EFFECTS OF FLOODING ON HERBACEOUS SPECIES OF THE WHITE CEDAR-TAMARACK WOODS IN CEDARBURG BOG

ABSTRACT

A part of the northern lowland forest of Cedarburg Bog was flooded about eight years ago as a result of clogged road culverts. Studies of the effects of flooding on species composition, productivity, hydrology and soils were begun in 1982. Post flooding studies will commence when the natural water levels are restored (ca 1984). This paper compares the frequencies of herbaceous species in the flooded woods with an adjacent portion of unflooded woods. The pattern of species' abundances within the flooded woods is related to the degree of inundation and grazing history of the site. Significantly different frequencies were found for eight species between the flooded and unflooded woods.

INTRODUCTION

The effects of flooding on individual plants have been studied extensively (see Kramer 1951, Gill 1970 and Whitlow and Harris 1979, for reviews) as have effects on plant communities (see Whitlow and Harris 1979, for a review). These studies have been concerned mainly with the woody species of the reservoirs and riparian communities of the southern and southeastern United States. Recovery from flooding of less than 3 months in duration and the effects of seasonal flooding have been described for some riparian communities (Harris and Marshall 1963, Bedinger 1971, Conner et al. 1981). The effects of raised water levels on northern bog or lowland forest communities or on their indigenous species remains essentially unexplored (Whitlow and Harris 1979). In addition, we know of no studies of wetland recovery from the effects of long-term flooding after restoration of the natural water regime.

This lack of information is noteworthy since many northern wetlands have been damaged as a result of disrupted drainage, especially from inadequate, damaged or plugged road culverts. Stoeckeler (1967) noted that over half of 70 wetland road crossings observed in a northeastern Minnesota survey showed timber damage resulting from a rise in the water table. Data on recovery of northern lowland forests from the effects of flooding will be extremely useful to wetland managers who seek to preserve the quality of natural areas. Ability to predict post-flooding vegetation dynamics could lead to better informed and more timely management decisions.

At the northern end of the Cedarburg Bog State Scientific Area an eight-acre section of Cedar-Tamarack woods was flooded eight years ago (1976) when the culverts through a small farm road were plugged with debris (Fig. 1 and 2). This study, initiated in 1982, is designed to: 1) document the effects of long-term flooding on the northern lowland forest community; 2) study the recovery of vegetation after the

