

Presettlement landscape heterogeneity: Evaluating grain of resolution using General Land Office Survey data

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Abstract

General Land Office Survey (GLOS) records from the A.D. 1840s provide data for quantitative characterization of presettlement vegetation across western Mackinac County, Michigan, located within the mixed conifer-northern hardwoods forest region. We analyzed data from land survey plat maps and 1958 bearing, witness, and line trees from 162 surveyed section and quarter-section corners in order to map vegetation cover types at a level of spatial resolution appropriate for characterizing landscape heterogeneity using standard landscape ecological metrics. As also demonstrated by a number of both classic and contemporary plant-ecological studies, the distribution of landforms, soils properties, hydrology, and location of fire breaks all contribute to the heterogeneity in vegetation observed at a landscape scale in the region. Through a series of spatial landscape analyses with differing grain of resolution, in this study we determine that a grid cell size of 65 ha (0.5 mi × 0.5 mi or 0.25 mi²) to 259 ha (1 mi²) gives a conservative characterization of landscape heterogeneity using standard metrics and is therefore appropriate for use of GLOS data to study historical landscape changes.

1. Introduction

Numerical indices that describe landscape mosaic patterns in terms of the distribution, diversity, dominance, connectivity, contagion, and fractal complexity of vegetation cover types are sensitive to both grain of resolution and extent of landscape examined (Turner 1989; Turner and Gardner 1990). It is thus important to understand the range of values expected in each metric across natural landscape mosaics before applying the measures to interpreting landscape changes resulting from recent land use. Objective comparison of original landscapes with present-day patterns of land use in turn is critical to determining the nature of landscape dynamics (Turner *et al.* 1993) as well as the trajectory of landscape change over time (Flader 1983; Stearns 1987; Turner 1989; Williams 1989; White and Mladenoff 1994).

The records of the General Land Office Surveys (GLOS) conducted in the late A.D. 1700s to mid-

1800s (White 1983) contain a wealth of ecological information concerning the distribution and composition of presettlement and early settlement vegetation (Bourdo 1956, 1983; Stearns 1974, 1987). In the Great Lakes region, and elsewhere in the eastern United States, GLOS data have been used to map tree distributions, vegetation types, and disturbance regimes (representative studies include those of Kenoyer 1934, 1940, 1942; Stearns 1949, 1951, 1974; Bourdo 1956, 1983; Marschner undated, 1957, 1974, 1979; Finley 1951, 1976; McIntosh 1962; Lindsey *et al.* 1965; Crankshaw *et al.* 1965; Gordon 1966, 1969; Anderson 1970; Lindsey 1973; Delcourt and Delcourt 1974, 1977; Lorimer 1977; Mladenoff and Howell 1980; Grimm 1984; Canham and Loucks 1984; Whitney 1986, 1990; Iverson and Risser 1987; Iverson *et al.* 1989; Leitner *et al.* 1991; Schwartz 1994; White and Mladenoff 1994). Despite the large number of descriptive studies, however, only one study (Iverson and Risser 1987) has considered

the potential and limitations of GLOS data in providing spatially explicit information that can be quantified using landscape ecological metrics. No studies to date have attempted to determine the optimal grain of analysis for a given extent of study area for adequately quantifying vegetation patterning on natural landscapes using GLOS data.

In this study, we explore the potential of using GLOS data to quantify landscape heterogeneity across a selected portion of eastern Upper Michigan in which strong gradients exist in soil texture, moisture, and nutrient availability because of heterogeneous distribution of landforms (Simpson *et al.* 1990; Albert *et al.* 1986). Covering a total land area of 34,851 ha adjacent northern Lake Michigan, the study area encompasses the land within five townships (T42N R10W, T43N R10W, T44N R10W, T43N R9W, and T44N R9W) in western Mackinac County in upper Michigan (Fig. 1). We document the original distribution of trees and the composition of forest communities in western Mackinac County, as recorded by GLOS land surveys. We develop objective methods to determine and map boundaries between presettlement vegetation types independent of underlying geology and soils in order to allow for treatment of vegetation and soils data as independent variables. Through a series of tests, we determine the appropriate grain of sample size with respect to landscape extent and precision of land survey plat maps in order to calculate landscape metrics describing the original vegetation mosaic.

2. Methods

2.1. Geology and soils

We compiled a surficial geologic map depicting the locations of bedrock knolls, glacial deposits, and postglacial shoreline features using the work of Farrand (1982) and Farrand *et al.* (1984), as well as our own field observations (Petty *et al.* 1996; Delcourt *et al.* 1996). We mapped soil types, initially following the detailed soil survey descriptions for western Mackinac County (Veatch 1953, 1959; Whitney *et al.* 1995). We prepared thematic maps for both geologic features and soils to emphasize contrasting landform topography and gene-

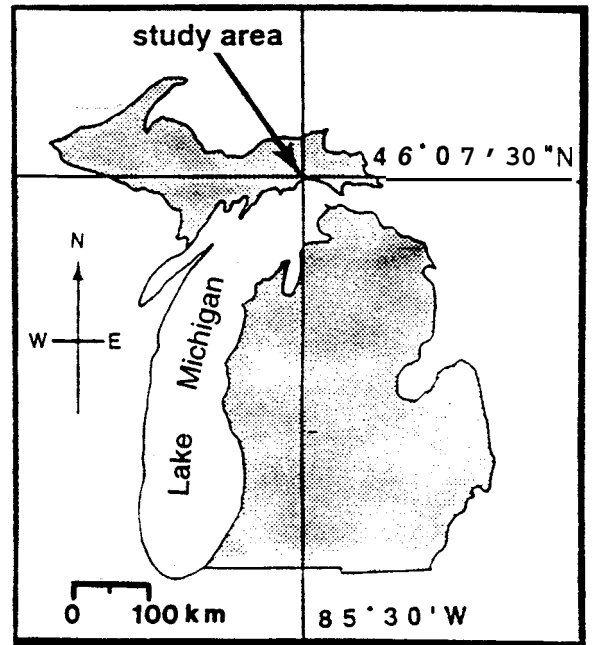


Fig. 1. Location map of study area in western Mackinac County, Michigan, USA.

sis, soil texture, and soil chemistry (Veatch 1953; Franzmeier *et al.* 1963). We mapped nine cover types for each landscape thematic map to be comparable with the type-map resolution at which we analyzed the presettlement vegetation.

2.2. Presettlement vegetation

2.2.1. GLOS surveys of Burt, Burt, and Ives

We mapped the distributions of individual species of trees and woody shrubs across the study area using data from the GLOS from the 1840-41 Township Survey of William Austin Burt and the 1844 and 1849-50 Section Surveys directed by John A. Burt (William Burt's son) and William Ives, covering T42-44N, R9-10W, western Mackinac Co., Michigan. Judge William A. Burt was a highly respected deputy land surveyor who was known for his careful attention to detail (Martin 1986). Praising Burt for his "long experience and superior skill", the Surveyor General employed Burt in particular surveys for which "the greatest accuracy is required" or when an impartial, fair review was mandated for rechecking possibly erroneous or even fraudulent work by fellow surveyors (Stewart

1935, pages 54-56, 86-88, 157-158).

Judge Burt collected plants for identification as documented by vouchered herbarium specimens (Burt and Cooley 1850), and he invented the solar compass that made accurate surveying possible in the iron ranges of Upper Michigan where magnetic compasses were useless (Burt 1881). In his manual, William Burt (1881) published explicit instructions and solutions for problems commonly encountered by federal land surveyors in field surveys in the Great Lakes region. Deputy surveyors John Burt and William Ives apprenticed with William Burt on the 1840 survey; their methods were consistent with his. The Appendix to this paper includes specific instructions for General Land Office Surveys conducted between 1833 and 1850, the time interval during which mapping of the eastern Upper Peninsula of Michigan was completed by William Burt and others.

