



114
291
THS



3 1293 10533 6477

LIBRARY
Michigan State
University

This is to certify that the
thesis entitled
THE VEGETATION AND HYDROLOGY
OF A LAKESIDE WETLAND
presented by
George William Knoecklein

has been accepted towards fulfillment
of the requirements for

MS degree in Fisheries &
Wildlife

Major professor

Date June 10, 1981



OVERDUE FINES:

25¢ per day per item

RETURNING LIBRARY MATERIALS:

Place in book return to remove
charge from circulation records

09 JUN 07 2000

SEP 28 1973

FEB 6 1973

OCT 5 1990

DEC 22 1998

326

SEP 10 1997

JUN 06 1999

THE VEGETATION AND HYDROLOGY
OF A LAKESIDE WETLAND

By
George William Knoecklein

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Fisheries and Wildlife

1981

ABSTRACT

THE VEGETATION AND HYDROLOGY OF A LAKESIDE WETLAND

By

George William Knoecklein

The vegetation of a lakeside wetland was mapped according to Cowardin *et al.* (1979). Elevations of the growing surfaces were measured. The tendency for inundation within types was obtained from the 20-year average lake-surface elevation. *Lythrum salicaria* L. (purple loosestrife) escaped inundation on high hummocks at the shore. *Larix laricina* (DuRoi.) K. Koch. (tamarack), *Sphagnum* sp., *Betula pumila* L. (bog birch), and *Cornus stolonifera* Michx. (red oiser dogwood) occupied relatively dry sites. Wet sites were occupied by a deciduous forest (*Fraxinus americana* L. white ash, dominant), and a band of *Viburnum lentago* L. (nannyberry) and *Ilex verticillata* (L.) Gray. (winterberry) that surrounded it. *Carex* spp. (sedges) dominance was confined to intermediate hydric sites. The distribution of *Typha angustifolia* L. (cattail) was unrelated to the annual water cycle. It dominated portions of the Lake Lansing wetland where the annual rate of water renewal was highest.

to my wife and parents

ACKNOWLEDGMENTS

I would like to express my sincere thanks to Professor Clarence D. McNabb for providing essential support, inspiration, and guidance in both the completion of this work and in my own personal development.

Thanks is extended to Doctors Howard E. Johnson and S. N. Stephenson for serving on my graduate committee. Special acknowledgment is due Dr. Stephenson for verifying the identification of the plants collected in the wetland.

My fellow graduate students, Ted R. Batterson, Robert P. Glandon, and Frederick C. Payne deserve thanks, especially Maureen Wilson who spent many hours helping me collect data in the wetland.

Special thanks are due my friends, Frederick Kisbany, Paul Roettger, and John R. Craig (Limnological Research Laboratory Director), who gave much of their time to this work.

Mehdi Siami is sincerely thanked for providing me with his eternal optimism.

My deepest appreciation goes to my wife, Pamela, for without her this work would not have been accomplished.

This study was supported by funds provided by the U.S. Environmental Protection Agency, Clean Lakes Program, under Cooperative Agreement No. CR 805046-01.

TABLE OF CONTENTS

	Page
LIST OF TABLES	<i>v</i>
LIST OF FIGURES	<i>vi</i>
INTRODUCTION	1
METHODS	3
RESULTS	13
DISCUSSION	29
LITERATURE CITED	35

LIST OF TABLES

Table	Page
1. Vegetation of the Lake Lansing wetland system classified according to criteria of Cowardin <i>et al.</i> (1979)	24

LIST OF FIGURES

Figure	Page
1. The Lake Lansing watershed, showing basin, wetlands (pattern), study site (inset), and transect used to probe the lake for sediment depth (AB)	4
2. Aerial view of the western portion of the Lake Lansing wetland	9
2. Continued, aerial view of the eastern portion of the Lake Lansing wetland	11
3. Vertical profile of the early post-glacial lake basin along line AB of Figure 1	14
4. Bathymetry of the early post-glacial lake basin under the wetland. Existing boundaries of the lake's surface are shown by the dashed line . . .	16
5. Contour map of the wetland surface. Hummocks dominated the topography lakeward of the stippled zone; they did not exist shoreward of that zone	19
6. Vegetation types dominating the Lake Lansing wetland after Cowardin <i>et al.</i> , (1979) with additional refinements; the zone of <i>Sphagnum</i> occurrence, sedge dominance in the Persistent Emergent Wetland type, and nannyberry/winterberry dominance in the Broad-leaved Deciduous Scrub-Shrub Wetland type are shown	21
7. Range of elevation of growing surface for each vegetation type displayed against the annual fluctuation in lake level averaged over a 20 year period	26

INTRODUCTION

Wetlands in the temperate zone have vegetation patterns that have developed since Pleistocene glaciation. Vegetation patterns continue to change over time. For example, wetlands on the shores of lakes tend to expand as sediments build up in the adjacent shallows and the leading edge of vegetation encroaches on the basin. Lakeside wetlands that have been developing for long periods of time tend to have a slope to the hydrosol leading from the edge of the lake to the older and higher landward portions. Changes in the elevation of the water in such wetlands will coincide with changes in the elevation of the surface of the lake. The interaction between the slope of the soil and changes in the elevation of water produce a set of environmental conditions that could influence the distribution of plants.

The distribution of wetland plants has been shown to be influenced by the depth of standing water (Reed, 1902; Pearsall, 1919; Graham and Henry, 1933; Sharp, 1951; Kadlec, 1962; Harris and Marshall, 1963; Dix and Smeins, 1967; Walker and Coupland, 1968; Millar, 1973; Van der Valk and Davis, 1976; Teskey and Hinckley, 1977). Fluctuations of water level within and between seasons (Lewis *et al.*, 1928; McDonald, 1955; Rutter, 1955), and the length of the annual

