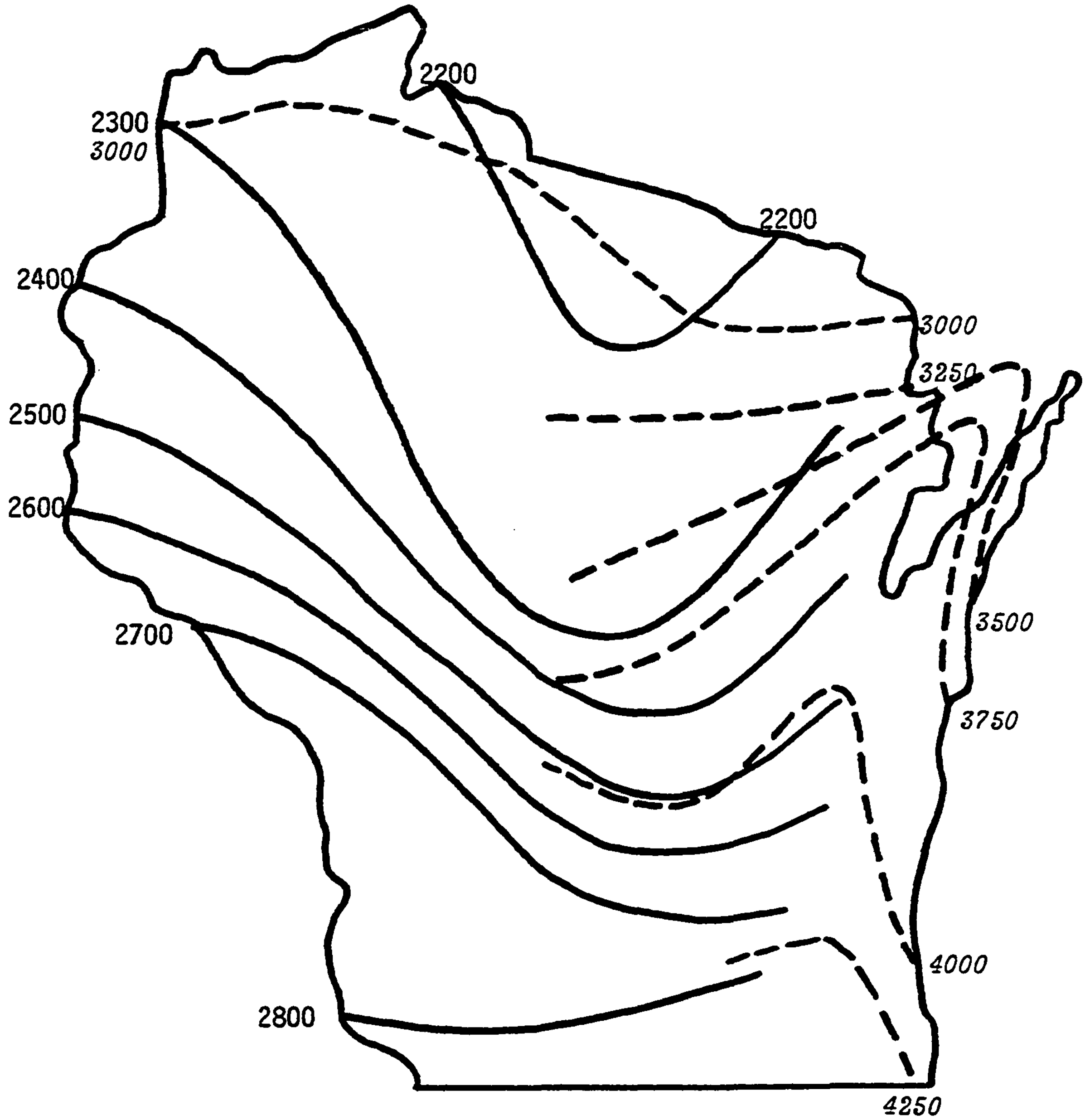


Figure 38. The tension zone in Wisconsin, after Curtis (1959).

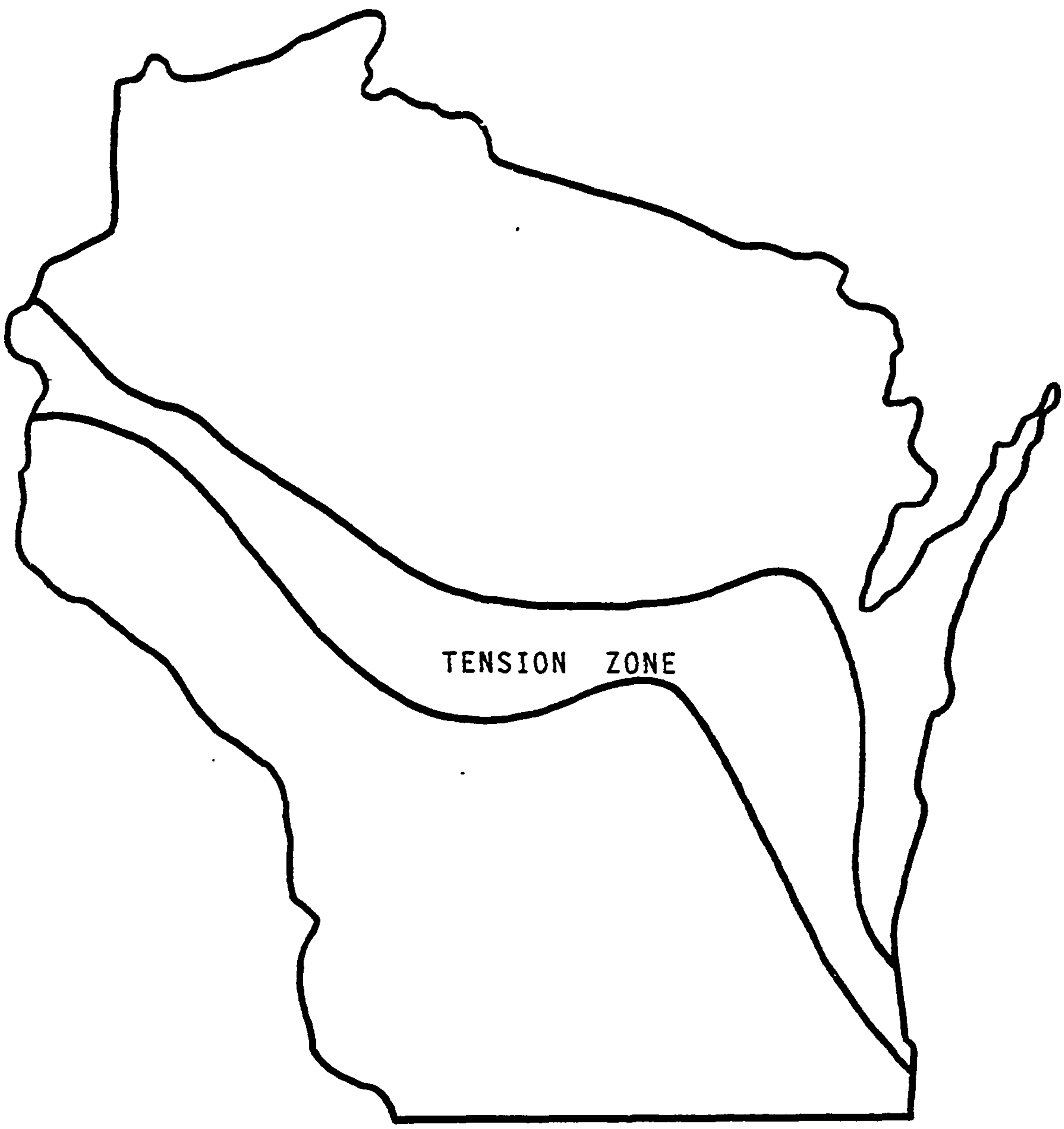


Figure 39. Growing degree days in southern Ontario, base 42° F., after Phillips and McCulloch (1972).

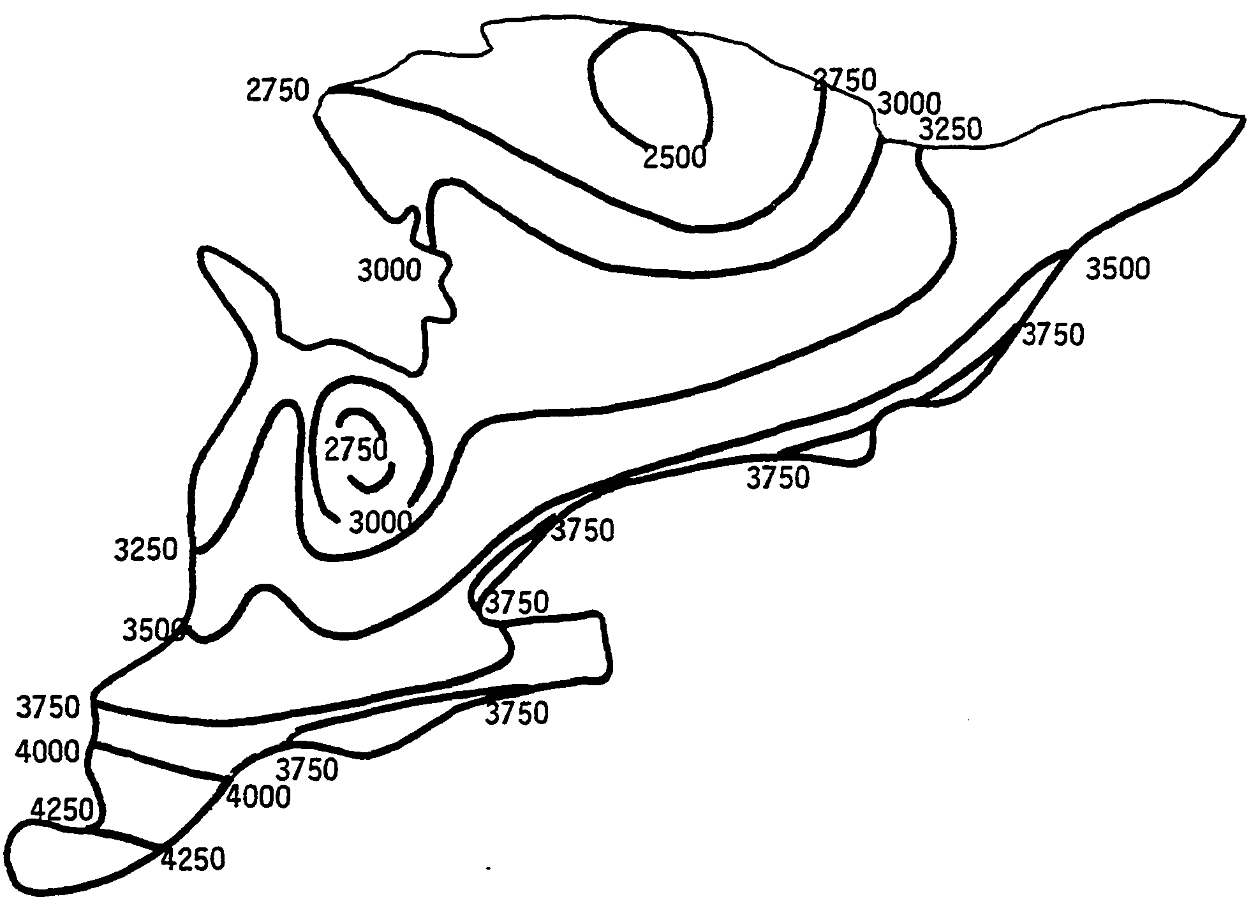


Figure 40. The tension zone in southern Ontario (blackened area). The numbers are similar to my zone index values (Thaler and Plowright, 1973).

Competition, according to Griggs (1914) and MacArthur (1972), sets many southern range limits of northern organisms. Although relicts and transplants show us that northern plants can live in the south, the southern plants do better there. If competition with southern plants is setting the vegetation boundary, the northern plants would be found in the south where competition is lessened. Special microclimates and persistence in, for instance, bogs may favor northern species. Wet habitats are cooler and more humid (more like the north) than the south in general. Northern plants found in the south but not typically found in wet habitats would be particularly worth investigating.

## History of the Tension Zone

Fluted projectile points of early Paleo-Indians and fossils of mammoths and mastodons are found in the southern Lower Peninsula south of the Mason-Quimby line (Fitting, 1975). This shows a tantalizing correlation with the present-day vegetation tension zone. Was there a tension zone from about 14,000 to 10,000 years ago, when these animals and their hunters were present (Martin, 1967)? I don't think so. The Ubly outlet channel and swampland could well have been a barrier to the animals (Fitting, 1975) but less so for plants. There was probably a narrow band of tundra near the ice front and lake margins with spruce parkland over most of the Lower Peninsula (Quimby, 1960; Fitting, 1975); whatever ecotones there were probably shifted with the various glacial advances and retreats and with the changes in the Great Lakes. The fossil pollen dates and other data which could show differences in con-

temporaneous vegetation north and south of the tension zone are not available for Michigan. In Wisconsin, spruce pollen is found across the state at 12,000 years ago (Curtis, 1959) and it was probably the same in Michigan.

About 10,500 years ago there was a major change in climate (Ogden, 1967) and many species of plants began migrating into the area (Davis, 1976; Kapp, 1977). It is more likely that the tension zone was set up then. For Wisconsin, Curtis (1959) summarized many fossil pollen diagrams which show a tension zone since about 10,000 years ago. There was apparently a shift of 40 to 60 miles northward at the xerothermic peak about 3,500 years ago. In Michigan, Wilson and Potzger (1943) found consistent amounts of pine, hemlock, and broad-leaved tree pollen in the north from the beginning of the pine period (dated in Wright (1976) as 10,000 years ago) to settlement. For the same period in a Washtenaw County core, they (Potzger and Wilson, 1941) found oak consistently most abundant. In the present tension zone, the pine:oak ratio fluctuated (Potzger, 1946). This he interpreted as indicating shifts in forest type reflecting climatic changes too small to be shown north or south of the tension zone.

Present-day climate in Michigan depends largely on the Great Lakes (Niedringhaus, 1966). They have been free from the direct influence of the glaciers since at least 9,500 years ago (Dorr and Eschman, 1970). This means that rapid changes in climatic factors, including growing degree days, well could have occurred at the same location since then although the values would have been different

when the climate was colder or warmer. Plant ranges would have been concentrated in the zone of rapid change in the number of growing degree days just as they are today, although the species with ranges there would change with the climate.

# CHAPTER VI

## SUMMARY

The plant tension zone in Michigan is indicated on maps as a boundary between two vegetation types. In this study, the tension zone is shown to be the northern range boundary of many southern plant species (Figure 6). The southern limits of northern plants, however, are not concentrated into a tension zone (Figure 4). Although the typical northern vegetation has a boundary at the tension zone northern plants are found scattered in the south (Figure 5). These are probably postglacial relicts not considered part of the vegetation.

Zone index calculations, based on county distribution records, show the center of the tension zone is from Muskegon to Bay to northern St. Clair County (Figure 11).

Several factors which could set plant range boundaries in Michigan were investigated. These included soils, topographical barriers, precipitation (amount, season, and kind), evaporation, temperature extremes, frost-free season length, and amount of cold and heat. Based on the pattern of each factor, the hypothetical tension zone which would be caused by each factor was described. Plant ranges, if limited by that factor, would follow the trends of the isolines of that factor. Where the isolines were concentrated---where there was a sharp change---would be many range lines and thus a tension zone. Some factors are fairly evenly distributed; for these no tension zone would be predicted.

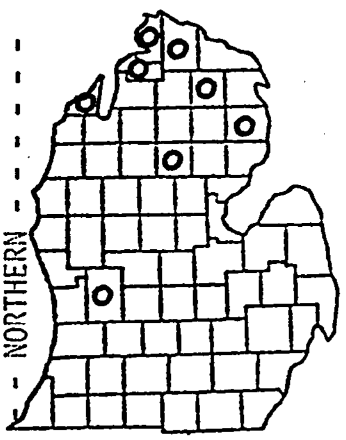
The range boundary trends and tension zone predicted by the hypothesis that insufficient heat sets the range limits of southern plants were shown by the bulk of the data. Some individual plant ranges matched predictions made by supposing that other factors caused range limits, but no other single hypothesis was supported by many of the range lines. As predicted by growing degree day data (the best available measure of heat), many range lines are found in a band from Muskegon to Bay to St. Clair County. The band is most distinct in the east and is diffuse at the Lake Michigan shoreline, where the northernmost ranges are extended northward and the southernmost range lines are deflected southward (Figures 8-10).

Growing degree day data also correctly predict the tension zones in Wisconsin and southern Ontario. Additional support for the hypothesis that insufficient heat limits many southern plants is that annual plants, for which insufficient heat means no reproduction, are disproportionately limited in Michigan. There are no annuals among northern plants which reach their southern borders here.

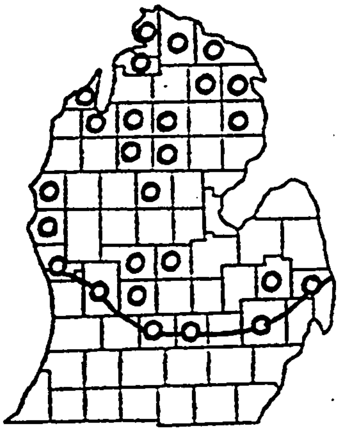
It is likely that the tension zone has existed in Michigan for about 10,000 years. The climate has certainly changed (and continues to change) but the pattern of climate has probably been similar since then, with a steep gradient in growing degree days at the tension zone. Shifts in individual range boundaries with climatic changes would not necessarily mean a shift in the tension zone.

Appendix 1

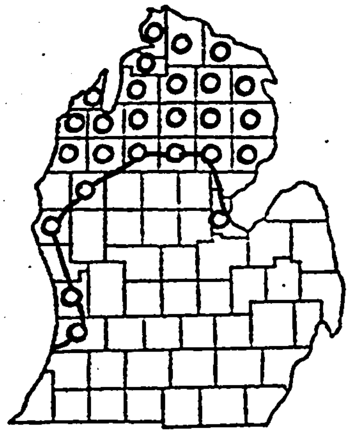
Dicots which have range limits in the Lower Peninsula of Michigan. Circles indicate a herbarium or literature record; range lines used are shown. Records in Cole (1901), Beal (1904, 1908), Hanes and Hanes (1947), Swink (1969) and Mustard (1979) were used as supplements throughout; other sources are noted. Plant names follow Gleason and Cronquist (1963). Life forms are indicated as ph=phanerophyte, ch=chamaephyte, h=hemicryptophyte, c=cryptophyte, and th=therophyte. Introduced plants indicated by "int" and northern plants of wet habitats by "wet." Northern plants are listed first, followed by southern plants. Within each group, families then species are in alphabetical order.



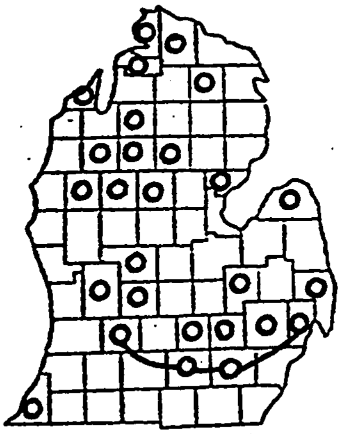

*ACERACEAE*
*Acer penslyvanicum* L. ph



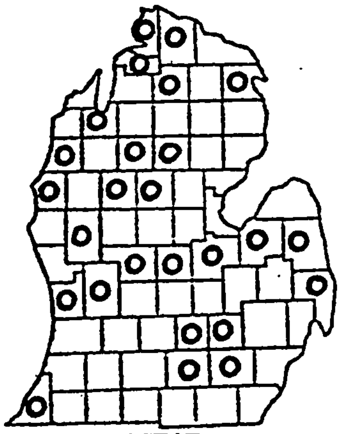
*Acer spicatum* Lam. ph



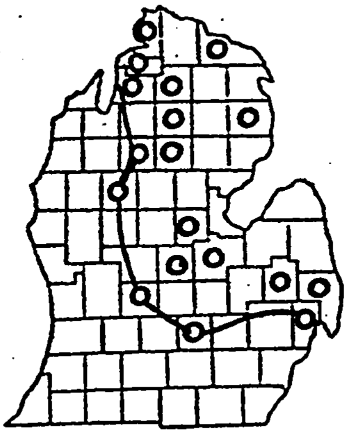
*ANACARDIACEAE*
*Rhus radicans* var. *rydbergii* (Small) Redher. (Gillis, 1962) ph



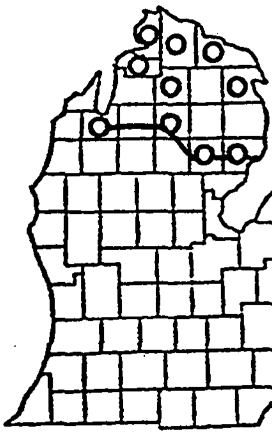
*AQUIFOLICACEAE*
*Nemopanthus mucronatus* (L.)Trel. ph wet



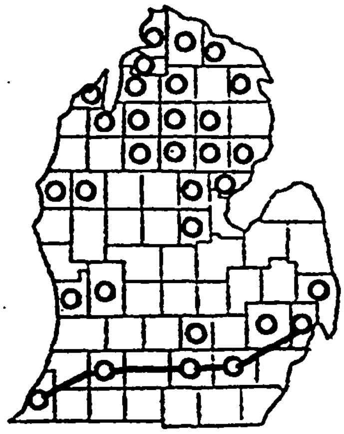
*BETULACEAE*
*Betula papyrifera* Marsh. ph



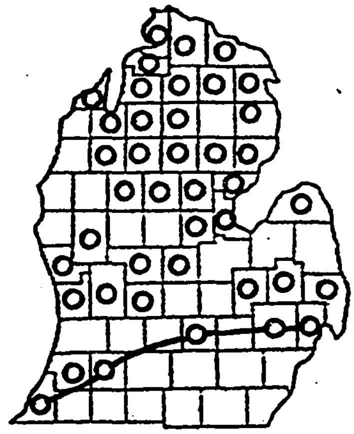
*Corylus cornuta* Marsh. ph



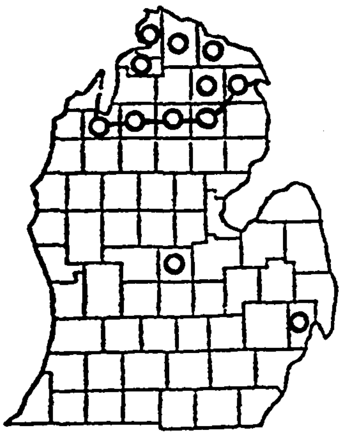
*BORAGINACEAE*
*Cynoglossum boreale* Fern. h



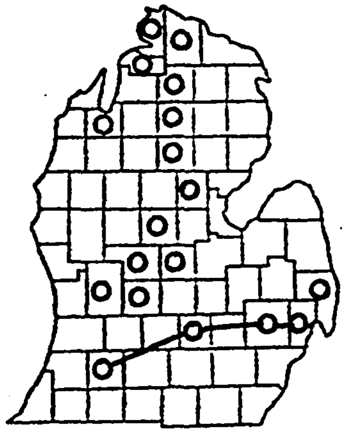
*CAPRIFOLIACEAE*
*Linnaea borealis* L. Ch wet



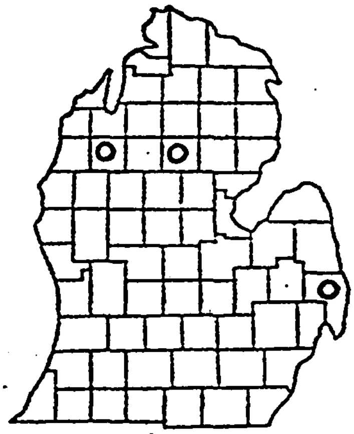
*Lonicera canadensis* Marsh. ph



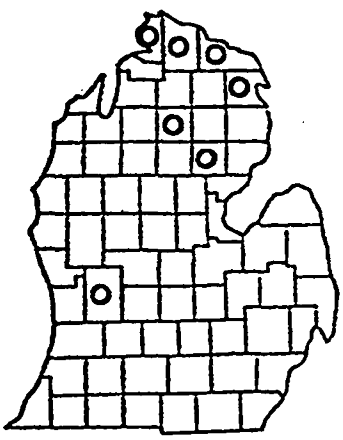
*Lonicera hirsuta* Eat. ph



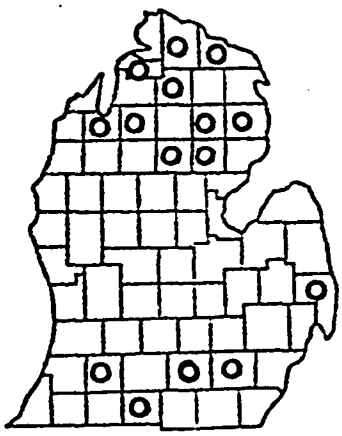
*Lonicera oblongifolia* (Goldie) Hook. ph wet



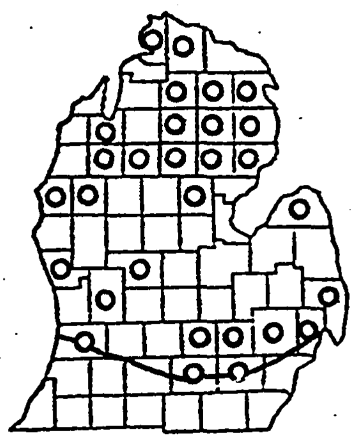
*Lonicera villosa* (Michx.)R.TS. ph wet



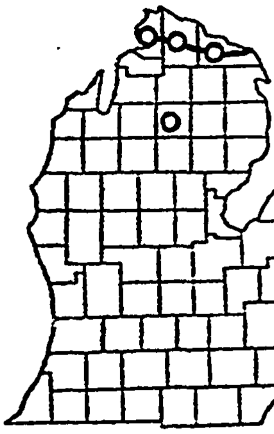
*COMPOSITAE*
*Aster ciliolatus* Lindl. (Van Faasen, 1971) h



