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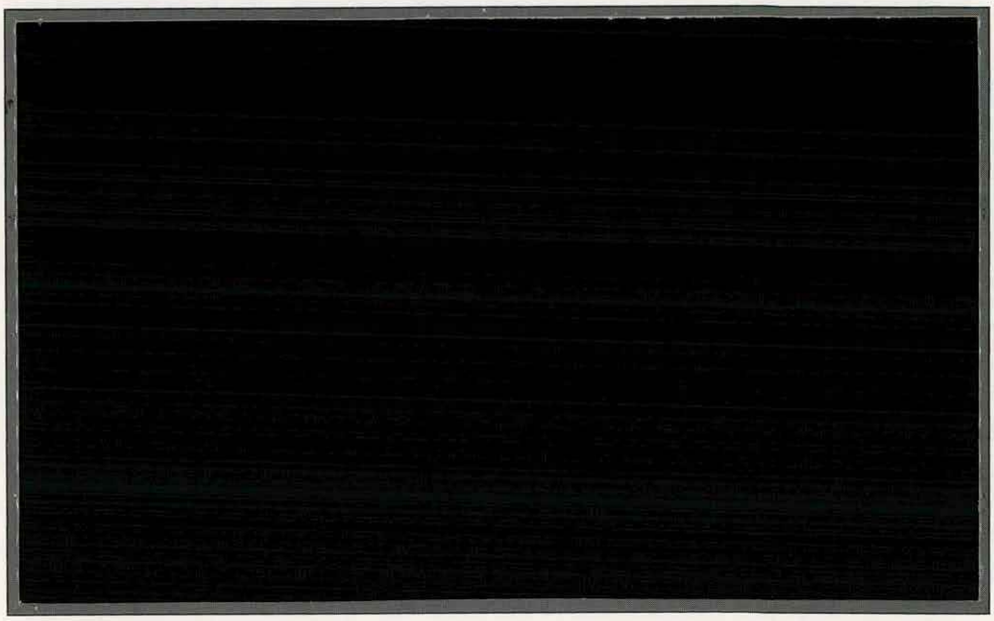

Natural Environment Research Council

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Report date: October 1990
Report to: North West Water plc
IFE Ref: W1/4051/61
TFS Project No.: T04051a5

PHOSPHORUS DYNAMICS IN WINDERMERE

Interim Report 1990

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1. Introduction

This brief, interim report presents findings and provisional deductions about the present sedimentary fluxes of particulate phosphorus fractions in Windermere and the lake-wide levels of hydroxide - extractable phosphorus present in the superficial sediments. In meeting these objectives, the report complies with a contractual requirement and, at the same time, reveals a high level of consistency in the quantitative data, providing a clear and usable reference base.

2. Sedimentary flux of particulate phosphorus

In Table 1, the results of particulate phosphorus analyses of material collected in sediment traps are presented. The traps and the means of their suspension are of a well-tested design - polystyrene jars equipped with pre-drilled and sleeved caps - the performance characteristics of which are already well known (Reynolds 1979). Traps were deployed in pairs, at each of three depths, close to the deepest points of North and South basins. The sedimented material was digested for analysis of its total phosphorus content. The results are expressed in terms of ug P cm^{-2} per trapping period (approximately one calendar month).

Besides showing a remarkably good between-pair agreement, the results also show -

(a) the consistently higher fluxes apparent in the South Basin.

(b) the seasonality of deposition, being highest towards the end of the spring bloom period (Sholkovitz & Copland, 1982).

(c) the lagging of mainly (biogenic) production reaching the deep-water traps during the period of summer stratification. The importance of phosphorus cycling of the (sometimes) slow settlement through the hypolimnion and remineralisation of organic material in Windermere has been previously highlighted (Hamilton-Taylor et al. 1984).

3. Phosphorus content of superficial sediments

Following (c) it cannot be assumed that the sedimentary flux is recruited to the permanent sediments; moreover, the superficial sediments themselves are liable to disruption and resuspension by wave-action, especially those in shallow water, when particulate phosphorus may then be secondarily sedimented and soluble reactive phosphorus in the interstitial water is released back into the open water.

During the study period, 27 of 30 selected sites have been regularly sampled for the hydroxide-extractable phosphorus of the upper 40 mm, i.e. the fraction representing potential sediment load of soluble phosphorus to the overlying water, given an appropriate concentration gradient, under oxic conditions. Three sites (11, NB and 8, 9 SB) had to be abandoned owing to their rocky substrata. In Tables

2 & 3, the preliminary results (i.e. expressed as µg P per g dry sediment and not areally corrected) are presented. Note that the numbering of sites follows a sampling sequence; the data are, however, arranged in the Tables in approximately ascending order of water depth.

For the dates chosen, the quantities of phosphorus located in upper-sediment, interstitial water are scarcely excessive but there are several points of interest. It is apparent, once again, that depth for depth, the samples from South Basin contain, on average, 50-100% more phosphorus than those from the North. In both basins, however, there is a tendency for the variability in values at any given station to be dwarfed by between-station differences which broadly correlate higher phosphorus content with greater depth. This is not easily explained in terms of gross recruitment by the sedimentary flux of phosphorus-containing biogenic material being greater in deeper rather than shallow water but it is possible, however, to point to the frequency of resuspension of particulate material and leachate from decomposing algae into the interstitial water surrounding shallow-water sediments as a factor in the reworking and net transport (or "Focusing") of exposed shallow-water sediment to more permanent, protected deep-water locations. While the deep-water reserve of phosphorus appreciates and, indeed, represents an increasingly important potential source of the recycled element, the likelihood of its realisation through mechanical disturbance becomes steadily weaker, lying increasingly upon the generation of a concentration gradient across the sediment/water interface and/or local anoxia.