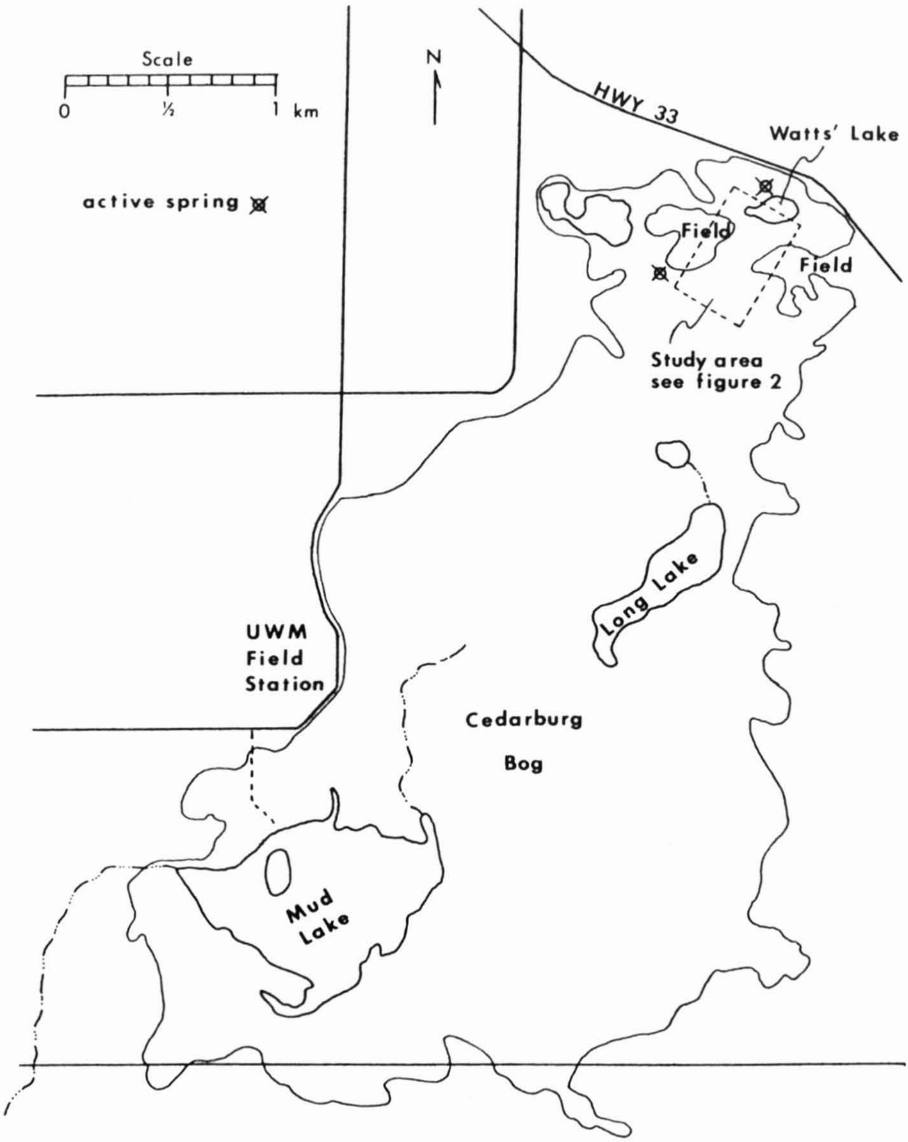


Figure 1. Cedarburg Bog, study area and springs.