The GLOS data set for western Mackinac County, Michigan, includes locations, distances and directions from survey corners, and diameters (ranging from 7.5 cm [3"] to 102 cm [40"] for 1958 bearing and witness trees (marked at square-mile or section corners and at 0.8 km [0.5 mi] intervals, or quarter-section corners), and line trees (encountered on surveyed sectional lines), as well as additional woody plants encountered on survey lines. Bearing, witness, and line trees recorded by surveyors included the following species (nomenclature follows Gleason and Cronquist 1963 and Barnes and Wagner 1981; common names are those used by the surveyors): Alder (*Alnus rugosa*). Aspen (*Populustremuloides*, *Populus grandidentata*), Balm of Gilead (*Populus balsamifera*), Beech (*Fagus grandifolia*), Black Ash (*Fraxinus nigra*), Black Oak (possibly *Quercus velutina*, more probably *Quercus rubra* [P. Comer, *written communication*, 1994]), Cedar (*Thuja occidentalis*), Cherry (*Prunus serotina*), Cottonwood (*Populus deltoides*), Elm (*Ulmus americana*), Fir (*Abies balsamea*), Ground Hemlock (*Taxus canadensis*), "Hazle" (hazel, probably *Corylus cornuta*, possibly including *Corylus americana*), Hemlock (*Tsuga canadensis*), Ironwood (*Ostrya virginiana*, *Carpinus caroliniana*), Lynn (Basswood, *Tilia americana*), Maple (probably Red Maple, *Acer rubrum*), Spotted Maple (probably Moosewood and Striped Maple, *Acer pennsylvanicum*; possibly Mountain

Maple *Acer spicatum*), Spruce (*Picea glauca*, *Picea mariana*), Spruce Pine (also listed as Norway Pine, *Pinus resinosa*), Sugar or Sugar Maple (*Acer saccharum*), Tamarack (*Larix laricina*), White Ash (*Fraxinus americana*), White Birch (*Betula papyrifera*), White Pine (*Pinus strobus*), Yellow Birch (includes Cherry Birch, *Betula allegheniensis*), Yellow Pine (Jack Pine, *Pinus banksiana*), Willow (probably *Salix nigra*).

In his 1850 general instructions to his surveyor deputies, Charles Noble, Surveyor General for Michigan, authorized the abbreviations of "Sugar" for Sugar Maple and "Maple" for Soft Maple as conventionally used by surveyors identifying bearing trees in Michigan's Upper Peninsula (White 1983, page 377).

Usage of common names for *Pinus resinosa* and *Pinus banksiana* by the Burt, Burt, and Ives surveys of western Mackinac County apparently differs from that used in surveys (by at least six deputy surveyors including William A. Burt) conducted from 1836-1859 in northern Lower Michigan (Whitney 1986; P. Comer, *written communication*, 1994). Whitney (1986) interpreted both "spruce pine" and "pitch pine" as jack pine (*Pinus banksiana*) because the witness trees so designated were generally small-statured and scattered across xeric sand plains. Trees designated by the land surveyors as "Norway pine" and "yellow pine" were attributed by Whitney (1986) to red pine (*Pinus resinosa*). In the eastern Upper Peninsula area, however, *Pinus banksiana* was called "yellow pine" both by surveyors and by subsequent loggers (Rowe *et al.* 1977). In our study area of western Mackinac County, Michigan, occasionally Norway pine (or spruce pine), white pine (*Pinus strobus*), and yellow pine were all witness trees recorded at the same survey corner.

The Burt, Burt, and Ives surveys were conducted along Township, Range, and Section lines; this procedure potentially limited the spatial resolution of the survey (Iverson and Risser 1987). The Burt, Burt, and Ives survey teams, however, ran meander lines offset across or around each stream, lake, and open bog they encountered along section lines, venturing across the interior of each section of land (Burt 1881). Minimum spatial resolution was mandated by contract; surveyors were required to map locations of ponds and lakes of 40 acres (16.2 ha)

or more in extent that were situated entirely within the interior of each square-mile section (see Appendix). The grain of the landscape they portrayed on their detailed plat maps, however, was much finer and included forest openings, swamps, bogs, and lakes as small as 4 ha (about 10 acres or 0.016 mi²). These surveyors also recognized and were required by contract to map natural disturbances such as windfalls (Stearns 1949; Canham and Loucks 1984; Frelich and Lorimer 1991) and fires, as well as human-caused disturbances such as forest openings, burned areas, trails, campgrounds, and maple sugar camps made by Native Americans (see Appendix). We used the original plat maps to determine the boundaries of lakes, wetlands, and forest openings. Surveyors' descriptions of dominant woody plants as written on the plat maps were useful in preliminary characterization of upland and wetland forest communities.

2.2.2. *Quantitative analysis of GLOS data*

The GLOS data set consists of both surveyed plat maps on which vegetation boundaries were identified by the surveyors, and discrete samples of forest composition recorded at 162 surveyed section corners (averaging 12 witness trees per 1.6 km-diameter sample centered at each section corner). Each sample of forest composition, with the importance of each tree species calculated as percent of total trees, included all witness, bearing, and line trees recorded within 0.8 km (0.5 mi) radius of each section corner. Thus, the forest samples are tallies of all trees recorded by the surveyors in consecutive and non-overlapping areas of uniform size, along a systematic gridwork of 162 section corners situated at 1.6km intervals.

In order to identify positions of ecotones between upland plant communities whose boundaries were not delineated on surveyor plat maps, we used Detrended Correspondence Analysis (DCA, DECORANA; Gauch 1982; Clappitt 1986) to ordinate species' relative abundances across the study area using the 162 samples of forest composition (Fig. 4a). Ecotones were determined as steepened portions of the gradients in Beta diversity identified by indirect gradient analysis. DCA sample scores were plotted on a map at each of the section corners, then the values were contoured (Fig. 4b). The rate of change in forest composition per unit dis-

tance was graphically portrayed (Fig. 4c), with contoured values representing the difference in sample scores between adjacent section corners (delta Beta SD on DCA Axis I). Gauch (1982) considered that a delta Beta value of 4.0 SD on DCA Axis I represents a 100% turnover in species composition. Values of 1.0 and 2.0 delta Beta SD on Fig. 4c therefore represent 25% and 50% turnover in species composition, respectively. We used these contours to locate primary ecotone boundaries between presettlement vegetation cover types (Delcourt and Delcourt 1992).

We constructed a cover type map for plant communities (Fig. 5) based on (1) the delineations of swamp and lake boundaries on the original surveyors' plat maps that anchored the borders between upland and wetland vegetation types; (2) ecotones determined by Detrended Correspondence Analysis (DCA, Figs. 4b, 4c); (3) species contour maps (for instance, 15% contours for white pine, aspen, and/or white birch delimited the perimeter of a specified forest type); and (4) presence-absence of high-fidelity indicator species (for example, boundaries of the Sugar Maple-Elm-Ironwood-Lynn (Basswood) Forest circumscribed by the combined distributions of ground hemlock, elm, lynn, and ironwood).

We used a PC-version of Turner's Spatial Analysis (SPAN) program (M.G. Turner, *personal communication*, 1994) to derive general statistics to characterize spatial heterogeneity of presettlement vegetation across the study area (Fig. 6). As written, the PC-SPAN program is intended to accommodate up to nine cover types and has been used as the basis for interpretation of landscape heterogeneity in several papers and that are now considered classics in the field of landscape ecology (Turner 1989; Turner and Gardner 1990). We elected to use the original version of SPAN in this characterization of presettlement vegetation for the purpose of direct comparability with previous studies.

Our classification and mapping of nine cover types of presettlement vegetation is comparable with the level of classification of Upper Michigan virgin forests and nonforested wetlands considered appropriate by other researchers. For example, in characterizing extant sands of relatively undisturbed, old-growth forests, Simpson *et al.* (1990) sampled and mapped landscape ecosystems in the

Huron Mountains in northcentral Upper Michigan, 200 km northwest of our study area. Nine broad categories of vegetation cover types were considered necessary and sufficient by Simpson *et al.* (1990) to reflect the primary environmental gradient of soil moisture. In addition to a nonforest cover type (that included wetlands, beaches, and open meadows), diverse forest communities in the Huron Mountains were classified into eight major categories (listed from xeric to hydric habitat): mixed pine, pine-oak, white pine-hemlock-hardwood, birch-aspen, hemlock-northern hardwood, northern white cedar-hemlock-hardwood, floodplain, and swamp (Simpson *et al.* 1990, page 39).