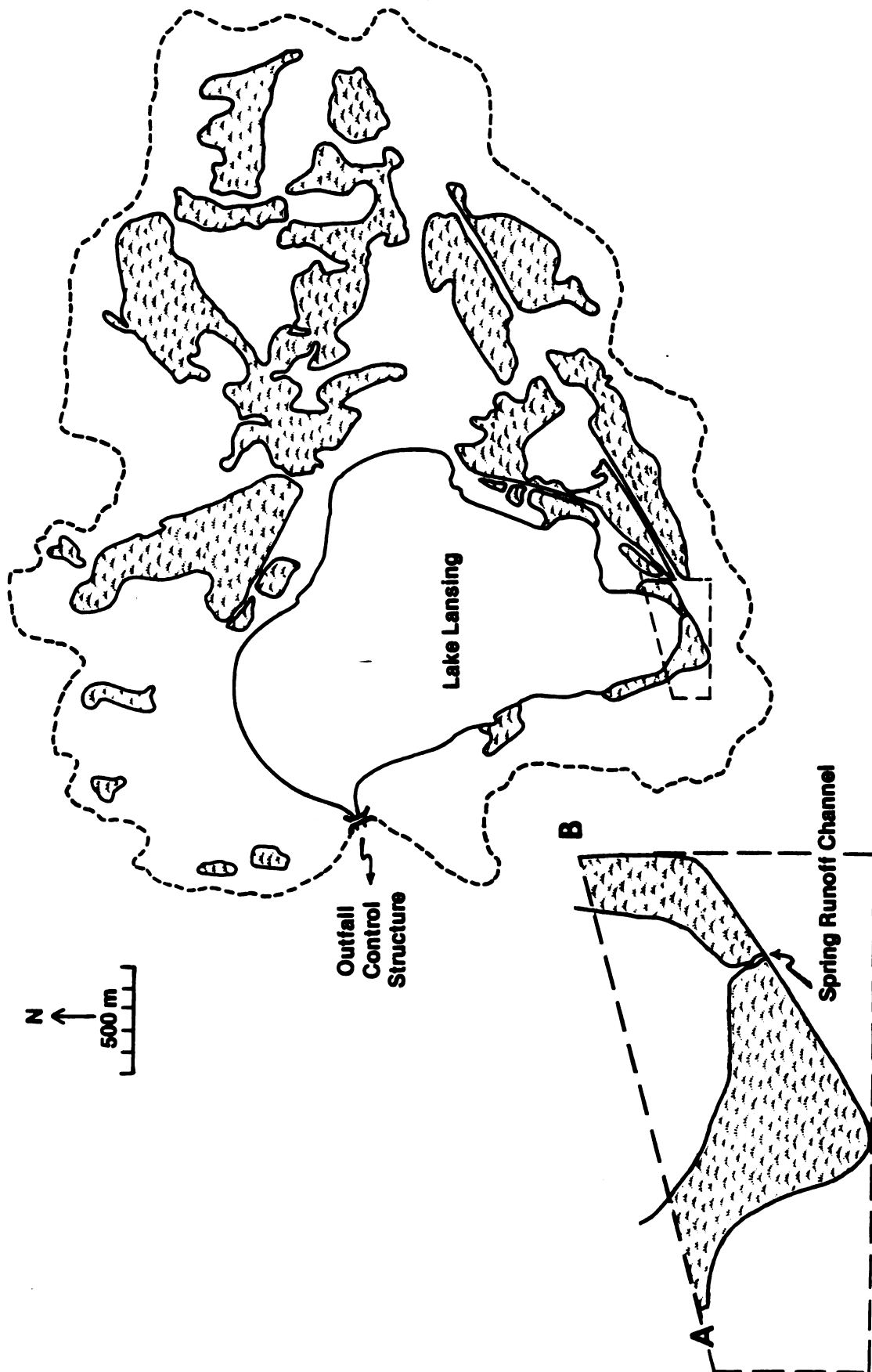
period of inundation (Sharp, 1951; Harris and Marshall, 1963; Millar, 1973; Teskey and Hinckley, 1977) have been implicated as well. Edaphic factors such as redox potential, soil chemistry and organic content (Misra, 1938; Pearsall, 1938), water chemistry (Walker and Coupland, 1968; Dix and Smeins, 1967; Walker and Wehrhahn, 1970), and competition (Rutter, 1955) have also been examined as determiners of the distribution of plants in wetlands. However, a consensus emerges from the literature that the water dominates the set of environmental factors controlling distribution (Rutter, 1955; Dix and Smeins, 1967; Walker and Coupland, 1968).

The purpose of this investigation was to examine the relationship between the distribution of wetland vegetation and changes in the elevation of water in lakeside wetland over the course of a year. Maps of the depth of sediments accumulated in the lake basin beneath the wetland, and of the distribution of plants on these sediments, were developed so that changes in these features of the wetland over time could be documented.

METHODS

The site of this work was Lake Lansing, Ingham County, Michigan. The lake and its watershed are shown in Figure 1. The Lake Lansing basin lies on the LaGrange Moraine of the glacial front known as the Saginaw Lobe (Martin 1955). Most of the adjacent land has a sand-gravel-clay soil deposited during the retreat of Pleistocene glaciers (Army Corps of Engineers, 1970). The lake has a surface area of 181.6 ha, a volume of $4124 \times 10^3 \text{ m}^3$, mean depth of 2.3 m, and a maximum depth of 10 m. Shallows are extensive in the lake basin; 79% of the lake is 3 m or less in depth. An outlet drains the lake; it typically discharges only in the spring. Six intermittent streams, draining wetlands in the eastern portion of the watershed, empty into the lake. Six storm drains discharge into the lake along its western boundary. Seepage has been found to be a major factor in the annual water budget of the lake (Batterson and McNabb, unpublished). Estimates of net seepage for intervals of the year have shown a large seepage input to the lake typically occurs in the spring. There is a net seepage loss from the lake in summer, fall, and winter. These movements of water are thought to occur primarily through the wetlands around the lake (Batterson, 1980). The retention time (volume of the lake/

Figure 1. The Lake Lansing watershed, showing basin, wetlands (pattern), study site (inset), and transect used to probe the lake for sediment depth (AB).



volume of annual stream discharge) has been calculated to be 19.5 years (ibid.). The location of the lakeside wetland used in this study is shown in Figure 1.

The position of the early post-glacial clay seal of the Lake Lansing basin was determined by probing downward in the substrate beneath the wetland and the adjacent lake. Three-meter attachable sections of 1.9 cm diameter galvanized pipe were used for this. The end of the pipe was open and a plug of clay brought to the surface was used as verification that the probe had been in the bottom. Measurements of the sediments were made through the ice at 20 m intervals along line AB of Figure 1 in the winter of 1979-1980. Six transects running lakeward from the roadway surrounding the wetland were established at measured distances from the runoff channel of the wetland. Two of these transects were located to the east of the runoff channel; four were to the west. Sediment depths were determined along these at intervals of 5 to 20 m. The position of depth contours in the space between these transects was estimated from random measurements made between the transects. A bathymetric map of the early post-glacial lake basin beneath the hydrosol was made from these data.

A contour map of the soil-surface of the wetland was made from measurements of elevation along the transect lines used to determine the depths of sediments. The position of contours between these transects was estimated from random measurements made between the six transects. These data were

volume of annual stream discharge) has been calculated to be 19.5 years (ibid.). The location of the lakeside wetland used in this study is shown in Figure 1.