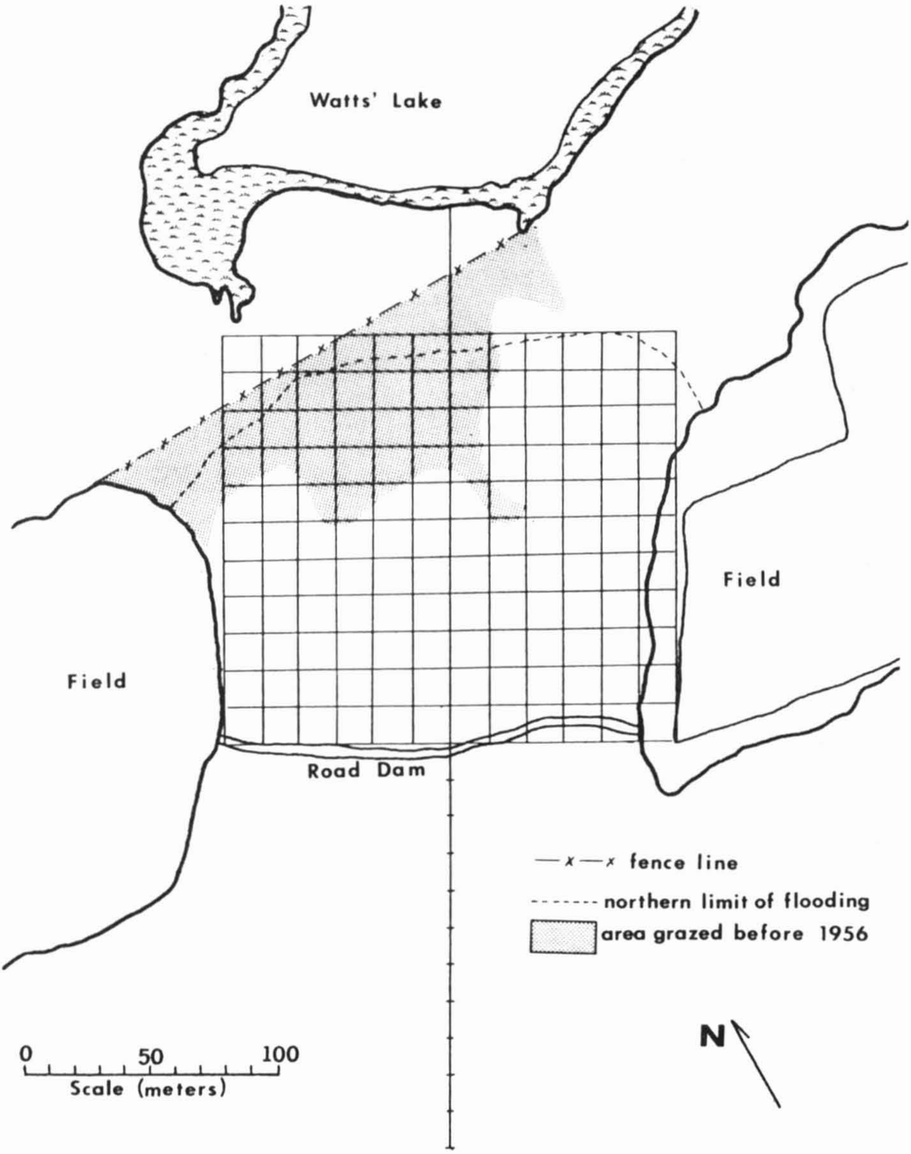


Figure 2. Study area: permanent grid system in the flooded woods, transect in unflooded woods, limit of flooding and the area grazed before 1956.

natural water levels have been restored, and 3) investigate the effects of flooding and subsequent draining on the soils and hydrology of this wetland.

This paper describes the herbaceous vegetation of the flooded woods and compares it to that of the unflooded woods "downstream" from the road dam. We also qualitatively relate the observed pattern of herbaceous species' abundance to the severity of flooding and disturbance history of the woods.

METHODS

A permanent 15m x 15m grid was established in the flooded woods and a line transect divided into 15 meter segments was established in the unflooded woods south of the road dam (Fig. 2). From 19 January to 26 February 1982, while surveying the grid system, numerous areas of thin ice were encountered. These areas, most of which were long, narrow channels, were mapped.

Peat depth was determined at each grid point using a 2.5cm diameter peat corer. When the corer met resistance at the bottom of the peat, a core was taken in order to describe the material that lined the basin.

During the summer of 1982 three $1m^2$ sample quadrats were located at random within alternating quadrats in the flooded woods and along the transect in the unflooded woods. Herbaceous and woody species were recorded in each quadrat and total herbaceous coverage was estimated and assigned a value using the Daubenmire cover sacle (Daubenmire 1968). Estimates were also made of the percent of area in each quadrat which was occupied by hummock, fallen log and standing water. The sample included 183 quadrats, 153 in the flooded and 30 in the unflooded woods.

Sampling required the entire summer (late June to mid-August) making it difficult to identify some plants to species (e.g. Bidens). Voucher specimens have been deposited in the UW-M Field Station herbarium. Nomenclature for spring flowering species follows that of Fassett (1980) and for later flowering species, Gleason and Cronquist (1964).

Frequencies were calculated for each species in the flooded and unflooded woods. Herbaceous, hummock and standing water coverages were mapped. The number of three sample quadrats in which a species occurred within each grid unit was also determined and compared to the amount of standing water. A G-statistic was used to test for significant differences among the relative frequencies of species between the flooded and unflooded woods (Sokal and Rohlf 1981).

