Wetland water levels play a role in determining the availability of nutrients (Pant and Reddy 2001, Venterink et al. 2002, Aldous et al. 2005). Koerselman et al. (1993) demonstrated that water levels, along with properties of the soil and overlying water, controlled release rates of nitrogen, phosphorus, and potassium from wetland soils. When a wetland removes nutrients from inflowing water, we call it “filtering.” This process is a valuable ecosystem service. But when a wetland soil releases nutrients, we call it “internal eutrophication” (Koerselman et al. 1993), and the process can accelerate cattail invasions (Boers 2006).

When does a wetland switch from filtering to releasing nutrients? Let’s consider phosphorus, which seems to stimulate cattail invasions (Fig. 1). Most wetlands have fluctuating water levels or drawdowns for at least part of the year. When the water level is low, iron in the wetland soil (ferric iron or Fe³⁺) bonds with phosphorus and forms an insoluble complex. This filtering process locks up phosphorus in a form that cattails cannot access.

When the wetland is flooded, however, the soil becomes anaerobic due to the increased use of oxygen by microbial organisms, and Fe³⁺ is chemically reduced to ferrous iron (Fe²⁺), and the iron complex releases its phosphorus and makes it available to plants (Patrick and Khalid 1974, Lee et al. 1977). If a wetland is flooded for a week or more, the soil can release phosphorus through its own chemical activity, that is, without any new influx of phosphorus from the watershed. Thus, a wetland could be harmed if a dam or other structure is installed and marsh water levels become stable. The soil would be anaerobic all the time, and it could release enough phosphorus to stimulate growth of invasive cattails. In fact, long-term observations have shown that wetlands with stabilized water levels do experience rapid expansions of cattails (Wilcox et al. 1985, Shay et al. 1999).
Aaron Boers asked three important questions about cattail stands in Wisconsin in his recently-completed dissertation:

1. Do cattails invade wetlands behind dams more readily than where water levels are more variable?
2. Does the wetland soil actually release phosphorus when the flooding period is prolonged, as behind a dam?
3. Can invasive cattails take advantage of phosphorus released by internal eutrophication? All three answers were “yes,” according to his exciting new evidence.

1. Cattails invade wetlands behind dams more readily than where water levels are more variable.

In wetlands with low phosphorus influx (in the upper Mukwonago River watershed, Fig. 2), Boers compared the rate of spread of cattails in wetlands with and without artificially stabilized water levels. He mapped cattail clones using air photos taken over a period of 37 years. During that time, cattails (both *T. angustifolia* and *T. x glauca*) expanded to dominate 304.5 hectares (74%) of the wetland behind the dam that stabilizes water levels in Eagle Spring Lake (Fig. 3). The radii of individual clones expanded by 3.9 + 0.6 meters per year. In contrast, cattails (*T. angustifolia* and some of the native *T. latifolia*) expanded to only 8.6 hectares (5%) of a wetland near Lulu Lake, which had fluctuating water levels (Fig. 4). The radii of those cattail clones expanded only 2.5 + 0.7 meters per year on average (Table 1).

2. Wetland soils release phosphorus when the flooding period is prolonged.

Boers compared phosphorus release from the soil of the Mukwonago wetlands under flooded and moist conditions

<table>
<thead>
<tr>
<th>Table 1.</th>
<th>Stabilized water (west side of Eagle Spring Lake)</th>
<th>Fluctuating water (west side of Lulu Lake)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattail spread (annually)</td>
<td>81,152 m²</td>
<td>2,327 m²</td>
</tr>
<tr>
<td>Clonal expansion (annually)</td>
<td>3.9 m</td>
<td>2.5 m</td>
</tr>
<tr>
<td>Area dominated by cattail</td>
<td>73.8%</td>
<td>5.3%</td>
</tr>
<tr>
<td>Year when wetland will be 100% cattails at this rate</td>
<td>2014</td>
<td>2684</td>
</tr>
</tbody>
</table>
and documented internal eutrophication. The average concentration of phosphorus in the soil water was about four times as high under flooded than moist conditions (1.09 + 0.13 mg/L vs. 0.24 + 0.07 mg/L). At the end of the experiment, total iron and total phosphorus in the wetland soils were positively correlated; that is, 79% of the variation in released phosphorus was explained by iron content.

3. Invasive cattails can take advantage of phosphorus released by internal eutrophication.

Boers grew invasive cattails (T. × glauca) in microcosms at the Arboretum and showed that cattails could increase their growth when more phosphorus is available, as with internal eutrophication. First, he showed that phosphorus was limiting to cattail growth, because pots with phosphorus added had 23% more biomass of roots and shoots than those without phosphorus addition. Next, he showed that prolonged flooding increased both phosphorus uptake and cattail growth; that is, cattails can take up and make use of phosphorus when soils are simply flooded—without phosphorus addition from an external source (Fig. 5).
**ARE ARBORETUM WETLANDS UNDERGOING INTERNAL EUTROPHICATION?**

Wherever structures stabilize water levels, we suspect internal eutrophication (phosphorus release), and wherever water levels are just right for cattails, invasions could be accelerated via increased rates of phosphorus uptake. Gardner Marsh is the most likely place (see Leaflet 5), but lower parts of Wingra Marsh, the former South Shore Fen, and parts of Southeast Marsh are also likely candidates. All of these places have dams, culverts, or berms that stabilize water levels, and all have cattail clones poised to expand, if they are not already on the march.

**IS THERE A CURE?**

First, we need to know if internal eutrophication is underway in Arboretum wetlands. Then, we need to test the effects of reinstating fluctuating water levels to see if wetland soils would shift from releasing to filtering phosphorus. One thing is clear, however. If we design our new stormwater detention ponds to have stable water levels, we should expect some phosphorus to be released by the anaerobic soil, and the phosphorus could counteract the intended filtering function of such ponds.

As part of any project designed to filter nutrients, we recommend monitoring and research to determine the balance between phosphorus-filtering and phosphorus-release processes.

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**References**