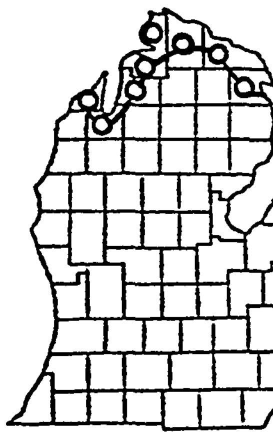
*Echinacea pallida* Nutt. h



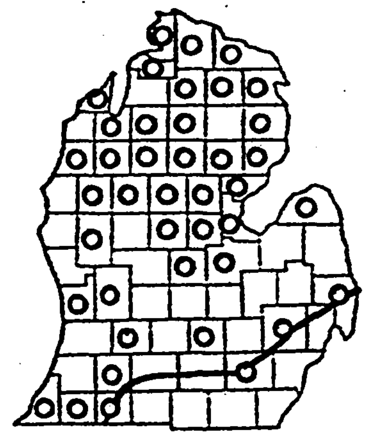
*Hieracium venosum* L. h



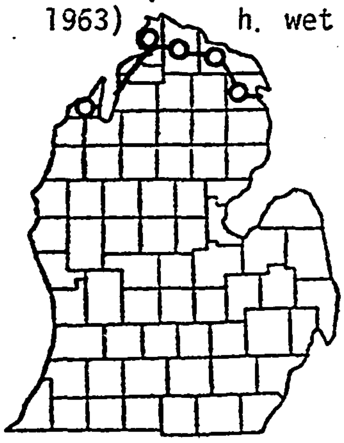
*Solidago houghtonii* T.&G. (Guire and Voss, 1963) h. wet



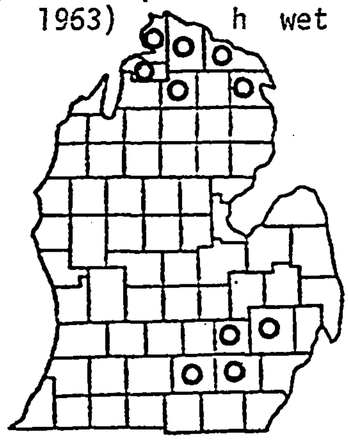
*Tanacetum huronense* Nutt. (Guire and Voss, 1963) h wet



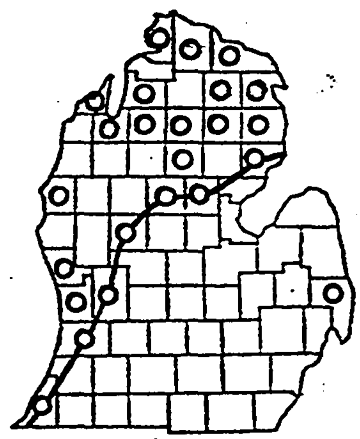
*CORNACEAE*
*Cornus canadensis* L.
h wet



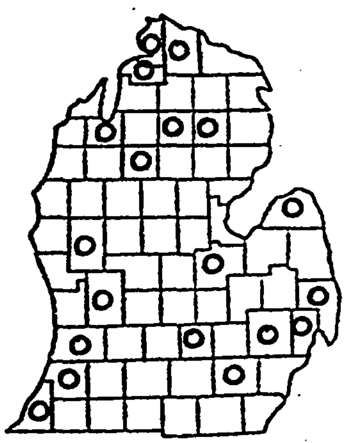
*CRUCIFERAE*
*Arabis holboelii* Hornem. h



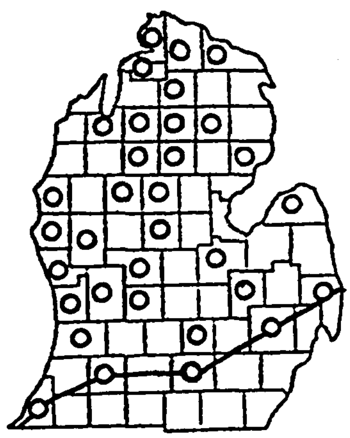
*DROSERACEAE*
*Drosera linearis* Goldie. h wet



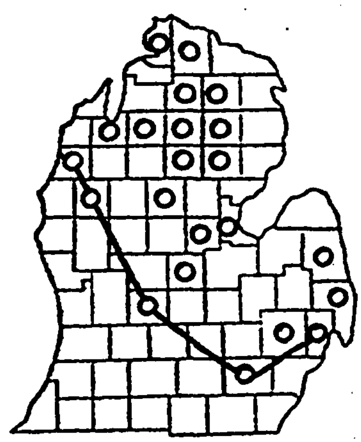
*ERICACEAE*
*Arctostaphylos uva-ursi* (L.)Spreng. ch



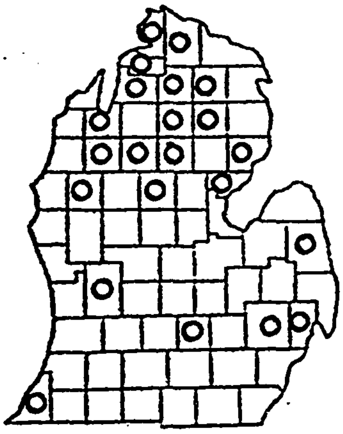
*Chimaphila umbellata* (L.)Bart. h



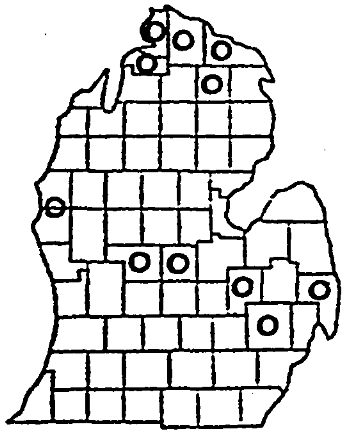
*Epigaea repens* L. ch



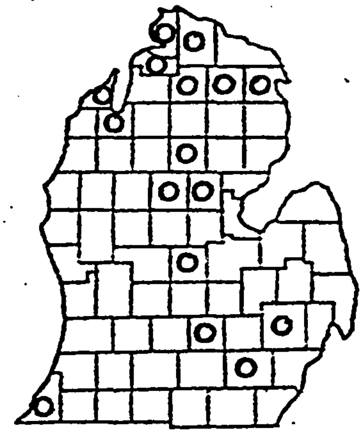
*Kalmia polifolia* Wang. ph wet



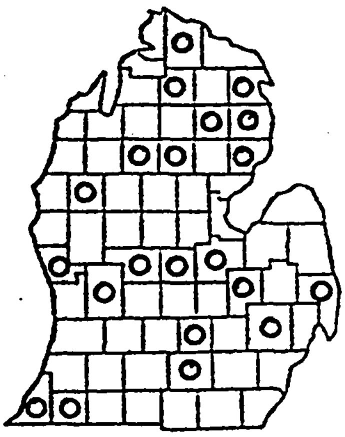
*Ledum groenlandicum* Oeder. ph wet



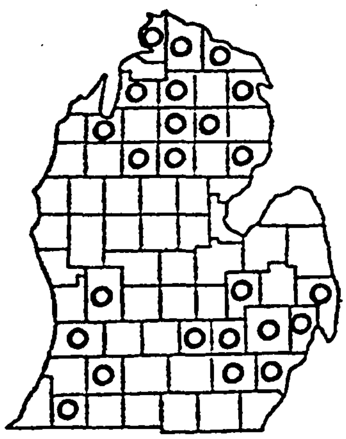
*Moneses uniflora* (L.)Gray. c wet



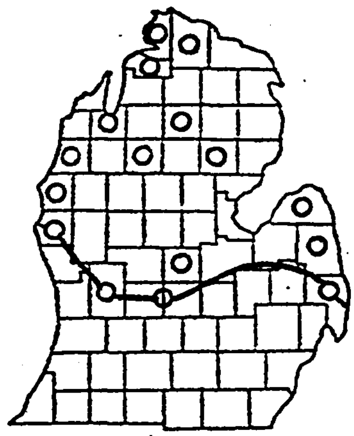
*Pyrola asarifolia* Michx. h wet



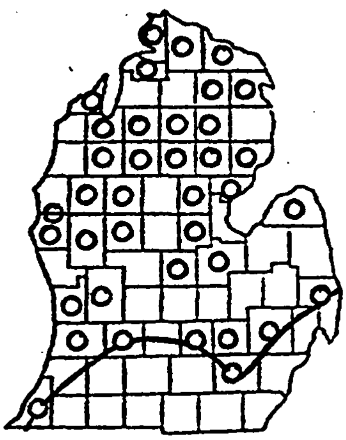
*Pyrola rotundifolia* L. h wet



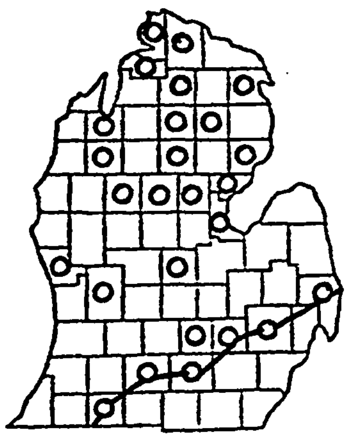
*Pyrola secunda* L. h wet



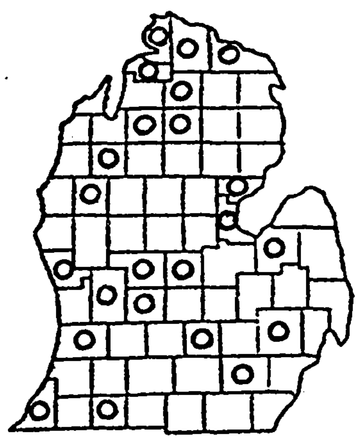
*Pyrola virens* Schweigg. h



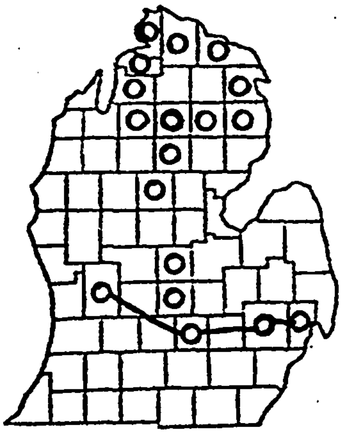
*Vaccinium angustifolium* Ait. ph



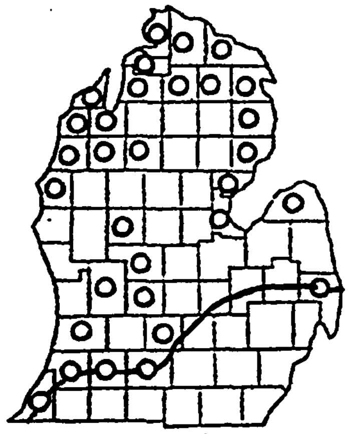
*Vacciunium myrtilloides* Michx. ph wet



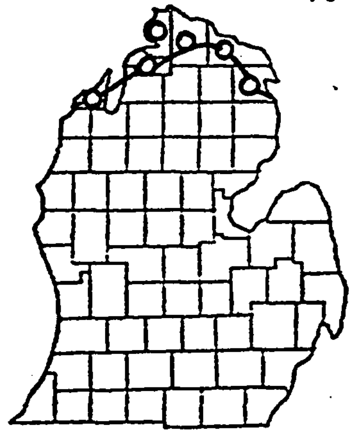
*Vaccinium oxycoccos* L. ch wet



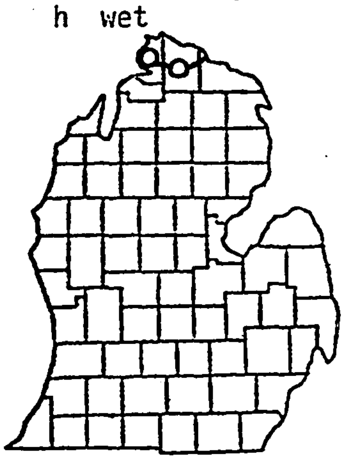
*GENTIANACEAE*
*Gentiana rubricaulis* Schw. (Pringle,1968) h wet



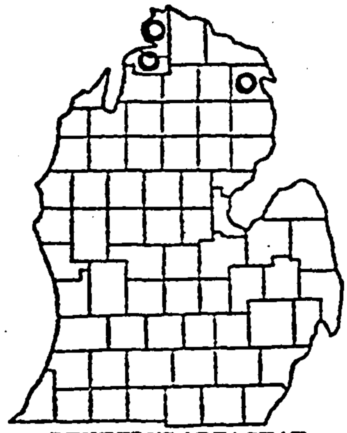
*LABIATAE* (all: Waterman, 1960)
*Satureja glabella* (Michx.) h



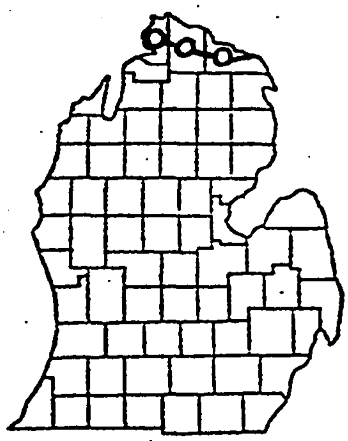
*Satureja vulgaris* (L.)Fritsch. h



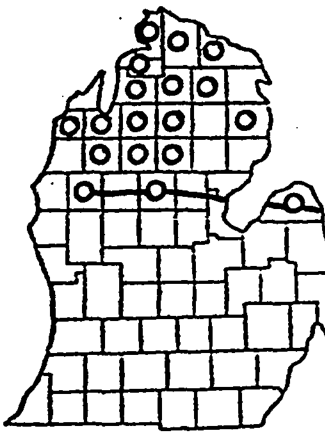
*Stachys palustris* L. c wet



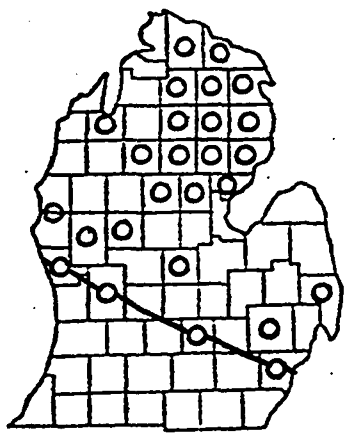
*LENTIBULARIACEAE*
*Pinguicula vulgaris* L. h wet



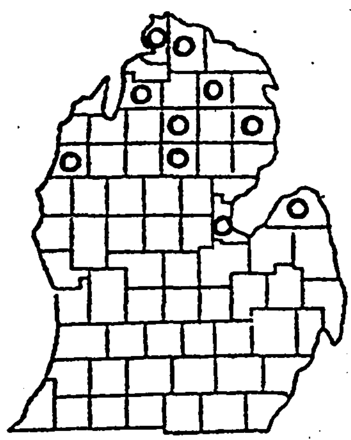
*Utricularia geminiscarpa* Benj. c wet



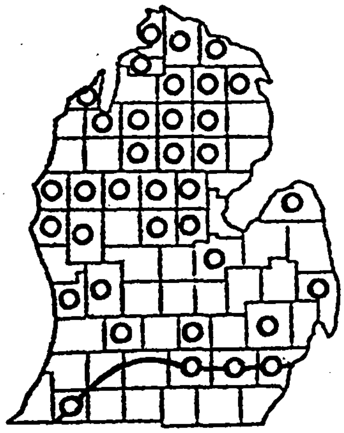
*LORANTHACEAE*
*Arceuthobium pusillum* Peck. ph wet



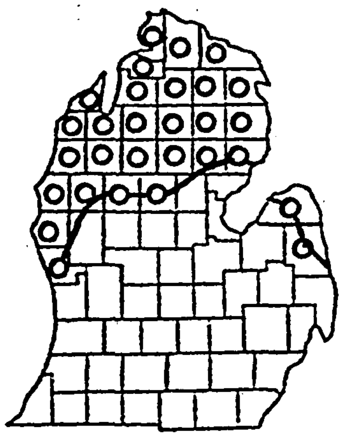
*MYRICACEAE*
*Myrica aspleni-folia* L. ph



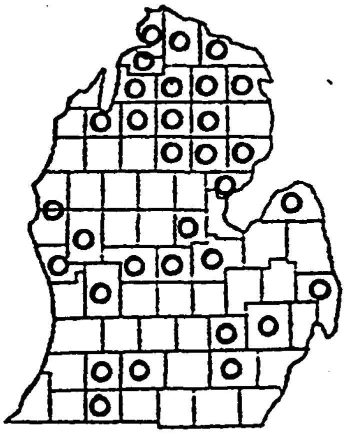
*Myrica gale* L. ph wet



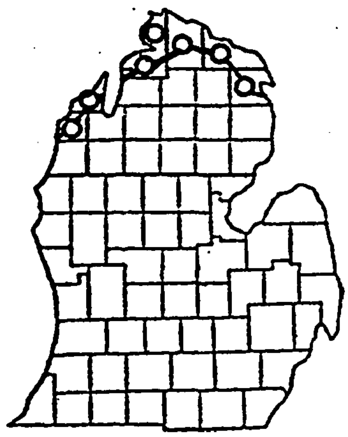
POLYGALACEAE
*Polygala paucifolia*
Willd. h



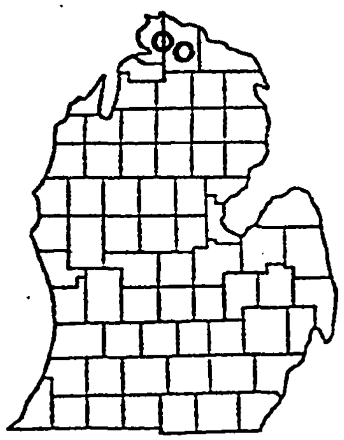
PORTULACACEAE
*Claytonia caroliniana*
Michx. (Voss, 1968) c



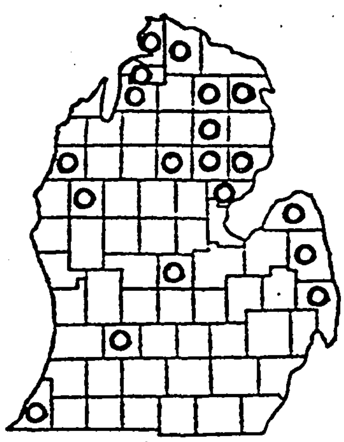
PRIMULACEAE
*Trientalis borealis*
Raf. h wet



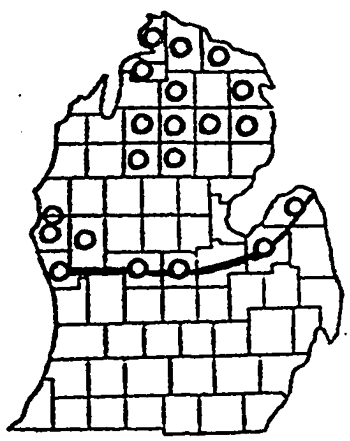
RANUNCULACEAE
*Anemone multifida*
Poir. h



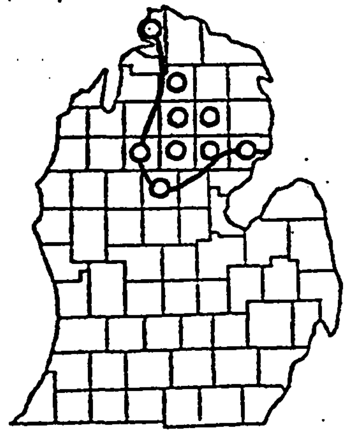
ROSACEAE
*Amelanchier bartram-iana* (Tausch)Roemer.
ph wet



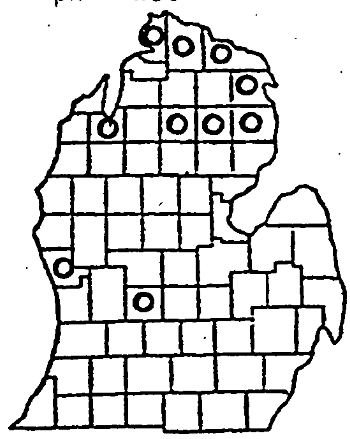
*Amelanchier san-guinea* (Pursh)DC.
ph wet



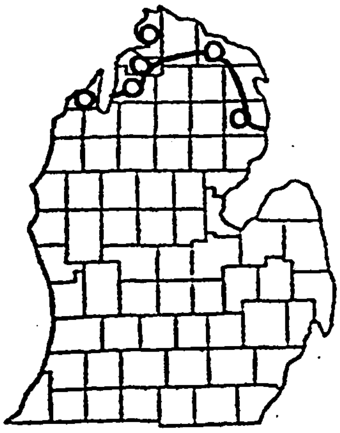
*Amelanchier spicata*
(Lam.)K.Koch. ph



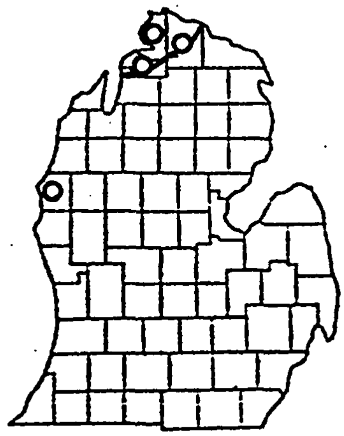
*Potentilla tri-dentata* Soland. ch



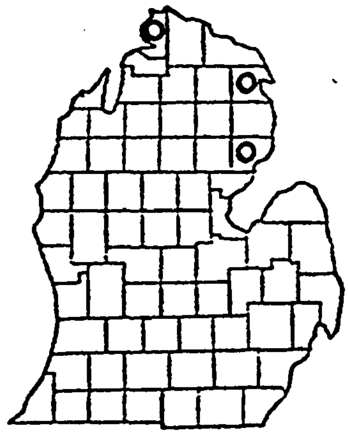
*Rosa acicularis*
Lindl. ph



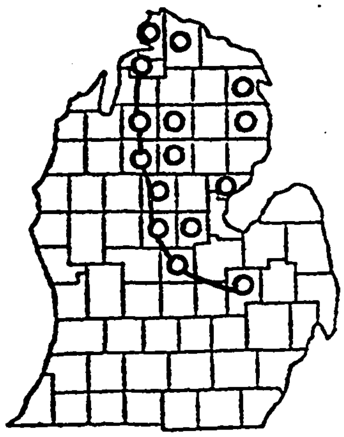
*Rubus parviflorus* Nutt. h



*Sorbus americana* Marsh. ph wet

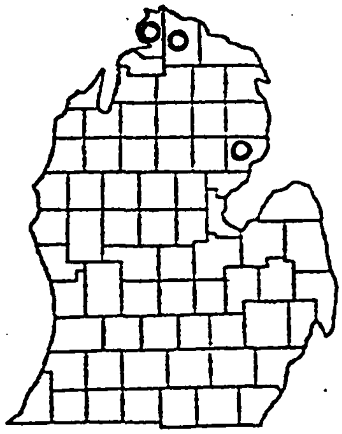


*Sorbus decora* (Sarg.)C.K.Schneid. ph

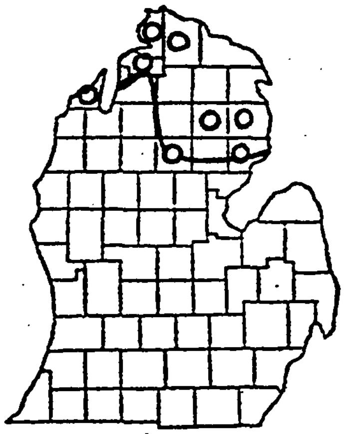


*SAXIFRAGACEAE*

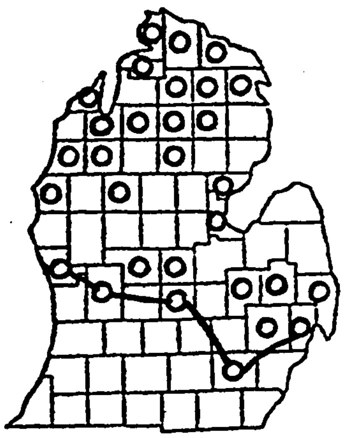
*Ribes glandulosum* Grauer. ph wet



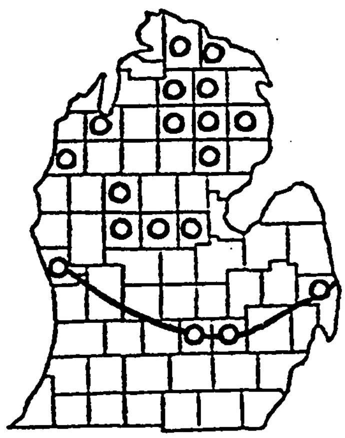
*Ribes hudsonianum* Richards. ph wet



*Ribes lacustre* (Pers.) Poir. ph wet

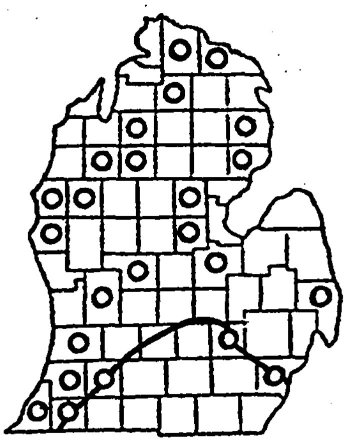


*Ribes triste* Pall. ph wet

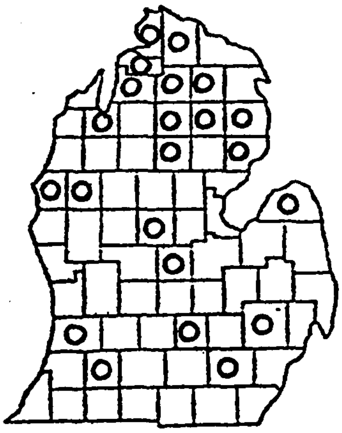


*VIOLACEAE*

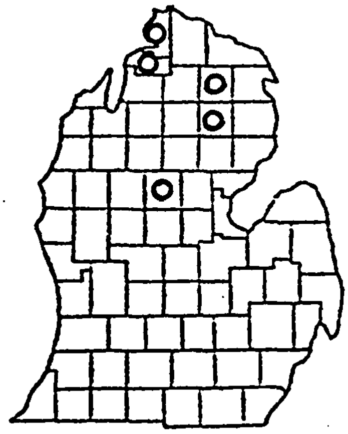
*Viola adunca* Sm. c



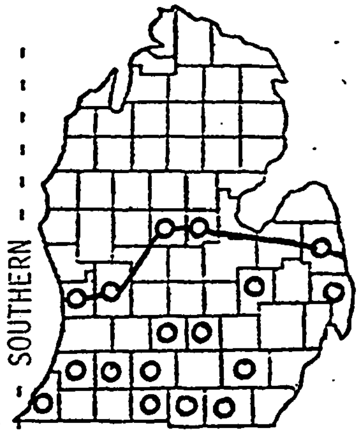
*Viola lanceolata* L. h wet



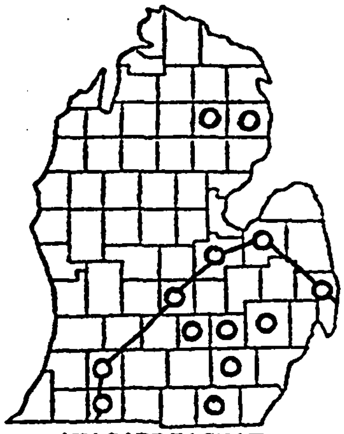
*Viola renifolia*
Gray. c wet



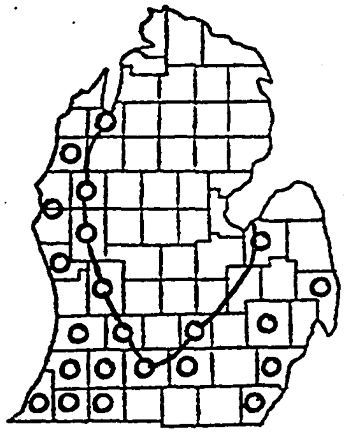
*Viola selkirkii*
Pursh. h



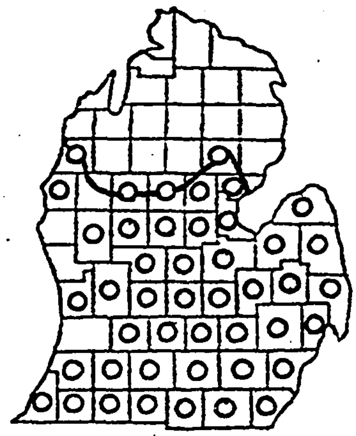

*ACERACEAE*
*Acer nigrum*
Michx.f. ph



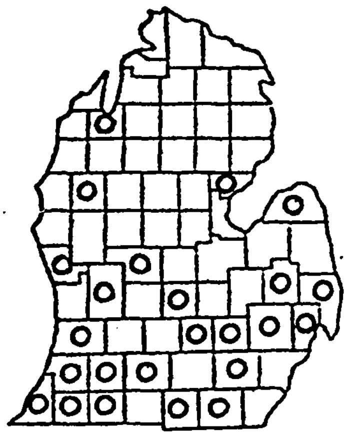
*ANACARDIACEAE*
*Rhus aromatica* Ait.
ph