We used standard metrics (Turner 1989; Turner and Gardner 1990) to characterize patchiness, dominance, diversity, contagion, and fractal index for each of the nine cover types of presettlement vegetation (Fig. 6). In the version of PC-SPAN that we used, the nearest-neighbor rule included 4 adjacent N-S and E-W cells in the data matrix, but did not include diagonals in the calculations. The SPAN program calculated the following commonly used indices of spatial pattern:

(1) the fraction or proportion of the landscape in each cover type

$$p_i = \frac{n_i}{N},$$

where n_i = number of cells of type i ; N = all cells in landscape

(2) relative richness of cover types

$$R = \frac{S \times 100}{S_{\max}},$$

where S = number of cover types observed, and S_{\max} = maximum cover types possible

(3) Diversity index (evenness; high values indicate high diversity, low values indicate low diversity)

$$H = \frac{-\sum_{K=1}^s p_k \ln(p_k)}{\ln(s)}$$

where p_k = proportion occupied by K , and S = number of cover types

(4) Dominance index (values range from 0 to 1, low values indicate many cover types; high values indicate one or a few cover types)

$$D = \frac{H_{\max} + \sum_{K=1}^s p_k \ln(p_k)}{H_{\max}},$$

where s = number of cover types

(5) Contagion index (high values indicate landscape elements are clumped, low values indicate a dissected landscape)

$$C = \frac{s \ln(s) + \sum_i \sum_j q_{ij} \ln(q_{ij})}{s \ln(s)}$$

where s = number of cover types, $s \ln(s)$ = maximum value using a q_{ij} matrix

(6) Patch distributions (mean number of patches, mean patch size, frequency distributions)

(8) Fractal index ($D = 1.0$ for a square, with higher values between 1 and 2 for more highly convoluted shapes)

$$D = (1/d)^*2, \text{ where } d = \ln(\text{size})/\ln(\text{perim}/4)$$

(note that $d = 2.0$ for a perfect square)

In order to determine the optimal grain (= cell or pixel size) of analysis for characterizing presettlement landscape heterogeneity, we ran PC-SPAN using a wide range of scales of spatial resolution (Fig. 6). We varied the grain of resolution from 37,296 ha (approximately 144 mi²) with one sample encompassing the entire study area, to 4.05 ha (0.016 mi², a total of 8612 sample plots), the size of the smallest vegetation feature drawn on the original plat maps. In this way we determined the finest sample grid that can be obtained reliably from GLOS data as well as the optimal sample size for use with GLOS data for a study area of comparable extent to ours. Because we were primarily interested in determining the finest scale at which GLOS data can be considered spatially explicit, and therefore made compatible with modern land use analyses (*e.g.*, White and Mladenoff 1994), in this study we did not experiment with expanding the spatial extent of the sampled region.

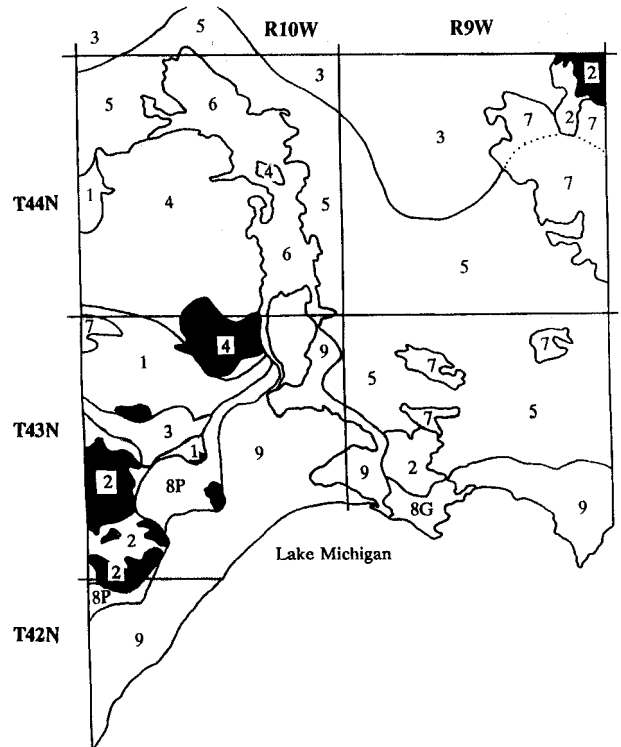
In our study, the bounds of certain vegetation types were necessarily smoothed beyond what would be obtained by using topography or soils as constrains (P. Comer, *written communication, 1995*). However, because we derived the cover type distributions of presettlement vegetation completely independently from landform and soils maps, we were also able to look at the degree of correspondence between original plant communities and soil cover types (Fig. 7).

3. Results

3.1. Geology and soils

In the classification of regional landscape ecosystems of Michigan, the study area lies within the region designated "13.1", the St. Ignace Subdistrict of the Mackinac District, in Eastern Upper Michigan. The terrain consists of limestone bedrock knolls, oriented as upland cuestas along the Niagara Escarpment (Fig. 2), and a series of topographically lower, wave-cut coastal terraces and sandy lake plains consisting of gently undulating ridges and swales of relict beach strands (Albert *et al.* 1986).

Glacial ice covered the study area until between 11,600 and 11,200 yr B.P.; a minor glacial readvance occurred in the northernmost Upper Peninsula about 10,100 yr B.P. (Futyma 1981; Farrand and Drexler 1985; Larsen 1987; Fraser *et al.* 1990). Late Wisconsinan ground moraines and drumlin fields sculpted in stratified tills of sandy loam and of reworked lacustrine clays occur primarily west of Lake Millecoquins (a large inland lake located in the approximate center of the study area). Proglacial lake deltas, composed of heterogeneous deposits of clays to cobbles, and sandy outwash aprons that formed along the ice margin as meltwaters flowed into ancestral Lake Algonquin are also represented to the west of Lake Millecoquins (Farrand 1982; Farrand *et al.* 1984). Postglacial uplift due to isostatic rebound created a series of wave-cut, coastal terraces of reworked outwash sands, representing relict shorelines at elevations up to 265 m and perched as much as 88 m above present-day Lake Michigan (Futyma 1982). These features are preserved primarily to the east of Lake



GEOLOGY

■ SILURIAN LIMESTONE QUATERNARY DEPOSITS

LATE WISCONSINAN GLACIATION:

GROUND MORAINE:

- 1 Clayey Till (redeposited red-brown lake clay)
- 2 Sandy Loam Till

GLACIO-FLUVIAL DESPOSITS:

- 3 Outwash Valley/Plain (with fine to coarse sand)
- 4 Proglacial Delta (interbedded clay, silt, sand, and gravel lay

PROGLACIAL LAKE ALGONQUIN DEPOSITS:

- 5 Shoreline Strands (fine to medium sand)

HOLOCENE INTERGLACIATION:

PEATLANDS:

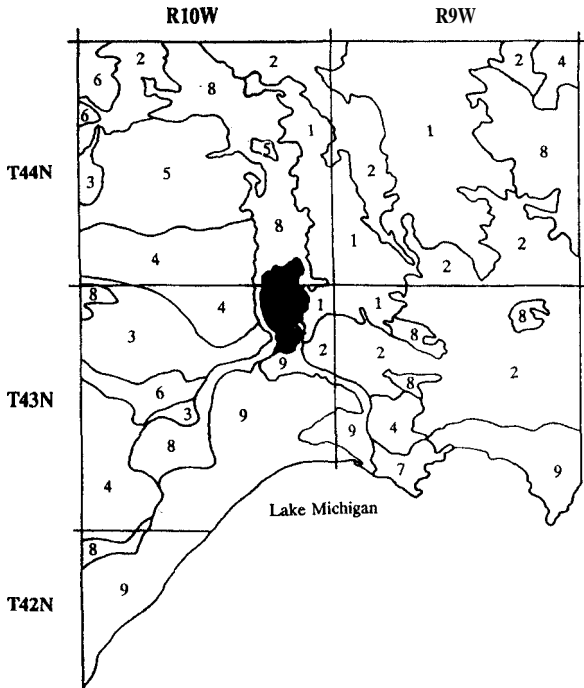
- 6 Fluvial Swamps and Marshes (peaty muck and sand)
- 7 Upland Peatlands (peaty mucks, perched groundwater table)

COASTALLAKE PLAIN:

- 8 Wave-cut Benches:
 - 8G Gravelly Sand over Sandy Loam Till
 - 8P Peaty Muck over Clayey Till
- 9 Beach Ridges, Sand Dunes, and Swales

Fig. 2. Geologic map of landforms and deposits for western Mackinac County, Michigan (this study). Each block of township and range (e.g., Township 44 North, Range 10 West) is 9.7 km (6 mi) on a side.

