AN ANALYSIS OF THE VEGETATION AT TURTLE MOUND, VOLUSIA COUNTY, FLORIDA: TWENTY YEARS LATER

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ABSTRACT: *Turtle Mound, located 13 km south of New Smyrna Beach, Volusia County, Florida, is a shell midden built by the Timucua Indians. Its vegetation and soil were studied in 1971-73 and again twenty years later. Recent severe freezes have led to the disappearance of several tropical species that were at or near their northern limit. These include the following taxa:* Cereus gracilis *var.* simpsonii; Exothea paniculata; Sideroxylon foetidissimum, Ocotea coriacea *and* Schoepfia chrysophylloides. *However, frequency of more temperate woody plants has increased along with several vines,* (Cissus trifoliata, Cynanchum scoparium, Parthenocissus quinquefolia, *and* Ipomea indica).

chemical + physical characteristics of soil w/o ref to climate

EAST central Florida is a region where the temperate and subtropical biota overlap. Low temperatures, and to a lesser extent edaphic conditions, restrict the movement of tropical plants northward. It has long been noted (Harper, 1921; Small, 1927) that shell mounds tend to be richer in tropical plant taxa than surrounding areas.

Turtle Mound, one of the largest Indian mounds remaining on the east coast of Florida, is situated 13 km south of New Smyrna Beach, along Mosquito Lagoon, at the northern end of Canaveral National Seashore. This area is indicated by Greller (1980) as the northern limit of the subzone of temperate broadleaf evergreen forest and tropical forest. The Mound is approx. 12 m high and 0.5 ha in size. Its early history is reviewed in Norman (1976). Twenty years ago, a vegetational study revealed that approx. 30% of the vascular flora growing there was of tropical origin (Norman, 1976). Several of the tropical taxa had their northern limit on the Mound. Since that time, a series of severe freezes has occurred in central Florida. The main purpose of this new study is to determine what changes in vegetation have occurred on the Mound since the first detailed study was made. Have some species vanished and new ones appeared? Have some become more frequent? Have others become rarer?

MATERIALS AND METHODS — *Abiotic factors.* - Twelve soil samples were collected from the Mound and neighboring areas in an attempt to replicate locations from which soil was sampled 20 years ago. Soil analysis was done as before (Norman, 1976) at the Soil Laboratory of the University of Florida. The methodology for soil analysis has changed. Twenty years ago, the ions were extracted with ammonium acetate, while in 1993 Mehlich-1 extract was used. We report the data obtained by this method although realistic comparison cannot be made with past data (Kidder, 1994).

Data on below-freezing temperatures were obtained from 1973 - 1993 from the Daytona Beach Weather Station. Mean minimum temperatures were computed and compared with those obtained for a period of 55 years, 1920-1926, 1935-1973 (Norman, 1976).

To compare data on soil temperatures on and off the mound, as before (Norman, 1976), two maximum-minimum thermometers were buried approximately 10 cm below the soil surface. One was buried near the top of the Mound in almost pure shells. The second was placed off the Mound under live oak trees.

VEGETATION—Plant collections were made during 1992-1993 (with permission of John Stiner, Resource Manager, Canaveral National Seashore). In addition, 24 transect lines at 15' intervals were erected, beginning at the base of a large Celtis laevigata se of T junction of boardwalk at top of Mound. This tree was selected because it was adjacent to the large Citrus aurantium, which had been used as base twenty years ago, but had died and was removed. The plants within 0.5 m of either side of the line were counted. Seedlings of woody

plants were not included if less than 1 m high. An estimate of herbs and vines was obtained. The vine density was especially difficult to ascertain. These plants often grow very thickly and it is almost impossible to determine where each is anchored to the ground.

TABLE 1. Soil analysis from Turtle Mound and vicinity, 1993.