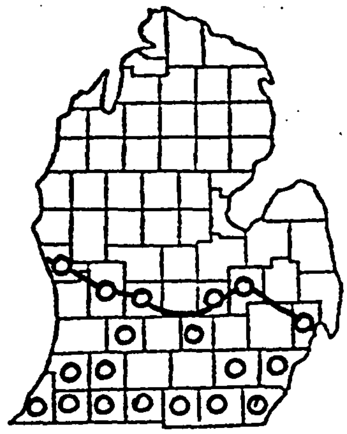
*Rhus copallinum* L.
ph



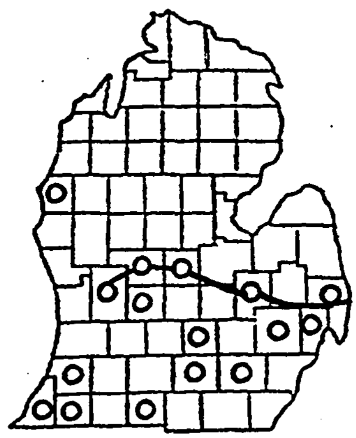
*Rhus radicans* var.
*radicans* (Gillis,
1962) ph



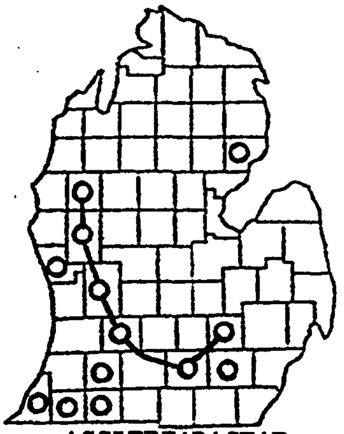
*Rhus vernix* L.
ph



*ANNONACEAE*
*Asimina triloba*
(L.)Dunal. ph

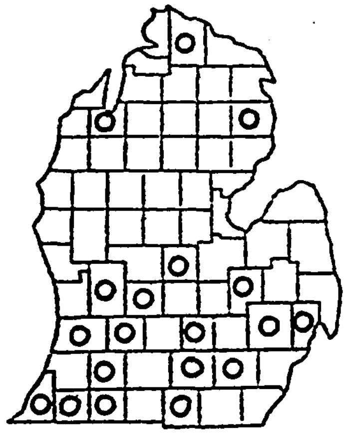


*ARALIACEAE*
*Panax quinquefolium* L.
c

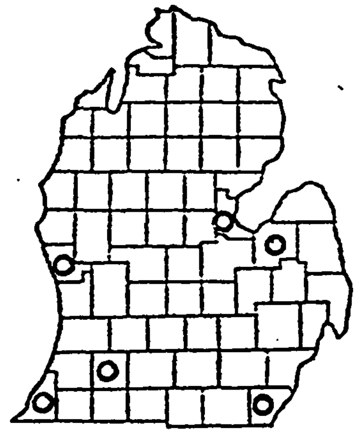


ASCLEPIADACEAE

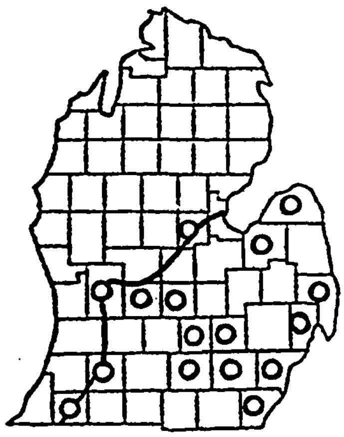
*Asclepias amplexi-caulis* Sm. h



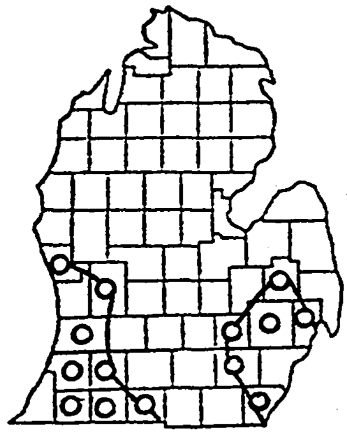
*Asclepias exaltata* L. h



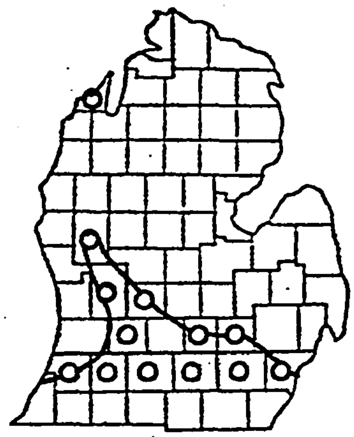
*Asclepias hirtella* (Pennell)Woodson. h



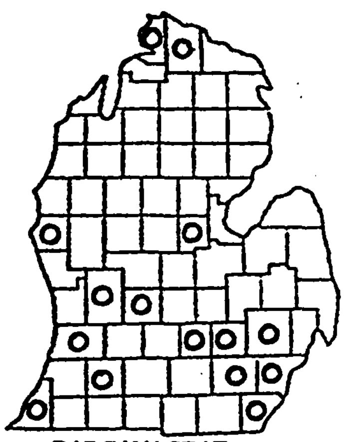
*Asclepias purpurascens* L. h



*Asclepias verti-cillata* L. h

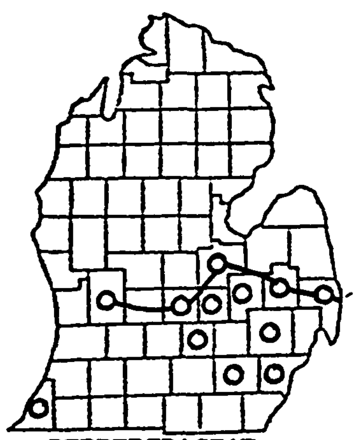


*Asclepias viridi-flora* Raf. h



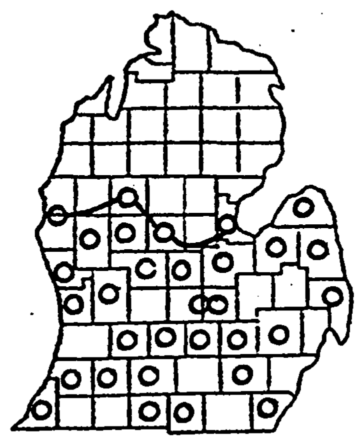
BALSAMACEAE

*Impatiens biflora* Walt. th

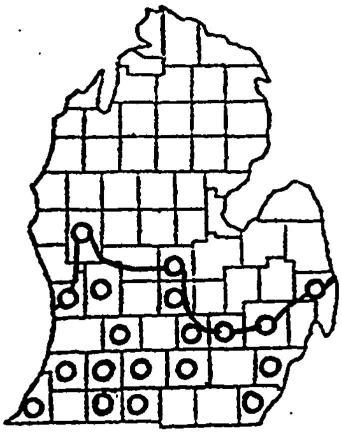


BERBERIDACEAE

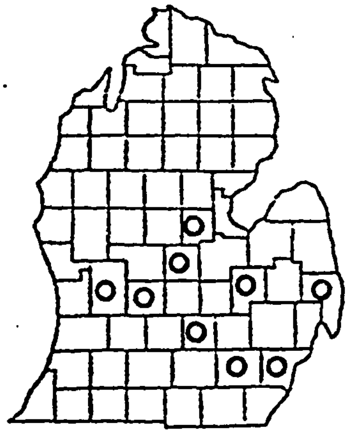
*Jeffersonia diphylla* (L.)Pers. c



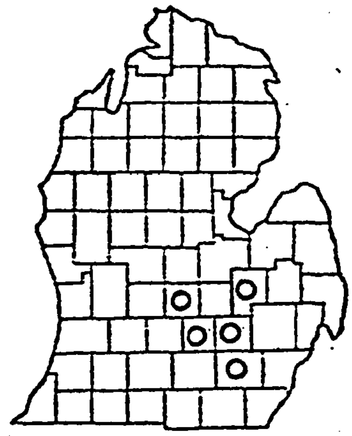
*Podophyllum peltatum* L. c



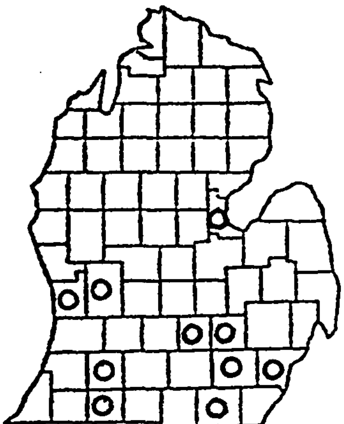
BETULACEAE
*Corylus americana* Walt. ph



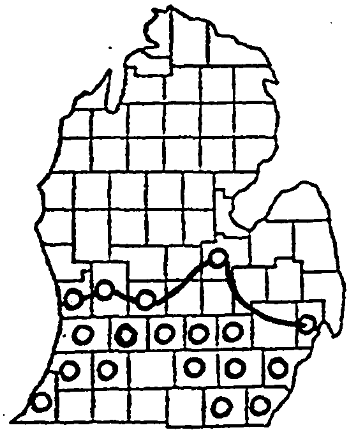
BORAGINACEAE
*Lithospermum latifolium* Michx. h



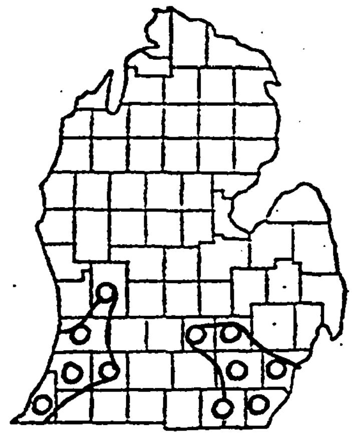
*Mysotis verna* Nutt. th



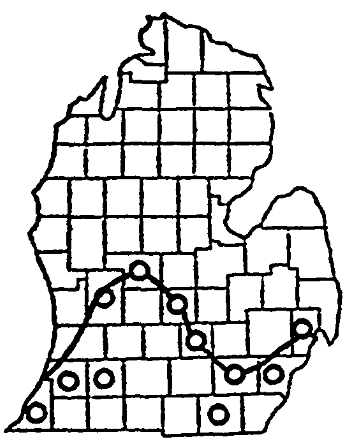
CAESALPINIACEAE
*Cassia marilandica* L. ph



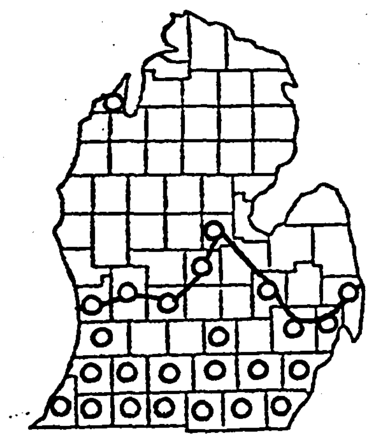
*Cercis canadensis* L. ph



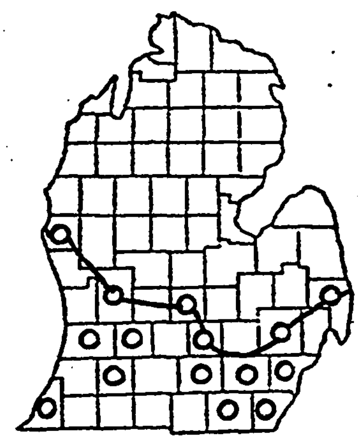
*Gleditsia triacanthos* L. ph



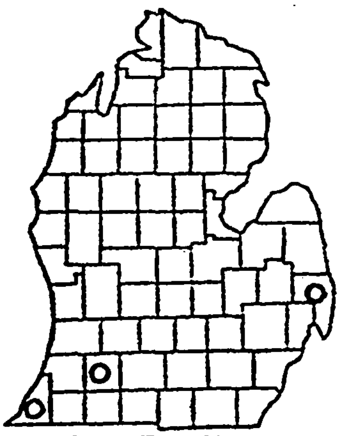
*Gymnocladus dioica* (L.)K.Koch. ph



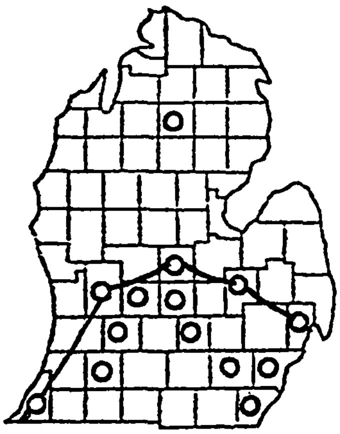
CAMPANULACEAE
*Campanula americana* L. (Shelter, 1962) th



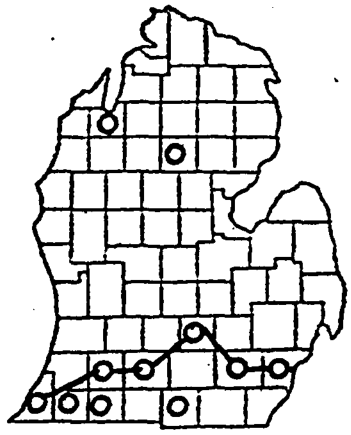
*Triodanis perfoliata* (L.)Nieuwl. th



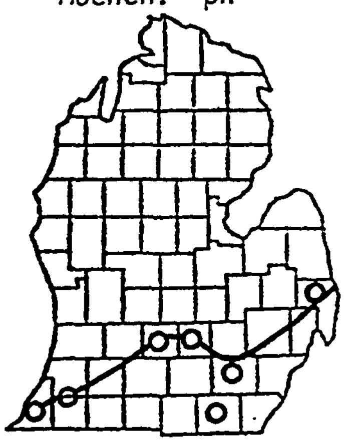
*CAPRIFOLIACEAE*
*Symphoricarpus orbiculatus* Moench. ph



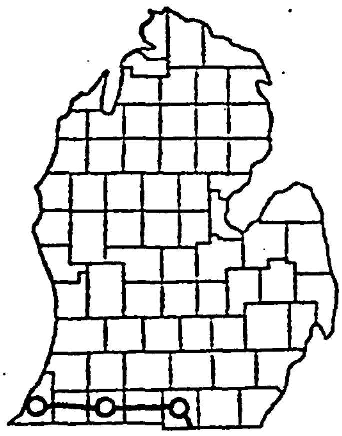
*Triosteum perfoliatum* L. h



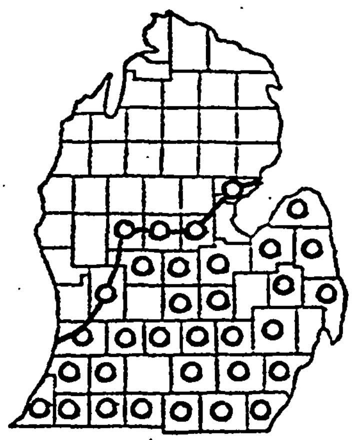
*Viburnum prunifolium* L. ph



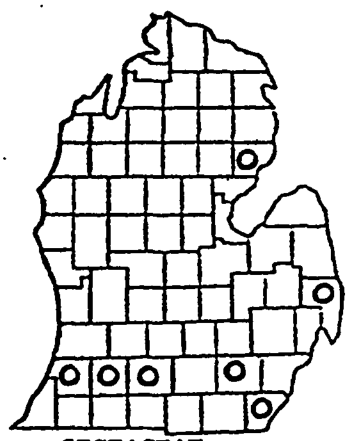
*CARYOPHYLLACEAE*
*Arenaria lateriflora* L. h



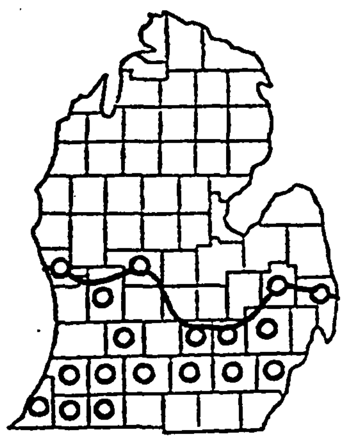
*Silene stellata* (L.)Ait.f. h



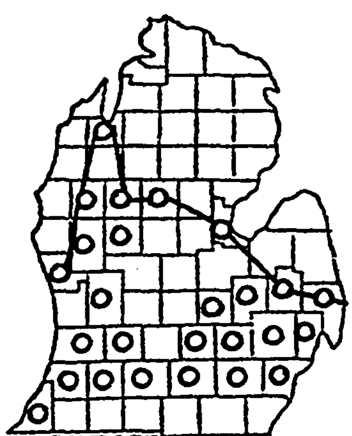
*CELASTRACEAE*
*Euonomus obovatus* Nutt. ph



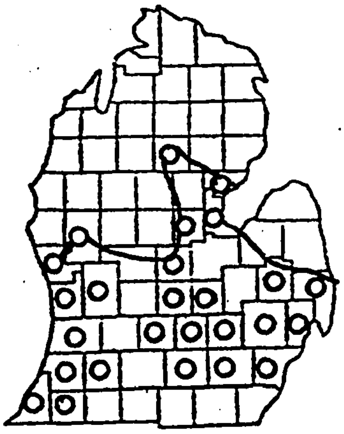
*CISTACEAE*
*Lechea minor* L. h



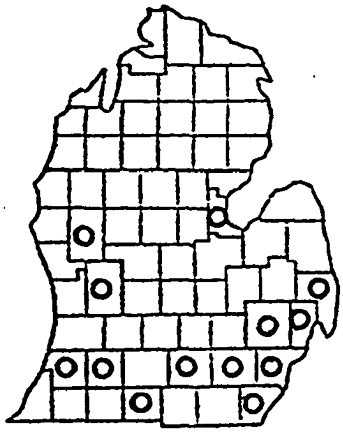
*Lechea villosa* Ell. h



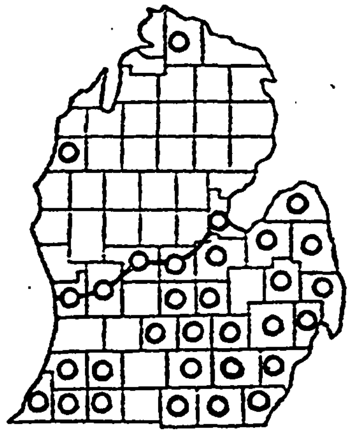
*COMPOSITAE*
*Aster azureus* Lind. (all asters: Van Faasen, 1971) h