Millecoquins (Fig. 2). A "stair-step" sequence of Holocene beach ridges, sand dunes, and inter-ridge swales is distributed in a series of arcuate bands



SOIL COVER TYPES

WELL-DRAINED SOILS

- 1 Acidic Fine to Medium Sand without Ortstein
- 2 Acidic Fine to Medium Sand with Ortstein

MODERATELY DRAINED

(TO SEASONALLY POORLY DRAINED) SOILS

- 3 Calcareous Clay to Clayey Loam
- 4 Calcareous Silty to Fine Sandy Loam over Shallow Limestone
- 5 Calcareous Silty to Fine Sandy Loam over Shallow Clay
- 6 Neutral to Acidic Fine Sandy Loam

POORLY DRAINED SOILS

- 7 Calcareous to Neutral Gravelly Loam
- 8 Acidic Peats and Mucks
- 9 Acidic Sands and Mucky Peats

Fig. 3. Soil cover types of western Mackinac County, Michigan (modified from Whitney *et al.* 1995).

oriented parallel to the present shoreline of Lake Michigan (Fig. 2) (Delcourt *et al.* 1996):

Distribution of soil cover types in general parallels underlying geology, with well-drained sandy soils developed over glacio-fluvial deposits, calcareous soils developed on ground moraines veneered over Silurian limestone, and acidic sands and mucky peats characteristic of coastal terraces and poorly drained bogs (Figs. 2, 3). Spodosols that developed in the mid-Holocene interval (6900 to 3200 yr B.P.; Petty *et al.* 1996) contain well-devel-

oped ortstein horizons (quartz sands strongly cemented together with iron and aluminium sesquioxides). These iron-cemented "pan" horizons occur within glacial outwash and lake-plain sandy soils (Typic Haplorthods, Soil Type 2 in Fig. 3). The ortstein layers hinder downward penetration of tree roots and impede water percolation, creating a seasonal perching of local water table and more mesic to hydric conditions in these upland soils than occur on sandy substrates without ortstein (Lambert and Hole 1971).

In the past 2200 to 3500 years, in response to the onset of late-Holocene cool, wet climate (Bernabo 1981) that allowed water tables to perch over relatively impermeable ortstein layers, clays, and silty loams, peatlands (Soil Type 8) expanded locally across level terrain in the northeast quadrant of the study area (Figs. 2, 3) as elsewhere in the eastern Upper Peninsula (Futyma 1982; Madsen 1987; Petty 1994).

3.2. Presettlement vegetation

The study area is located within the mixed conifer-northern hardwoods forest (Hemlock-White Pine-Northern Hardwoods Forest Region of Braun 1950), a vegetation region about which much is known in terms of fundamental relationships of tree species to environment because of many classic (Whitford 1901; Transeau 1905; Harshberger 1911; Nichols 1935; Halliday 1937; Graham 1941; Braun 1950; Stearns 1951; Brown and Curtis 1952; Curtis 1959; Rowe 1972) and contemporary (Pregitzer and Barnes 1984; Spies and Barnes 1985a, b; Simpson *et al.* 1990; Pastor and Broschart 1991; Frelich and Lorimer 1991; Frelich *et al.* 1993; Mladenoff *et al.* 1993) plant-ecological investigations.

3.2.1. Detrended correspondence analysis

In the DCA ordination of species scores (Fig. 4a), ironwood, elm, lynn, and sugar maple cluster in the middle range of the soil moisture gradient and at an extreme that represents nutrient-rich soils with high cation-exchange capacity. At the opposite end of the scale (Fig. 4a), aspen, white birch, white pine, and yellow pine represent species characteristic of nutrient-poor, dry sites, whereas cottonwood, ce-

PRESETTLEMENT VEGETATION (A.D. 1840-1849)
DCA ORDINATION OF SPECIES SCORES

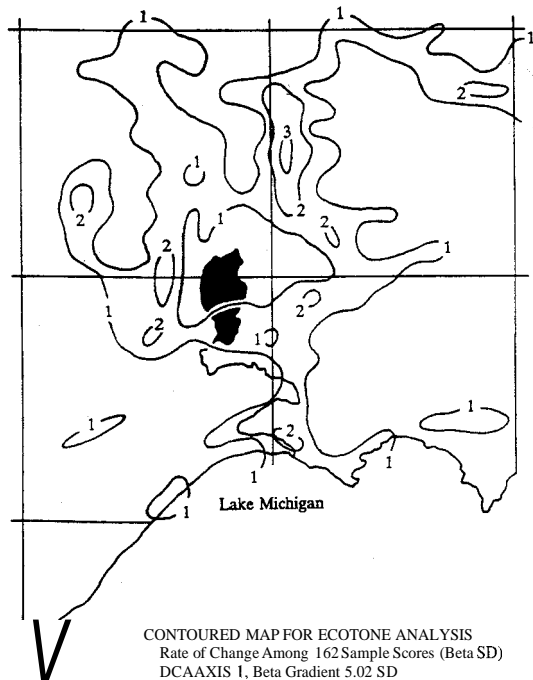
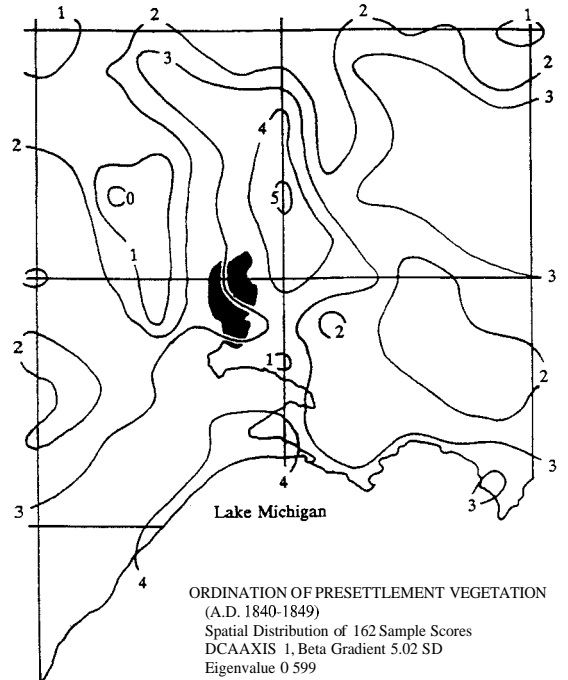
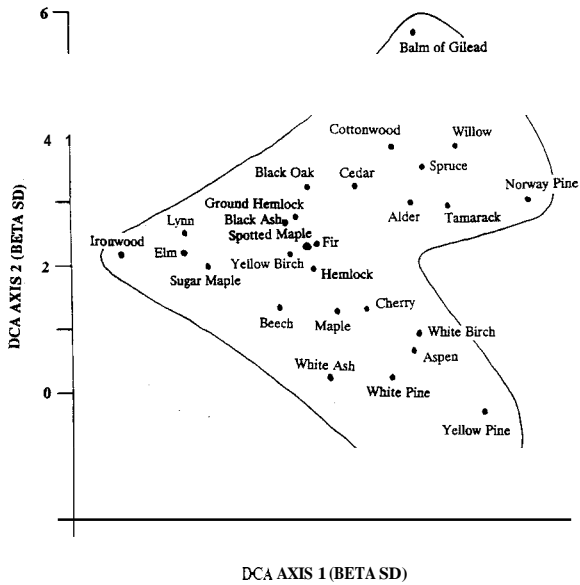
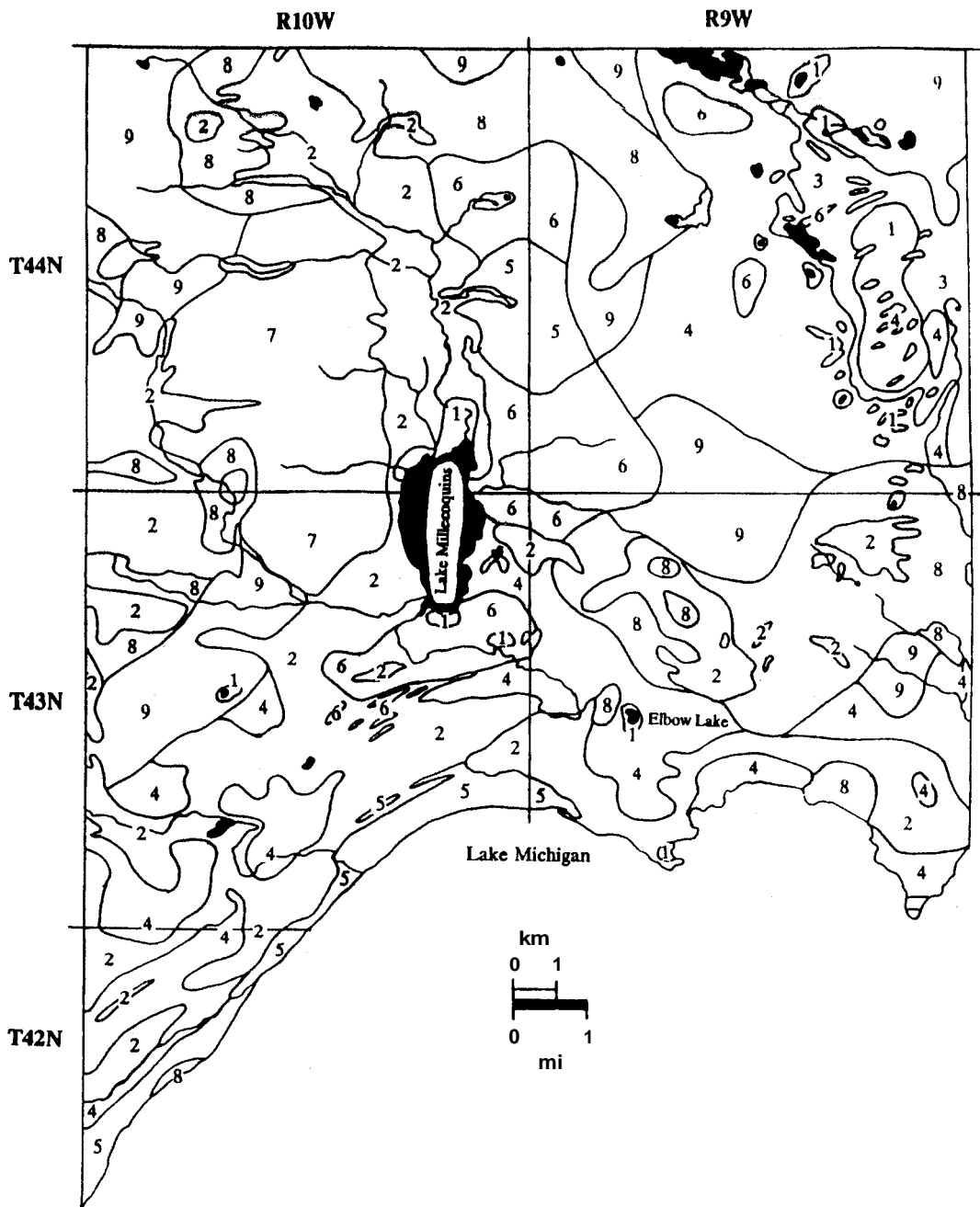