4. Recovery of Windermere

It is anticipated that a reduction in phosphorus loading on Windermere will reduce the amounts of phosphorus available to algae and, in due course, limit algal production in situ and reduce both the amount of sedimenting material and of its phosphorus content. The shallow water sediment will, in time, shed phosphorus until a new equilibrium between input and output is struck but rather longer is supposed to be required before the risks of a net internal loading from both chemical gradients or possible mechanical or anoxic nutrient release-events are substantially overridden by the progressive burial of the older, eutrophic, deep-water sediments.

The resolution of these outstanding questions will be addressed in the final report, after more data have been obtained and analyzed and a clearer picture of internal fluxes in the lake has been reconstructed.

Acknowledgements

The capable assistance of our colleagues Peter Allan and Peter Cubby, both in the deployment and recovery of sediment-tray arrays and in the programme of coring sediments, is acknowledged with grateful thanks. Our appreciation is also due to Sybil Smethurst who prepared the report.

References

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TABLE 1. Particulate phosphorus content of paired sediment traps (mean and range) exposed at selected depths in the North and South Basins of Windermere. All results in $\mu g\ cm^{-2}$ per trapping period.

Trapping Period	NORTH BASIN			SOUTH BASIN		
	10 m	30 m	60 m	10 m	30 m	40 m
1989:12 Sep - 10 Oct	26.33 (± 1.51)	17.23 (± 0.66)	24.04 (± 1.24)	25.84 (± 0.37)	34.43 (± 1.56)	25.31 (± 0.18)
10 Oct - 7 Nov	20.48 (± 0.69)	21.89 (± 4.23)	16.63 (± 0.97)	25.35 (± 0.59)	38.24 (± 1.06)	31.93 (± 3.96)
7 Nov - 5 Dec	24.58 (± 0.82)	14.60 (± 0.18)	17.57 (± 0.72)	32.27 (± 3.46)	34.17 (± 0.30)	23.75 (± 0.48)
5 Dec - 2 Jan	19.66 (± 0.51)	16.94 (± 0.81)	21.12 (± 1.17)	23.75 (± 0.40)	21.07 (± 0.29)	25.07 (± 0.47)
1990: 2 Jan - 30 Jan	36.89 (± 0.59)	34.29 (± 0.46)	14.99 (± 1.91)	37.09 (± 0.89)	25.26 (± 2.19)	16.30 (± 5.30)
30 Jan - 6 Mar	56.03 (± 0.48)	61.72 (± 1.32)	78.81 (± 3.26)	Traps Lost		
-						
27 Mar - 24 Apr	59.52 (± 0.60)	57.52 (± 0.25)	80.15 (± 5.98)	60.06 (± 1.25)	81.62 (± 0.89)	106.73 (± 19.42)
24 Apr - 22 May	23.66 (± 0.55)	26.43 (± 0.09)	48.67 (± 1.43)	29.01 (± 0.51)	38.60 (± 0.76)	9.13 (± 1.20)
22 May - 19 Jun	16.74 (± 0.65)	15.38 (± 0.33)	28.47 (± 1.10)	24.19 (± 0.70)	30.57 (± 1.11)	34.72 (± 1.26)
19 June - 17 July	23.22 (± 0.26)	-	-	44.58 (± 0.73)	39.76 (± 2.37)	15.29 (± 2.53)

TABLE 2. (Hydroxide-extractable soluble reactive phosphorus content of sediments from the North Basin of Windermere. Results in µgP/g dry sediment.

		Date of Sample			
Site No	Depth of Water (m)	11 October 1989	8 January 1990	18 April 1990	11 July 1990
Site 16	~1	493	593	413	645
Site 9	~2	765	786	919	158
Site 12	~2	496	415	656	460
Site 13	~2	394	•	386	•
Site 4	~5	488	272	293	•
Site 5	~5	774	769	464	231
Site 8	~5	•	967	1162	839
Site 1	~20	1616	1383	1354	1508
Site 2	~20	2258	1309	1236	997
Site 3	~25	1784	2061	1972	1906
Site 10	~25	1096	1265	1227	980
Site 7	~30	1683	1256	1534	1566
Site 14	~30	1442	1892	1608	1898
Site 15	~32	1385	1346	1131	1689
Site 6	~58	1914	2350	2177	1664

TABLE 3. (Hydroxide-extractable) soluble reactive phosphorus content of sediments from the South Basin of Windermere. Results in µgP/g dry sediment.

		Date of Sample			
Site No	Depth of Water (m)	12 October 1989	18 January 1990	28 April 1990	18 July 1990
Site 4	~2	734	296	495	588
Site 5	~2	618	465	405	1114
Site 10	~2	678	405	383	349
Site 12	~2	904	682	788	744
Site 2	~5	635	581	381	599
Site 11	~5	323	503	453	300
Site 14	~10	939	857	835	1109
Site 1	~15	904	757	1315	730
Site 13	~15	1102	1218	910	n/a
Site 3	~25	1682	2090	1871	3296
Site 7	~32	2587	3095	2983	2852
Site 6	~36	2557	2834	3031	2986

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