Samples	pH	Concentration, ppm. Ca	Mg	P	K
Dunes, surface	8.1	6055	66	21	8
Dunes, profile 6"-19"	8.4	6099	64	15	13
Dunes, profile 19"-4'	6.8	6154	50	14	12
Oaks, e. of Mound, surface	8.5	6356	58	193	18
Oaks, e. of Mound, 6"-4'	8.4	6487	47	260	14
E. base of Mound surface	-	5326	822	222	158
E. base of Mound 8"	7.7	5559	691	281	101
E. base of Mound 12"	8.1	5983	431	499	52
Top of Mound, surface	8.1	6351	428	1117	114
Top of Mound 8" - 12"	8.2	6461	423	1231	107

TABLE 2. Minimum-maximum soil temperature on or near Turtle Mound

Dates	Top of Mound °F	Top of Mound °C	Off Mound °F	Off Mound °C
4-24-92	64-98	18-37	64-92	18-33
5-23-92	63-97	17-36	63-90	17-32
6-12-92	60-98	16-37	60-82	16-28
6-19-92	74-96	23-36	74-84	23-29
6-24-92	64-94	18-34	63-91	17-33
7-08-92	73-106	23-41	75-91	24-33
8-15-92	73-93	23-37	74-88	23-30
9-22-92	73-98	23-37	75-94	24-34
10-26-92	75-87	24-31	70-82	21-28
11-30-92	62-84	17-29	65-78	18-25
12-21-92	59-74	15-23	54-69	12-21
1-31-93	60-75	16-24	54-74	12-23
2-17-93	46-71	8-22	50-71	10-22
3-15-93	45-81	7-27	44-73	7-23
4-24-93	64-82	18-28	64-79	18-26
5-31-93	57-99	14-37	58-80	14-27
6-11-93	78-111	26-44	72-90	22-32

TABLE 3. Exterpated and new taxa at Turtle Mound 1973 - 1993

EXTIRPATED	
Arenaria lanuginosa	**Ocotea coriacea*
Boerhavia diffusa	*Rivina humilis*
**Cereus gracilis* var. *simpsonii*	**Schoepfia chrysophylloides*
Chamaesyce hirta	**Mastichodendron foetidissimum*
Chenopodium album	**Tillandsia fasciculata*
**Exothea paniculata*	**Tillandsia simulata*
Hymenocallis latifolia	*Urtica chamaedryoides*
**Iresine diffusa*	*Vittaria lineata*
NEW	
Carya glabra	
**Conocarpus erecta*	*Passiflora incarnata*
Hydrocotyle bonariensis	*Salicornia bigelowii*
Kosteletzkya virginica	**Schinus terebinthifolius*
Lippia nodiflora	*Smilax auriculata*
Mikania cordifolia	*Spartina patens*
Oenothera laciniata	*Suaeda linearis*
	Zamia pumila

* = tropical

RESULTS—*Abiotic factors*. - The results of the soil analysis are given in Table 1. Data on % organic matter and nitrogen were not available. The soils on the Mound and in nearby dunes are moderately alkaline with a large amount of calcium.

The mean annual minimum air temperature at Daytona Beach airport in 1973-1993 was 26.2° F (-3.2° C) with four days below 20° F (-7° C) (Fig. 1). In 1983, there was a period of 48 hrs when the temperature was below freezing. The available data for a 55 year period before the present study indicate that the mean annual minimum temperature was 1° C higher at that time. The temperature fell below -7° C only twice during the 55-year period (Norman, 1976).

Table 2 shows the minimum-maximum soil temperatures over a period of 15 months. The range of soil temperatures on the Mound tend to be larger than in nearby sand.

Vegetation—As expected, the vegetation at Turtle Mound is a mixture of floristic elements characteristic of several plant communities as follows: 23% from tropical hammocks, 24% from temperate hammocks, 34% from salt marshes and dunes, 15% ruderals, and 4% from mangrove. In 1993 we found 106 species in 55 families, a slight decrease in diversity from 1973 as shown in the Annotated List of Species.

Most of the extirpated taxa (Table 3) are members of the tropical hammock community. The woody representatives from the extirpated species were all at their northern limit at Turtle Mound twenty years ago. They were only known from one specimen each, except for *Exothea paniculata* which was then frequent. At that time all these species were reproductive except for *Mastichodendron* and *Ocotea*.

The new species (Table 3) are mostly temperate hammock species and inhabitants of salt marshes. The only new tropical taxa are *Conocarpus erecta* (buttonwood), and the exotic, *Schinus terebinthifolius*, (Brazilian pepper).

The transect studies (Table 4) showed that all the tropical trees and shrubs that were common in 1973 diminished in frequency and in number of transects in which they are

TABLE 4. Comparison of plant and transect frequencies in 1973 and 1993.