The position of the early post-glacial clay seal of the Lake Lansing basin was determined by probing downward in the substrate beneath the wetland and the adjacent lake. Three-meter attachable sections of 1.9 cm diameter galvanized pipe were used for this. The end of the pipe was open and a plug of clay brought to the surface was used as verification that the probe had been in the bottom. Measurements of the sediments were made through the ice at 20 m intervals along line AB of Figure 1 in the winter of 1979-1980. Six transects running lakeward from the roadway surrounding the wetland were established at measured distances from the runoff channel of the wetland. Two of these transects were located to the east of the runoff channel; four were to the west. Sediment depths were determined along these at intervals of 5 to 20 m. The position of depth contours in the space between these transects was estimated from random measurements made between the transects. A bathymetric map of the early post-glacial lake basin beneath the hydrosol was made from these data.

A contour map of the soil-surface of the wetland was made from measurements of elevation along the transect lines used to determine the depths of sediments. The position of contours between these transects was estimated from random measurements made between the six transects. These data were

collected in the interval March 1980 to September 1980. The reference point for all measurements was the 259.60 m elevation datum on the concrete outfall structure of the lake. On days when soil elevation was measured in the wetland, elevation of the lake's surface was first measured at the dam. Elevation of the soil-surface was then determined by measuring its position in relation to the elevation of the lake and groundwater in the wetland. These data were collected on mornings following periods of calm air in order to avoid seiche effects. In the lakeward portion of the wetland, hummocks formed the surface from which dominant plants grew. Here, the elevation of the top of the hummocks was used to construct the contour map of the surface of the wetland.

A record of the surface elevation of Lake Lansing for the interval 1960 to 1980 was obtained from the U.S. Geological Survey. Their measurements were made from late March through November, the ice-free period for the lake. Measurements at 5-day intervals over the 20-year period were averaged. From the result, predictions could be made of the most probable elevation of water in the wetland for intervals of the growing season. Knowing elevations of the soil in the wetland, inferences could be made concerning the timing of inundation, and the degree of inundation in various parts of the wetland.

The vegetation of the Lake Lansing wetland was mapped using the classification scheme given by Cowardin *et al.* (1979). The boundaries of vegetation types were located in

relation to the six transects in the wetland and to portions of line AB (Figure 1) that ran through the wetland. The pattern of distribution of the vegetation was transposed to a scaled map made from the 1970 U.S. Geological Survey's topographic map of the East Lansing, Michigan quadrangle. Low level aerial photographs of the wetland (Figure 2) were examined to confirm the general position of vegetation types and the shapes of their boundaries. Once boundaries were established, measurements of elevation were made to obtain the range in elevation occupied by each type. The sampling procedure was biased toward points of maximum and minimum elevation. A comparison of the ranges in elevation occupied by types could indicate preference of types for wet or drier portions of the system.

A list of the common species in the wetland was generated from collections made over the course of two years; species were grouped according to vegetation types of Cowardin *et al.* (1979). Plant nomenclature follows Gleason and Cronquist (1963).

Figure 2. Aerial view of the western portion of the Lake Lansing wetland.

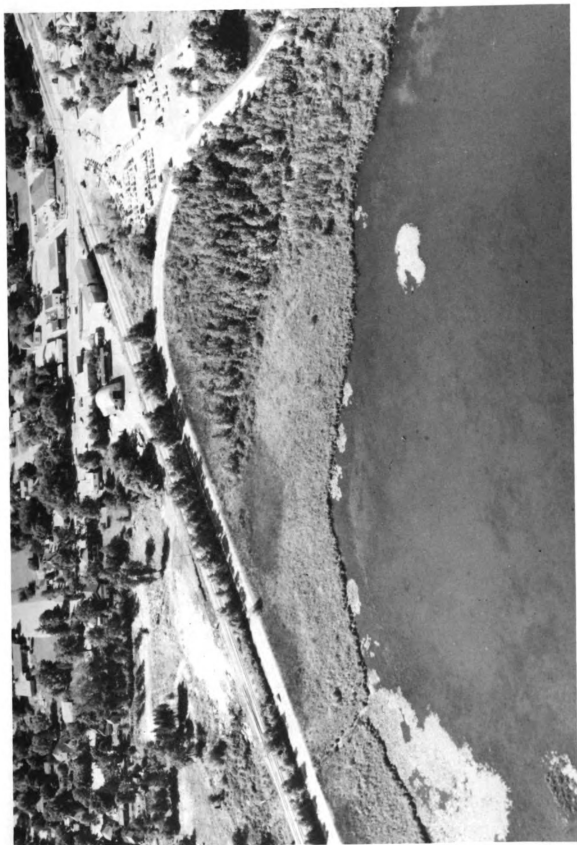


Figure 2 continued. Aerial view of the eastern portion of the Lake Lansing wetland.



RESULTS

The Lake Lansing wetland is a dynamic system that has been developing since recession of the Pleistocene glaciers. Evidence for this exists in the sediments accumulated beneath the wetland and in the adjacent lake. Figure 3 shows a vertical profile of the early post-glacial basin along line AB of Figure 1. The accumulation of sediments along line AB has resulted in a displacement of the lake toward the east. Organic material dominates the appearance of sediments beneath the wetland; the data of Siami (1981) suggests the organic matter content is in the range of 30 to 65% of the dry weight. The low relief topography of the land surrounding the wetland, the small size of the drainage basin adjacent to the south portion of the lake, and the absence of appreciable stream flow through the wetland, argue for the position that eroded soil materials have not contributed appreciably to the buildup of the sediments. They have originated primarily from the growth and partial decomposition of the vegetation of the wetland itself. Figure 4 shows the bathymetry of the portion of the early post-glacial lake basin over which the wetland has grown. The parent sediment of the lake basin lies 2 m to 11 m below the surface of the wetland.

A contour map of the surface of the wetland is given in

Figure 3. Vertical profile of the early post-glacial lake basin along line AB of Figure 1.

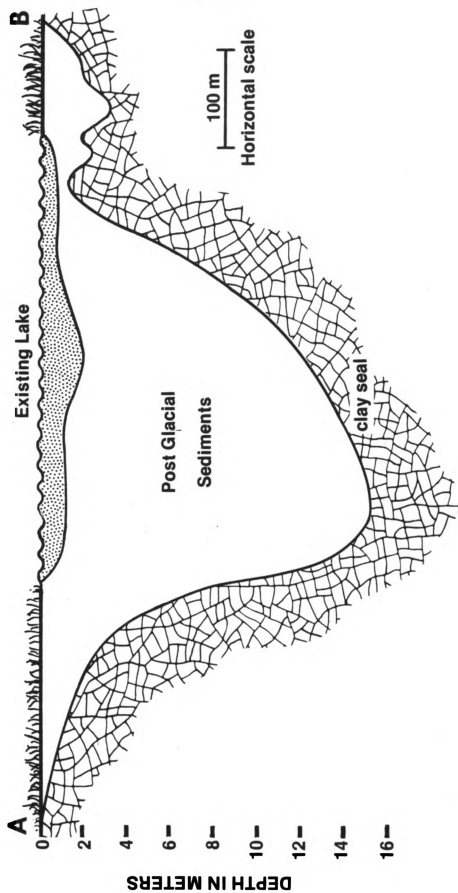


Figure 4. Bathymetry of the early post-glacial lake basin under the wetland. Existing boundaries of the lake's surface are shown by dashed line.