RESULTS

Eight species exhibit significantly different frequencies in the flooded and unflooded woods (Table 1). Beggar-ticks (Bidens spp.), Canada blue joint grass (Calamagrostis canadensis), cut-leaf water hemlock (Cicuta bulbifera), duckweed (Lemna minor) and cattail (Typha latifolia) all have significantly higher frequencies in the flooded woods. Hog peanut (Amphicarpa bracteata), wild calla (Calla palustris) and naked miterwort (Mitella nuda) had significantly higher frequencies in the unflooded woods. Marsh marigold (Caltha palustris) had a greater frequency ($.05 < P < .10$) in the flooded woods, while water hemlock

Table 1. Relative frequencies of herbaceous species in $1m^2$ quadrats in the flooded and unflooded woods. *, $p < .05$; **, $p < .01$; ***, $p < .001$ according to G-, or log likelihood ratio test.

Species	Relative frequency	
	Unflooded Woods (n=30)	Flooded Woods (n=153)
Amphicarpa bracteata	43.3	5.2***
Aralia sp.	10.0	9.2
Arisaema atrorubens	6.7	2.0
Aster spp.	36.7	22.2
Bidens spp.	40.0	61.4*
Calamagrostis canadensis	0.0	9.2***
Calla palustris	46.7	20.3**
Caltha palustris	3.3	14.4
Carex pseudo-cyperus	6.7	17.0
Carex spp.	46.7	59.5
Cicuta bulbifera	6.7	37.9***
Cicuta maculata	16.7	5.2
Coptis trifolia	3.3	0.7
Eleocharis sp.	3.3	3.3
Equisetum fluviatile	50.0	45.1
Eupatorium maculatum	10.0	9.8
Eupatorium perfoliatum	3.3	2.0
Galium spp.	13.3	18.3
Glyceria sp.	13.3	3.3
Impatiens capensis	56.7	61.4
Leersia oryzoides	20.0	30.7
Lemna minor	36.7	81.7***
Lycopus uniflorus	23.3	24.2
Lysimachia thyrsiflora	50.0	43.8
Maianthemum canadensis	26.7	16.3
Mitella nuda	23.3	0.7***
Onoclea sensibilis	3.3	1.3
Parthenocissus quinquefolia	16.7	10.5
Phalaris arundinacea	10.0	9.2
Pilea pumila	10.0	7.8
Poaceae spp.	10.0	6.5
Polygonatum pubescens	3.3	0.7
Rubus pubescens	33.3	19.6
Rumex orbiculatus	3.3	7.8
Solanum dulcamara	46.7	34.6
Solidago spp.	10.0	7.2
Symplocarpus foetidus	3.3	7.8
Thelypteris palustris	16.7	29.4
Trientalis borealis	6.7	3.3
Typha latifolia	3.3	34.0***
Viola spp.	23.3	12.4

(Cicuta maculata) and manna grass (Glyceria spp.) occurred more frequently ($.05 < P < .10$) in the unflooded woods, but these differences were not significant.

The history of disturbance, relative degree of inundation and depth of peat may all have important effects on the distribution of herbaceous species in the flooded area (Fig. 2). Water stands between the hummocks in the flooded area, at levels higher than in the unflooded woods, throughout the year. The northern part of the flooded area (upper left of grid) was grazed until sometime between 1941 and 1956

(Figure 2). Aerial photographs taken in 1937 and 1941 show that the area south of the east-west fence line was cleared and grazed. By 1956, this area had been invaded by woody vegetation and has not been disturbed since.

The percentages of quadrat area occupied by hummock (Fig. 3a) and by standing water (Fig. 3b) show distributions which are roughly inverse. Portions of the quadrats not occupied by raised hummock or open water were flat and muddy, and inundated during high water. Standing water was most extensive closest to the road dam and in the right half of the grid system (Fig. 3b). Hummock cover was highest in the upper left of the grid system (Fig 3a).