Fig. 4. Detrended Correspondence Analysis (DCA) and ecotone analysis. (a) ordination of species scores; (b) contour map of DCA-ordinated sample scores, DCA Axis 1, Beta Gradient 5.02 SD (4.0 SD denotes 100% turnover in forest composition); (c) contour map of delta beta SD (illustrating rate of change in species turnover of forests across the landscape).



PRESETTLEMENT VEGETATION (GLOS)

MAP LEGEND

- | | |
|---------------------------------------|---|
| ■ LAKE | 6 YELLOW (JACK) PINE-ASPEN FOREST |
| 1 OPEN MARSH, MEADOW, OR BOG | 7 SUGAR MAPLE-ELM-IRONWOOD-LYNN (BASSWOOD) FOREST |
| 2 CEDAR-SPRUCE-TAMARACK-ALDER SWAMP | 8 HEMLOCK-HARDWOOD FOREST |
| 3 SPRUCE-TAMARACK SWAMP | 9 SUGAR MAPLE-FIR-BEECH-YELLOW BIRCH FOREST |
| 4 WHITE PINE-WHITE BIRCH-ASPEN FOREST | |
| 5 NORWAY PINE FOREST | |

Fig. 5. Cover type map of presettlement vegetation for western Mackinac County, Michigan.

dar, willow, alder, spruce, and tamarack are characteristic of nutrient-poor but hydric soils. In part this diagram (Fig. 4a) also represents gradients in disturbance, with late-successional, mesic hardwood species clustering together, fire-adapted pioneer upland species of pines, white birch, and aspen co-occurring, and fire-sensitive, wetland species adapted to fluvial disturbance with fluctuating levels of stream flow including willow, alder, tamarack, cedar, and spruce.

On the DCA ordination plot of species scores (Fig. 4a), we interpret Axis 1 as a gradient in soil pH and fertility, inferred from the ordination values graphed for species of sugar maple, beech and pines. We interpret Axis 2 as a gradient in soil moisture and texture, with cedar and willow representing hydric species and pines representing xeric species. These patterns of species distributions are consistent with what is known of their autecology (Simpson *et al.* 1990; Burns and Honkala 1990a, 1990b) and with the results of classic ecological gradient analyses in adjacent areas of the Midwest (Brown and Curtis 1952; Curtis 1959).

A plot of the spatial distribution of sample scores (Fig. 4b), along a beta gradient of 5.02 SD, reveals that a complete turnover in species composition (Gauch 1982; Delcourt and Delcourt 1992) occurred across the presettlement soils/disturbance gradient in the study area. A map of values for rate of change in species composition (delta beta SD; Fig. 4c) shows the locations of strong ecotones across the region (greater than 1.0 beta SD per 1.6 km [1 mi]). The greatest contrast between forest types appears across the region from the northeast to the northwest of Lake Millecoquins (beta gradient of 5.02 SD across 6.4 km [4 mi] distance; Fig. 4b). This gradient encompasses forest boundaries for xeric Norway Pine (Spruce Pine) Forest and Yellow Pine-Aspen Forest, hydric Cedar-Spruce-Tamarack-Alder Forest, and mesic Sugar Maple-Elm-Ironwood-Lynn (Basswood) Forest (Fig. 5).

3.2.2. Presettlement vegetation map

Three distinctive plant communities characterized wetlands across the study area. Open Marsh, Meadow, and Bog (Vegetation Cover Type 1 on Fig. 5) included nonforest to sparsely forested wetlands as well as Indian campgrounds and a Native American

Table 1. Summary of area statistics for presettlement vegetation cover types (Type Number on Fig. 5), western Mackinac County, Michigan.

Cover type	Number of cells (1 cell = 4.0468 ha)	Area (ha)	% Land area
Cedar-Spruce-Tamarack-Alder Swamp (2)	2192	8871	25.5
White Pine-White Birch-Aspen Forest (4)	1648	6669	19.1
Hemlock-Hardwood Forest (8)	1367	5532	15.9
Sugar Maple-Fir-Beech-Yellow Birch Forest (9)	1313	5313	15.2
Sugar Maple-Elm-Ironwood-Lynn (Basswood) Forest (7)	721	2918	8.4
Yellow Pine-Aspen Forest (6)	629	2545	7.3
Norway Pine (Spruce Pine) Forest (5)	312	1263	3.6
Spruce-Tamarack Swamp (3)	273	1105	3.2
Open Marsh, Meadow, and Bog (1)	157	635	1.8
Land subtotal	8612	34,851	100.0
Inland lakes	133	538	
Lake Michigan	471	1907	
Total study area	9216	37,296	

village. This vegetation type was most extensive in a large peatland complex located in the northeastern quadrant of the study area (Figs. 2 and 3). Interspersed within this peatland were a series of higher, sandy ridges supporting groves of pine and aspen. A second, smaller area of open marsh occurred at the north end of Lake Millecoquins where tributary streams converged to form a delta. Cedar-Spruce-Tamarack-Alder Swamp (Vegetation Cover Type 2) was extensive (8871 ha; Table 1), particularly in the drainageways leading into the north end of Lake Millecoquins and along the lake plain, that is, the ridge and swale topography of late-Holocene beach ridge complexes immediately inland of the northern shore of Lake Michigan west of the Millecoquins River (Fig. 2). Cedar-Spruce-Tamarack-Alder Swamp was typically dense and difficult to traverse on foot by the survey parties. Spruce-Tamarack Swamp (Vegetation Cover Type 3) lacking cedar surrounded the open bog area in the Cranberry peatland of the northeastern quadrant of