	1973		1993	
	N. Plants	N. Transects	N. Plants	N. Transects
TREES AND SHRUBS				
Amyris elemifera	105	19	18	8
Ardisia escallonoides	64	12	63	16
Celtis laevigata	95	23	173	24
Chiococca alba	46	13	12	7
Eugenia axillaris	175	24	75	22
Forestieria segregata	49	21	38	18
Ilex vomitoria	N.A.		40	8
Myrcianthes fragrans	152	19	203	24
Opuntia stricta	34	17	18	10
Persea borbonia	34	10	46	9
Rapanea punctata	22	7	8	4
Xanthoxylum fagara	90	23	27	12
Yucca aloifolia	57	20	2	1
VINES				
Cissus trifoliata	35	18	127	23
Cynanchum scoparium	27	14	64	17
Ipomoea indica	N.A.		77	23
Parthenocissus quinquefolia	69	18	95	24
Passiflora suberosa	45	20	6	5
Plumbago scandens	44	20	121	22
Sageretia minutiflora	46	14	58	14
HERBS				
Bidens alba	15	7	15	10
Galium hispidulum	20	6	13	3
Malvastrum coromandelianum	28	13	11	7
Mentzelia floridana	N.A.		110	12
Oplismenus setarius	50	4	3	3
Parietaria praetermissa	290	23	54	12
Pavonia spinifex	N.A.		26	12
Phyodina cordifolia	50	4	3	3

TABLE 5. Frequency analysis of number of plants and number of transects in 1993 compared to 1973.

Frequency analysis	Trees/Shrubs	Vines	Herbs	Cramer's V	P
N. of plants					
increase	4	6	2	.492	0.0382*
decrease	9	1	5		
N. of transects					
increase	4	5	3	.422	0.09
decrease	9	1	5		

DF = 2 * = $p =< 0.05$

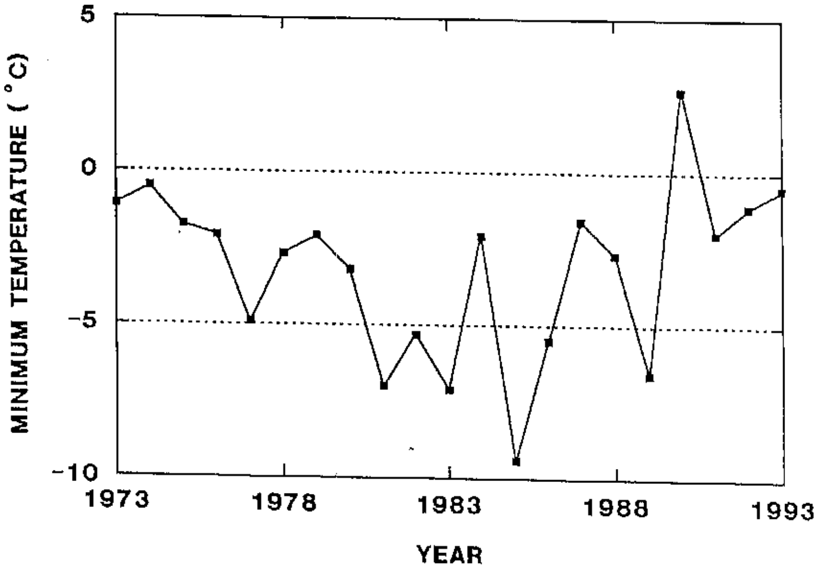

FIG. 1. Annual minimum temperatures at Daytona Beach, 1973-1993.