Areas of thin ice, which must represent groundwater discharge, moving water, or both, were concentrated in the right half of the grid system where open water was more prevalent during the summer. Impermeable clay lined most of the basin in the study area, directly under the peat and post glacial lake sediments. Only six of the 62 cores taken terminated in permeable material (sand or gravel). These cores occurred in two areas,the top line of the grid and in the center of the lower left quarter of the grid; only the latter was covered by thin ice. It is probable that there is considerable groundwater discharge in the study area since there are active springs in close proximity (Fig. 1). The outlet of Watts' Lake is just above the right half of the gridded area (Fig. 2); most of the thin ice in that part of the study area may have been the result of the lake outflow through the bog forest.

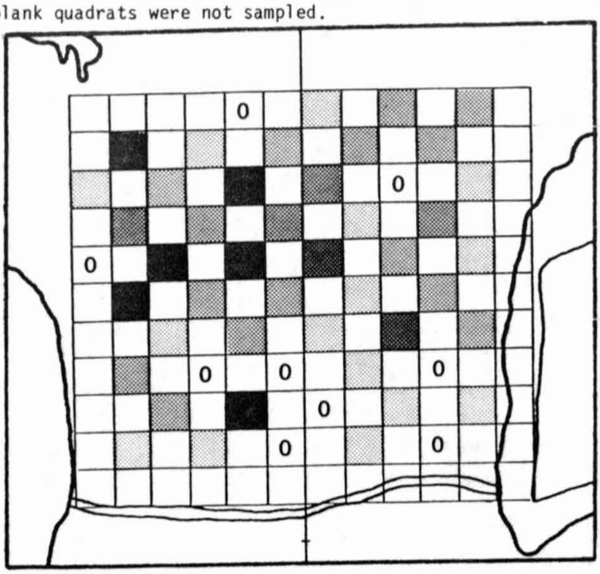
Peat depth varies considerably in the study area. Subpeat depressions over 6 meters deep occur in the upper left and center parts of the gridded area. The farm road was constructed so that it lies partially on a natural bar of sand and gravel where peat is one meter or less deep.

Distribution of six of the least spacially homogeneous herbaceous species are mapped (Figs. 4a to 4f). Other species were either uniformly distributed or occurred too infrequently to demonstrate a pattern.

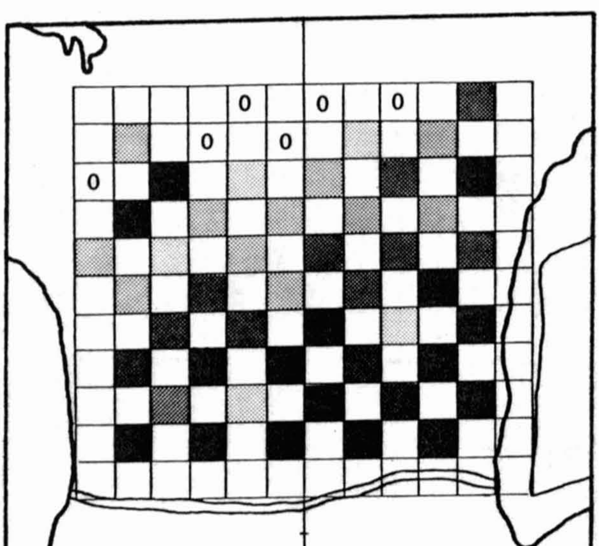
DISCUSSION

Tree species are known to differ widely in their ability to withstand flooding. While only one month of flooding is enough to cause mortality in some species (e.g., black cherry (*Prunus serotina*) or black oak (*Quercus velutina*), Bell and Johnson 1974, 1975), other trees can survive flooding for over four years. However, little is known about the relative flood tolerance of northern lowland forest species. McKim, et al. (1975, cited in Whitlow and Harris 1979) provide some data to indicate that paper birch (*Betula papyrifera*) is susceptible to mortality from flooding. On the other hand, green and black ash (*Fraxinus pennsylvanica* and *F. nigra*) are able to withstand a great deal of flooding (Broadfoot and Williston 1973; Hall and Smith 1955; Loucks and Keen 1973; Sena Gomes and Kozlowski 1980) and probably represent the tolerant end of the spectrum for northern swampspecies. The responses of white cedar (*Thuja occidentalis*) and tamarack (*Larix laricina*) to inundation are poorly documented.