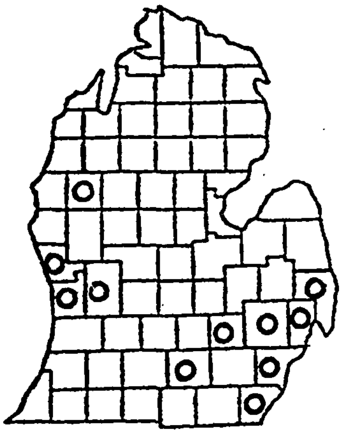
*Aster cordifolius*
L. h



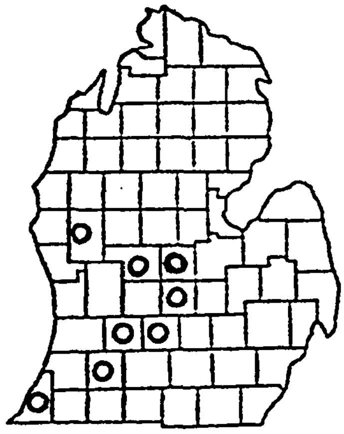
*Aster ericoides*
L. h



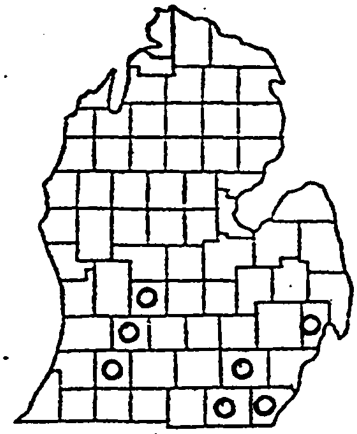
*Aster novae-angliae* L. h



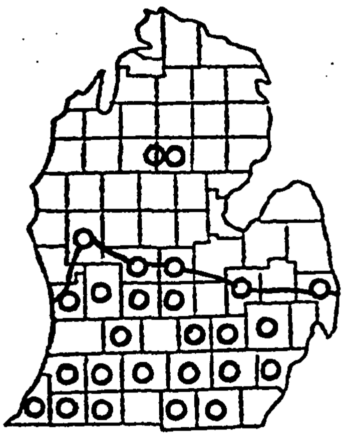
*Aster praealtus*
Poir. h



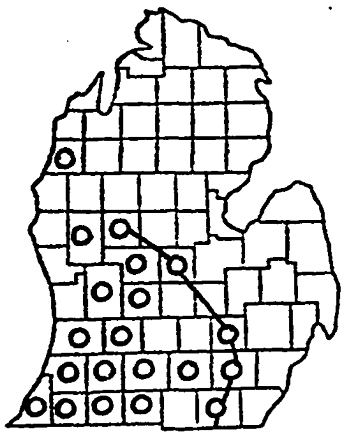
*Aster sagittifolius*
Willd. h



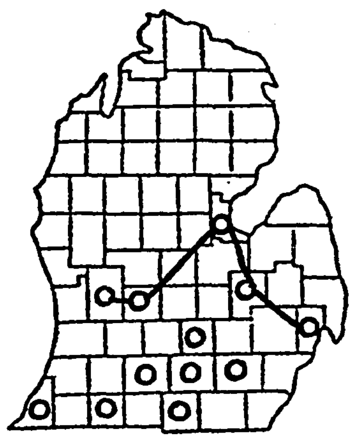
*Aster shortii*
Lindl. h



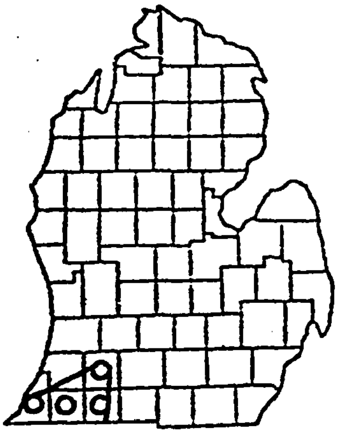
*Bidens coronata*
(L.)Britt. th



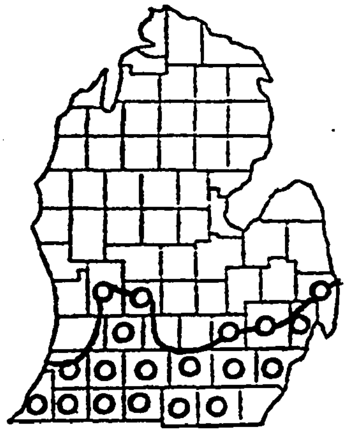
*Cacalia atriplicifolia* L. h



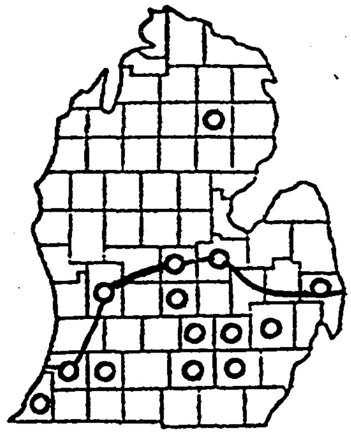
*Cirsium altissimum*
(L.)Spreng. h



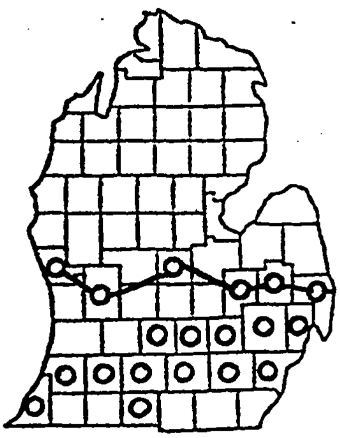
*Coreopsis palmata* Nutt. h



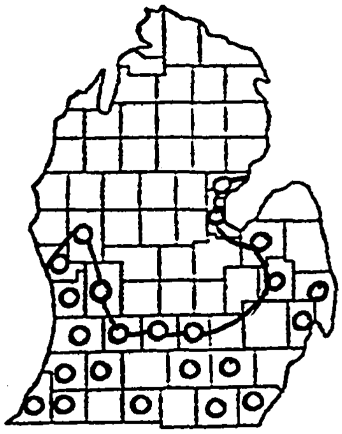
*Coreopsis tripteris* L. h



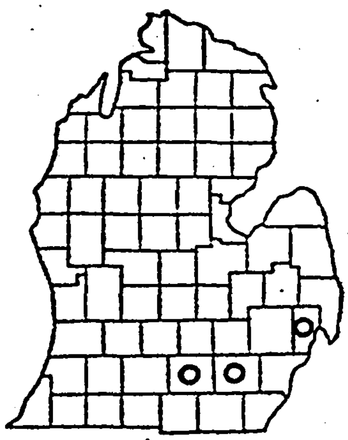
*Erigeron pulchellus* Michx. h



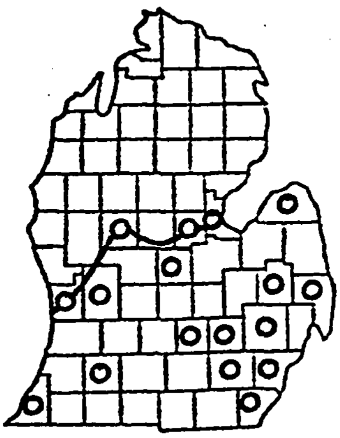
*Eupatorium purpureum* L. h



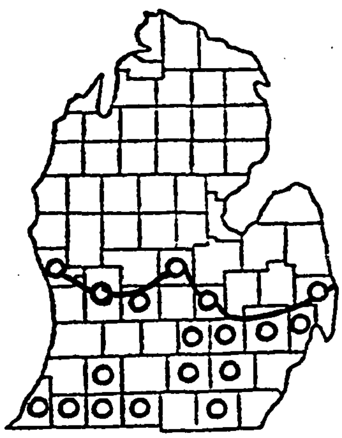
*Eupatorium rugosum* Houtt. h



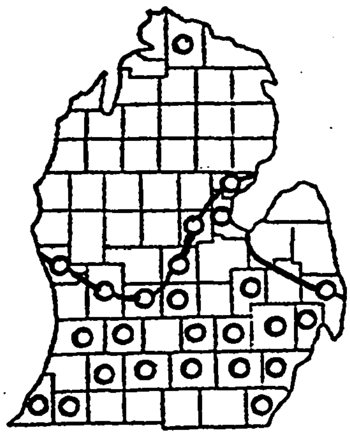
*Eupatorium sessilifolium* L. h



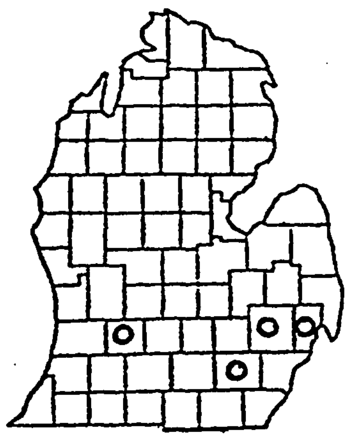
*Helenium autumnale* L. h



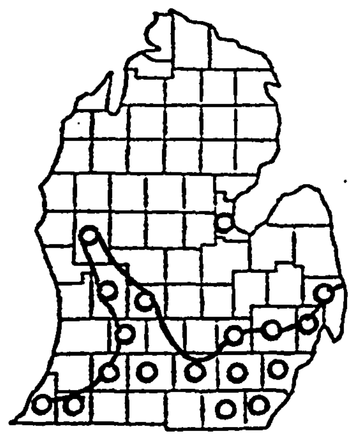
*Helianthus decapetalus* L. c



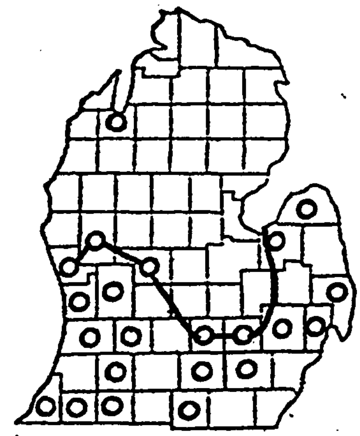
*Helianthus giganteus* L. h



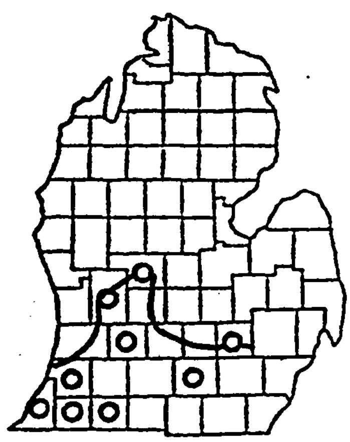
*Helianthus hirsutus* Raf. c



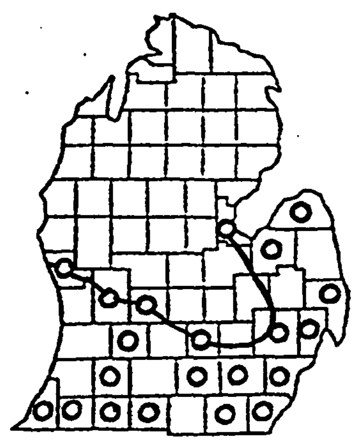
*Helianthus stumosus* L. c



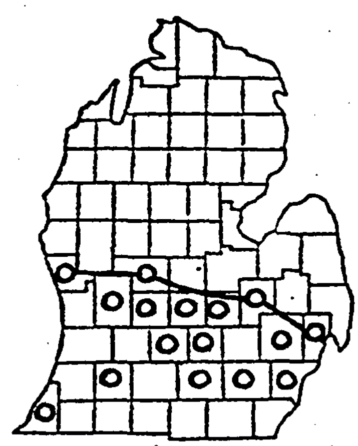
*Hieracium longipilum* Torr. h



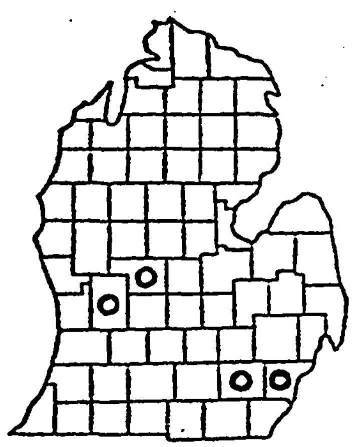
*Kuhnia euputori-oides* L. h



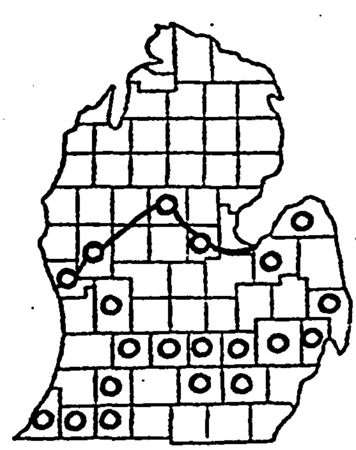
*Liatris spitaca* (L.)Willd. c



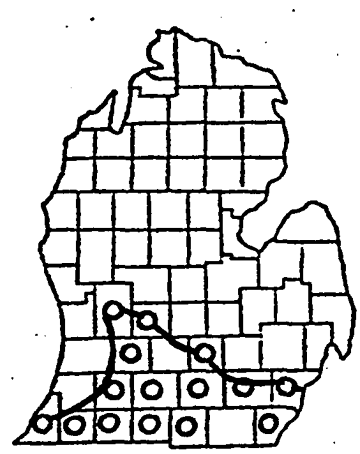
*Polymnia canadensis* L. (Wells,1967) h



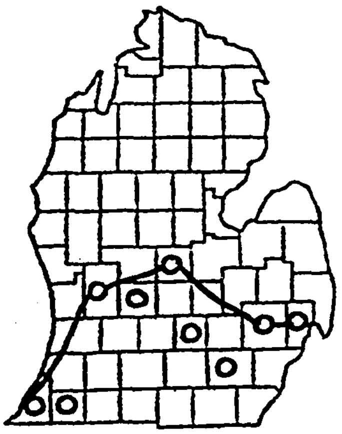
*Polymnia uvedalia* (L.)L. (Wells,1967) h



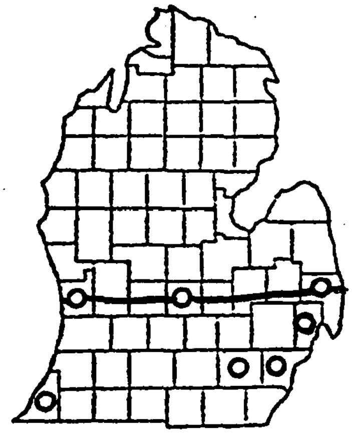
*Prenathes altissima* L. h



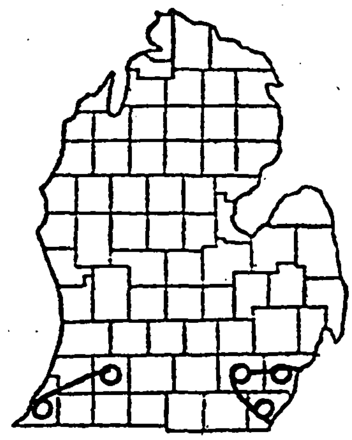
*Ratibida pinnata* (Vent.)Barnh. c



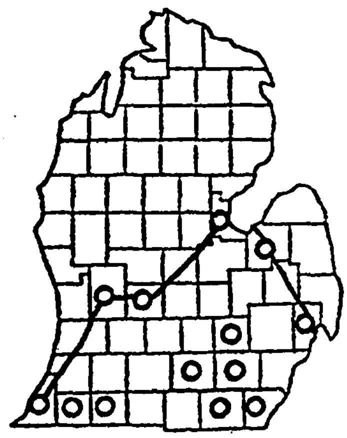
*Rudbeckia fulgida* Ait. h



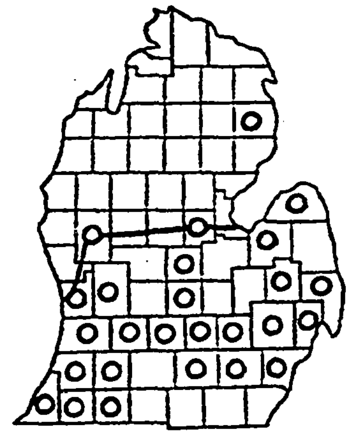
*Rudbeckia triloba* L. h



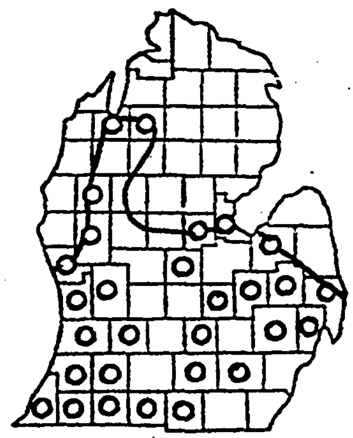
*Silphium perfoliatum* L. h



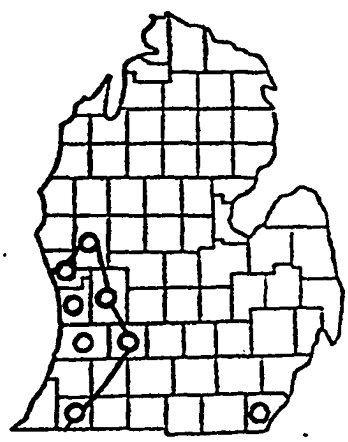
*Silphium terebinthinaceum* Jacq. h



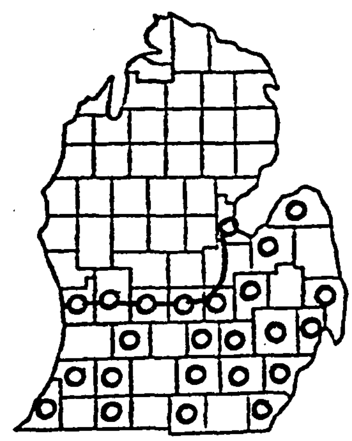
*Solidago caesia* L. h



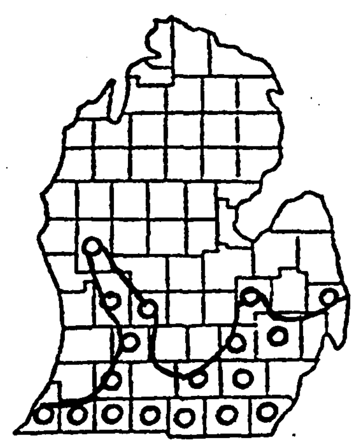
*Solidago patula* Muhl. h



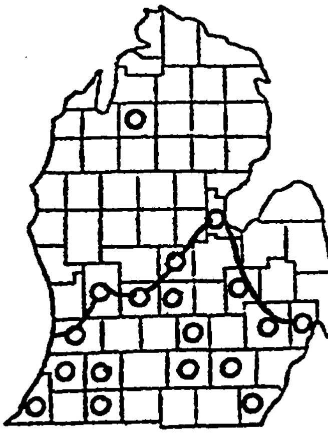
*Solidago remota* (Greene)Friesner. h



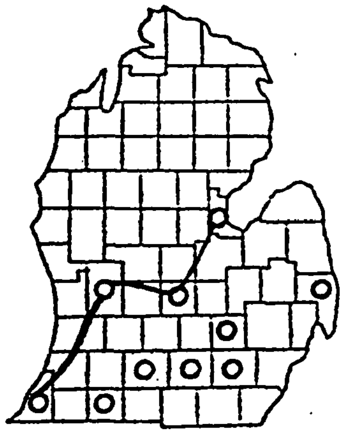
*Solidago riddelli* Frank. h



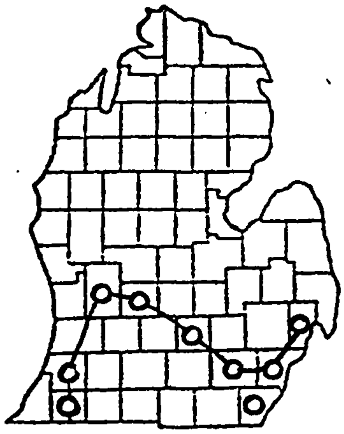
*Solidago rigida* L. h



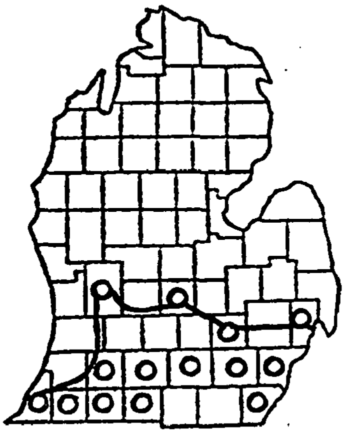
*Solidago ulmifolia*
Muhl. h



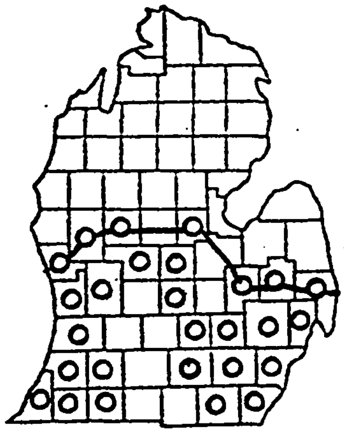
*Vernonia altissima*
Nutt. h



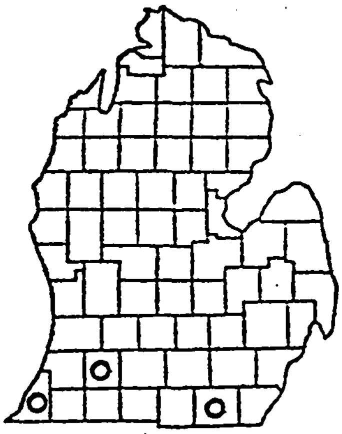
*Vernonia fasiculata*
Michx. h



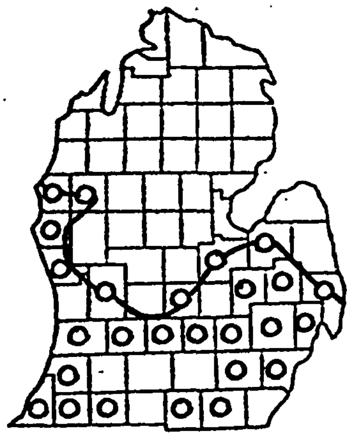
*Vernonia missurica*
Raf. h



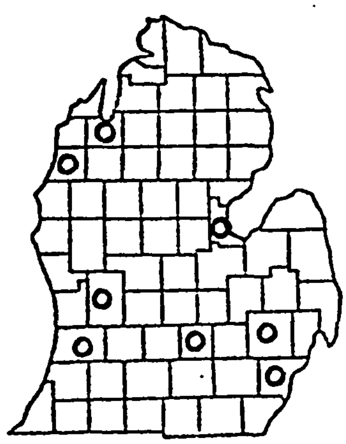
*CONVOLVULACEAE*
*Cuscuta gronovii*
Willd. th



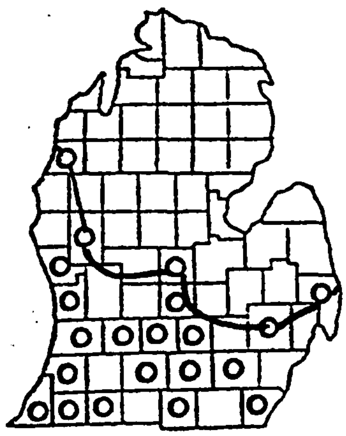
*Ipomaea pandurata*
(L.)G.R.W.Meyer c



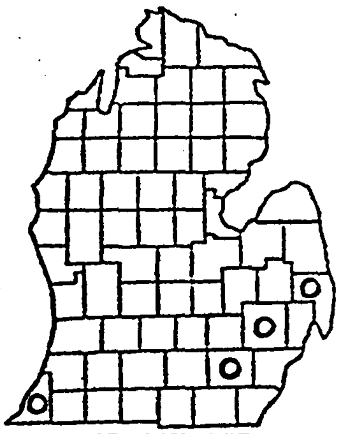
*CORNACEAE*
*Cornus florida*
L. ph



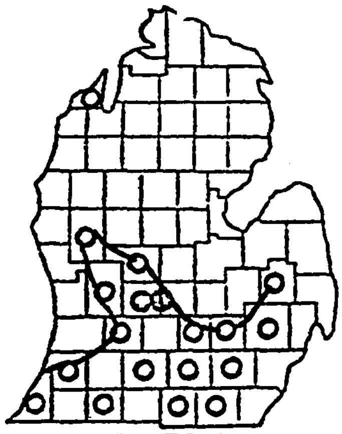
*Cornus purpusi*
Koehne. ph



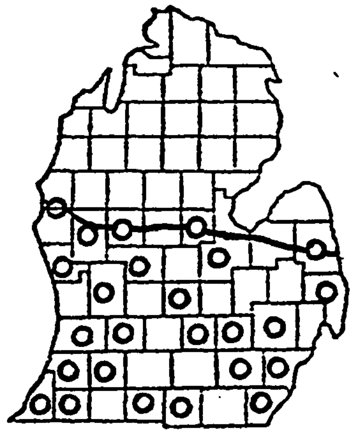
*Nyssa sylvatica*
Marsh. ph



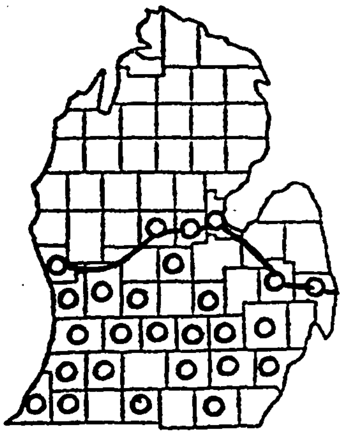
*CRASSULACEAE*
*Sedum ternatum*
Michx. c



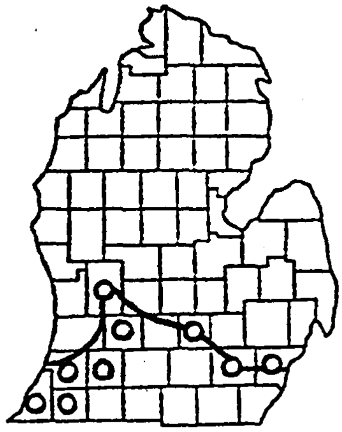
*CRUCIFERAE*
*Arabis canadensis*
L. h



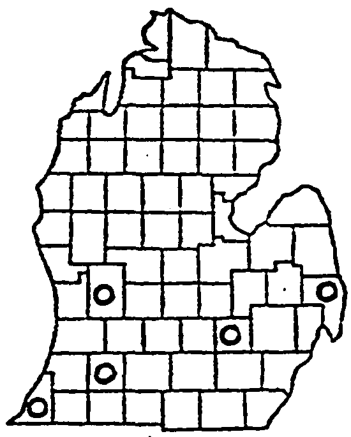
*Cardamine bulbosa*
(Schreb.)BSP. (Stuckey, 1962) c



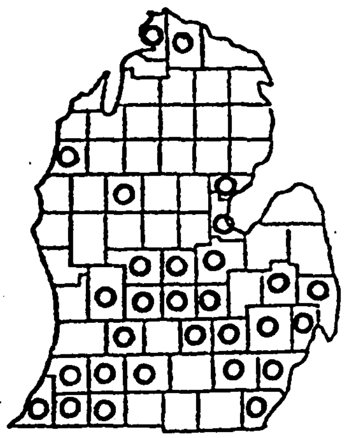
*Cardamine douglassii*
(Torr.)Britt.
(Stuckey,1962) c



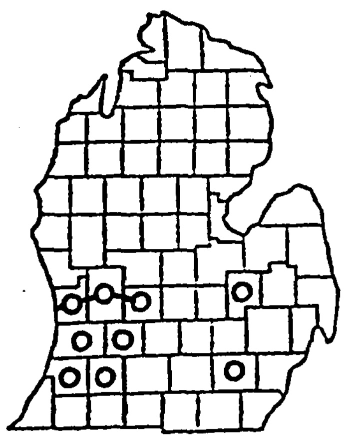
*Dentaria laciniata*
Muhl. c



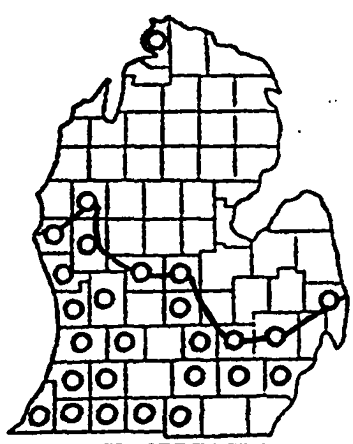
*Draba reptans*
(Lam.)Fern. th



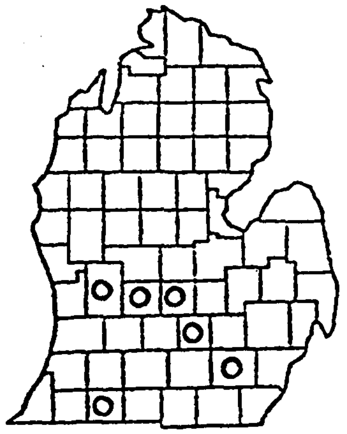
*CUCURBITACEAE*
*Echinocystis lobata*
(Michx.)T.&G. th



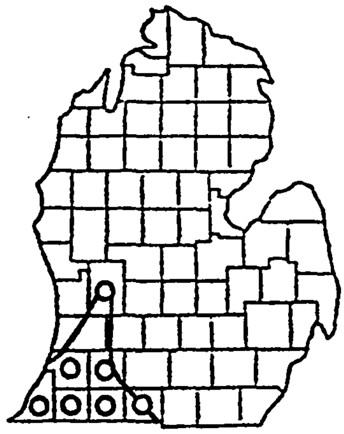
*ERICACEAE*
*Chimaphila maculata*
(L.) Bart. h