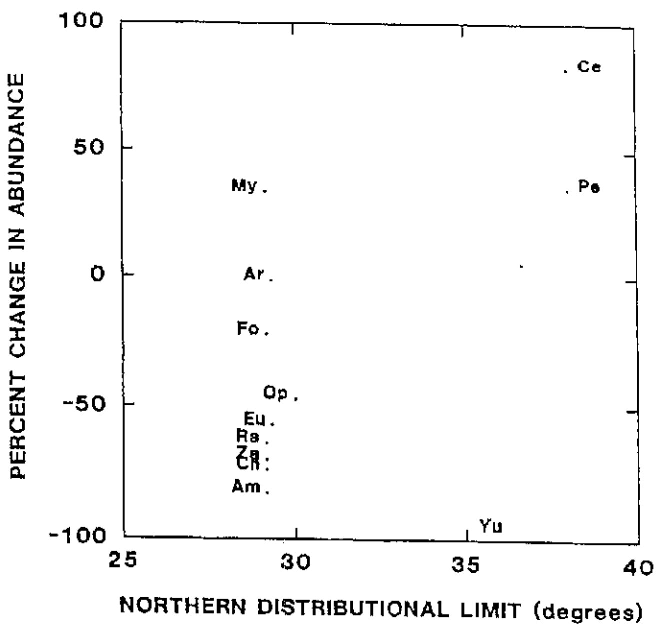

FIG. 2. Percent change in abundance of shrub and tree species at Turtle Mound correlated with their northern distributional limit. Abbreviations refer to generic names.

found with the exception of *Myrcianthes fragrans*, (nakedwood). The temperate trees, especially *Celtis laevigata*, increased in number of plants and transects. *Yucca aloifolia*, which was abundant at the base of the Mound in 1973 has declined dramatically.

We did a contingency analysis comparing frequencies of the most common species in 1973 and 1993 and also frequencies in transect number of these taxa (Table 5). There was a significant difference in frequency of plants but not in transect number. Figure 2 shows the correlation between percent change in abundance and present northern limit. A correlation analysis of these two variables was nearly significant ($r=0.5327$, $0.05 < p < 0.10$).

The frequency of vines has increased for both temperate and tropical species except for *Passiflora suberosa*, (passionflower) (Table 4). Three new vines have invaded the Mound *Mikania cordifolia* (climbing hempweed), *Passiflora incarnata* (maypop), and *Smilax auriculata* (catbrier). The vine cover has become luxuriant, not only growing over shrubby vegetation, but often also over the canopy species including *Celtis laevigata*. The high climbers are *Cissus trifoliata* (possum grape), *Parthenocissus quinquefolia* (Virginia creeper), and *Cynanchum scoparium* (leafless Cynanchum).

Among the herbs, *Mentzelia floridana* (poor man's patches) and *Pavonia spinifex* (spur bur), have become more frequent, while creeping plants such as *Oplismenus setarius* (basketgrass), and *Phyodina cordifolia* have almost disappeared. The frequency of *Parietaria praetermissa* (pellitory), has declined by 81%. This may be due in part to the timing of our census because this species is only conspicuous from February to May.

An attempt was made to locate present northern limits of extirpated tropical woody taxa. *Ocotea coriacea* (lancewood) is found at Castle Windy Midden, 8 km s of Turtle Mound. *Schoepfia chrysophylloides* (whitewood) survives in a hammock at Lori Wilson Park in Cocoa Beach. The plants there have many dead stems due to freeze damage (Taylor, 1994). Populations of *Exothea paniculata* (inkwood), *Sideroxylon foetidissimum* (mastic), and *Cereus gracilis* (night blooming Cereus), are known from s of Melbourne Beach, approx. 80 km south of Turtle Mound (Hames, 1994).

DISCUSSION—The maximum-minimum thermometers showed that the soil temperatures on the Mound were warmer than in nearby soils. This is what was found previously. In general, there is a greater range between the maximum and minimum temperatures for each reading on the Mound than off the Mound, as before. However, this time the minimum temperatures on the Mound tended to be higher than off the Mound. This may be due to the fact that the off mound readings were done under a heavy oak canopy and the soil was consistently moister there than on the Mound. Another factor may be the unusually warm air temperatures during the 92-93 season.

Many ecologists predict a global warming of 1.5° - 5° C during the next fifty years due to increasing levels of CO_2 (Overpeck et al., 1991; Baskin, 1993; Roberts, 1989). It has been inferred that this will bring about a mass migration of plants northwards or to higher altitude. Scientists have already shown this phenomenon to be occurring in alpine plants (Grabherr et al., 1994). These models and observations contrast with the recent extreme minimum temperatures found throughout Florida (Chen and Gerber, 1985). The authors found a negative trend with an average slope of -0.02° C/yr, which equaled a drop in minimum temperature of 1.8° C for the last 88 years. Comparing the present situation with the past they infer that Florida is going through a cold period. Successive extremes, and long periods of subfreezing temperatures, as we had in the 1980s, tend to have a cumulative effect on tropical and subtropical plants, both cultivated such as citrus, as well as native taxa (Chen and Gerber, 1990).