Figure 3. Map of study area with mean percent of a) hummock and b) open water in three 1m² quadrats in each permanent grid quadrat. 0 - 0%; - 10%; - 20%; - 30%; - 40%; -50%; - 60%; - 70%; - 80%; blank quadrats were not sampled.

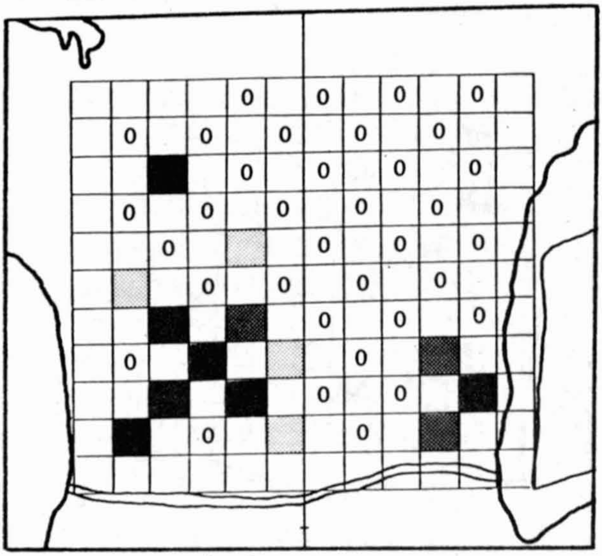


a) hummock

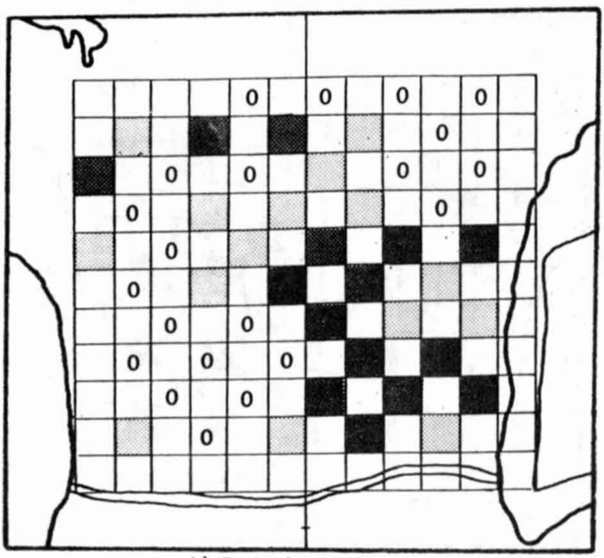


b) open water

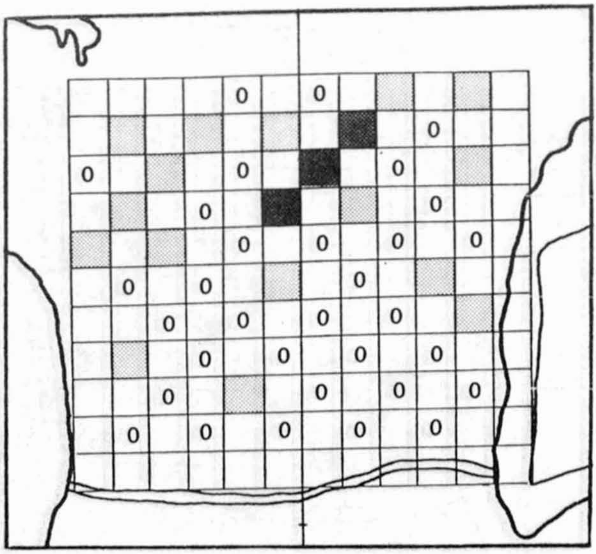
Figure 4. Number of three $1m^2$ sample quadrats within each $125m^2$ permanent grid quadrat which contained: a) *Calla palustris*; b) *Typha latifolia*; c) *Caltha palustris*; d) *Lysimachia thyrsiflora*; e) *Cicuta bulbifera*; f) *Equisetum fluviatile*. [0] - 0; [light] - 1; [dark] - 2; [black] - 3, blank quadrats were not sampled.