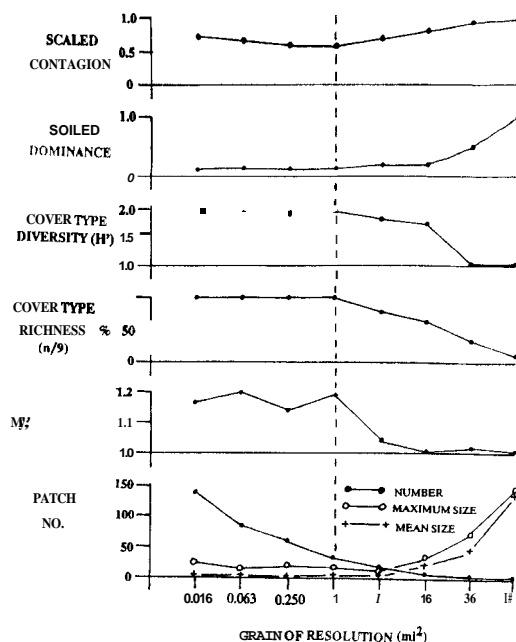
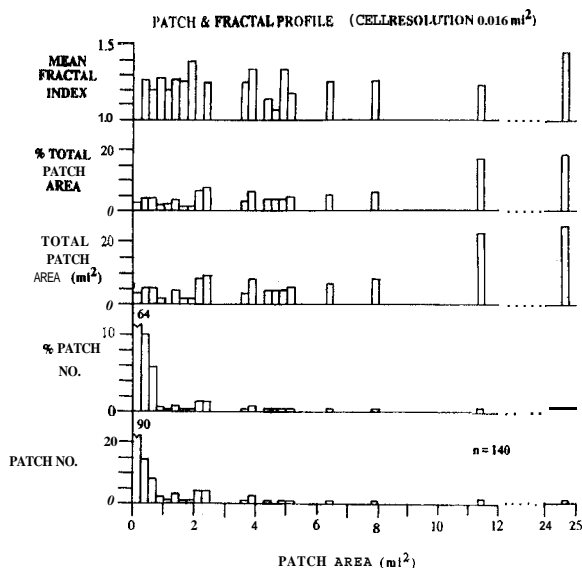


Fig. 6. Grain vs. extent: landscape ecological metrics on varying spatial scales of sampling, presettlement vegetation mosaic of western Mackinac County, Michigan.

the study area (Fig. 5). The Spruce-Tamarack Swamp was described by the surveyors as characterized by scattered individual trees of spruce and tamarack in a predominantly shrubby health-dominated wetland.

Xeric upland sites were occupied by one of several pine forest communities. White Pine-White Birch-Aspen Forest (Vegetation Cover Type 4), including at least 4 km² of old-growth white pine stands, covered much of T44N R9W west of the extensive Cranberry peatland complex (comprised of Vegetation Cover Types 1 and 3). White Pine-White Birch-Aspen Forest also occurred to the southeast and southwest of Lake Millecoquins on sands of former shorelines of glacial Lake Algonquin and Holocene Lake Michigan (Fig. 2). Forest composed of more than 15% Norway pine (spruce pine) (Vegetation Cover Type 5) was confined to an area northeast of Lake Millecoquins and a second swath along the Lake Michigan coast west of the Millecoquins River. A third distinctive pine forest type, the Yellow Pine-Aspen Forest (Vegetation Cover Type 6), is mapped (Fig. 5) where yellow pine exceeded 15% of the forest composition and Norway pine was less than or equal to 15%. This

forest type occurred both north and south of the Norway (spruce) Pine Forest to the northeast of Lake Millecoquins. A second extensive area of Yellow Pine-Aspen Forest was located on mid-Holocene sand ridges and dunes, located south of Lake Millecoquins along the Millecoquins River in the vicinity of the Native American village.

Mesic Sugar Maple-Elm-Ironwood-Lynn (Basswood) Forest (Vegetation Cover Type 7) was distributed in one large, contiguous patch northwest of Lake Millecoquins (Fig. 5), constrained farther to the west and to the east by extensive poorly-drained Cedar-Spruce-Tamarack-Alder swamps (Vegetation Cover Type 2). To both the north and the south, this mesic forest community was bounded by less species-rich Hemlock-Hardwoods and Sugar Maple-Fir-Beech-Yellow Birch forests (Vegetation Cover Types 8 and 9, respectively). Other extensive areas of Hemlock-Hardwoods Forest (Vegetation Cover Type 8) occurred on uplands in the north-central and east-central portions of the study area, with Sugar Maple-Fir-Beech-Yellow Birch Forest communities (Vegetation Cover Type 9) occurring north and east of the Cranberry bog in the northeast quadrant, as well as in the east-central

FIGURE

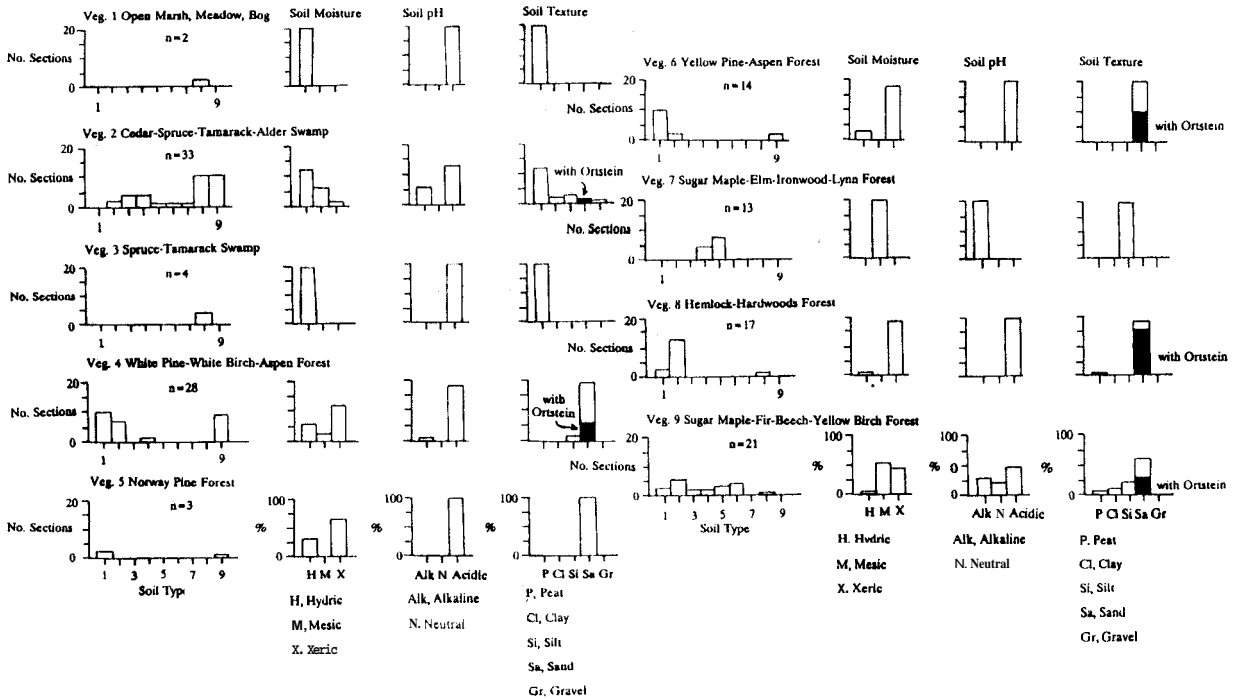
VEGETATION/SOILS RELATIONSHIPS (1 mi² grid)

Fig. 7. Vegetation/soils relationships, based on presettlement vegetation cover types (Fig. 5) and soil map cover types (Fig. 3).

portion of the study area (between Hemlock-Hardwoods and White Pine-Aspen and Yellow Pine-Aspen forests).

3.2.3. Spatial analysis

On the vegetation cover type map (Fig. 5), the boundaries of several upland forest types (such as the Sugar Maple-Fir-Beech forest) were necessarily smoothed relative to those of certain wetland types (e.g., Open Marsh, Meadow, and Bog). We tested the importance of this artifact of conservative mapping of vegetation boundaries in subsequent spatial analyses performed at different scales of resolution to see at what scales it made a difference in interpretation of landscape heterogeneity.

For the GLOS data from the Burt, Burt, and Ives surveys, the effective lower limit of confidence in interpreting features on surveyors' plat maps was 4 ha (10 acres or 0.016 mi²). At this level of resolution, several measures of landscape heterogeneity such as fractal index and minimum patch size were well characterized (Table 1, Fig. 6). For those

GLOS surveys at which this grain of resolution can be obtained reliably, results of GLOS data analysis could be compared with fine-scale spatial resolution available for today's forests from aerial photographs (Pastor and Broshart 1990; Mladenoff *et al.* 1993).