*EUPHORBIACEAE*
*Euphorbia corollata* L.
c

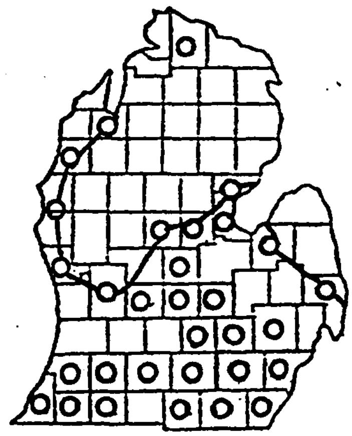


*Euphorbia preslii* Guss. th

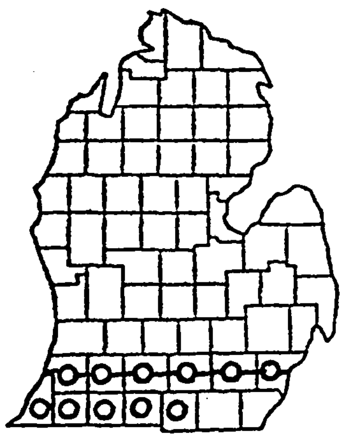


*FABACEAE*

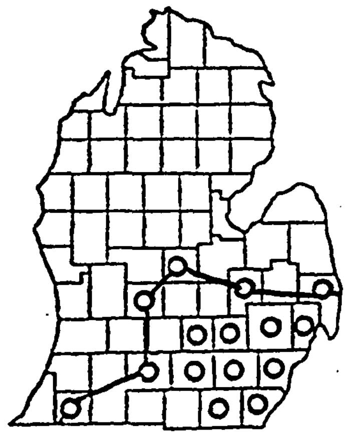
*Amorpha canescens* Pursh. ph



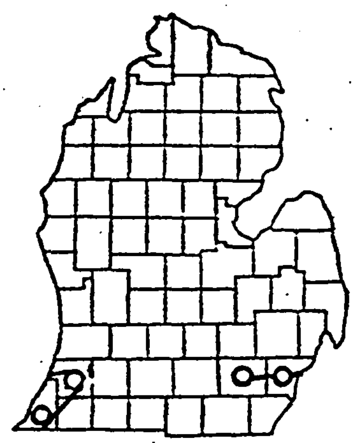
*Amphicarpa bracteata* (L.)Fern. h



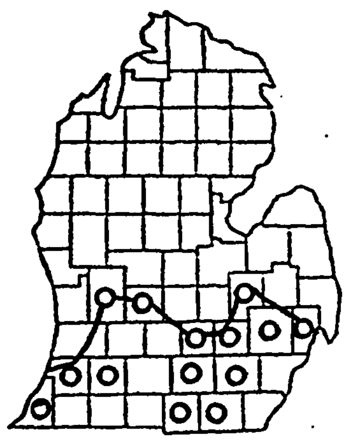
*Baptisia leucantha* T.&G. h



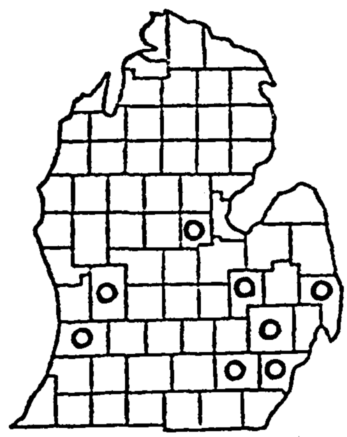
*Baptisia tinctoria* (L.)R.Br. h



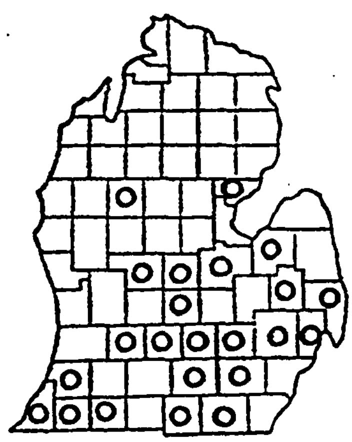
*Desmodium canescens* (L.)DC. h



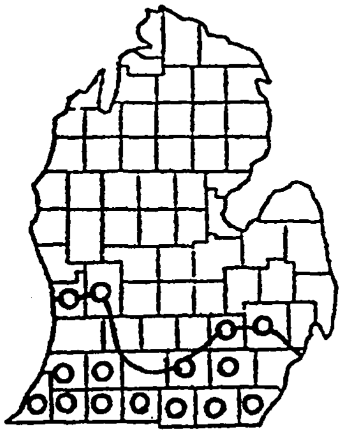
*Desmodium cuspidatum* (Muhl.)Loud. h



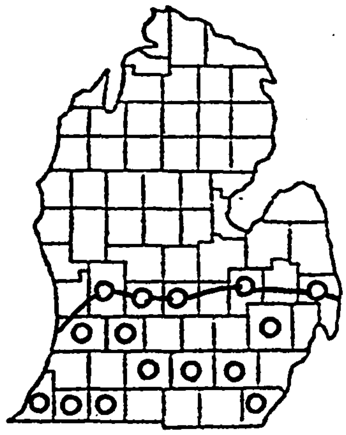
*Desmodium dillenii* Darl. h



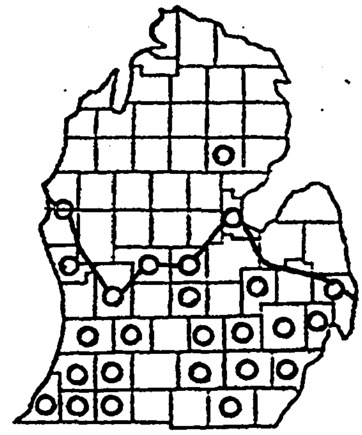
*Desmodium glutinosum* (Muhl.)Wood. h



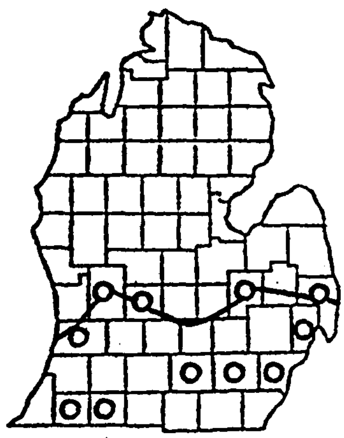
*Desmodium illinoense* Gray. h



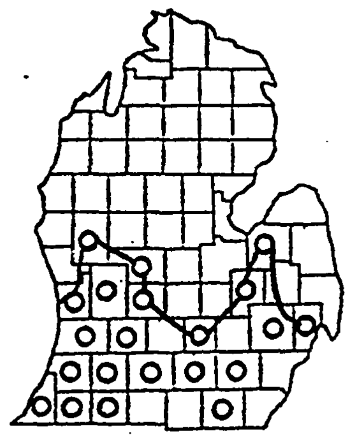
*Desmodium marilandicum* (L.)DC. h



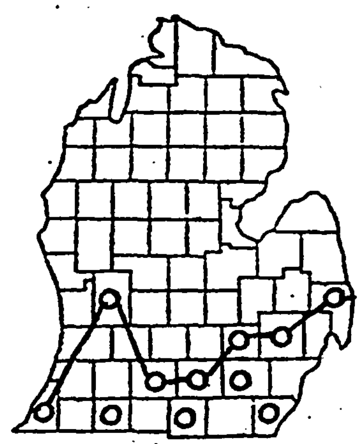
*Desmodium nudiflorum* (L.)DC. h



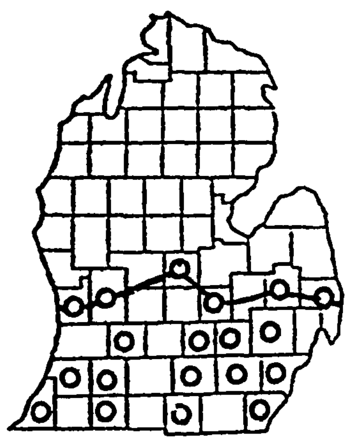
*Desmodium rigidum* (Ell.)DC. h



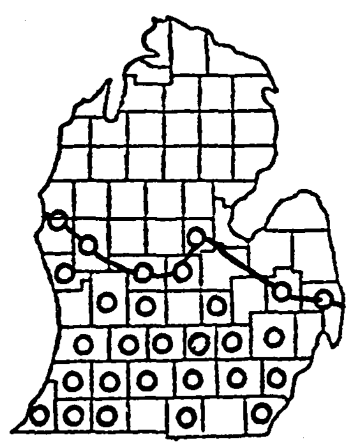
*Desmodium rotundifolium* DC. h



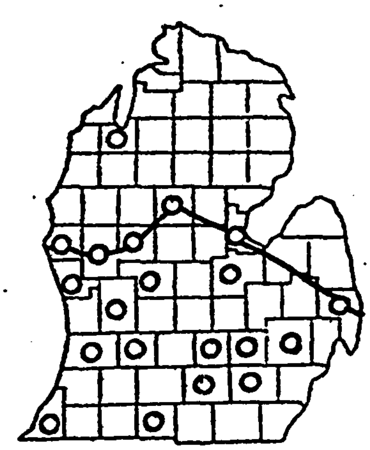
*Desmodium sessiliflorum* (Torr.)T.&G. h



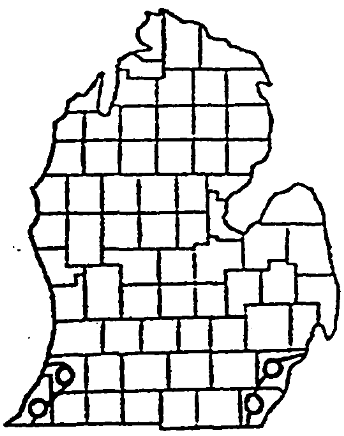
*Lespedeza capitata* Michx. h



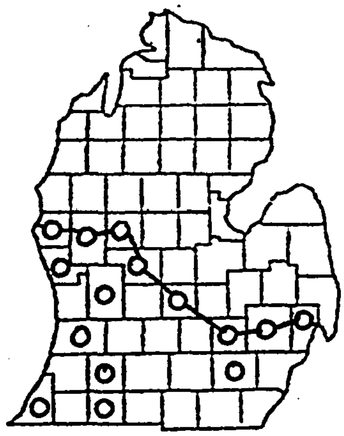
*Lespedeza hirta* (L.)Hornem. h



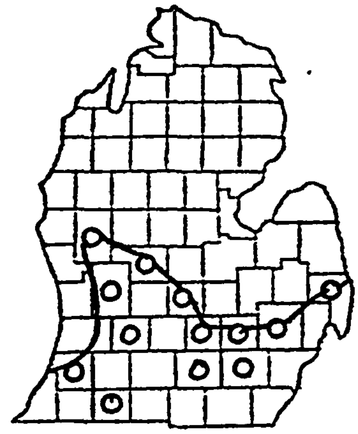
*Lupinus perennis* L. h



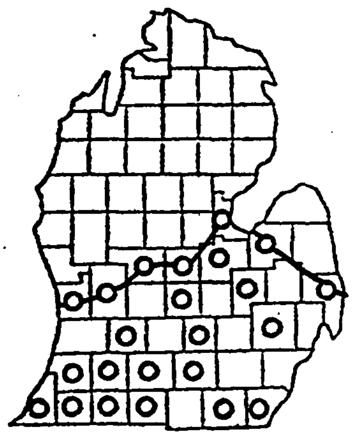
*Strophostyles helveola* (L.)Ell. th



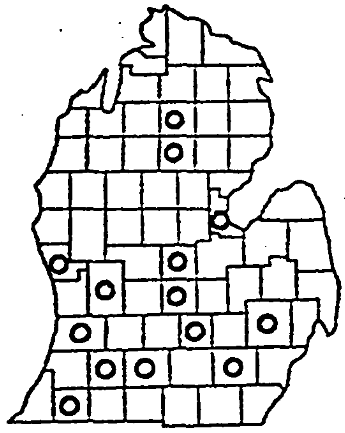
*Tephrosia virginiana* (L.)Pers. h



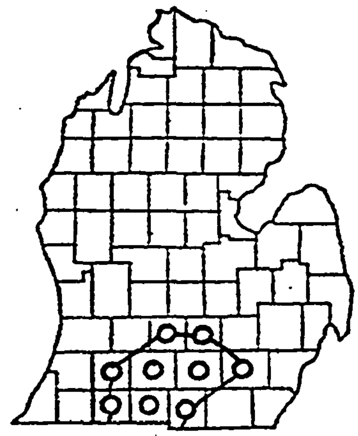
*Vicia caroliniana* Walt. h



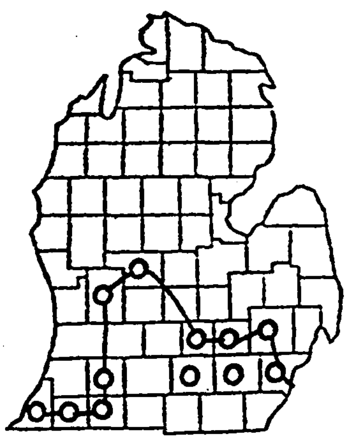
*FAGACEAE*
*Quercus bicolor* Willd. ph



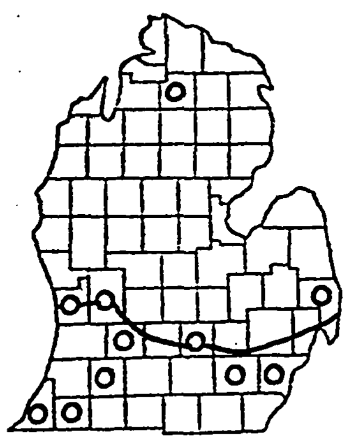
*Quercus coccinea* Muenchh. ph



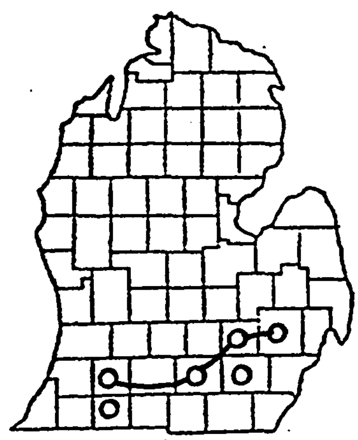
*Quercus imbricaria* Michx. (Wagner and Shoen, 1976) ph



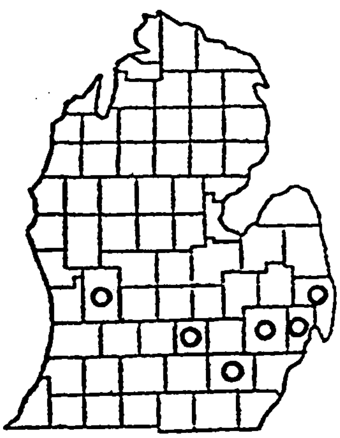
*Quercus prinoides* Willd. ph



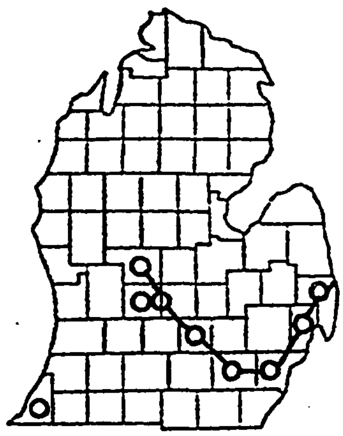
*FUMARIACEAE*
*Dicentra canadensis* (Goldie.)Walp. c



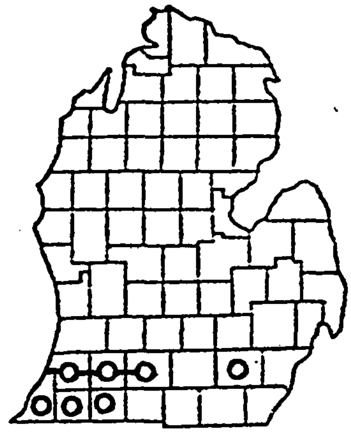
*GENTIANACEAE*
*Gentiana alba* Muhl. (Pringle, 1965) h



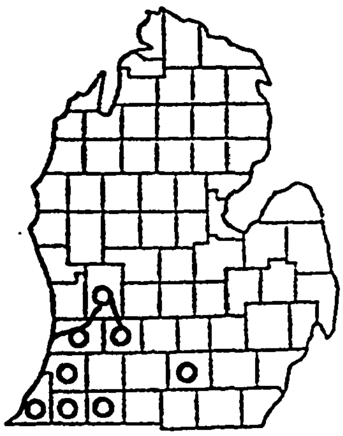
*Gentiana puberula* Michx. h



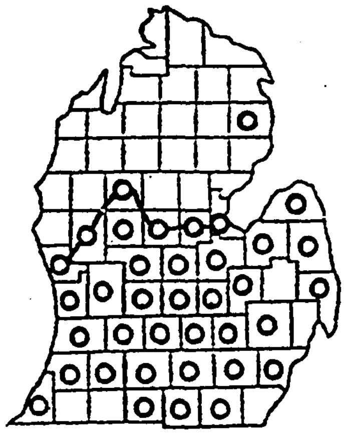
*Gentiana quinquefolia* L. th



*Sabatia angularis* (L.)Pursh. th

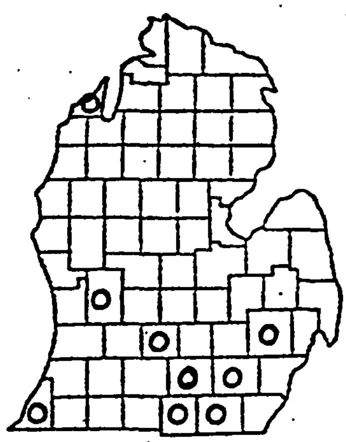


*Swertia carolinianus* (Walt.)Kuntze. h



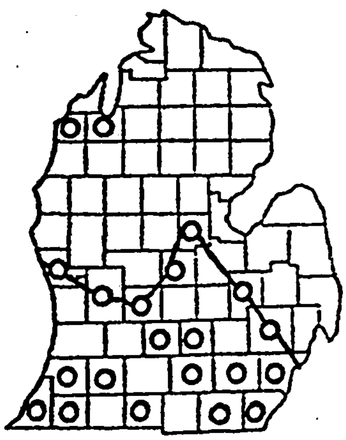
*GERANIACEAE*

*Geranium maculatum* L. h



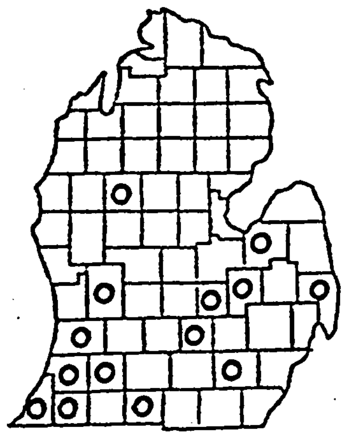
*HIPPOCASTANACEAE*

*Aesculus glabra* Willd. ph

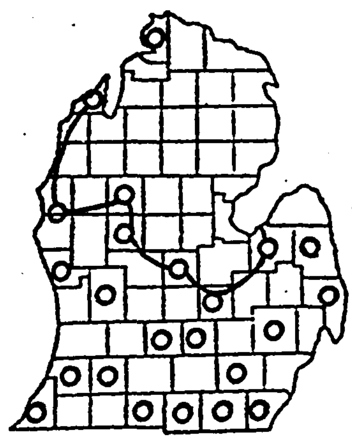


*HYDROPHYLLACEAE*

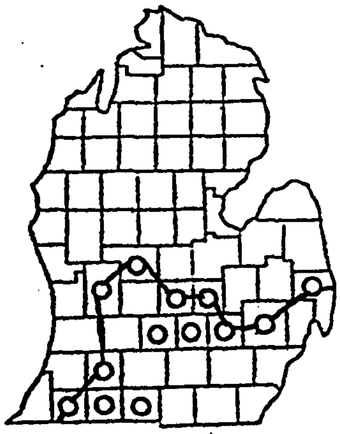
*Hydrophyllum appendiculatum* Michx. h



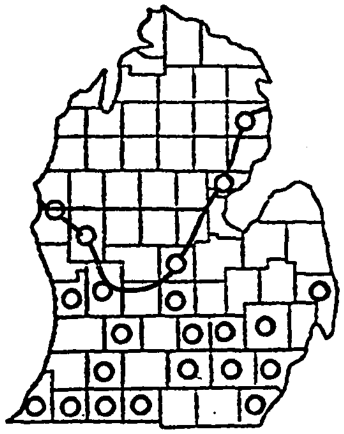
*Hydrophyllum canadense* L. c



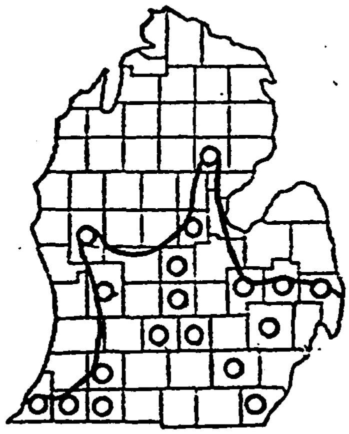
*Hydrophyllum virginianum* L. h



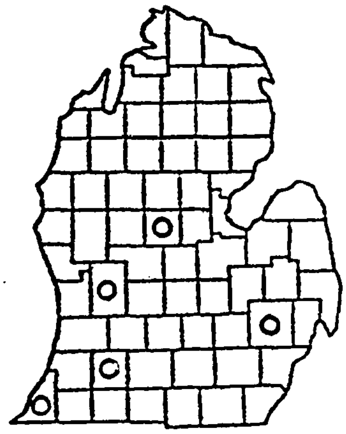
*HYPERACEAE*
*Hypericum prolificum* L. ph



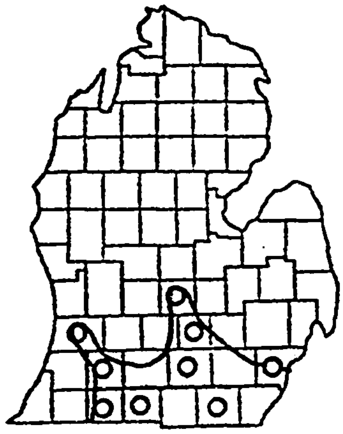
*Hypericum punctatum* Lam. h



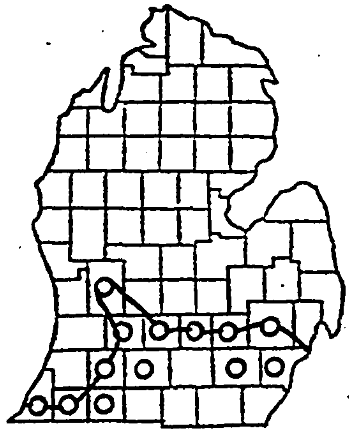
*JUGLANDACEAE*
*Carya cordiformis* (Wang.)K.Koch. ph



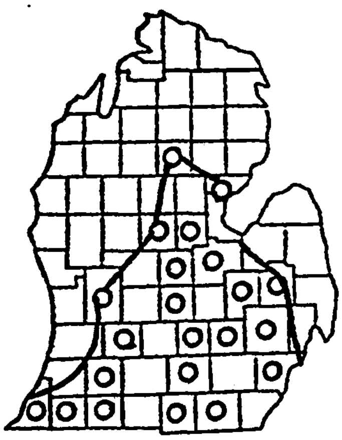
*Carya glabra* (Mill.)Sweet. ph



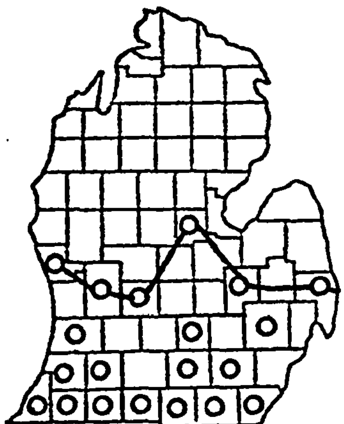
*Carya lacinosa* (Michx.f.)Loud. ph



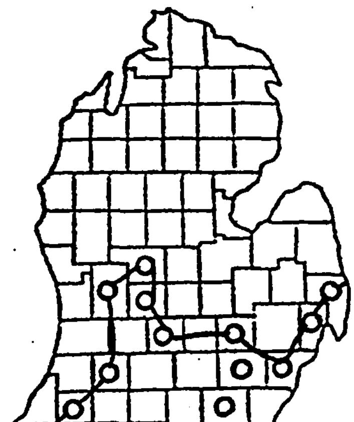
*Carya ovalis* (Wang.)Sarg. ph



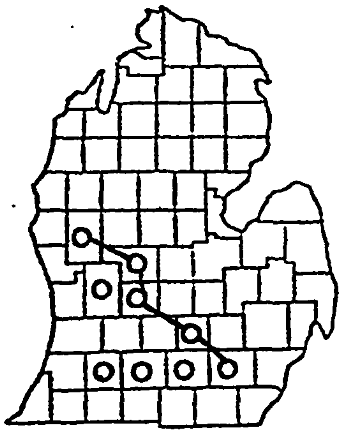
*Carya ovata* (Mill.)K.Koch. ph



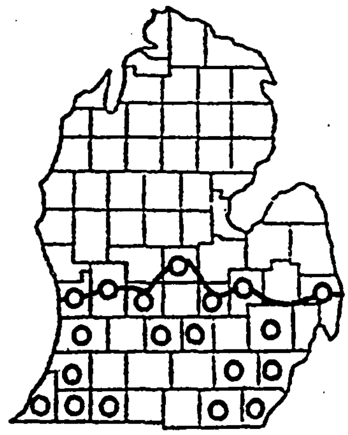
*LABIATAE* (all: Waterman, 1960)
*Agastache nepetoides* (L.) Kuntze. h



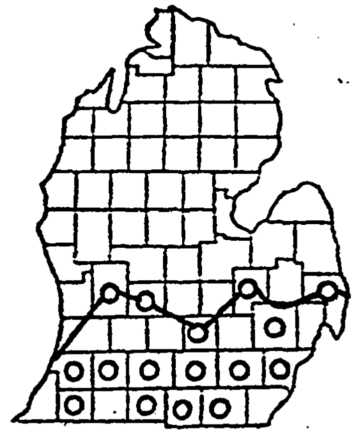
*Agastache scrophulariaefolia* (Willd.) Kuntze. h