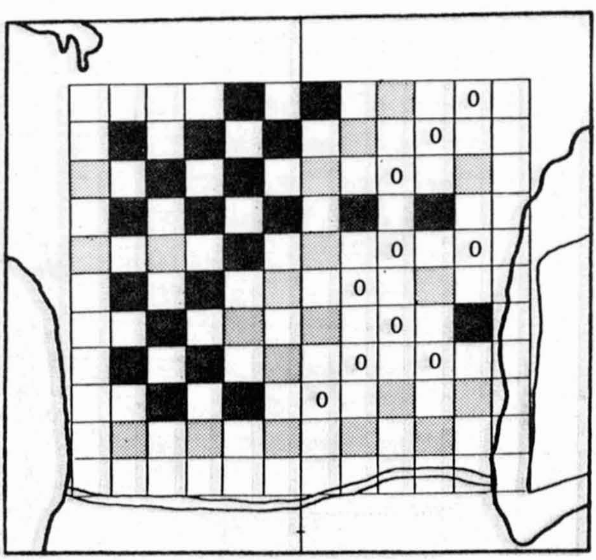
a) *Calla palustris*



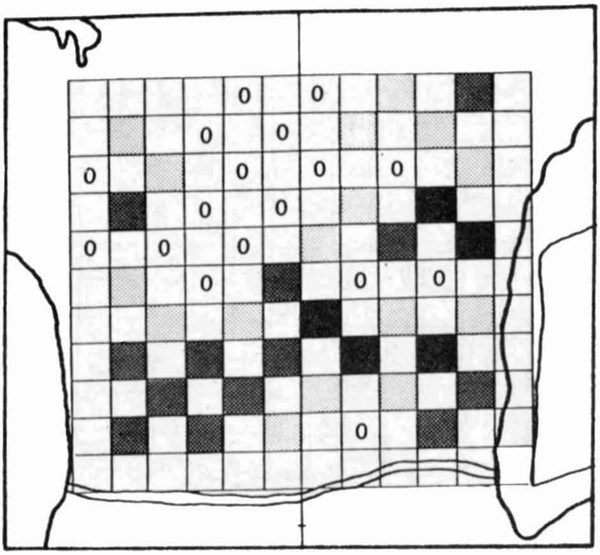
b) *Typha latifolia*



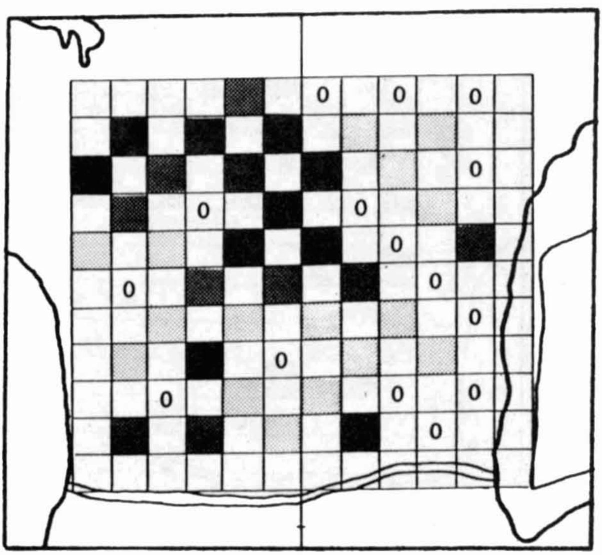
c) Caltha palustris



d) Lysimachia thyrsiflora



e) Cicuta bulbifera



f) Equisetum fluviatile

In aerial photographs taken before flooding, the study area appeared to support forest similar to that north of the flooded area and south of the road dam. Eight years of flooding has killed most of the trees in the study area, and severely damaged many of those that remain alive. This reduction in tree density has increased light levels at the herbaceous stratum.