Several papers chronicle the effects of cold temperatures on native vegetation in both Florida and Texas. Mangrove vegetation has received most attention. Provancha and co-workers (1986) report that at Merritt Island, black, white and red mangroves were affected by the 1983 and 1985 freezes with some individuals destroyed but mostly with death of leaves and branches. Myers (1986) indicated that *Laguncularia* and *Conocarpus* are the least freeze hardy, followed by *Rhizophora* and *Avicennia*. Surprisingly, *Conocarpus* recently colonized the Mound's flora, probably in the last ten years. In Texas, only *Avicennia* is native (Sherrod and McMillan, 1981). McMillan and Sherrod (1986) showed that the Texan Gulf Coast populations of this species are more cold resistant than those of Louisiana and the w coast of Florida. Still the 1983 freeze brought about an 80-85% reduction in these populations. A study of the effects of freezes in the Everglades National Park (Olmsted et al., 1993) revealed that *Rhizophora* was the most affected of the mangrove species and *Avicennia* the least. As expected, at Turtle Mound black mangrove is by far the most abundant species, with only a few plants of the other three mangroves present. Sherrod and McMillan (1985) concluded on the basis of geological evidence, that prior to the pleistocene era, mangrove populations reached as far north as South Carolina. This was followed by a great constriction during the pleistocene and recolonization northward from tropical regions since then. Even in the last two hundred years we can see this kind of expansion and contraction on a smaller scale. Andre´ Michaux, a French botanist traveling and collecting plants in Florida in 1788 noted (Sargent, 1889) the red mangrove growing on Anastasia Island, adjacent to St. Augustine. Today *Rhizophora* extends only as far as the northern boundary of Volusia County, 75 km to the south.

Among other hardwood tropical plants that are found on the Mound and were affected by freezes at nearby Merritt Island in Brevard Co. are *Ocotea*, *Rapanea*, *Ardisia* and *Psychotria* (Provancha et al., 1986). In the lower Rio Grande Valley, Texas, freezes occurred at about the same period as in Florida (Lonard and Judd, 1991). The species showing the most damage, which also grow on Turtle Mound, were *Chiococca alba* and *Erythrina herbacea*. *Zanthoxylum fagara* was much less damaged. These data only correlate partially with our findings at Turtle Mound. *Ocotea* has vanished from the Mound, but *Zanthoxylum*, *Rapanea* and *Chiococca* have decreased by 64-74% while the frequency of *Ardisia* has remained stable (Table 4). Obviously, other factors besides freeze damage are involved in determining the frequency of a species near its northern limit. Some of these factors are: ability to resprout, rate of growth, reproductive potential, and dispersal ability (Myers, 1986). *Myrcianthes fragrans* is the only tropical shrub or tree species that has increased in frequency since our last census. Johnson and Barbour (1990) point out the prominence of this species in the temperate-tropical transition zone. At the present time its northern limit is Green Mound, approx. 25 km n of Turtle Mound. Earlier (Curtiss, 1879) it was known to occur on shell islands at the mouth of the St. John's River.

The radical decrease (Table 4) in *Yucca aloifolia* at Turtle Mound is not due to freezing temperatures as this species ranges north to North Carolina. The most likely explanation is the increase in shading due to dense growth of vines. Vines are opportunistic plants that thrive in disturbed areas and at the margins of forests (Putz, 1984). Freezes caused considerable dying back of vegetation. The building of a boardwalk through the Mound and continued removal of encroaching vegetation have undoubtedly stimulated the growth of vines. Many of the vines have rhizomes or tubers which can survive underground and sprout readily after a cold period.

Future vegetation surveys of Turtle Mound should prove enlightening in view of its strategic location and interesting microcosm of plant communities.

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MALVACEAE

Kosteletzkya virginica (L.)Presl. ex A. Gray. saltmarsh mallow. Rare on riverside.
Malvastrum coromandelianum (L.)Garcke. false mallow. Abundant along trail.
Pavonia spinifex (L.) Cav. spur bur. Frequent along trail.

MYRICACEAE

Myrica cerifera L. wax myrtle. Occasional base of mound.