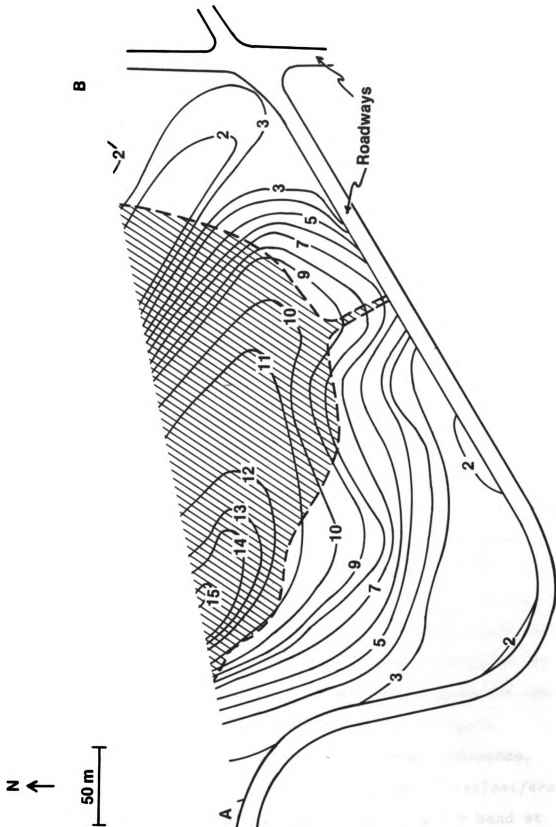


Figure 5. Lakeward of elevation <259.70 m, hummocks dominate the soil topography. They are not found shoreward of the demarkation line shown in Figure 5. The height of hummocks increases going lakeward from the demarkation line. This is shown in Figure 5 where elevations within the zone of hummocks are for hummock tops. The soil was loose underfoot in the hummock zone; the root-mat of the vegetation was the sole source of support in the wetland near the lake. Shoreward of the demarkation zone, the soil was firm. Comparison of Figure 5 with the bathymetric map of Figure 4, shows that approximately 3 m of firm soil occurred in the southeast corner of the wetland; as many as 5 m of firm soil existed in the southwest portion.

Vegetation types dominating various portions of the Lake Lansing wetland are shown in Figure 6. Confining the description of the vegetation to the categories of Cowardin *et al.* (1979) resulted in a loss of detail in regard to dominant forms. In particular, the broad-leaved deciduous type was dominated by *Viburnum lentago* L. (nannyberry) and *Ilex verticillata* (L.) Gray (winterberry) on the south and east of the forested wetland, while *Betula pumila* L. (bog birch) and *Cornus stolonifera* Michx. (red osier dogwood) dominated the remaining portion of the type. The persistent emergent wetland could similarly be separated into areas of *Typha angustifolia* L. (cattail) and *Carex* spp. (sedge) dominance. *Lythrum salicaria* L. (purple loosestrife) and *C. stolonifera* dominated the few species that were found in a 3 m band at

Figure 5. Contour map of the wetland surface. Hummocks dominated the topography lakeward of the stippled zone; they did not exist shoreward of that zone.

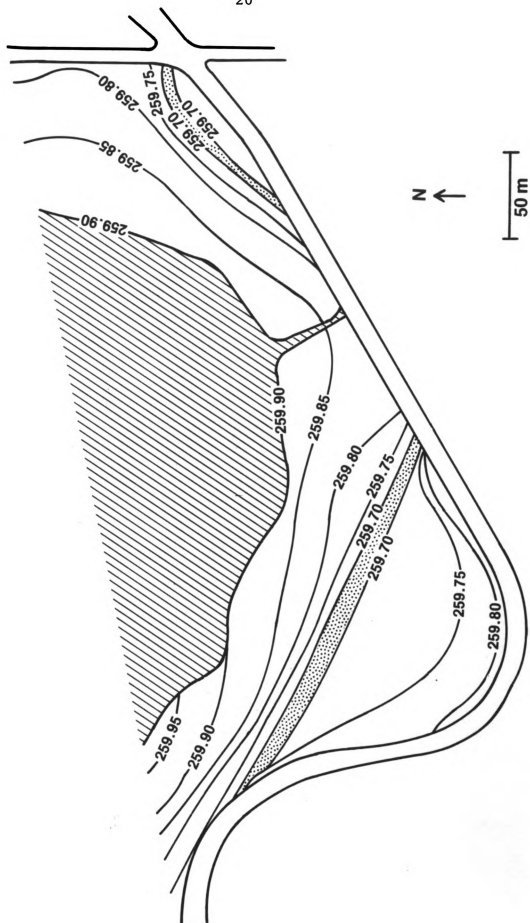
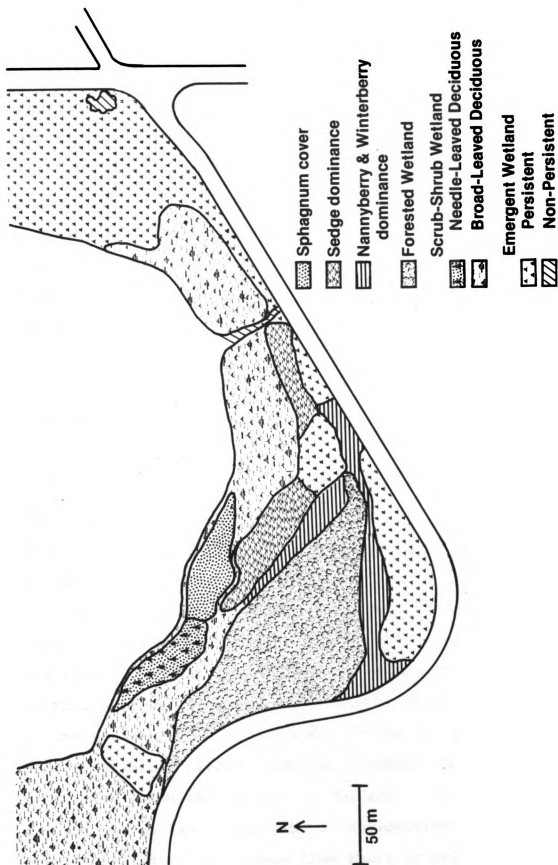


Figure 6. Vegetation types dominating the Lake Lansing wetland after Cowardin *et al.*, (1979) with additional refinements; the zone of *Sphagnum* occurrence, sedge dominance in the Persistent Emergent Wetland type, and nannyberry/winterberry dominance in the Broad-leaved Deciduous Scrub-Shrub Wetland type are shown.



the shoreline of the wetland. *Sphagnum* sp., while not dominating the cover, grew in a bed beneath the needle-leaved deciduous type and extended south eastward beyond the boundary of that type. These refinements of the vegetation pattern are shown in Figure 6. Species found within the vegetation types are shown in Table 1.