Many of the landscape measures were only grossly approximated at the most coarse grain of resolution we examined (one unit of 37,296 ha or 144 mi²); in general, apparent landscape heterogeneity decreased with increasing grain size, and at spatial scales of 1036 ha (4 mi²) or broader, not all cover types were resolvable. At a grid cell size of one section of land, 259 ha (640 acres or 1 mi²), however, all 9 presettlement vegetation cover types were resolved and metrics for dominance, diversity, contagion, and fractal index gave results comparable to those at the next several finer scales of spatial resolution (Fig. 6). The degree of spatial smoothing required to map certain vegetation types whose boundaries were not directly delineated on the plat maps was not an obstacle to comparing

landscape heterogeneity if a spatial resolution of 65 ha (0.25 mi² [0.5 mi x 0.5 mi]) to 259 ha (1 mi²) was used.

3.3. Vegetation/soils relationships

In general, mesic hardwood forest communities tended to be associated with calcareous, mesic, silty and sandy loamy soils distributed to the north, west, and southeast of Lake Millecoquins, with pine forests occurring on upland sands of glacial outwash and lake plains to the east of Lake Millecoquins (Fig. 7). Particularly striking is the relationship of the Sugar Maple-Elm-Ironwood-Lynn (Basswood) Forest (Vegetation Cover Type 7) with the Battydoe and Moltke Soil Series (Soil Cover Types 4 and 5) developed over shallow Silurian limestone, overlain by fine-grained glacial tills containing reworked lake clays and by stratified deposits of a proglacial delta (interbedded clay, silt, sand, and gravel layers) (Figs. 2 and 3).

The White Pine-White Birch-Aspen Forest (Vegetation Cover Type 4) occurs primarily on Rubicon and Kalkaska Soil Series (Soil Cover Types 1, 2), which are very well drained, acidic spodosols developed on fine to medium quartz sands, derived from glacial outwash and dunes of ancient post-glacial shorelines. White pine forests also occurred on Eastport Sands (Soil Cover Type 9) developed on quartz-sand beach ridges formed in the past 5400 yr (Fig. 2) (Petty *et al.* 1996).

The Kalkaska Soil Series has a well-developed ortstein layer, a precipitate of cemented iron and aluminium sesquioxides (Lambert and Hole 1971), which results in somewhat more mesic soil conditions. Within medium-textured, quartz-sand soils of northern Michigan, ortstein layers (variously described as hardpan and fragipan) have been demonstrated to increase both water-holding capacity and nutrient availability (Franzmeier *et al.* 1963), thereby favoring development of old-growth white pine stands as well as mature hemlock-hardwoods (Figs. 3, 5, 7) (Spies and Barnes 1985a, 1985b; Simpson *et al.* 1990; Pastor and Broschart 1990). In our study area, radiocarbon-dated sequences of lake sediments and paleosols document that formation of the ortstein horizon in quartz-sand substrates occurred between 6900 and 3200 yr B.P. (Petty *et*

al. 1996). The pedogenic establishment of semi-permeable to impermeable soil horizons has influenced the local perching of water tables and has favored late-Holocene paludification of uplands (Futyma 1982). The laterally continuous ortstein "seal" has ponded water in the Cranberry peatland, favoring accumulation of acidic, peaty muck soils (Figs. 3 and 7) and has generated late-Holocene habitat for the upland swamp we designate as the Spruce Tamarack Swamp (Cover Type 3; Fig. 5).

The mutually exclusive distributions of mesic hardwood and pine forests in part reflect the patterns of wildfire occurrence and natural fire breaks. Some forest communities tended to be distributed broadly over gradients in soil moisture, pH, and texture, *e.g.*, the Sugar Maple-Fir-Beech-Yellow Birch Forest (Vegetation Cover Type 9; Figs. 3 and 5). These vegetation-soil relationships are similar to those documented in northern Lower Michigan (Veatch 1953, 1959; Whitney 1986; Medley and Harman 1987) and western Upper Michigan (Spies and Barnes 1985a, 1985b; Simpson *et al.* 1990).

4. Discussion

From the several forms of evidence extracted from the Burt, Burt, and Ives GLOS of the 1840s, it is evident that the presettlement vegetation of western Mackinac County, Michigan, was a complex mosaic in which species of woody shrubs and trees composed plant communities distributed according to differences in landform, topography, and soils properties. The presettlement landscape mosaic as a whole can be described as highly heterogeneous, with relatively high diversity of cover types but with relatively low dominance values (Fig. 6). The contagion values indicate that landscape elements were distributed in a contiguous vegetation mosaic rather than a dispersed series of fragmented patches (Fig. 6). The region was almost continuously forested, with relatively few forest openings except (1) in the pine lands where fire was an important agent of disturbance in resetting secondary succession; (2) in wetlands characterized by extensive tracts of open bog; and (3) meadows and clearings made by Native Americans. Cover types were nearly evenly distributed in terms of area of cover and dominance. Only two vegetation types (Cover

Types 3 and 7) occurred as single, large patches; the rest occurred as a few smaller patches separated by dissimilar vegetation.

The fractal index was relatively low, despite the map pattern of interdigitating wetlands along stream courses draining uplands and the occurrence of numerous inland lakes. This result may be explained as an artifact of the necessity of generalizing the boundaries between adjacent upland forest types, based upon the broad, 1.6-km intervals between section corner samples of bearing trees. More complex boundaries would be created by delimiting vegetation types along prominent topographic escarpments such as relict wave-cut coastal terraces (Fig. 2) (P. Comer, *written communication*, 1994). In this study, however, we wished to keep the vegetation mapping strictly independent of the landform distributions, topographic relief, and soils mapping to avoid circular reasoning in subsequent interpretations of landscape patterning. We emphasize that caution should be exercised in interpreting fractal index from interpolated map boundaries such as represented on Fig. 5, unless the vegetation map is simplified to include only the boundaries between uplands and wetlands as portrayed on the original plat maps.

In a study of changes in extent of wetlands in Illinois since A.D. 1960s, Iverson and Risser (1987) tested the spatial resolution of GLOS data by measuring area of wetlands within a buffer zone of 200 m delimited along each side of surveyed section lines. Their assumption was that GLO surveyors would not have documented wetlands within the interiors of sections beyond their typical line of sight from measured section boundaries. In the three Illinois counties examined, significantly more wetlands appeared on plat maps along surveyed lines than in section interiors, indicating that surveyor bias resulted in an underestimate of total wetland area by between 20 and 50% (Iverson and Risser 1987). In any of the Michigan surveys conducted by William A. Burt or his trainees, however, the centers of surveyed sections were traversed routinely (Burt 1881), and wetlands mapped were thus subject to much less bias in areal estimates.

5. Conclusions

Research in restoration ecology and management of old-growth forests (Barnes 1989) relies on establishing vegetation patterns for a presettlement timeline that represents the "original" forest conditions with which to compare present vegetation composition (Whitney 1986, 1987, 1995; Mladenoff and Howell 1980; Stearns 1987; Iverson and Risser 1987; Leitner *et al.* 1991; White and Mladenoff 1994). In a study comparing landscape heterogeneity between existing stands of old-growth hemlock-hardwoods forests with managed forests on similar substrates in the western Upper Peninsula of Michigan, Mladenoff *et al.* (1993) concluded that post-settlement landscapes are simpler in structure as a result of land use history. This conclusion is similar to that obtained from broad-scale analysis of land use maps examined across eastern North America (O'Neill *et al.* 1988). In a multi-temporal spatial analysis of changes in forest communities of northern Wisconsin since A.D. 1860s, White and Mladenoff (1994) demonstrated that, although species composition has been altered, post-logging northern hardwood forests have regenerated in a similar spatial pattern to pre-European settlement hardwood forests because of the strong control of geologic-edaphic constraints on species distributions across the landscape. Today the Border Lakes landscape of northern Wisconsin contains remnant old-growth patches within a matrix of managed forest. Changes in overall landscape heterogeneity since the time of EuroAmerican settlement thus primarily reflect changes in successional status of forest trees following broad-scale timber clearance (White and Mladenoff 1994).

Based upon recent studies from the Upper Great Lakes region (Mladenoff *et al.* 1993; White and Mladenoff 1994), changes in landscape heterogeneity resulting from changes in land use through the past 150 years may be expressed primarily as differences in number, kind, and dominance values of vegetation cover types, as well as by changes in importance of species within vegetation of similar physiognomy. Our analysis shows that, along with measures of landscape heterogeneity such as patchiness and dominance of vegetation types, measures of contagion between adjacent communities, reflecting the strength of regional ecotones (quanti-

fied through delta beta diversity, *e.g.*, Fig. 4c), are valuable additional measures to use in further studies of the transformation from presettlement to present forest conditions. Results of this study indicate that GLOS records provide appropriate data with which to analyze important aspects of presettlement landscape heterogeneity at a spatial scale that can be interfaced readily with contemporary vegetation mapping and analysis. GLOS data therefore constitute an important resource for continuing studies of “original” vegetation throughout much of North America (Stearns 1974).