Little is known about the response of the herbaceous stratum to flooding. Flooding has severely affected a number of the herbaceous species in the study area. Many owe their survival in the flooded woods to the raised hummocks at the base of most trees. Many of the low, frequently inundated areas between the hummocks have been colonized by cattail (Typha latifolia) and jewel weed (Impatiens biflora).

Hummocks in the flooded woods act as a refugia for those species that cannot tolerate inundation. Therefore, the percent of quadrat area occupied by standing water and hummock correlates well with the patterns of abundance of several species. Grazing before 1956 in the northern part of the study area and the discharge from Watts' Lake along the right half of the grid system may also affect distribution patterns.

The invasion by cattail (Typha latifolia) is one of the most noticeable effects of flooding. If flooding continues, the proportion of the study area occupied by cattail would be expected to increase. Currently cattail is confined primarily to the southeast portion of the grid area, close to the road where standing water is most abundant and where the outflow from Watts' Lake probably approaches the road dam. Lowered water levels will probably curtail expansion of the cattail. Linde, et al. (1976) observed that rising water levels over a period of time tended to increase cattail growth and that shortly after water levels begin to decline, cattail growth declined abruptly. However, a secondary disturbance associated with drainage could facilitate cattail growth.

Either beggar-ticks (Bidens spp.) or Canada blue joint grass (Calamagrostis canadensis), both of which responded positively to flooding, could continue to increase in importance in the flooded area. However, neither of these species seem as aggressive as cattail. Calamagrostis, which still has a low average frequency in the flooded woods, was found mostly in the SW quarter of the grid.

Cut-leaf water hemlock (Cicuta bulbifera) and duckweed (Lemna minor) have much higher frequencies in the flooded woods than in the unflooded woods, but neither appears robust enough to become dominant in large parts of the unflooded area. The distribution of Cicuta bulbifera parallels closely that of quadrats with a high percentage of open water. It is almost entirely absent from the area that was once grazed and is common in cattail areas where there is considerable water movement.

While wild calla (Calla palustris) has a much lower frequency in the flooded than in the unflooded woods; its distribution north of the road is confined primarily to the most severely flooded area along the road dam. Wild calla was often observed growing in low areas with shallow water. The apparent negative response to flooding and a distribution which includes only the wettest areas may result, in large part, from the unexpectedly high frequency it achieves in our sample of the unflooded woods. Marsh marigold (Caltha palustris) shows the opposite pattern. It was found more commonly in the flooded woods but was distributed only in the area farthest from the road dam where flooding is less severe.

Tufted loosestrife (Lysimachia thyrsiflora) and horsetail (Equisetum fluviatile) had roughly equal frequencies in the flooded and unflooded woods but had specific distribution patterns in the flooded area. Horsetail is most abundant in the grazed area which is also the area with the most hummocks and least standing water. Loosestrife frequency is inversely proportional to the percentage of standing water. It is most common in those areas where flooding is least severe.

Two species, hog peanut (Amphicarpa bracteata) and naked miterwort (Mitella nuda), common in the unflooded woods, appear to have been so adversely affected by flooding that they are now nearly absent in the flooded area. This sensitivity to flooding may result from the raised water levels or from increased light levels associated with canopy mortality.

It is evident that the composition of the herbaceous community has undergone a dramatic change since the onset of flooding. Some species have been favored by the higher water levels while others have been extirpated from the flooded area. A comparison of the distribution data discussed with information on community dynamics after drainage of the area to eliminate flooding, will be useful to those studying or managing wetland communities. Study of post-flooding recovery is currently scheduled to begin in 1984 when new culverts will be installed in the road dam. Flooded baseline conditions will be studied in the 1983 season to provide additional details.

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