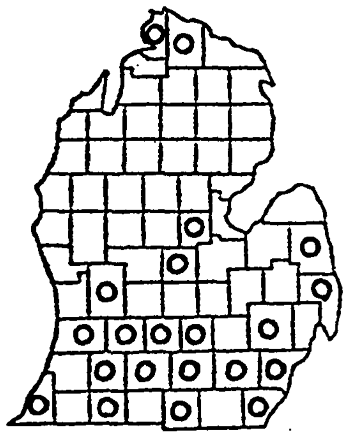
*Blephilia ciliata* (L.)Benth. h



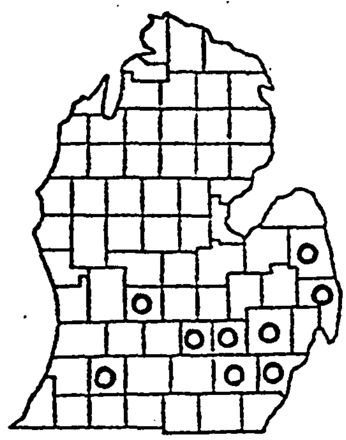
*Blephilia hirsuta* (Pursh.)Benth. h



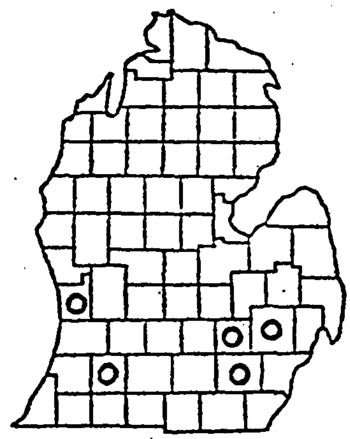
*Collinsonia canadensis* L. c



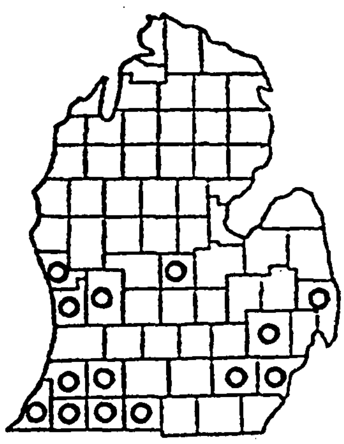
*Glecoma hederacea* L. h



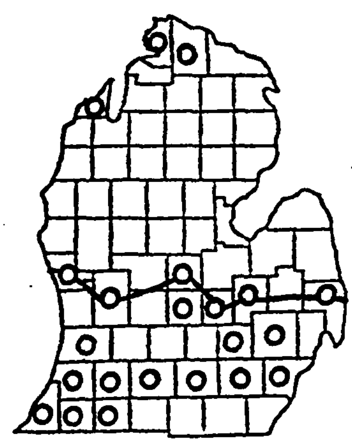
*Lamium amplexicaule* L. h int



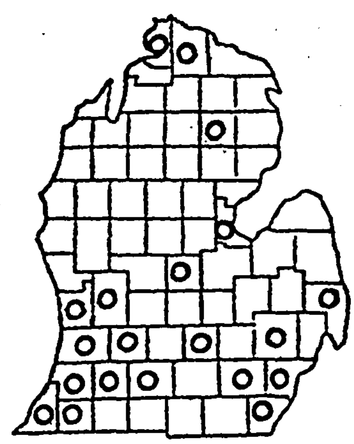
*Lamium purpureum* L. th int



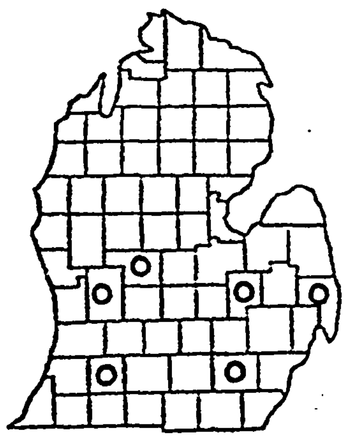
*Lycopus rubellus* Moench. h



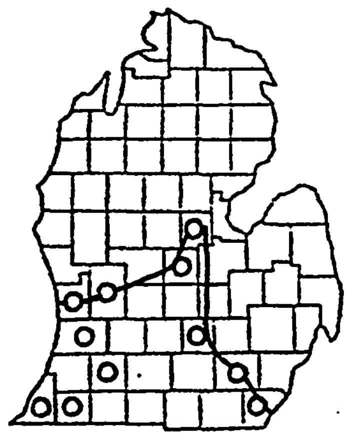
*Mentha piperita* L. h int



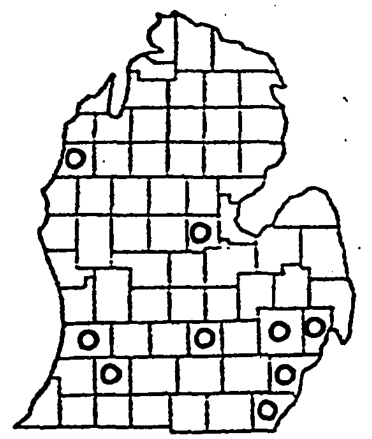
*Mentha spicata* L. h int



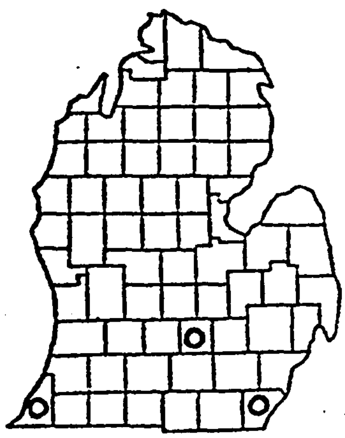
*Monarda didyma* L.
h



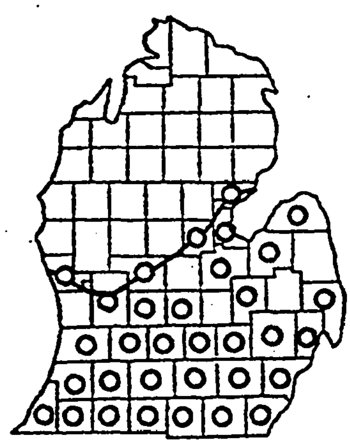
*Physostegia virginiana* (L.)Benth. h



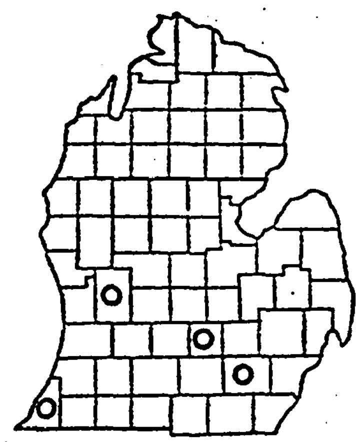
*Pycnanthemum flexuosum* (Walt.)BSP. h



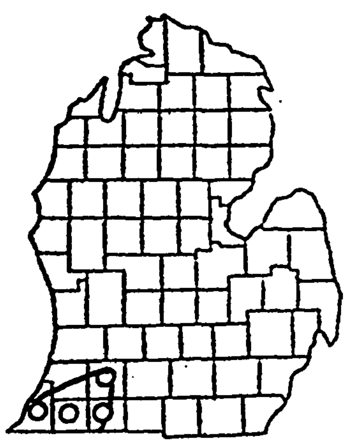
*Pycnanthemum pilosum* Nutt. h



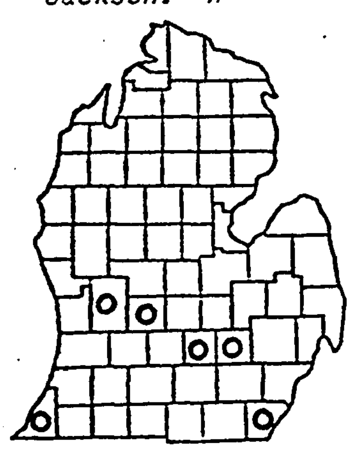
*Pycnanthemum virginianum* (L.) Durand & Jackson. h



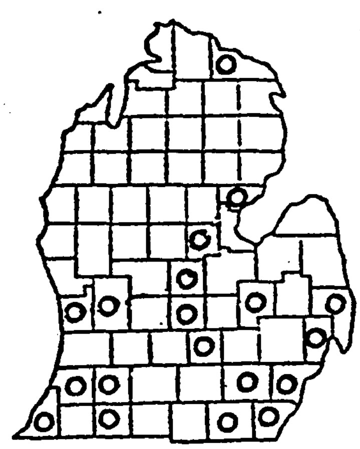
*Satureja hortensis* L. th int



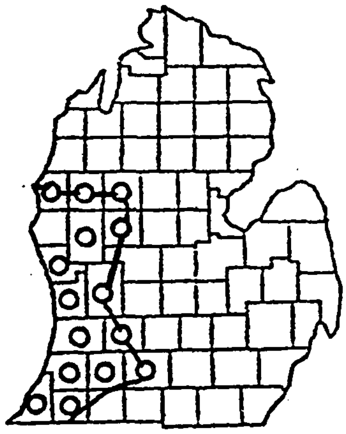
*Scutellaria elliptica* Muhl. c



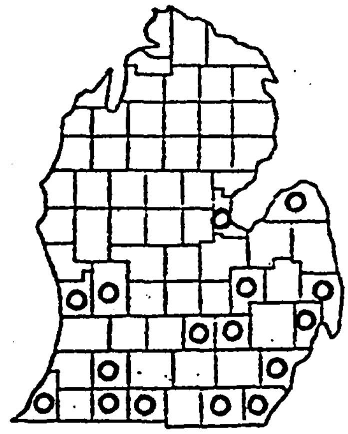
*Scutellaria parvula* Michx. c



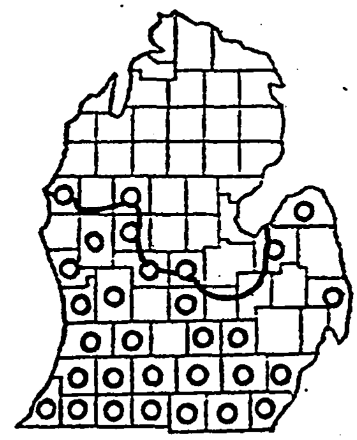
*Stachys hispida* Pursh. h



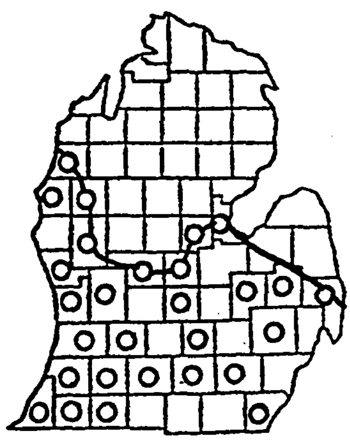
*Stachys hyssopifolia*
Michx. h



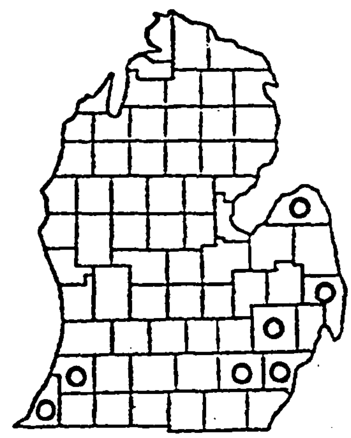
*Stachys tenuifolia*
Willd. h



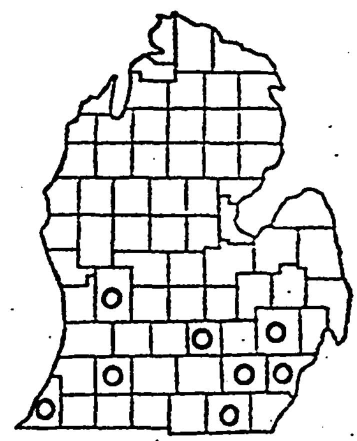
*LAURACEAE*
*Lindera benzoin*
(L.)Blume. ph



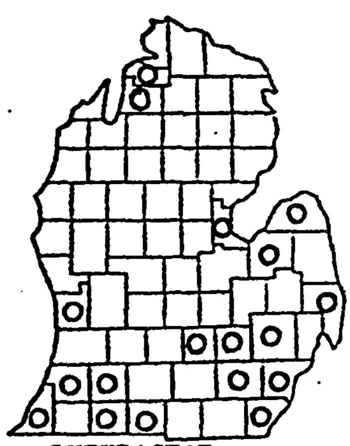
*Sassafras albidum*
(Nutt.)Nees. ph



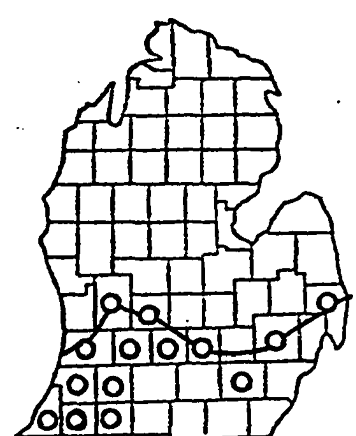
*LINACEAE*
*Linum medium*
(Planch.)Britt. h



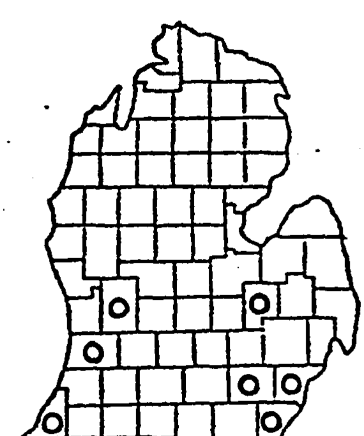
*Linum virginianum*
L. h



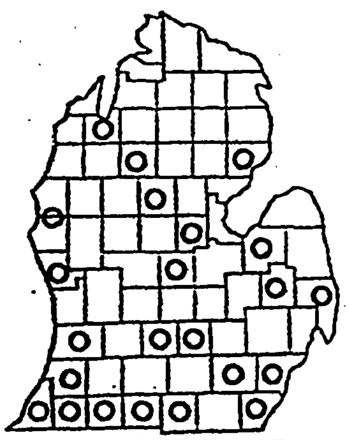
*LYTHRACEAE*
*Lythrum alatum*
Pursh. h



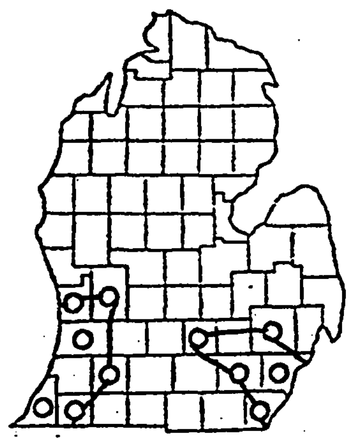
*MAGNOLIACEAE*
*Liriodendron tulipifera* L. ph



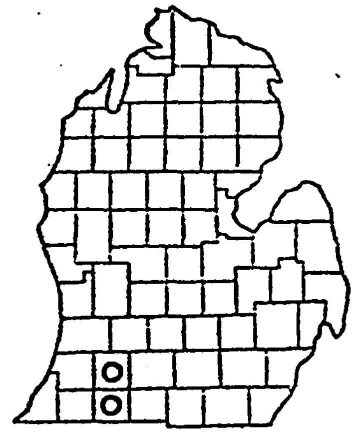
*MALVACEAE*
*Hibiscus moscheutos*
L. h



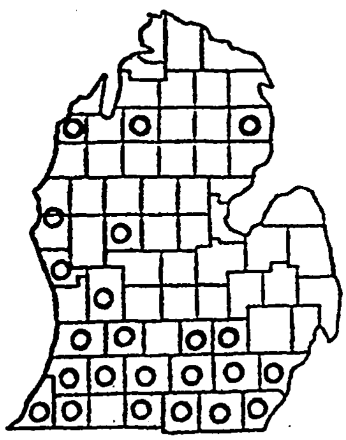
*MENISPERMACEAE*
*Menispermum canadense* L. ch



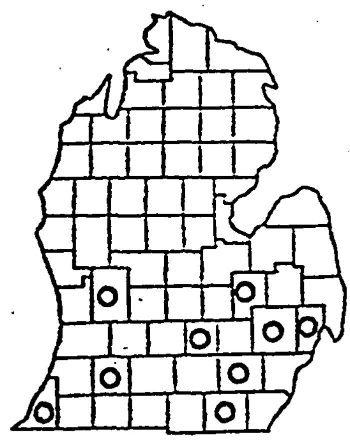
*MORACEAE*
*Morus rubra* L. p



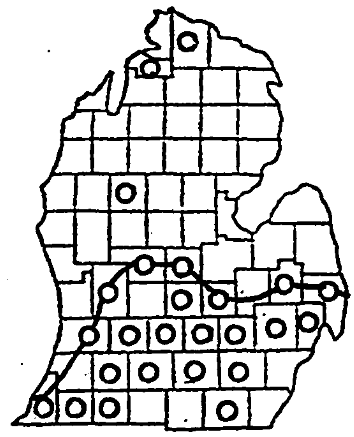
*NYMPHACEAE*
*Cabomba caroliniana* Gray. c



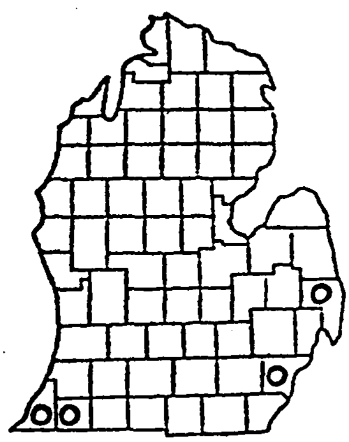
*Nuphar advena* (Ait.)Ait.f. c



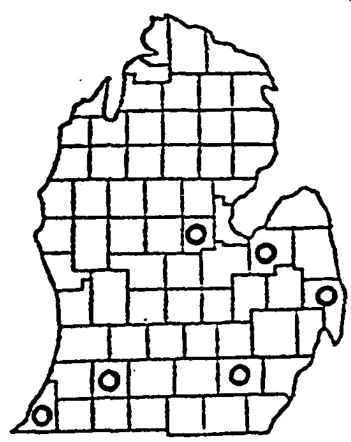
*OLEACEAE*
*Fraxinus quadrangulata* Michx. ph



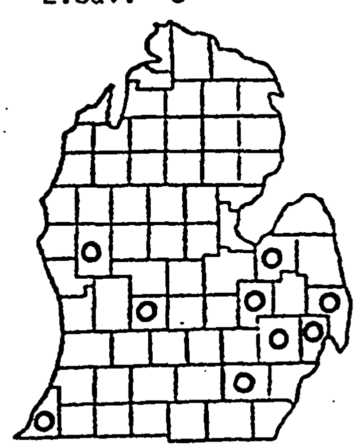
*ONOGRACEAE*
*Circaea quadrisculcata* (Maxim.)Franch.& L.Sav. c



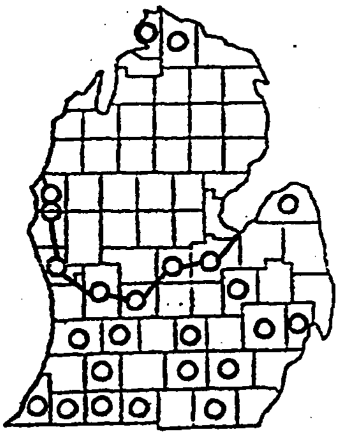
*Ludwigea alternifolia* L. h



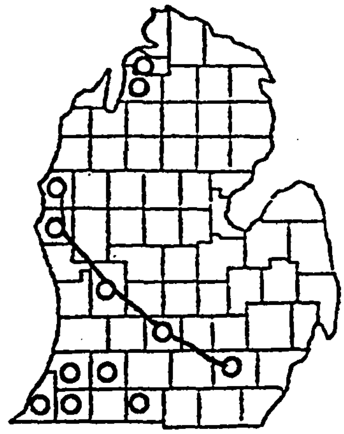
*Ludwigia polycarpa* Short & Peter. h



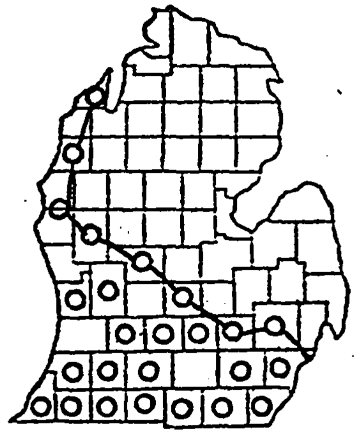
*Oenothera pilosella* Raf. h



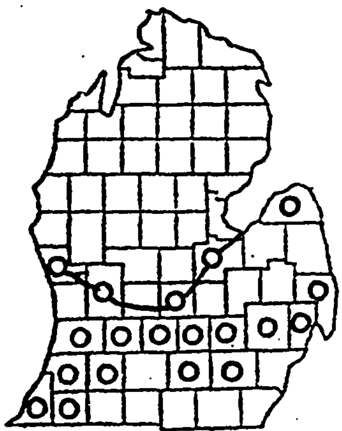
*OROBANCHACEAE*
*Conopholis americana*
(L.)Wallr. c



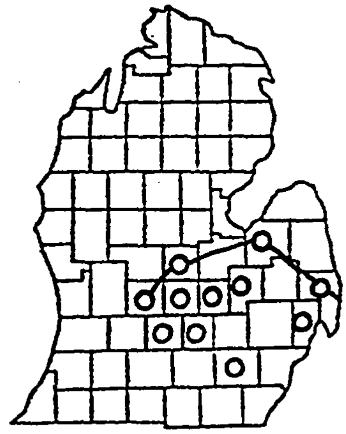
*PAPAVERACEAE*
*Stylophorum diphyllum* (Michx.)Nutt.
h



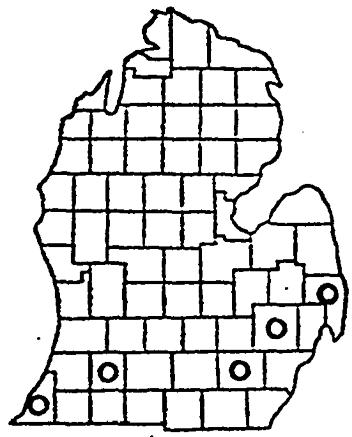
*PHYTOLACCACEAE*
*Phytolacca americana*
L. c



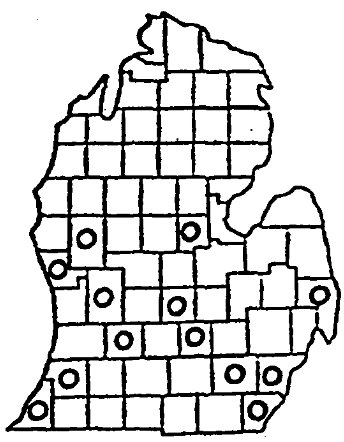
*PLANTAGINACEAE*
*Plantago aristida*
Michx. th



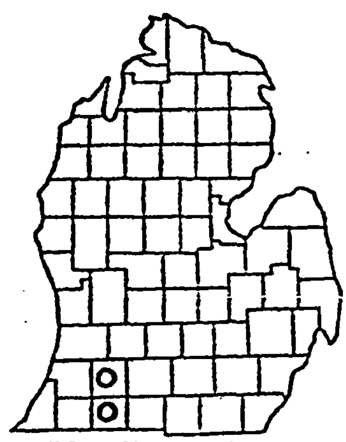
*Plantago cordata*
Lam.(Tessene, 1969) c



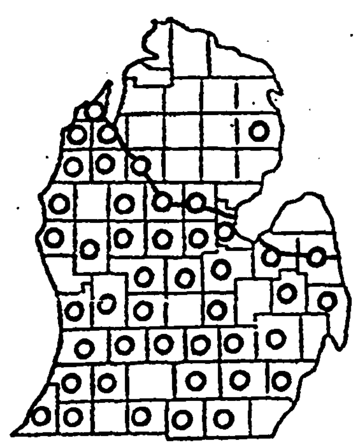
*Plantago virginica*
L. h



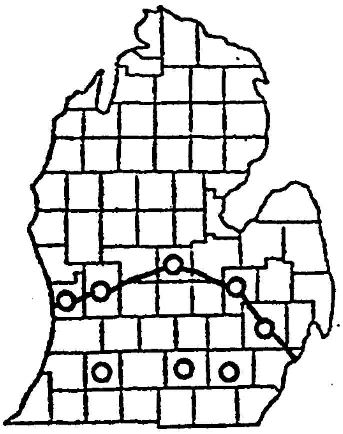
*PLATANACEAE*
*Platanus occidentalis*
L. ph



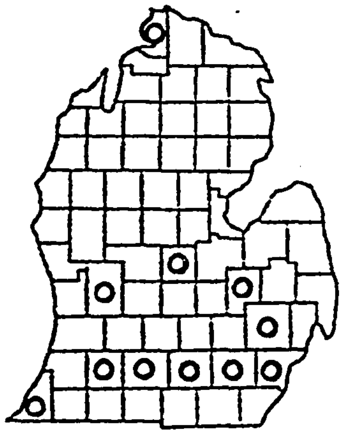
*POLEMONIACEAE*
*Phlox bifida*
Beck. h



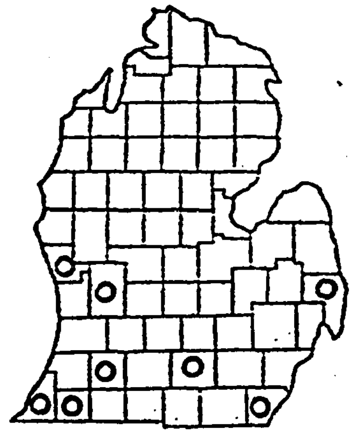
*Phlox divaricata*
L. ch



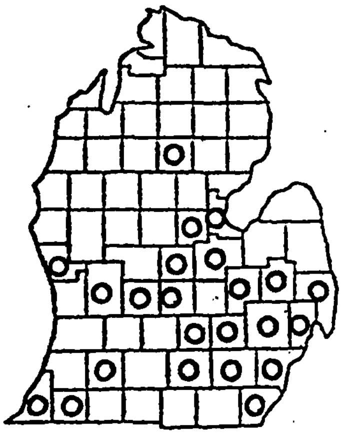
*Phlox glaberrima*
L. h



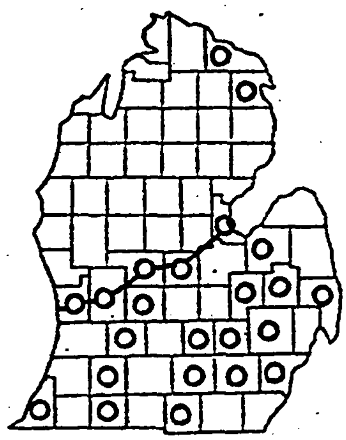
*Phlox subulata*
Beck. ch



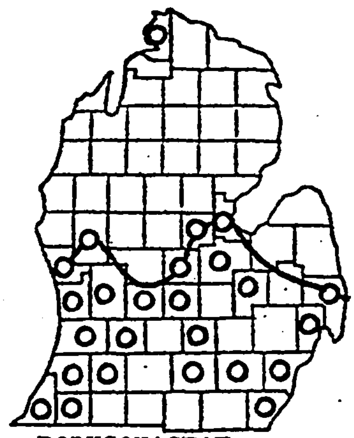
*POLYGALACEAE*
*Polygala cruciata*
L. th



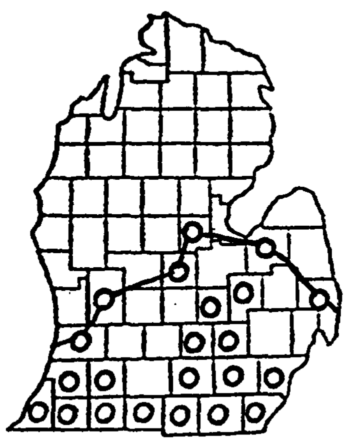
*Polygala sanguinea*
L. th



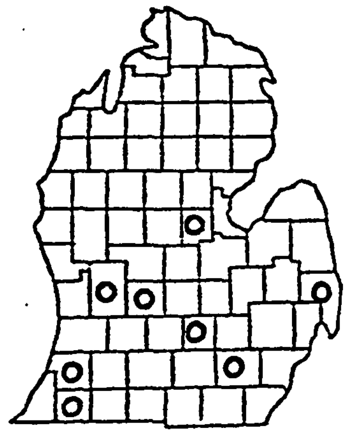
*Polygala senega*
L. h



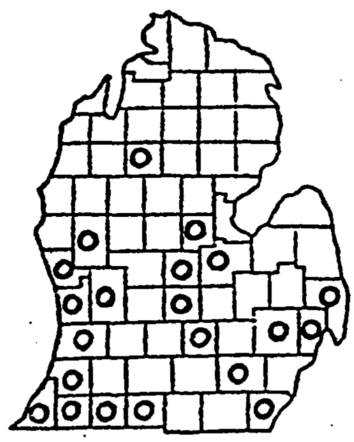
*POLYGONACEAE*
*Polygonum pensyl-vanicum* L. th



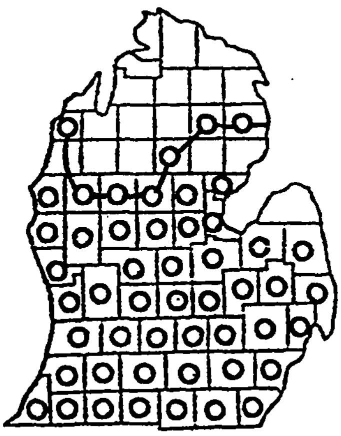
*Polygonum virginianum*
L. c



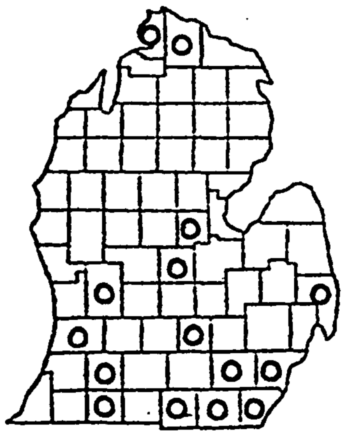
*Rumex altissimus*
Wood. h



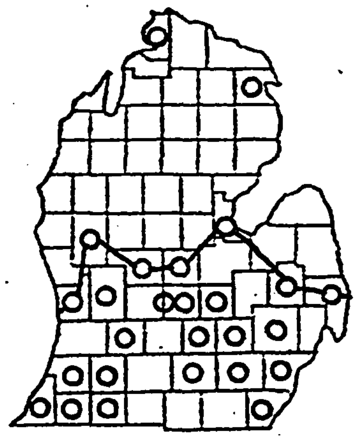
*Rumex verticillatus*
L. h



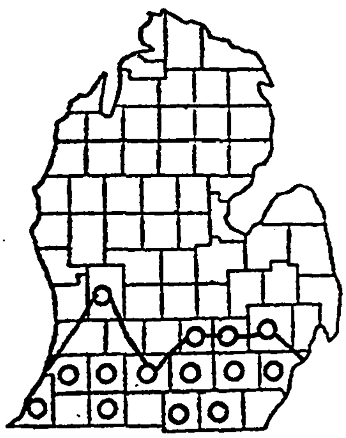
*PORTULACACEAE*
*Claytonia virginica*
L. (Voss, 1968) c



