Lake creation represents an increasingly important post-harvesting land-use option for cutaway peatlands in Ireland. The current research assesses the trophic status of four experimental cutaway lakes in Co. Offaly, with particular focus on phosphorus dynamics. Results indicated that many cutaway lakes exhibit elevated total phosphorus levels and, concurrently, support high phytoplankton growth rates. Abiotic and biotic processes involved in the regeneration of inorganic phosphate from refractory organic phosphorus compounds were found to play an important role in maintaining a constant supply of available phosphorus to phytoplankton communities in cutaway lakes.

Key words: cutaway peatland, phosphate regeneration, UV labile phosphate, phosphatase enzymes

INTRODUCTION

By 2030, over 80,000 hectares of industrially-milled peatland will be redundant in Ireland. Bord na Móna estimates that more than 50% of this will be designated as non-commercial semi-natural wilderness areas, encompassing 15,000-20,000 hectares of shallow lakes and wetlands (Egan 1999). A series of experimental lakes has already been created within a 2,000-hectare cutaway site in Co. Offaly, called the Lough Boora Parklands. The current research sought to investigate the trophic status of four of these cutaway lakes and to understand the complex physico-chemical and biological processes operating in these essentially artificial ecosystems. A particular focus of the research was to evaluate the occurrence and significance in cutaway lakes of alternative abiotic and biotic mechanisms involved in the regeneration of bioavailable phosphate from the dissolved organic phosphorus pool.

MATERIALS AND METHODS

Four selected cutaway lakes, Finnamore, Tumduff, Turraun and Clongawny, were sampled over the three-year period between August 2001 and September 2004, at two-week intervals for the first year and monthly thereafter. For detailed descriptions of the study lakes, see Higgins & Colleran (2004) and Higgins (2005). The chlorophyll \(a\) concentration of near surface (1m) water samples from each lake was determined using the spectrophotometric method described by Burnison (1980), involving acetone-DMSO (1:1v/v) extraction. Concentrations of various phosphorus fractions were determined using the procedure of Murphy & Riley (1962), involving persulphate digestion for total phosphorus (TP) and total soluble phosphorus (TSP) analyses. Filtered water samples (GF/C filter, 1.2 µm pore size) were used for the measurement of soluble reactive phosphorus (SRP) and TSP, while unfiltered samples were used for TP determination.

On seven sampling occasions during 2004-05 (2/06/04, 30/06/04, 14/07/04, 6/08/04, 26/08/04, 28/09/04 and 26/01/05), filtered water samples from each cutaway lake were analysed for their response to two alternative phosphate regeneration mechanisms: UV-induced phosphate release and enzymatically hydrolysable phosphate release. UV-induced phosphate (P-UV) release was measured using modifications of the methods described by Francko & Heath (1982) and Cotner & Heath (1990). Duplicate samples from each lake were irradiated for 4h using UV radiation of similar strength to mild solar radiation in Ireland (0.9 mW cm\(^{-2}\) at 365nm). The difference between SRP concentrations in the UV irradiated samples and equivalent dark controls was considered as the P-UV fraction of the soluble phosphorus pool. The enzymatically hydrolysable phosphorus fraction (P-EH) was determined on cutaway lake samples using the method described by Chrost et al. (1986). One litre of filtered (GF/C) water samples from each lake were placed in 1-litre sterile flasks, to which was added 10 ml of 1.0 M tris buffer and 50 ml of pure chloroform. Samples were shaken well, to ensure sterility, and incubated at 25°C for five days to promote the action of existing extracellular phosphatase enzymes. After incubation, samples were analysed immediately for SRP. According to this method, any increase in SRP after incubation, termed P-EH, is due to free microbially-produced dissolved phosphatases (Bradford & Peters 1987; Chrost et al. 1986).

RESULTS

The data presented in Table 1 highlight the contrasting trophic statuses of the four cutaway peatland lakes. Both Finnamore and Tumduff were mesotrophic lakes, Turraun was a meso-eutrophic lake, while Clongawny, was a eutrophic-hypereutrophic lake. Mean SRP levels in the four lakes were consistently very low (<1.6 µg l\(^{-1}\)), while soluble organic phosphorus (SOP) were moderately high. The very large TP pool in Clongawny was dominated by particulate phosphorus, indicating a high concentration of planktonic organisms in this lake.

Table 2 presents the results of the two phosphate regeneration mechanisms investigated. These data indicate that the phosphate regeneration mechanisms studied consistently resulted in a mean increase in SRP concentrations in the four study lakes. UV light produced the smaller change in SRP, stimulating a mean increase in SRP of 0.9µg l\(^{-1}\) across all lake samples. Release of UV-labile phosphorus was highest in Turraun (1.1µg l\(^{-1}\)) and lowest in Clongawny (0.6µg l\(^{-1}\)). The cutaway lake samples showed a greater release of SRP in response to enzymatic hydrolysis, which resulted in a mean increase in SRP concentrations of 2.6µg l\(^{-1}\). Release of P-EH was greatest in Tumduff (3.0µg l\(^{-1}\)) and lowest in Clongawny (2.1µg l\(^{-1}\)).
PHOSPHORUS IN CUTAWAY PEATLAND LAKES

Table 1 – Phosphorus and chlorophyll concentrations in the cutaway lake samples. Values shown are mean (n=54), ±standard error of the mean. (TP-total phosphorus; SRP-soluble reactive phosphorus; SOP-soluble organic phosphorus; PP-particulate phosphorus).