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Appendix: Instructions to General Land Office Surveyors, A.D. 1833–1850

The following instructions, given to General Land Office Surveyors of the Michigan Territory that included the lands surveyed by Judge William A. Burt and his survey parties, are quoted from White (1983). These instructions provide insight about the spatial resolution of the surveys, accuracy of the plat maps, as well as selection of bearing, witness, and line trees used to document Township, Range, and Section lines and corners.

From his office in Cincinnati, Ohio, in 1833, Micajah T. Williams, Surveyor General of the United States, for the States of Ohio and Indiana, and the Territory of Michigan, published a document of “General Instructions To His Deputies”. This is the set of detailed instructions used by William A. Burt during his first federal land surveys started in November, 1833.

Williams' instructions specified the blazing of four trees at section corners and at least two trees at quarter-section corners. No mention was made of surveyor preference of selection of available tree species, their presumed longevity or their diameter, only their physical proximity to the post set at each corner.

However, the inscribing of bearing tree designations of letters and numbers on an **ax** blaze of the tree trunk would effectively require a minimum tree diameter of about 3 inches. These instructions state (White 1983, pp. 291–300):

“At all posts thus established for section or township corners, there shall be cut with a marking iron, on a bearing tree or some other tree, within each section, and as near as may be to the corner thereof [sic], the number of such section: and over it the letter T, with the number of the township, and annexed thereto, the letter N or S as the township may be north or south of the Base Line; and above this, the letter R with the number of the Range, and annexed thereto, the letter E or W, as the range may lay east or west of the principal meridian; thus:

R4E

T9N

36

The letters and numbers thus marked should be made in a regular chop, cut into such tree, and neatly squared off and faced, so as to be always readily distinguished from a mere blaze.

But at the quarter-section corners there are no numbers to be made: the [corner] post is to be flattened on two opposite sides, and thus marked: ‘I-4S’, to indicate that it is a quarter section post: and the nearest adjoining tree on each side of the sectional line, must be similarly marked.”

The survey teams were required to range widely in a belt transect, spanning the survey lines, and to map prominent geographic features such as lakes that lie completely within the interior of a section, not intersecting the regular line.

“All lines which you may survey, are to be marked in the following manner; viz: all those trees which your line cuts, must have two notches made on each side of the tree, where the line cuts it; but no spot or blaze is to be made thereon. These are indifferently called ‘station trees’, ‘line trees’, or ‘sight trees’. And all those trees on each side of the line, and within ten to fifteen links thereof [3.0 m, or 9.9 ft] (or farther if the land should be thinly timbered) must be marked with two spots or blazes, diagonally or quartering towards the line; which blazing must be made so conspicuous, that the line may be readily found and traced.”

“... You are to enter in your Field Book, in a neat and distinct manner; notes or minutes of the following objects:

1. The description, course and length of every line which you shall have run.

2. The name, and estimated diameters of all corner and bearing trees, and the courses [the direction or compass ‘bearing’] and distance of the bearing trees from their respective corners.

3. The description of all mounds which you shall erect as corners in prairies, or places where there shall be no trees convenient for bearings.

4. The names and estimated diameters of all those trees which fall in your lines, called station or line trees, with their exact distances on the line.

5. The face of the country, whether level, rolling, broken, hilly, or mountainous.

6. The quality and character of the soil, and whether first, second, or third rate.

7. The several kinds of timber and undergrowth, with which the land may be covered, naming each kind of timber in the order in which it is most prevalent; and in prairie, the kind of grass or other herbage, which it produces.

8. All rivers, creeks and smaller streams of water, with their width, and the course they run where the lines of your survey intersect or cross them, and whether the current be rapid, sluggish, or otherwise ...

11. All lakes and ponds, with the description of banks surrounding them, and whether the water be deep or shallow, pure or stagnant.

12. The meanders of all lakes, navigable rivers, bayous, islands, and streamforming boundaries.

13. All prairies, swamps, and marshes

16. All towns and villages, Indian towns and wigwams, houses or cabins, fields or other improvements, sugar-tree groves, and sugar camps [for tapping maple syrup] ...

21. All travelled roads, and 'trails', with their courses, and denoting the places from, or to which they lead.

22. The tracks of tornados or hurricanes, commonly called 'windfall', or 'fallen timber', shewing the direction of the wind, as indicated by the fallen trees.

Wherever the section or township lines intersect lakes, streams of water, or islands, which are to be meandered [surveyed by offset lines], posts are likewise to be established on the margin or banks thereof ... Should any lake or pond which you shall meander, be situated within any one section, so as not to be intersected by any of the lines thereof, you will run and measure a line very exactly, but without marking, from one of the corners, or one of the half mile posts, or other given point on one of the lines of said section, to the point on the margin of the lake at which you shall commence the meanders thereof. The true location of such lakes is necessary, in order to calculate the contents of the subdivisions of such sections."

From his office in St. Louis, Missouri, on January 9, 1834, Elias T. Langham, U.S. Surveyor General of Illinois and Missouri, sent a written set of "General Instructions to Deputy Surveyors". These mandates differed regionally in methods for how bearing trees were to be selected (White 1983, pp. 301–312). This 1834 document mentioned that:

"you will ascertain and state in your field notes, the course and distance from the several Section and Township corner posts, trees, and stones, to a tree in each Section for which they stand [witness] as a corner ... Quarter-Section corners will be perpetuated by a post ... from which you will state in your field notes the course and distance of two of the most suitable trees in two different quarter-Sections for which you are establishing the corner ..."

Further explanation of "suitable trees" was offered by William Pelham, Surveyor General of Arkansas at Little Rock. In the "General Instructions to Deputy Surveyors", published in 1843 (White 1983, page 333), Pelham admonished that:

"You will select for bearing trees those which are the soundest and most thrifty in appearance, and of the size and kinds of trees which experience teaches will be the most permanent and lasting."

In a letter dated July 14, 1849, from Detroit, Michigan, Surveyor General Lucius Lyon wrote to Guy H. Carleton, Deputy Surveyor, preparing to subdivide Townships 42 to 45 North of Ranges 12 and 13 West in Michigan's Upper Peninsula. Lyon noted (White 1983, page 357) that the General Instructions from his office were out of print. Carleton was referred to the May 28, 1846 set of printed instructions from the Surveyor General's Office at DuBuque. In all cases, Lyon wrote, there were to be at least two bearing trees noted at every corner. The 1846 surveyor document for Wisconsin and Iowa stated (White 1983, pages 341–343):

"Trees, employed either for the purpose of bearing or witness trees, are to be alive and healthy and not less than five inches [12.7 cm] in diameter ... In subdividing any one township, you are to meander as hereinafter directed, any lake or ponds, lying entirely within the boundaries thereof, of the area of forty acres [16.2 ha] and upwards, and which cannot be drained and are not likely to fill up, or from any cause to become dry."

In 1850, Charles Noble, then Surveyor General for the States of Ohio, Indiana and Michigan, published from his Detroit, Michigan, office a 117-page document, listing "General Instructions to Deputy Surveyors", providing the contractual framework for the township subdivision of sections in the study area conducted by John A. Burt (William A. Burt's son) and William Ives in 1849–1850. Noble's 1850 instructions required the use of the survey instrument of "Burt's Improved Solar Compass", with measurements made without the use of the magnetic-needle compass (White 1983, page 361):

"At all township corners, and at all section corners on range, or township lines, four bearing trees are to be marked ..., one within each of the adjoining sections ..."

For the two bearing trees as quarter-Section corners,

"the nearest adjoining tree on each side of the sectional line, must be similarly marked."

The letters and numbers for Range, Township, and Section (White 1983, page 365)

"must be neatly and very distinctly cut into the wood of such tree with a good marking tool, the bark thereof having been first hewn or peeled off from a spot on the side facing the corner, large enough for that purpose, unless the tree be a beech [beech], in which case its bark, if smooth, may remain on."

The Field Notes were to include (White 1983, page 370)

"The names and estimated diameters of at least one or two of those trees which fall in your lines, called station or line trees, with their exact distances on the line, between every two corners."