The water level of Lake Lansing fluctuates on an annual cycle that tends to be constant from year to year. The annual cycle is characterized by high water early in the growing season; maximum elevations tend to occur in late April and early May. Elevation of the lake's surface declines through the growing season to a low in September. The water level typically rises slowly in the fall. The hydrosol of the wetland is frozen in winter, and covered with snow in most years. Runoff from the watershed usually begins in late February (Glandon *et al.*, 1981). The surface of the lake thaws near mid-March, and the hydrosol of the wetland, shortly thereafter.

The average annual surface elevation cycle for Lake Lansing is shown in Figure 7. A comparison of elevation of the lake with elevation in the wetland (Figure 5) yields information on the tendencies for inundation to occur in parts of the wetland. In the southwest sector for example, an elevation gradient exists; near the roadside, water does not ordinarily reach the surface of the soil. In the lowest portion of the wetland, (the zone of demarkation for hummocks), the soil tends to be flooded from April to mid-July. Going

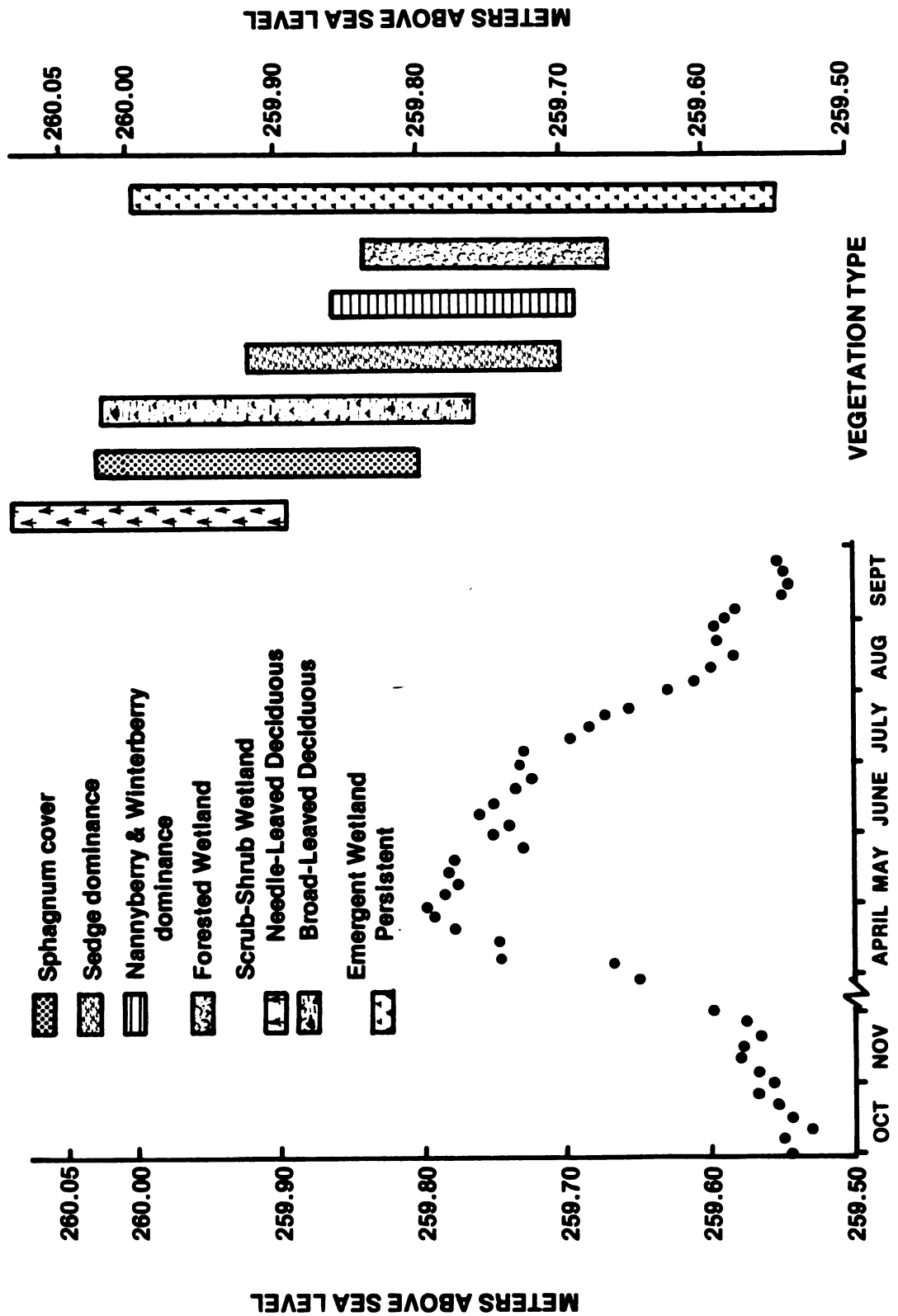
Table 1. Vegetation of the Lake Lansing wetland system classified according to criteria of Cowardin et al. (1979).

