The importance of aquatic plants in regulating stream bed sediment structure and phosphorus transport through the Loch Leven catchment

B.M. Spears[1a], L. H. Defew[1], K. Heal[2], B. D'Arcy[3] and L. May[1]

[1] The Centre for Ecology and Hydrology, Bush Estate, Penicuik, Midlothian, EH26 0QB, Scotland, UK.
[a] Corresponding author email: spear@ceh.ac.uk
[2] University of Abertay Dundee, Level 5 Kydd Building, Bell Street, Dundee, DD1 1HG, Scotland, UK
[3] The University of Edinburgh, School of GeoSciences, Crew Building, West Mains Road, Edinburgh, EH9 3JN, Scotland, UK.

Keywords: Stream; sediment; phosphorous

Background

Loch Leven is a large (13.7 km^2) shallow (mean depth 3.9 m) loch in east central Scotland with a long and well documented history of elevated catchment P loading (May et al., 2010). Point source P inputs have been reduced significantly over the past 20 years (Defew, 2008) and it has become evident that diffuse source particulate P inputs are now the dominant source of P to the loch (May et al., 2010). Around 80% of the catchment is under intense agricultural use and large quantities of P laden sediments are expected to be delivered into feeder streams during periods of heavy rainfall and surface runoff (Defew, 2008).

The role of aquatic vegetation in regulating the transfer of particulate P along streams to Loch Leven is expected to be important, although it has not been comprehensively studied. This study addressed this knowledge gap by comparing sediment traits (i.e. particle size structure, phosphorus composition and uptake/release kinetics (EPC_0)) and P transport along two streams of contrasting high (Camel Burn; 90-100% cover by *Phalaris arundinacea*) and low (Pow Burn; low cover) aquatic vegetation cover.

Study site and methods

The Pow Burn is a 2nd order stream (< 10% vegetation cover) draining a catchment area of 11.72 km^2 and the Camel Burn is 1st order stream (>90% vegetation cover by *Phalaris arundinacea*) draining a catchment area of 2.09 km^2 (Figure 1.1). In both catchments, agriculture dominates the land use and population density is low. There are no known point source inputs (sewage treatment works or industrial effluents) entering either stream.

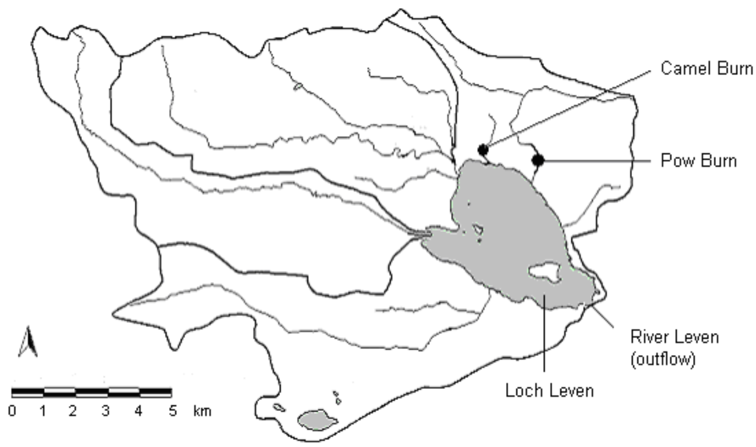

Figure 1.1 Loch Leven and its catchment. The two case study streams are indicated.

Stream bed sediments were collected at four different times of the year (January, April, July and October 2007) from each stream. On each sampling occasion, 3 sediment samples were collected along a transect running perpendicular to stream flow. Duplicate stream water samples were also collected and analysed for soluble reactive phosphorus (SRP). Sediment was collected from the upper 5 cm of the bed using a Maitland corer. Particle size was analysed by laser diffraction using a Beckman Coulter LS particle size analyser. EPC_0 was estimated on each sediment sample after House and Dennison (2000). In this study, the P exchange by sediments was best expressed by Freundlich isotherms (Hwang et al., 1976). Sediment P fractionation was carried out using a sequential chemical extraction technique based on Psenner *et al.* (1988).

Results

Fine sediments (silts/clays; < 63µm diameter) dominated the bed material in the Camel Burn. Sediment EPC_0 ranged between 26 and 105 µg l^{-1} and water column SRP concentrations ranged between 15 and 25 µg l^{-1} indicating continual P release conditions under suspension throughout the study period, in the Camel Burn. Bed sediment traits in the Camel Burn closely resembled those of surface water run-off from a predominantly agricultural catchment. In contrast, medium-coarse sands (250-1000 µm diameter) dominated the sediment structure in the Pow Burn. Sediment EPC_0 ranged between 13 and 45 µg l^{-1} and water column SRP concentrations ranged between 30 and 53 µg l^{-1} indicating persistent P uptake conditions under suspension in the Pow Burn. Sequential phosphorus extraction analyses indicated significantly higher ($p<0.01$ in all cases) concentrations of reductant-soluble P, metal-adsorbed P, organic P and total P fractions in the bed sediments of the Camel Burn compared to the Pow Burn.

Significance of results

In rural catchments under intense agricultural use, large quantities of P-laden sediments often enter fluvial systems during periods of heavy rainfall and surface runoff (Edwards and Withers, 2008). These sediments may settle out onto the stream bed and be retained in the fluvial system for many months before downstream transport (Smith et al., 2006). This study has identified the role of aquatic vegetation as “ecosystem engineers” acting to alter the physical and chemical traits of surrounding bed sediments, thereby, buffering the transport of P to sensitive downstream ecosystems. Our results indicate that under high vegetation cover and low flow, fine sediment particles with a high P content accumulated in bed sediments. Although, this accumulation of fine particulate P on the stream bed represents a net reduction in the downstream P load, it may also represent a significant source of particulate P during storm events. Additionally, bed sediments under high vegetation cover, in this study, were a net source of SRP to the water column. The importance of these processes is discussed in relation to annual P loading to Loch Leven.

References

Defew, L. H. (2008) The influence of high-flow events on phosphorus delivery to Loch Leven, Scotland, UK. PhD Thesis, University of Edinburgh, 276 pp.

Edwards, A. C., Withers, P. J. A. (2008). Transport and delivery of suspended solids, nitrogen and phosphorus from various sources to freshwaters in the UK. Journal of Hydrology 350, 144-153.

May, L. and Carvalho,L. (2010) Maximum growing depth of macrophytes in Loch Leven, Scotland, United Kingdom, in relation to historical changes in estimated phosphorus loading. *Hydrobiol*. **646**: 123-131.

House, W. A., Denison, F. H. (2002). Exchange of inorganic phosphate between river waters and bed sediments. *Env. Sci. Tech*. **36**, 4295-4301.

Psenner, R., Bostrom, B., Dinka, M., Petterson, K., Pucsko, R. and Sager, M. (1988) Fractionation of phosphorus in suspended matter and sediment. *Arch. für Hydrobiol.* **30**: 98-103.

Smith, D. R., Warnemuende, E. A., Haggard, B. E. and Huang, C. (2006). Changes in sediment water column phosphorus interactions following sediment disturbance. *Ecol. Eng.* **27**, 71-78.