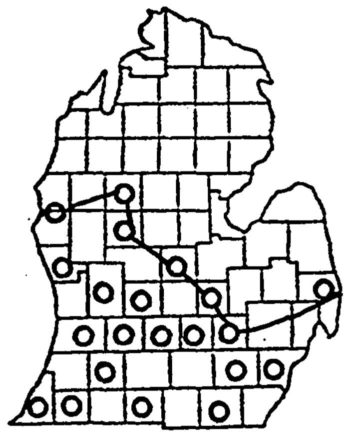
*PRIMULACEAE*
*Lysimachia nummularia*
L. ch int



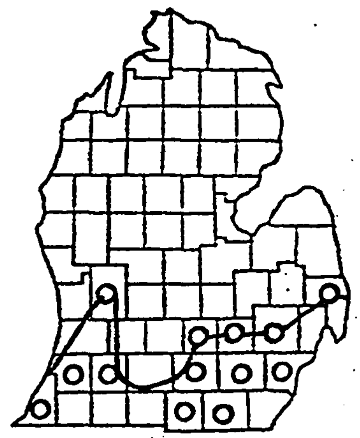
*RANUNCULACEAE*
*Anemone virginiana*
L. h



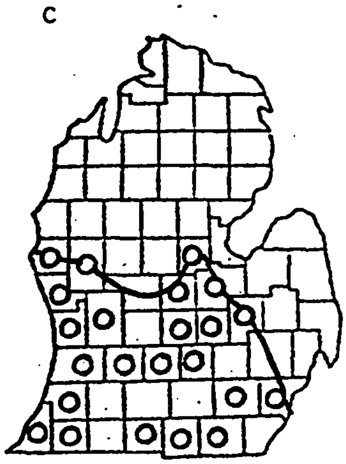
*Anemonella thalictroides* (L.)Spach.
c



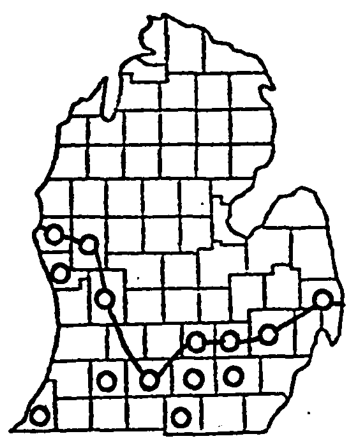
*Hepatica acutiloba*
DC. h



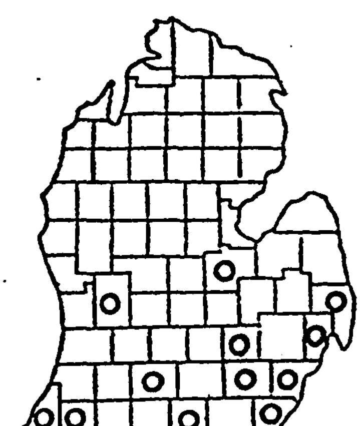
*Hydrastis canadensis*
L. c



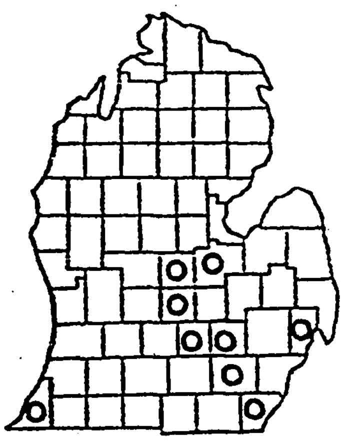
*Isopyrum biternatum*
(Raf.)T.&G. h



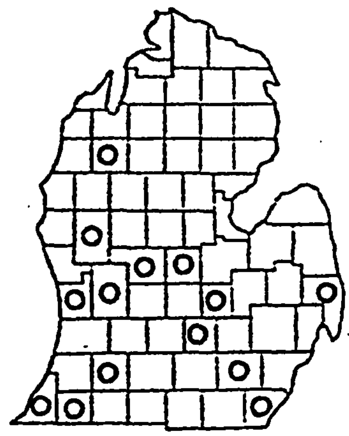
*Ranunculus fascicularis* Muhl. h



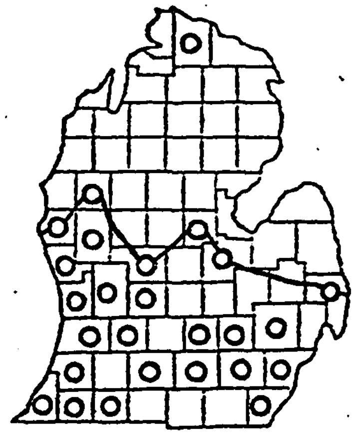
*ROSACEAE*
*Agrimonia parviflora*
Ait. h



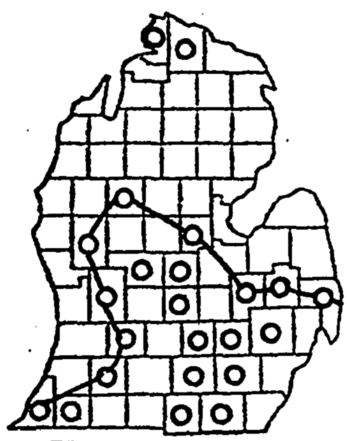
*Geum laciniatum*
Murr. h



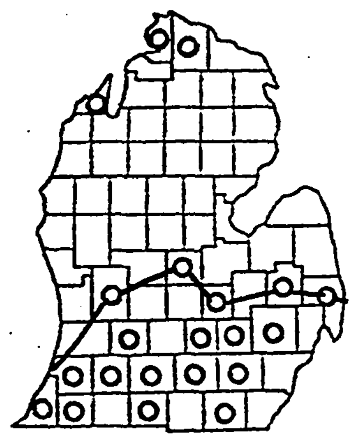
*Rubus occidentalis*
L. h



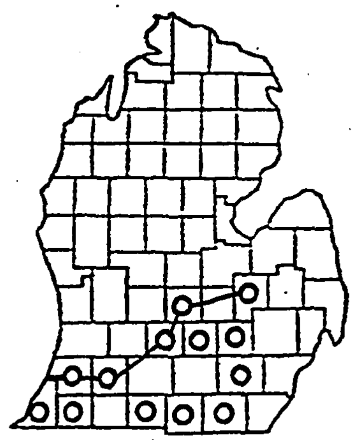
*Spirea tomentosa*
L. ph



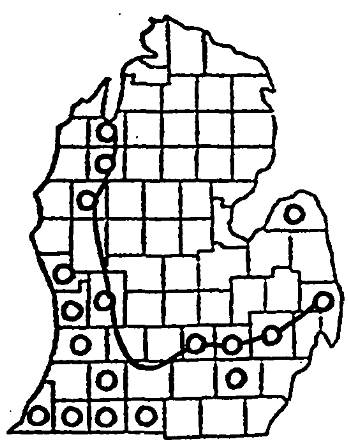
*RUBIACEAE*
*Galium boreale* L.
h



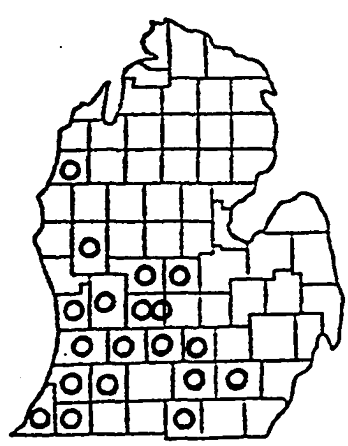
*Galium circaezans*
Michx. h



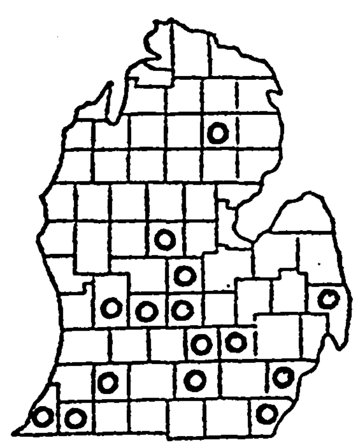
*Galium concinnum*
T.&G. h



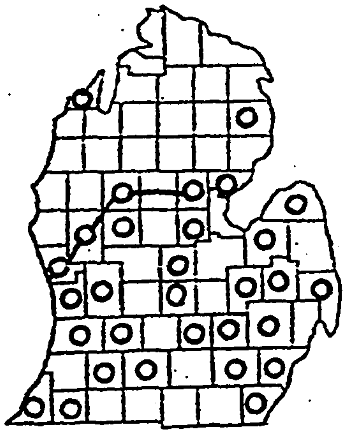
*Galium pilosum*
Ait. h



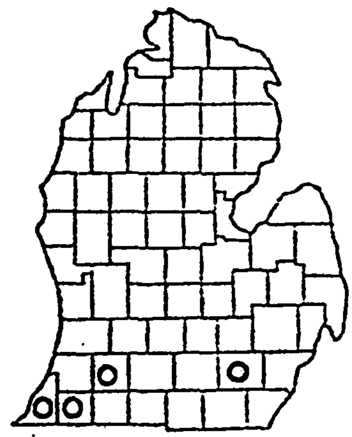
*RUTACEAE*
*Ptelea trifoliata*
L. ph



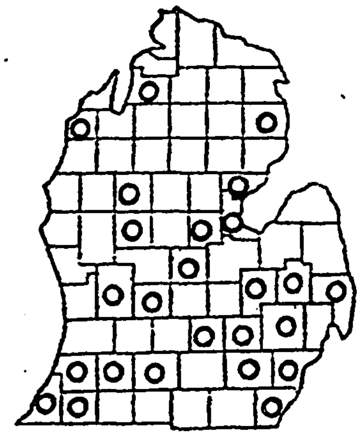
*Zanthoxylum ameri-*
*canum* Mill. ph



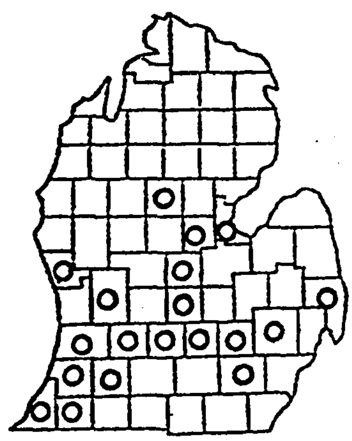
*SALICACEAE*
*Populus deltoides* Marsh. ph



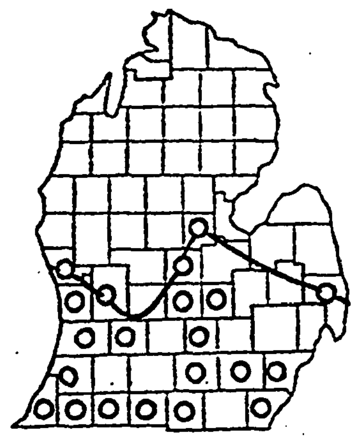
*Populus heterophylla* L. ph



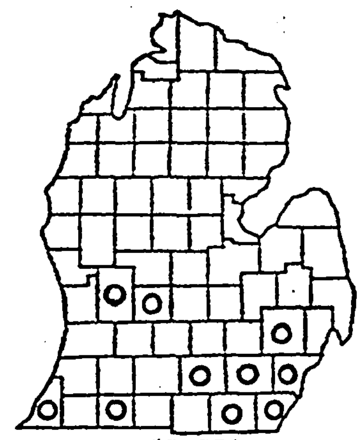
*Salix amygdaloides* Anderss. ph



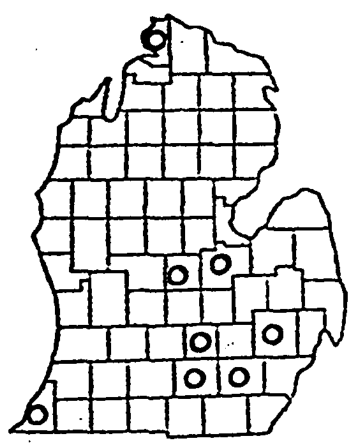
*Salix nigra* L.
ph



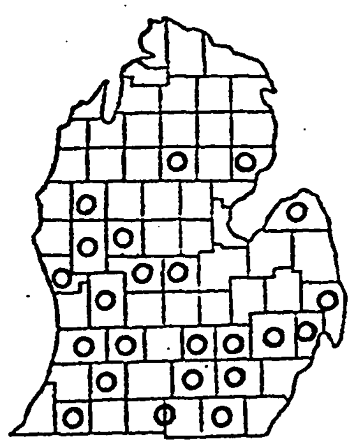
*SAURARACEAE*
*Saururus cernus* L. c



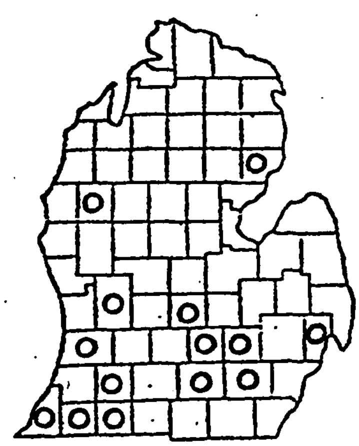
*SAXIFRAGACEAE*
*Heuchera americana* L. h



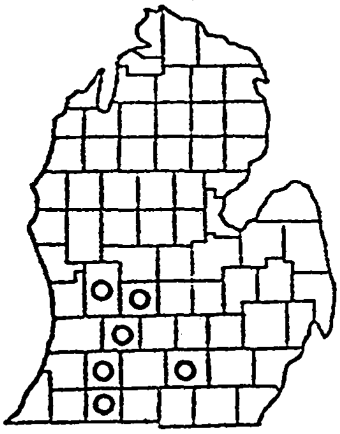
*Ribes odoratum* Wendl. ph



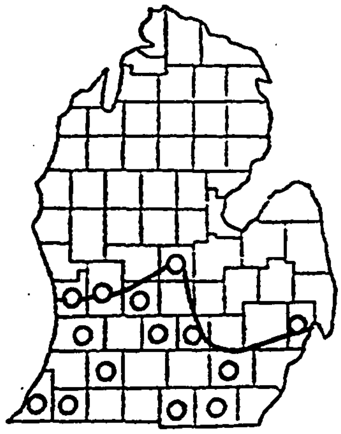
*SCROPHULARIACEAE*
*Aureolaria flava* (L.)Farw. h



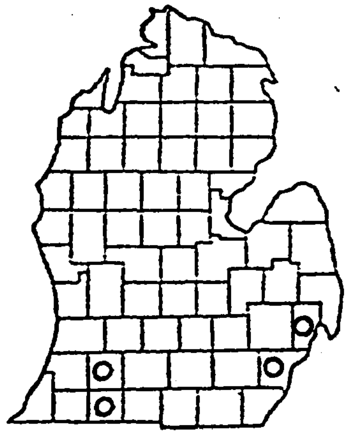
*Aureolaria virginica* (L.)Pennell. h



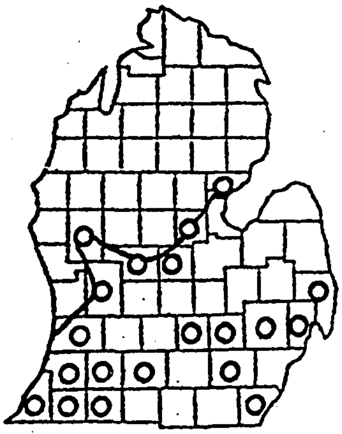
*Besseya bullii* (Eat.)Rydb. h



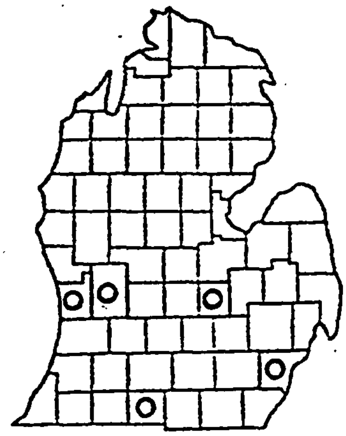
*Collinsia verna* Nutt. h



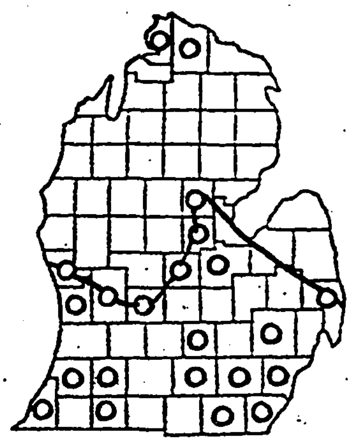
*Mimulus alatus* Ait. h



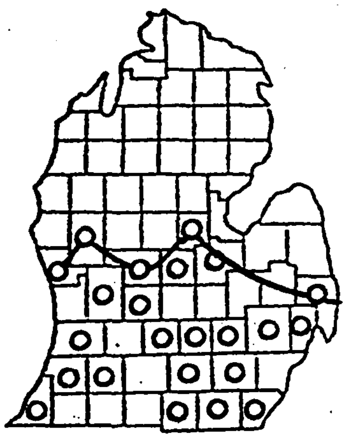
*Pedicularis lanceolata* Michx. h



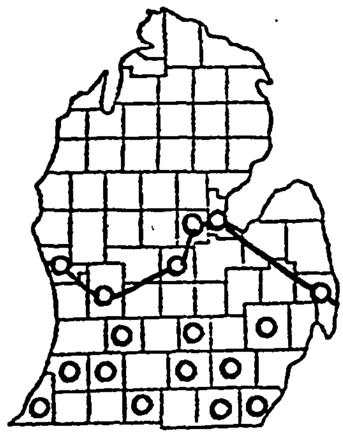
*Penstemon calycosus* Small. h



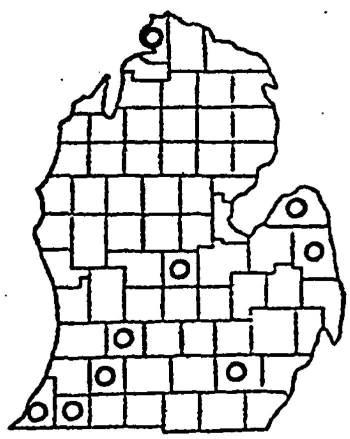
*Penstemon digitalis* Nutt. h



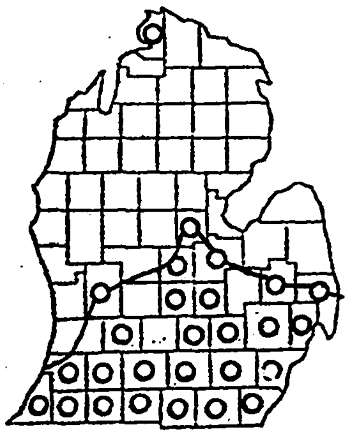
*Penstemon hirsutus* (L.)Willd. h



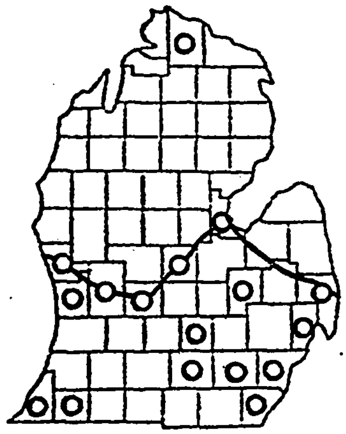
*Scrophularia marilandica* L. h



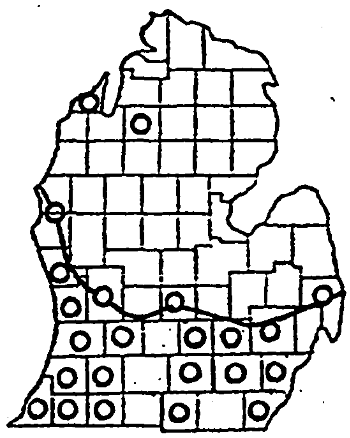
*Veronica officinalis* L. ch int



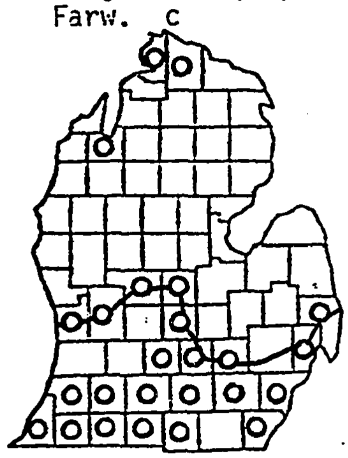
*Veronicastrum virginicum* (L.) Farw. c



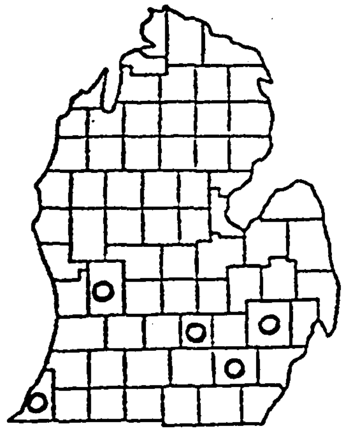
*SOLANACEAE*
*Datura stramonium* L. th int



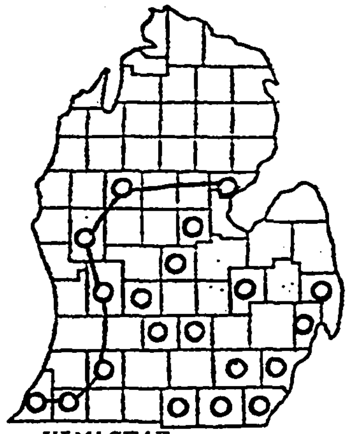
*Solanum carolinense* L. c



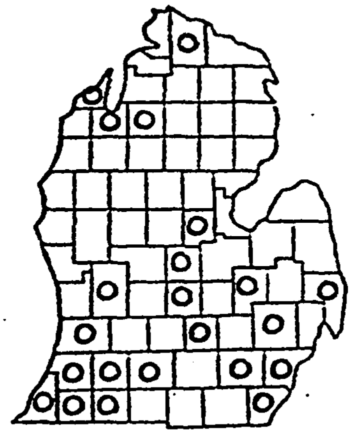
*Solanum nigrum* L. th



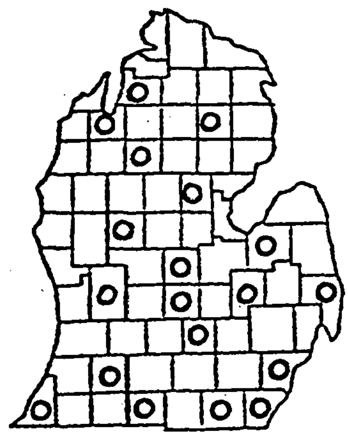
*STAPHYLACEAE*
*Staphylea trifolia* L. ph



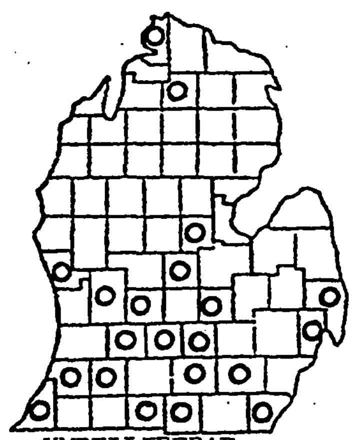
*ULMACEAE*
*Celtis occidentalis* L. (Wagner, 1974) ph



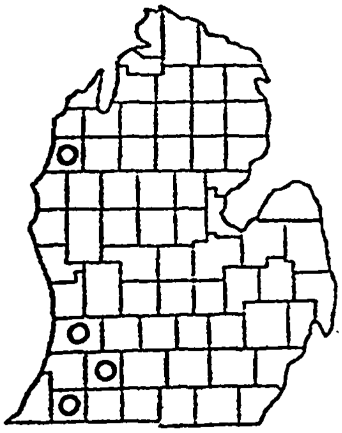
*Ulmus rubra* Muhl. ph



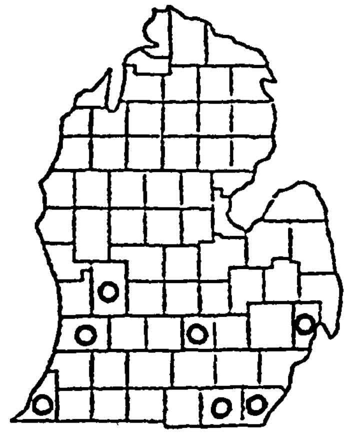
*Ulmus thomasi* Sarg. ph



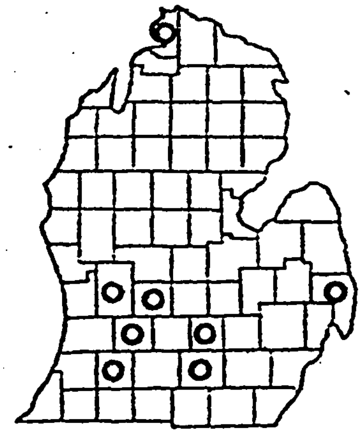
*UMBELLIFERAE*
*Angelica atropurpurea* L. h



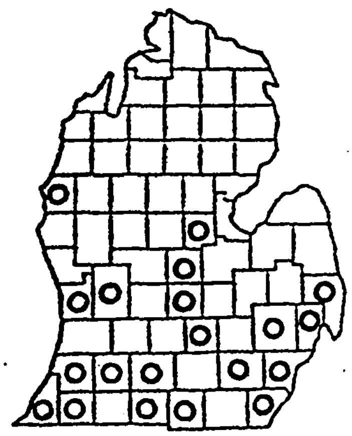
*Berula erecta* (Huds.)Cov. c



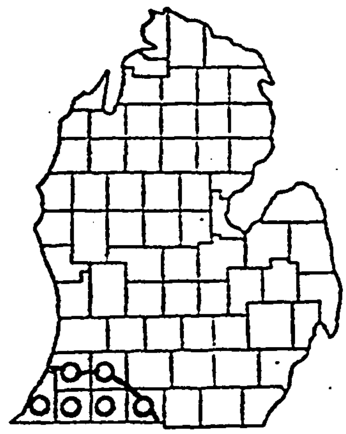
*Chaerophyllum procumbens* (L.)Crantz. th