Class	Subclass	Species present
Scrub and Shrub Wetland	Needle-leaved deciduous; <i>Larix laricina</i> (Tamarack) dominant.	<i>Acer rubrum</i> L. <i>Aronia melanocarpa</i> (Michx.) Ell. <i>Aronia prunifolia</i> (Marsh.) Rehder. <i>Betula pumila</i> L. <i>Cornus stolonifera</i> Michx. <i>Decodon verticillatus</i> (L.) Ell. <i>Drosera rotundifolia</i> L. <i>Fraxinus americana</i> L. <i>Iris pseudacorus</i> L.
		<i>Iris virginica</i> L. <i>Larix laricina</i> (DuRoi.) K. Koch. <i>Lathyrus palustris</i> L. <i>Lonicera dioica</i> L. <i>Lythrum salicaria</i> L. <i>Oxoclea sensibilis</i> L. <i>Osmunda regalis</i> L. <i>Rhus vernix</i> L. <i>Ribes americanum</i> Mill.
	Broad-leaved deciduous; <i>Betula pumila</i> (Bog birch) and <i>Cornus stolonifera</i> (Red osier dogwood) dominant, except near edge of deciduous forest where <i>Viburnum lentago</i> (Nannyberry) & <i>Ilex verticillata</i> (Winterberry) dominate.	<i>Acer negundo</i> L. <i>Acer rubrum</i> <i>Alisma plantago-aquatica</i> L. <i>Aronia melanocarpa</i> <i>Aronia prunifolia</i> <i>Asclepias incarnata</i> L. <i>Aster junceiformis</i> Rydb. <i>Betula pumila</i> <i>Boehmeria cylindrica</i> (L.) Sw. <i>Calamagrostis canadensis</i> (Michx.) Beauv. <i>Calopogon pulchellus</i> (Sw.) R. Br. <i>Caltha palustris</i> L. <i>Carex aquatilis</i> Wahl. <i>Carex comosa</i> Boott. <i>Carex lacustris</i> Willd. <i>Carex</i> spp. <i>Cardamine pratensis</i> L. <i>Cicuta bulbifera</i> L. <i>Cornus anomum</i> Mill. <i>Cornus racemosa</i> Lam. <i>Cornus stolonifera</i> <i>Decodon verticillatus</i> <i>Drosera rotundifolia</i> <i>Eleocharis</i> sp.
		<i>Galium trifidum</i> L. <i>Ilex verticillata</i> (L.) Gray. <i>Impatiens biflora</i> Walt. <i>Iris pseudacorus</i> <i>Iris virginica</i> <i>Lathyrus palustris</i> <i>Leersia oryoides</i> (L.) Sw. <i>Lysimachia ciliata</i> L. <i>Lysimachia terrestris</i> (L.) BSP. <i>Lysimachia thyrsiflora</i> L. <i>Mimulus ringens</i> L. <i>Partenocissus</i> sp. <i>Pilea pumila</i> (L.) Gray. <i>Phalaris arundinacea</i> L. <i>Phragmites communis</i> Trin. <i>Potamogeton crispus</i> L. <i>Potamogeton gramineus</i> L. <i>Potentilla palustris</i> (L.) Scop. <i>Proserpinaca palustris</i> L. <i>Rhamnus frangula</i> L. <i>Rhus vernix</i> <i>Ribes americanum</i> <i>Rosa palustris</i> <i>Rubus pubescens</i> Raf. <i>Rumex</i> spp.
		<i>Salix candida</i> Fluegge. <i>Salix lucida</i> Muhl. <i>Salix nigra</i> L. <i>Salix pedicellaris</i> Pursh. <i>Salix</i> spp. <i>Scirpus atrovirens</i> Willd. <i>Scirpus heterochaetus</i> Chase. <i>Scutellaria galericulata</i> L. <i>Solanum dulcamara</i> L. <i>Solidago gigantea</i> Ait. <i>Sparganium eurycarpum</i> Engelm. <i>Spiraea alba</i> DuRoi. <i>Triadenum fraseri</i> (Spach) Gl. <i>Typha angustifolia</i> L. <i>Typha latifolia</i> L. <i>Ulmus americana</i> <i>Utricularia intermedia</i> Hayne. <i>Utricularia minor</i> L. <i>Utricularia vulgaris</i> L. <i>Vaccinium corymbosum</i> <i>Viburnum cassinoides</i> L. <i>Viburnum lentago</i> L. <i>Vitis</i> sp.
		<i>Ribes oxycanthoides</i> L. <i>Rosa palustris</i> Marsh. <i>Sarracenia purpurea</i> L. <i>Sphagnum</i> sp. <i>Thelypteris palustris</i> Schott. <i>Ulmus americana</i> L. <i>Vaccinium corymbosum</i> L.

Table 1. continued.

Class	Subclass	Species present	
Forested Wetland	Broad-leaved deciduous; <i>Fraxinus americana</i> (White ash) dominant.	<i>Acer rubrum</i> <i>Alisma plantago-aquatica</i> <i>Aronia melanocarpa</i> <i>Aronia prunifolia</i> <i>Betula pumila</i> <i>Carex comosa</i> <i>Carex lacustris</i> <i>Cornus amomum</i> <i>Corylus americana</i> Walt. <i>Equisetum fluviale</i> L. <i>Fraxinus americana</i>	<i>Ribes americanum</i> <i>Ribes oxycanthoides</i> <i>Rosa palustris</i> <i>Sagittaria</i> sp. <i>Salix</i> spp. <i>Sambucus canadensis</i> L. <i>Sium suave</i> Walt. <i>Solanum dulcamara</i> <i>Ulmus americana</i> <i>Vaccinium corymbosum</i> <i>Vitis</i>
		<i>Glyceria striata</i> (Lam.) Hitchc. <i>Ilex verticillata</i> <i>Larix laricina</i> <i>Lathyrus palustris</i> <i>Onoclea sensibilis</i> <i>Osmunda regalis</i> <i>Phalaris arundinacea</i> <i>Populus deltoides</i> Marsh. <i>Quercus bicolor</i> Willd. <i>Quercus muehlenbergii</i> Engelm. <i>Rhus vernix</i>	
Emergent Wetland	Persistent emergent wetland; <i>Typha angustifolia</i> (Narrow-leaved cattail), <i>Carex</i> (sedges) and <i>Lythrum salicaria</i> (purple loosestrife) dominant.	<i>Acer rubrum</i> <i>Aster junceiformis</i> <i>Betula pumila</i> <i>Calamagrostis canadensis</i> <i>Campanula aparinoides</i> Pursh. <i>Carex aquatilis</i> <i>Carex comosa</i> <i>Carex</i> spp. <i>Cornus stolonifera</i> <i>Eleocharis</i> sp. <i>Eupatorium perfoliatum</i> L. <i>Eupatorium purpureum</i> L. <i>Iris virginica</i>	<i>Salix nigra</i> <i>Salix pedicellaris</i> <i>Salix</i> spp. <i>Scirpus atrovirens</i> <i>Scirpus heterochaetus</i> <i>Thelypteris palustris</i> <i>Triadenum fraseri</i> <i>Typha angustifolia</i> <i>Typha latifolia</i> <i>Utricularia intermedia</i> <i>Utricularia minor</i> <i>Utricularia vulgaris</i> <i>Vitis</i> sp.
		<i>Leersia oryzoides</i> <i>Lysimachia terrestris</i> <i>Lysimachia thyrsiflora</i> <i>Lythrum salicaria</i> <i>Melilotus officinalis</i> (L.) Desr. <i>Onoclea sensibilis</i> <i>Phalaris arundinacea</i> <i>Phragmites communis</i> <i>Potamogeton crispus</i> <i>Potamogeton gramineus</i> <i>Potentilla palustris</i> <i>Rhus vernix</i> <i>Salix candida</i>	
		<i>Pilea pumila</i> <i>Polygonum</i> sp. <i>Pontederia cordata</i> L. <i>Proserpinaca palustris</i>	<i>Sagittaria</i> sp. <i>Sparanium eurycarpum</i> <i>Scirpus heterochaetus</i> <i>Sium suave</i>
	Non-persistent emergent wetland; <i>Proserpinaca palustris</i> (Mermaid weed) dominant.	<i>Alisma plantago-aquatica</i> <i>Cicuta bulbifera</i> <i>Impatiens biflora</i> <i>Nasturtium officinale</i> R.Br.	