MYRSINACEAE

Ardisia escallonioides Schlecht. & Cham. marlberry. Dominant.
Rapanea punctata (Lam.)Lundell. Myrsine. Frequent.

MYRTACEAE

Eugenia axillaris (Sw.)Willd. white stopper. Dominant.
Myrcianthes fragrans (Sw.)McVaugh. nakedwood. Dominant.

OLEACEAE

Forestiera segregata (Jacq.)Krug. & Urban. Florida privet. Abundant.

ONOGRACEAE

Oenothera laciniata Hill. cut-leaved evening primrose. Rare at base.

OXALIDACEAE

Oxalis stricta L. yellow wood sorrel. Rare along trail.

PASSIFLORACEAE

Passiflora incarnata L. maypop. Occasional at base.
Passiflora suberosa L. corky-stemmed passionflower. Occasional.

PHYTOLACCACEAE

Phytolacca americana L. pokeweed. Rare.

PLUMBAGINACEAE

Plumbago scandens L. leadwort. Abundant.

POACEAE (GRAMINEAE)

Andropogon glomeratuscus var. glaucopsis (Ell.)Mohr. bushy bluestem. Occasional on riverside.
Cenchrus echinatus L. sandspur. Rare.
Distichlis spicata (L.)Greene. saltgrass. Occasional on riverside.
Eustachys petraea (SW.)Desv. fingergrass. Occasional on riverside.
Oplismenus setarius (Lam.)Roem.& Schult. Occasional in shade.
Panicum fasciculatum Swartz. browntop Panicum. Rare on riverside.
Setaria geniculata (Lam.)Beauv. knotroot bristlegrass. Occasional on riverside.
Setaria macrosperma (Scribn. & Merr.)Schum. foxtail.
Spartina patens (Ait.)Muhl. saltmeadow cordgrass. Occasional on riverside.
Sporobolus virginicus (L.)Kunth. seashore dropseed. Occasional on riverside.

POLYPODIACEAE

Phlebodium aureum (L.)Small. golden polypody. Rare epiphyte on Persea.

PORTULACACEAE

Portulaca pilosa L. pink purslane. Occasional at base.
Portulaca rubricaulis Kunth. yellow purslane. Rare on riverside.

RHAMNACEAE

Sageretia minutiflora (Michx.)Mohr. buckthorn. Abundant.

RHIZOPHORACEAE

Rhizophora mangle L. red mangrove. Rare on riverside.

ROSACEAE

Prunus caroliniana Ait. laurel cherry. Occasional at base.

RUBIACEAE

Chiococca alba (L.)Hitch. snowberry. Frequent.
Psychotria nervosa Sw. wild coffee. Frequent.
Galium hispidulum Michx. bedstraw. Occasional.

RUTACEAE

Amyris elemifera L. torchwood. Frequent.
Citrus aurantium L. sour orange. Occasional.
Xanthoxylum fagara (L.)Sarg. wild lime. Frequent.
Xanthoxylum clava-herculis L. hercules club. Occasional near base.

SAPOTACEAE

Bumelia tenax (L.)Willd. tough buckthorn. Occasional near base.

SMILACACEAE (LILIACEAE)

Smilax auriculata Walt. catbrier. Frequent at base.
Smilax laurifolia L. bamboo briar. Occasional at base.

SOLANACEAE

Capsicum frutescens L. Tabasco pepper. Rare.
Lycium carolinianum Walt. christmas berry. Occasional on riverside.
Physalis viscosa L. var. maritima (Curtis)Rydb.. ground cherry. Occasional at base.

ULMACEAE

Celtis laevigata Willd. hackberry. Dominant.

URTICACEAE

Parietaria praetermissa Hinton. pelitory. Frequent in shade.

VERBENACEAE

Callicarpa americana L. French mulberry. Occasional.
Lantana camara L. shrub Verbena. Frequent at base.
Lippia nodiflora (L.)Michx. carpetweed. Occasional on riverside.
Glandularia maritima (Small)Small. seaside Verbena. Rare on riverside.

VITACEAE

Cissus trifoliata (L.)L. possum grape. Dominant.
Parthenocissus quinquefolia (L.)Planchon. Virginia creeper. Dominant.
Vitis rotundifolia Michx. muscadine grape. Occasional at base of mound.
Vitis aestivalis Michx. summer grape. Occasional at base of mound.