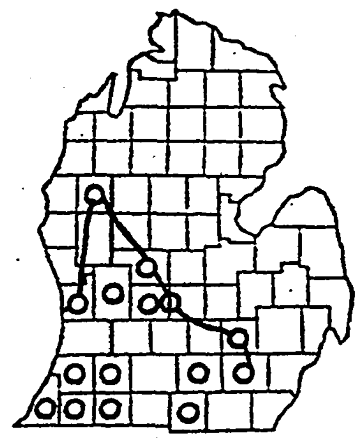
*Conium maculatum* L. h



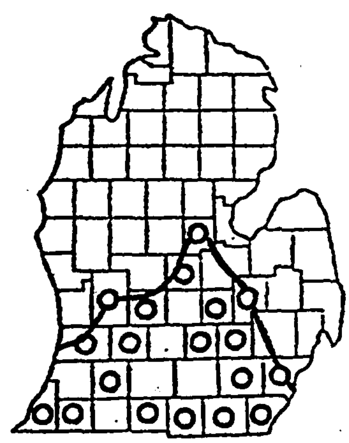
*Erigenia bulbosa* (Michx.)Nutt. c



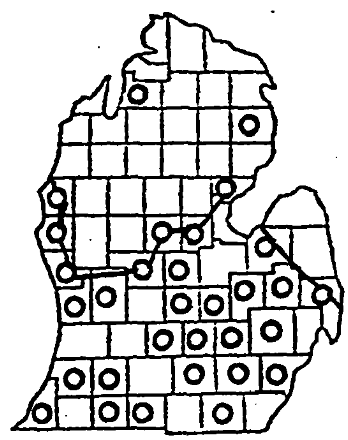
*Eryngium yuccifolium* Michx. c



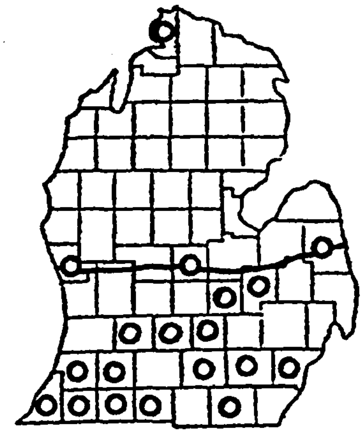
*Oxypolis rigidior* (L.)Raf. h



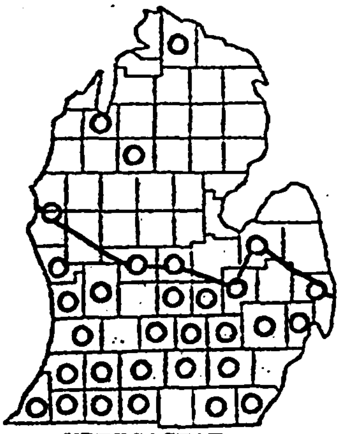
*Sanicula canadensis* L. h



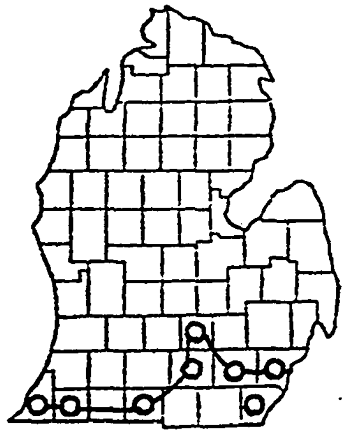
*Sanicula gregaria* Bickn. h



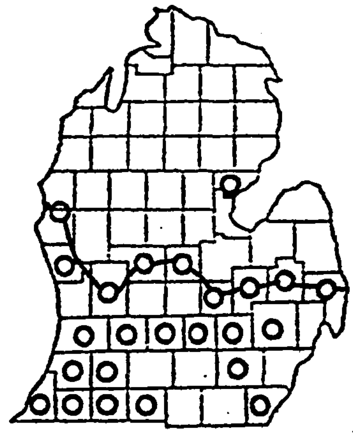
*Sanicula trifoliata* Bickn. h



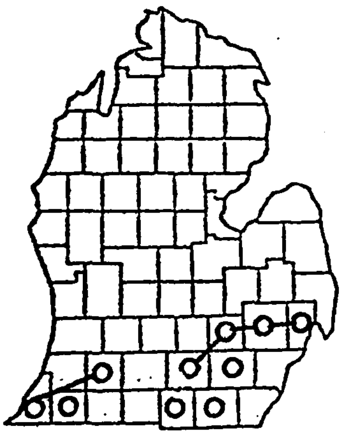
*URTICACEAE*
*Boehmeria cylindrica* (L.)Sw. c



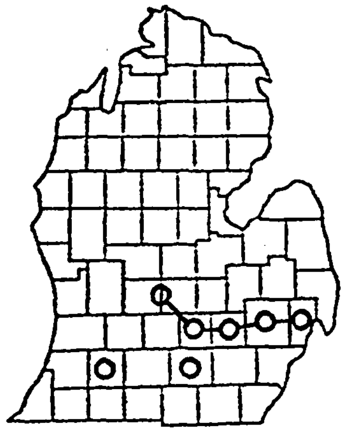
*Parietaria pensylvanica* Muhl. th



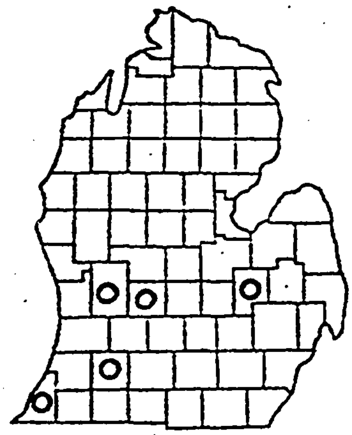
*Pilea pumila* (L.) Gray. th



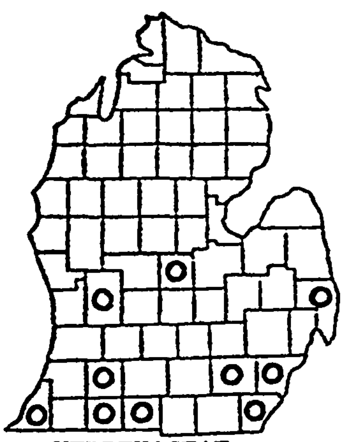
*VALERAINACEAE*
*Valeriana edulis* Nutt. c



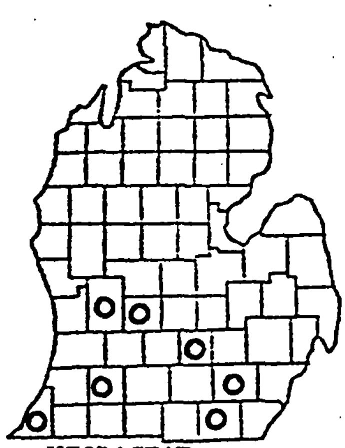
*Valeriana uliginosa* (T.&G.)Rydb. c



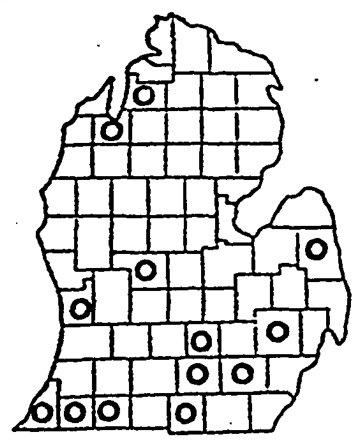
*Valerianella chenopodifolia* (Pursh)DC. th



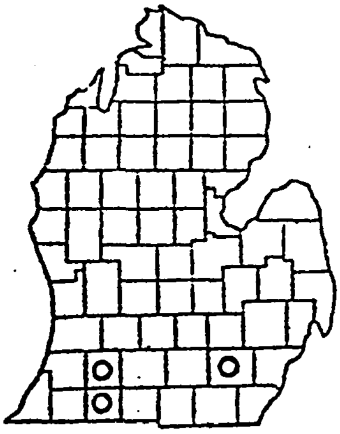
*VERBENACEAE*
*Phyla lanceolata* (Michx.)Greene. h



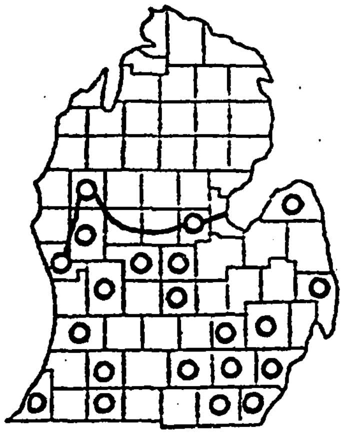
*VIOLACEAE*
*Cubelium concolor* (Forst.)Raf. h



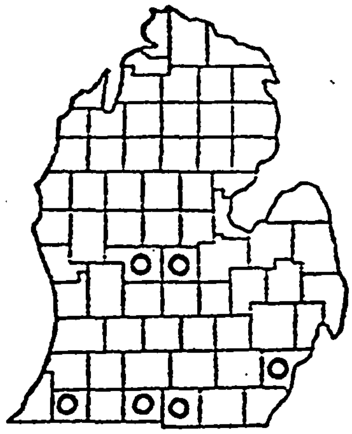
*Viola arvensis* Murr. th int



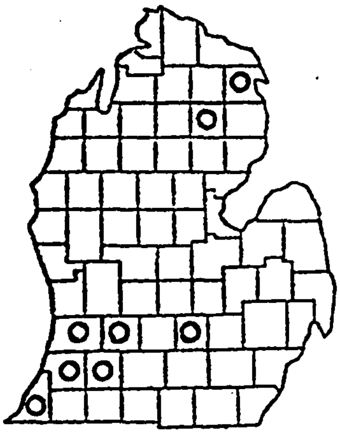
*Viola pedatifida*
G.Don. h



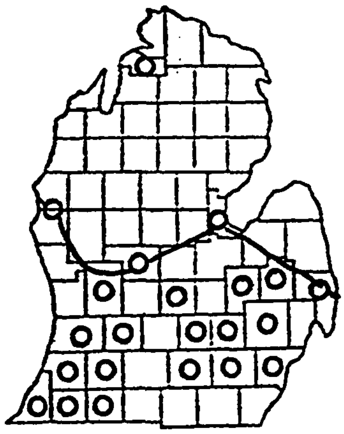
*Viola sagittata*
Ait. h



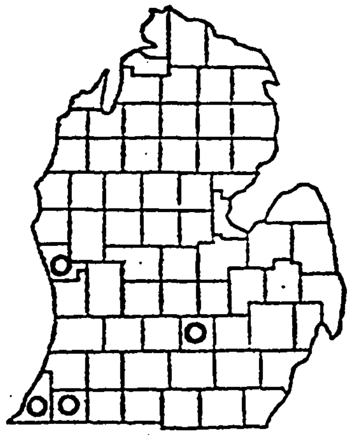
*Viola septentrionalis*
Greene. h



*VITACEAE*
*Parthenocissus vitacea* (Knerr.)
Hitchc. ph



*Vitis aestivalis*
Michx. ph



*Vitis labrusca* L.
ph

Appendix 2

Lower vascular plants, gymnosperms, and monocots with range limits in the Lower Peninsula of Michigan. Distribution maps are in Billington (1952) and Voss (1972). Names and order of names follow those sources. Life forms of flowering plants, northern species of wet habitats, and introduced species are noted as they were in Appendix 1.

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NORTHERN

*LYCOPODIACEAE*

*Lycopodium annotinum* L.
*L. tristachyum* Pursh.

*SELAGINELLACEAE*

*Selaginella selaginoides* (L.) Link

*OPHIOGLOSSACEAE*

*Botrychium lunaria* (L.) Sw.
*B. lanceolatum* var. *angustisegmentum* Pease & Moore

*POLYPODIACEAE*

*Dryopteris disjuncta* (Ledeb.) C.V.Mort. wet
*D. robertiana* (Hoffm.) Christens.
*D. phegopteris* (L.) Christens.

*PINACEAE*

*Pinus resinosa* Aiton ph
*P. banksiana* Lamb. ph
*Abies balsamea* (L.) Miller ph wet
*Picea mariana* (Miller) BSP. ph wet
*P. glauca* (Moench) A.Voss. ph wet

*CUPRESSACEAE*

*Thuja occidentalis* L. ph wet
*Juniperus horizontalis* Moench ch

*SPARGANIACEAE*

*Sparganium angustifolium* Michaux c wet

*POTAMOGETONACEAE*

*Potamogeton filiformis* Pers. c wet
*P. vaginitus* Turcz. c wet
*P. epihydrus* Raf. c wet
*P. alpinus* Balbis c wet
*P. hillii* Morong c wet
*P. obtusifolius* Mert.& Koch c wet

*GRAMINEAE*

*Poa saltuensis* Fern. & Wieg. h
*Melica smithii* (Gray) Vasey h
*Bromus pumpellianus* Scribner c
*Festuca occidentalis* Hooker h
*F. saximontana* Rydb. h
*Agropyron dasystachyum* (Hooker) Scribner c
*Koeleria macrantha* (Ledeb.) Schultes h
*Deschampsia flexuosa* (L.) Beauv. h
*Oryzopsis pungens* (Sprengel) Hitchc. c
*O. asperifolia* Michaux c
*Muhlenbergia uniflora* (Muhl.) Fern. h wet
*Cinna latifolia* (Goepp.) Griseb. h wet
*Panicum xanthophysum* Gray h

*CYPERACEAE*

*Carex gynocrates* Drejer c wet
*C. chordorrhiza* L.f. h wet
*C. tenuiflora* Wahl. c wet
*C. brunnescens* (Pers.) Poiret h wet
*C. exilis* Dewey h wet
*C. cephalantha* (Bailey) Bickn. h wet
*C. deweyana* Schw. h
*C. sychnocephala* Carey h wet
*C. adusta* Boott h
*C. aenea* Fern. h
*C. cumulata* (Bailey) Fern. h wet
*C. merritt-fernaldii* Mack. h
*C. crawfordii* Fern. h wet
*C. backii* Boott h
*C. deflexa* Hornem. c wet
*C. rugosperma* Mack. h
*C. lucorum* Link c
*C. peckii* Howe c
*C. scirpoidea* Michaux c wet
*C. concinna* R.Br. h wet
*C. vaginata* Tausch c wet
*C. ormostachya* Wieg. h
*C. castanea* Wahl. h wet
*C. capillaris* L. h wet
*C. houghtoniana* Dewey h
*C. paupercula* Michzux c wet
*C. gynandra* Schw. h wet
*C. schweinitzii* Schw. h wet
*Cyperus houghtonii* Torrey c
*Scirpus cespitosus* L. h wet
*S. hudsonianus* (Michaux) Fern. c wet
*S. microcarpus* Presl c wet
*Eriophorum spissum* Fern. h wet
*E. tenellum* Nutt. c wet

*XYRIDACEAE*

*Xyris montana* Ries h wet

*JUNCACEAE*

*Juncus brevicaudatus* (Engelm.) Fern. h wet
*J. militaris* Bigelow c wet

*LILIACEAE*

*Streptopus amplexifolius* (L.) DC. c wet
*S. roseus* Michaux c wet
*Trillium cernuum* L. c wet
*Clintonia borealis* (Aiton) Raf. c wet

*IRIDACEAE*

*Sisyrinchium mucronatum* Michaux h wet
*S. montanum* Greene h wet
*Iris lacustris* Nutt. c
*I. versicolor* L. c wet

*ORCHIDACEAE*

*Cypripedium arietinum* R. Br. c wet
*Calypso bulbosa* (L.) Oakes c
*Orchis rotundifolia* Pursh c wet
*Habenaria blephariglottis* (Willd.) Hooker c wet
*H. obtusata* (Pursh) Richardson c wet
*Corallorhiza trifida* Chat. c wet
*C. striata* Lindley c wet
*Listera cordata* (L.) R.Br. h wet
*L. convallarioides* (Sw.) Torrey h wet
*Malaxis monophylla* (L.) Sw. c wet
*Goodyera oblongifolia* Raf. h
*G. repans* (L.) R. Br. h wet

SOUTHERN

*OPHIOGLOSSACEAE*

*Botrychium dissectum* Spreng.

*POLYPODIACEAE*

*Dryopteris hexagonoptera* (Michx.) Christens.
*D. goldiana* (Hook.) Gray
*Polystichum acrostichoides* (Michx.) Schott
*Asplenium platyneuron* (L.) Oakes
*Woodwardia virginica* (L.) Sm.
*W. areolata* (L.) Moore

*CUPRESSACEAE*

*Juniperus virginiana* L. ph

*POTAMOGETONACEAE*

*Potamogeton crispus* L. c
*P. nodosus* Poiret c
*P. vaseyi* Robbins c
*P. pusillus* L. c

*NAJADACEAE*

*Najas gracillima* (A.BR.) Magnus c
*N. guadalupensis* (Sprengel) Magnus c

*ALISMATACEAE*

*Sagittaria rigida* Michaux c

*HYDROCHARITACEAE*

*Elodea nuttallii* (Planchon) St. John c

*GRAMINEAE*

*Triplasis purpurea* (Walter) Chapman h
*Tridens flavus* (L.) Hitchc. h
*Eragrostis hypnoides* (Lam.) BSP. th
*E. cilianensis* (All.) Mosher th int
*E. spectabilis* (Pursh) Steudel h
*E. pilosa* (L.) Beauv. th
*E. pectinacea* (Michaux) Nees th
*E. frankii* Steudel th
*Poa languida* Hitchc. h
*P. trivialis* L. h int
*P. sylvestris* Gray h
*P. paludigena* Fern. & Wieg. h
*Diarrhena americana* Beauv. h
*Bromus latiglumis* (Shear) Hitchc. h
*B. pubescens* Willd. h
*B. briziformis* Fischer & Meyer th int
*B. japonicus* Murray th int
*B. commutatus* Schrader th int
*B. racemosus* L. th int
*Festuca octoflora* Walter th
*Glyceria septentrionalis* Hitchc. h
*Puccinellia distans* (Jacq.) Parl. h int
*P. pallida* (Torrey) Clausen h
*Elymus riparius* Wieg. h
*E. villosus* Willd. h
*Hordeum pusillum* Nutt. th int
*Spenopholis nitida* (Biehler) Scribner h
*S. obtusa* (Michaux) Scribner h
*Arrhenatherum elatius* (L.) Presl h int
*Avena fatua* L. th int
*Holcus lanatus* L. h int
*Aristida oligantha* Michaux th
*A. basiramea* Vasey th

*A. longispica* Poiret th
*A. necopina* Shinners th
*A. purpurascens* Poiret h
*Stipa avenacea* L. h
*S. spartea* Trin. h
*Oryzopsis racemosa* (Sm.) Hitchc. c
*Muhlenbergia richardsonis* (Trin.) Rydb. h
*M. schreberi* J.F. Gmelin h
*M. tenuiflora* (Willd.) BSP. h
*M. sylvatica* Torrey h
*M. frondosa* (Poiret) Fern. c
*Alopecurus pratensis* L. h int
*A. carolinianus* Walter th int
*Sporobolus neglectus* Nash th
*S. heterolepis* (Gray) Gray h
*S. asper* (Michaux) Kunth h int
*Cinna arundinacea* L. h
*Agrostis perennans* (Walter) Tuckerman h
*Eleusine indica* (L.) Gaertner th int
*Cynodon dactylon* (L.) Pers. h int
*Leptochloa fascicularis* (Lam.) Gray th int
*Bouteloua curtipendula* (Michaux) Torrey h
*Spartina patens* (Aiton) Muhl. h
*Leersia virginica* Willd. h
*Cenchrus longispinus* (Hackel) Fern. th int
*Setaria verticillata* (L.) Beauv. th int
*S. italica* (L.) Beauv. th int
*Echinochloa walteri* (Pursh.) Heller th
*Digitaria sanguinalis* (L.) Scop. th int
*Paspalum ciliatifolium* Michaux h
*Leptoloma cognatum* (Schultes) Chase h
*Panicum dichotomiflorum* Michaux th
*P. philadelphicum* Trin. th
*P. rigidulum* Nees h
*P. microcarpon* Ell. h
*P. dichotomum* L. h
*P. clandestinum* L. h
*P. perlongum* Nash h
*P. oligosanthes* Schultes h
*P. leibergii* (Vasey) Scribner h
*P. sphaerocarpon* Ell. h
*P. commutatum* Schultes h
*P. praecocius* Hitchc. & Chase h
*Andropogon virginicus* L. h
*Sorghastrum nutans* (L.) Nash h
*Sorghum bicolor* (L.) Moench th int
*S. halepense* (L.) Pers. c int
*Tripsacum dactyloides* (L.) L. h int

*CYPERACEAE*

*Carex sartwellii* Dewey c
*C. foenea* Willd. h
*C. gravida* Bailey c
*C. cephaloidea* (Dewey) Dewey c
*C. sparganioides* Willd. c
*C. cephalophora* Willd. h
*C. annectens* (Bickn.) Bickn. h
*C. decomposita* Muhl. h
*C. crus-corvi* Kunze h
*C. alopecoidea* Tuckerman h
*C. laevivaginata* (Kuek.) Mack. h
*C. seorsa* Howe h
*C. howei* Mack. h
*C. bromoides* Willd. h
*C. muskingumensis* Schw. c
*C. alata* Torrey h
*C. suberecta* (Olney) Britton h
*C. albolutescens* Schw. h
*C. longii* Mack. h
*C. festucacea* Willd. h
*C. bicknellii* Britton h
*C. molesta* Mack. h
*C. brevior* (Dewey) Mack. h
*C. normalis* Mack. h
*C. jamesii* Schw. h
*C. emmonsii* Dewey h
*C. artitecta* Mack. h
*C. richardsonii* R. Br. c
*C. hirtifolia* Mack. c
*C. woodii* Dewey c
*C. tetanica* Schk. c
*C. careyana* Dewey h
*C. albursina* Sheldon h
*C. laxiculmis* Schw. h
*C. digitalis* Willd. h
*C. gracilescens* Steudel h
*C. blanda* Dewey h
*C. hitchcockiana* Dewey c
*C. oligocarpa* Willd. h
*C. conoidea* Willd. c
*C. amphibola* Steudel h
*C. davisii* Schw. & Torrey c
*C. formosa* Dewey c
*C. prasina* Wahl. h
*C. sprengelii* Sprengel c
*C. virescens* Willd. h
*C. swanii* (Fern.) Mack. h
*C. hirsutella* Mack. c
*C. emoryi* Dewey c

*C. lurida* Wahl. h
*C. subimpressa* Clokey c
*C. trichocarpa* Schk. c
*C. hyalinolepis* Steudel c
*C. frankii* Kunth h
*C. squarrosa* L. h
*C. typhina* Michaux h
*C. grayi* Carey h
*C. lupuliformis* Dewey h
*Scleria trigolmerata* Michaux c
*S. pauciflora* Willd. c
*Cyperus flavescens* L. th
*C. diandrus* Torrey th
*C. aristatus* Rottb. th
*C. schweinitzii* Torrey c
*C. filiculmis* Vahl c
*C. engelmannii* Steudel th
*C. strigosis* L. c
*C. erythrorhizos* Muhl. th
*C. odoratus* L. th
*C. esculentus* L. c
*Eleocharis equisetoides* (Ell.) Torrey c
*E. quadrangulata* (Michaux) R. & S. c
*E. radicans* (Poiret) Kunth h
*E. melanocarpa* Torrey h
*E. olivacea* Torrey c
*E. caribaea* (Rottb.) S.F. Blake th
*E. engelmannii* Steudel th
*Rhynchospora macrostachya* Gray h
*R. capitellata* (Michaux) Vahl h
*Bulbostylis capillaris* (L.) Clarke th
*Psilocarya scirpoides* Torrey th
*Hemicarpha micrantha* (Vahl) Pax th
*Scirpus clintonii* Gray c
*S. smithii* Gray th
*S. olneyi* Gray c
*S. fluviatilis* (Torrey) Bray c
*S. expansus* Fern. c
*Fuirena squarrosa* Michaux th
*Fimbristylis puberula* (Michaux) Vahl c
*F. autumnalis* (L.) R.& S. th

*ARACEAE*

*Arisaema dracontium* (L.) Schott c
*Peltandra virginica* (L.) Schott & Endl. c

*LEMNACEAE*

*Wolffia punctata* Griseb. c
*W. columbiana* Karstan c

*XYRIDACEAE*
*Xyris torta* Sm. h
*X. difformis* Chapman h

*COMMELINACEAE*
*Commelina communis* L. th int
*Tradescantia ohiensis* Raf. h
*T. virginiana* L. h

*JUNCACEAE*
*Luzula multiflora* (Retz.) Lej. h
*Juncus greenei* Oakes & Tuckerman h
*J. marginatus* Rostk. h
*J. biflorus* Ell. c
*J. gerardii* Loisel c
*J. scirpoides* Lam. c
*J. brachycarpus* Engelm. c
*J. acuminatus* Michaux h

*LILIACEAE*
*Smilax herbacea* L. h
*S. rotundifolia* L. ph
*S. lasioneura* Hooker h
*S. ecirrata* (Kunth) S. Watson c
*S. illinoensis* Mangaly c
*Polygonatum biflorum* (Walter) Ell. c
*Trillium recurvatum* Beck c
*T. sessile* L. c
*T. undulatum* Willd. c
*T. flexipes* Raf. c
*Erythronium albidum* Nutt. c
*Lilium michiganense* Farw. c
*Yucca filamentosa* L. ch
*Allium cernuum* Roth c
*A. vineale* L. c
*A. canadense* L. c
*Uvularia sessilifolia* L. c
*Aletris farinosa* L. c
*Camassia scilloides* (Raf.) Cory c

*DIOSCOREACEAE*
*Dioscorea villosa* L. c

*AMARYLLIDACEAE*
*Hypoxis hirsuta* (L.) Cov. c

*IRIDACEAE*
*Sisyrinchium strictum* Bickn. h
*S. albidum* Raf. h

*ORCHIDACEAE*

*Cypripedium candidum* Willd. c
*Isotria verticillata* (Willd.) Raf. c
*Orchis spectabilis* L. c
*Habenaria ciliaris* (L.) R. Br. c
*H. leucophaea* (Nutt.) Gray c
*H. flava* (L.) Sprengel c
*Corallorhiza odontorhiza* (Willd.) Nutt. c
*Epipactis helleborine* (L.) Crantz c int
*Triphora trianthophora* (Sw.) Rydb. c
*Aplectrum hyemale* (Willd.) Torrey c
*Liparis liliifolia* (L.) Lindley h
*Sprianthes lucida* (H.H. Eaton) Ames h

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