Figure 7. Range of elevation of growing surface for each vegetation type displayed against the annual fluctuation in lake level averaged over a 20 year period.



lakeward from the demarkation zone, the growing surface for plants becomes progressively drier due to increasing hummock height. At the lake shore, hummocks stand 10 cm or more above the 20-year average maximum lake elevation. The water table drops in the wetland as the lake's elevation declines during the growing season. In September, the water table is typically 15 cm to 35 cm below the surface of the wetland. The distribution of dominant vegetation types in relation to the annual cycle of lake elevation is shown in Figure 7.

DISCUSSION

The net productivity of the vegetation of the Lake Lansing wetland provides material annually for the buildup of the soil of the wetland and filling the adjacent lake basin. The data of Siami (1981) show that the Lake Lansing wetland has been advancing into the lake at a rate of $0.2 - 0.4 \text{ m yr}^{-1}$ over the past 23 years. *L. salicaria* forms a tight, narrow ($<3 \text{ m}$) fringe of vegetation at the edge of the wetland. The plant is adapted for pioneering the advance into the lake basin. Aerenchyma in the base of the stem and in the upper root system, provides buoyancy on the soft, unconsolidated, organic sediments at the fringe of the lake. The plants are anchored by a root system that is perennial, and that becomes extensive over time. Tight clusters of stems arise each year from the root stocks; stem density at Lake Lansing was found to be as high as $2000 \text{ shoots m}^{-2}$ of which 20% was new growth. At the fringe of the lake, biomass production by *L. salicaria* can be supported by mineral nutrients taken from the lake. Roots have access to lake water circulated by wave action at the fringe, particularly during the high water of April and May.

The growth habit of *L. salicaria* leads to the formation of woody and fibrous hummocks. In the Lake Lansing wetland,

the elevation of the tops of these hummocks at the edge of the lake, was higher than the elevation of hummocks that extended 50-75 m shoreward from the fringe. Plants behind the fringe, with the possible exception of *Carex* spp., did not appear to be hummock builders. From the observations at Lake Lansing, the question arises as to whether non-hummock builders behind the fringe could become dominant on established hummocks of *L. salicaria*, thus confining *L. salicaria* over time to a narrow fringe that moves lakeward on newly accumulated sediments. A repeat of this baseline study in the future could provide information to answer that question.

Figure 7 combines the elevation range of the growing surface for each vegetation type and the 20-year annual cycle of elevation of water in the lake and wetland. The figure can be used to identify three divisions of hydric sites in the system. The first and driest of the three was on hummocks in the lakeward portion of the wetland. The vegetation map shows that those hummocks higher than the 20-year maximum water elevation (259.80 m) were occupied by *Sphagnum* sp., the needle-leaved deciduous scrub-shrub type (*Larix laricina* (DuRoi) K. Koch. dominant), and the broad-leaved deciduous scrub-shrub type (*B. pumila* and *C. stolonifera* dominant). *Sphagnum* grew on the tops and sides of hummocks, but was not found on the sides below the mean maximum water elevation of 259.80 m. Wetzel (1975) and others have described the ombrotrophic tendency of *Sphagnum*; its water and nutrient requirements are met primarily by atmospheric input, rather

then by groundwater and soil. The data in Figure 7 show that the base of the stems of *L. laricina* (tamarack), *B. pumila*, and *C. stolonifera* were also not normally inundated. Regarding *L. laricina*, this is expected from its well known distribution in bogs (Lewis *et al.*, 1928). The literature lacks documentation of the water regime requirements for *B. pumila* and *C. stolonifera*. The consistency of the observation reported here, namely that the base of these plants tends to escape annual inundation, must await documentation from future studies.

The forested wetland type (*Fraxinus americana* L. dominant), and *V. lentago*-*I. verticillata* subtype of the broad-leaved deciduous scrub-shrub type, occupied the wettest portion of the Lake Lansing system. Hummocks were not present in the zones of dominance of these plants. The forest was largely confined to soil elevation of 259.67 - 259.84 m. On the average, it was inundated 35 days to 85 days each year. The period of annual inundation for *V. lentago* and *I. verticillata*, surrounding the forest on the south and northeast, tended to be the same as for the forest. While small specimens of many of the trees species of the forest were found on lakeware hummocks, representatives of the shrubs were not. There was a lack of firm substratum to support the weight of mature trees in the hummock zone; however, there was no evidence in the field, such as wind-blown saplings, that lack of a compacted substratum was limiting the lakeward spread of the forest. The literature is lacking in

sufficient information on the ecological requirements of the forest species and the shrubs (*V. lentago* and *I. verticillata*) to explain their confinement within wet-site boundaries of the Lake Lansing system.

In relation to the annual water cycle, sedges occupied a intermediate hydric site in the Lake Lansing wetland. Dominance of this plant type occurred on or near the 259.80 m contour. In this position, individuals would normally escape inundation, or be flooded for a short period in the spring. Sedges did not dominate intermediate sites throughout the wetland. Portions of stands of the broad-leaved deciduous scrub-shrub type (*B. pumila* and *C. stolonifera* dominant) and the persistent emergent type (*T. angustifolia* dominant) shared the intermediate water regime. Individuals of species of broad-leaved deciduous shrubs and cattails that grew on the banks of the drainage channel flowing into the wetland, were more robust and at least 1 m taller than those in the interior of the system at 50 m from the stream. This pattern suggests that interior hummocks regions of the wetland were nutrient poor. In addition, beds of *Carex* spp. in wetlands are thought to occupy sites that are nutrient poor (Prince, personal communication). The literature offers no insights regarding the interaction of water and nutrient regimes on control of sedge dominance in freshwater wetlands. The location of stands of *Carex* in the interior of the Lake Lansing wetland, may be a response, at least in part, to nutrient conditions too poor to support the cattails and shrubs.