<table>
<thead>
<tr>
<th></th>
<th>Finnamore</th>
<th>Tumduff</th>
<th>Turraun</th>
<th>Clongawny</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorophyll µg l⁻¹</td>
<td>5.2±0.4</td>
<td>3.3±0.2</td>
<td>12.7±1.4</td>
<td>52.5±6.2</td>
</tr>
<tr>
<td>TP µg l⁻¹</td>
<td>12.2±0.5</td>
<td>15.6±0.5</td>
<td>26.7±1.5</td>
<td>26.7±1.5</td>
</tr>
<tr>
<td>SRP µg l⁻¹</td>
<td>1.9±0.2</td>
<td>1.6±0.2</td>
<td>2.3±0.2</td>
<td>2.7±0.3</td>
</tr>
<tr>
<td>SOP 1 µg l⁻¹</td>
<td>5.2±0.3</td>
<td>8.2±0.4</td>
<td>9.0±0.4</td>
<td>7.4±0.6</td>
</tr>
<tr>
<td>PP 2 µg l⁻¹</td>
<td>5.2±0.3</td>
<td>6.0±0.5</td>
<td>14.5±1.4</td>
<td>28.9±3.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Trophic classification</th>
<th>Mestrophic</th>
<th>Mestrophic</th>
<th>Mestrophic -eutrophic</th>
<th>Eutrophic -hypereutrophic</th>
</tr>
</thead>
</table>

1SOP: TSP-SRP; 2PP: TP-TSP (where TSP: total soluble phosphorus).

DISCUSSION

Variations in the nutrient characteristics of the four cutaway lakes largely reflected contrasting land-uses in the catchment areas. Finnamore and Tumduff were mesotrophic lakes, reflecting their isolation from external phosphorus inputs and subsequently low chlorophyll a levels. Elevated summer phosphorus levels in Turraun, accompanied by large seasonal peaks in chlorophyll a, classified this lake on the boundary of the mesotrophic and eutrophic categories. The fourth study lake, Clongawny, was categorised as an eutrophic-hypereutrophic lake, a consequence of phosphorus fertilizer runoff from adjacent coniferous forestry plantations (Higgins et al. in press). Cutaway peatlands are highly vulnerable to nutrient leaching and the subsequent development of sudden and sustained phytoplankton blooms, due to a severe paucity of recolonist vegetation at these sites, the naturally poor chelating capacity of peat and the widespread susceptibility of industrially milled peatlands to runoff and erosion.

The phosphate regeneration experiments indicated that inorganic phosphate can potentially be released from the large dissolved organic P pool in cutaway lakes, by way of two alternative regeneration mechanisms: UV-induced cleavage, and hydrolysis by biologically produced phosphatase enzymes. The release of phosphate by enzymatic hydrolysis was found to be particularly important in the cutaway study lakes, supplementing SRP levels by 238-334%. Contrary to other reports (Jones 1972; McGarrigle & Kilmartin 1992) the occurrence of UV and enzyme-mediated phosphate regeneration did not vary significantly according to the trophic status of the cutaway lakes. Although their occurrence is often regarded as being indicative of a phosphate-deficient waterbody (Vrba et al. 1993), phosphate regeneration mechanisms are by no means irrelevant in productive waterbodies. Low SRP concentrations commonly occur in the photic zones of eutrophic and mesotrophic lakes during the growing season. A significant (p<0.05) inverse relationship between ambient SRP levels and P-EH release in Clongawny water samples (T. Higgins, unpublished data) suggests that enzymes are produced adaptively in this eutrophic-hypereutrophic lake in response to periodic depletions of SRP. It appears that the regeneration of SRP from the large internal SOP pools may significantly account for the development and prevalence of large phytoplankton populations in cutaway lakes, by maintaining a constant supply of available phosphate in these systems.

ACKNOWLEDGMENTS

This research was funded by Bord na Móna and facilitated by the Environmental Change Institute, NUI Galway.

REFERENCES


Table 2 – Phosphate release in the four cutaway peatland lakes by the two P-regeneration mechanisms (P-UV: UV-labile phosphate; P-EH: enzymatically hydrolysable phosphate). Values shown are the mean of seven sampling dates during 2004-2005. Mean percentage changes in SRP in response to the P-regeneration treatments are shown in parenthesis.

<table>
<thead>
<tr>
<th></th>
<th>P-UV µg l⁻¹</th>
<th>P-EH µg l⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finnamore</td>
<td>1.0 (54%)</td>
<td>2.5 (238%)</td>
</tr>
<tr>
<td>Tumduff</td>
<td>1.0 (70%)</td>
<td>3.0 (321%)</td>
</tr>
<tr>
<td>Turraun</td>
<td>1.1 (68%)</td>
<td>2.9 (257%)</td>
</tr>
<tr>
<td>Clongawny</td>
<td>0.6 (151%)</td>
<td>2.1 (334%)</td>
</tr>
<tr>
<td><strong>All lakes</strong></td>
<td><strong>0.9 (121%)</strong></td>
<td><strong>2.6 (362%)</strong></td>
</tr>
</tbody>
</table>