From the observations made in this study, experimentation regarding these factors appears to be in order.

T. angustifolia dominated the emergent wetland type shown on the map of the Lake Lansing system except for the area of sedge dominance and the *L. salicaria* fringe at the shore of the lake. The cattail was abundant on all three of the hydric sites. Its distribution appeared to be related to drainage patterns rather than to aspects of the annual cycle of water elevation. Stands of *T. angustifolia* in the northwest and southeast sectors surrounded intermittent drains. The plant dominated along the roadway forming the southern boundary of the study site. Runoff from the road entered the wetland in that area. Additionally, the roadbed served as a dam during periods of high runoff; overland flow was constricted to a culvert discharging to the stream channel through the wetland. Seepage likely took place through the roadbed at times when a head of water occurred behind it. These observations suggest that *T. angustifolia* could tolerate the variable range of water elevations existing in the wetland, and dominated in areas of relatively high water renewal rates. Prince (personal communication) suggested that stands of this plant tend to develop in portions of local wetland systems where availability of mineral nutrients is relatively high.

From this discussion, and Figure 7, it is apparent that the distribution of certain vegetation types in the Lake Lansing wetland could be correlated with the cycle of annual

inundation of the system. *L. salicaria* escaped inundation on high hummocks at the shore of the lake. Vegetation types dominated by *L. laricina*, *Sphagnum* sp., and scrub-shrub dominants *B. pumila* and *C. stolonifera*, occupied relatively dry sites on hummocks away from areas of intermittent drain flow, road runoff, and seepage. Wet sites were occupied by a deciduous forest (*F. americana* dominant), and a band of *V. lentago* and *I. verticillata* that surrounded it on three sides. Stands of drier-site scrub-shrub dominants tended to extend into intermediate sites. The distribution of *Carex* spp. dominance was confined to intermediate sites in the interior of the wetland system. In this position, the rate of mineral nutrient supply to *Carex* was hypothesized to be low. The distribution of *T. angustifolia* was unrelated to the annual cycle of inundation; the plant dominated across the hydric gradient in the system. It is suggested that *T. angustifolia* dominated portions of the Lake Lansing wetland where the annual rate of mineral nutrient input was highest.

Ecological controls on the distribution of dominant vegetation in freshwater wetlands are poorly known. The literature provides few insights as to the degree of generality of the observations made in this study. Comparable studies from other sites are needed.

LITERATURE CITED

LITERATURE CITED

- Batterson, T.R. 1980. Arsenic in Lake Lansing, Michigan. Ph.D. thesis, Michigan State University. 79 pp.
- Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetland and deepwater habitats of the United States. U.S. Government Printing Office Washington, D.C. 103 pp.
- Dix, R.L. and F.E. Smeins. 1967. The prairie, meadow, and marsh vegetation of Nelson County North Dakota. Can. J. Bot. 45: 21-58.
- Glandon, R.P., F.C. Payne, C.D. McNabb, and T.R. Batterson 1981. A comparison of rain-related phosphorus and nitrogen loading from urban, wetland, and agricultural sources. Water Research 15: 881-887.
- Gleason, H.A. and A. Cronquist. 1963. Manual of vascular plants of northeastern United States and adjacent Canada. VanNostrand. New York. 810 pp.
- Graham, H.W. and L.K. Henry. 1933. Plant succession at the borders of a kettle-hole lake. Bulletin of the Torrey Club 60: 301-315.
- Harris, S.W. and W.H. Marshall. 1963. Ecology of water-level manipulations on a northern marsh. Ecology 44(2): 331-343.
- Kadlec, J.A. 1962. The effects of a drawdown on a water fowl impoundment. Ecology 43: 267-281.
- Lewis, F.J., E.S. Dowding, and E.H. Moss. 1928. The vegetation of Alberta. Part II. The swamp, moor, and bog forest vegetation of Central Alberta. J. Ecol. 16: 19-70.
- Martin, H.M. 1955. Map of the surface formation of the southern Peninsula of Michigan. Publication No. 49. Michigan Department of Conservation, Lansing, Michigan.
- McDonald, M.N. 1955. Cause and effect of a die-off of emergent vegetation. J. Wildf. Man. 19: 24-35.

- Millar, J.B. 1973. Vegetation changes in shallow marsh wetlands under improving moisture regime. *Can. J. Bot.* 51: 1443-1457.
- Misra, R.D. 1938. Edaphic factors in the distribution of aquatic plants in English Lakes. *J. Ecol.* 26: 411-451.
- Pearsall, W.H. 1919. The aquatic and marsh vegetation of Esthwaite Water. Part V. The marsh and fen vegetation of Esthwaite Water. *J. Ecol.* 6: 53-74
- Pearsall, W.H. 1938. The soil complex in relation to plant communities. Part III. Moorlands and bogs. *J. Ecol.* 26: 298-315.
- Reed, H.S. 1902. A survey of the Huron River Valley. Part I. The ecology of a glacial lake. *Bot. Gazette* 32: 125-139.
- Rutter, A.J. 1955. The composition of a wetheath vegetation in relation to the water table. *J. Ecol.* 43: 507-543.
- Sharp, W.M. 1951. Environmental requirements of a freshwater marsh and the ecology of some aquatic plants. *Pro. Northeast Game Conf.* Feb. 23, 1951. mimeo 6 pp.
- Siami, M. 1981. Arsenic profiles in sediments and sedimentation processes along the slope of a lake basin. Ph.D. thesis, Michigan State University. 58 pp.
- Teskey, R.D. and T.M. Hinckley. 1977. The impact of water level changes on woody riparian and wetland communities. Vol. I. Plant and soil responses to flooding. Vol. III. Central forest region. U.S. Government Printing Office, Washington, D.C. 30 pp, 36 pp.
- U.S. Army Corps of Engineers. 1970. Reconnaissance Report Eutrophication Problem Lake Lansing, Michigan. U.S. Army Corps of Engineers, Washington, D.C. 25 pp.
- Van der Valk, A.G. and C.B. Davis. 1976. Changes in the composition structure and production of plant communities along a perturbed wetland coenocline. *Vegetatio* 32(2): 87-96.
- Walker, B.H. and R.T. Coupland. 1968. An analysis of vegetation-environment relationships in Saskatchewan Slought. *Can. J. Bot.* 46: 506-522.
- Walker, B.H. and C.F. Wehrhahn. 1970. Relationships between derived vegetation gradients and measured environmental variables in Saskatchewan wetlands. *Ecology* 52: 85-95.

Wetzel, R.G. 1975. Limnology. W.B. Saunders Co. Philadelphia. 743 pp.