Uncertainties in estimated phosphorus loads as a function of different sampling strategies and calculation methods.

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Background

Eutrophication is a widespread problem that is caused by nutrient pollution entering a waterbody from point and diffuse sources within its catchment. In many cases, phosphorus (P) is the main driver of eutrophication problems, especially in lakes. Although determining phosphorus (P) loads from point sources is relatively easy, estimating loads from diffuse sources is much more difficult. When designing a sampling programme to estimate the latter, two key issues need to be addressed (Walling and Webb, 1985; Rekolainen et al., 1991; Johnes et al., 2007). These are (1) how often should flow (*Q*) and concentration (*C*) be measured, and (2) which method should be used to calculate loads from these values?

Several studies have attempted to quantify the variability and uncertainty associated with estimating loads using different calculation methods and sampling strategies (e.g. Walling and Webb, 1981; Walling et al., 2001; Kronvang and Bruhn, 1996; Johnes, 2007). However, few studies have been performed at high enough frequency for the effects of high flow events on nutrient transport to be assessed (e.g. Zonta et al., 2005), and none have considered the uncertainties associated with estimating P loads from data collected at different time intervals.

Study site and methods

This study was undertaken on the Pow Burn, a stream that flows into a shallow, eutrophic loch in Scotland. The loch has suffered from eutrophication problems for many years as a result of high P loads from the catchment (Bailey Watts and Kirika, 1999). The Pow Burn is 12.9 km long and drains a catchment of 10.9 km^2, which is under intensive agricultural use for both arable farming and livestock rearing. During periods of heavy rainfall, this stream delivers large quantities of P to the loch in association with eroded soils and surface runoff (Defew, 2008; unpublished data). This study compares the uncertainty and variability in estimates of total P (TP), soluble reactive P (SRP) and particulate P (PP) loads associated with (a) different sampling strategies (weekly, daily and composite sampling), (b) different interpolation and extrapolation methods and (c) different sampling times.

Results

Based on 2-hourly measurements, ‘true’ P loads over a 10 week study period were estimated to be 459 kg for TP, 78 kg for SRP and 351 kg for PP. Together, 10 high-flow events of varying sizes contributed 363 kg (79%), 49 kg (63%) and 295 kg (84%) of the ‘true’ TP, SRP and PP loads, respectively. The largest storm event, alone, contributed 157 kg (34%), 13 kg (17%) and 136 kg (39%) of the ‘true’ TP, SRP and PP loads, respectively, highlighting the importance of storm events in P delivery.

When the data were subsampled at daily and weekly intervals, 67-84% of TP, PP and SRP loads were underestimated (Table 1.1). When composite samples were used in the calculations, more than 80% of TP and PP loads, but only 19% of SRP values, were underestimated (Table 1.1).

Table 1.1 Uncertainty associated with load estimations based on (a) weekly, (b) daily and (c) composite sampling strategies.

	Number of load estimates		
(a) Weekly Sampling	**TP**	**PP**	**SRP**
Overestimate	102 (15.2%)	107 (15.9%)	184 (27.4%)
Underestimate	567 (84.4%)	562 (83.6%)	480 (71.4%)
Equal to 'true' load	3 (0.4%)	3 (0.5%)	8 (1.2%)
Total No. of Estimates	672 (100%)	672 (100%)	672 (100%)

(b) Daily Sampling	**TP**	**PP**	**SRP**
Overestimate	20 (23.8%)	11 (13.1%)	26 (31%)
Underestimate	63 (75%)	66 (78.6%)	56 (66.6%)
Equal to 'true' load	1 (1.2%)	7 (8.3%)	2 (2.4%)
Total No. of Estimates	84 (100%)	84 (100%)	84 (100%)

(c) Composite Sampling	**TP**	**PP**	**SRP**
Overestimate	4 (19%)	4 (19%)	4 (19%)
Underestimate	17 (81%)	17 (81%)	16 (76.2%)
Equal to 'true' load	0 (0%)	0 (0%)	1 (4.8%)
Total No. of Estimates	21 (100%)	21 (100%)	21 (100%)

Significance and impact

The monitoring of nutrient loads to waterbodies usually involves regular sampling at very low frequencies, i.e. monthly or weekly (Greig, 2005). Low-frequency sampling was originally designed to characterise point source pollution which, until recently, was the dominant source of P within catchments. Now, in many catchments, diffuse sources of P are more important than point sources. The results of the present study show that, at low sampling frequencies, P inputs to receiving waters from diffuse sources can be significantly underestimated by these sampling methods. This is because they miss the high flow events that are responsible for most of downstream P transport from diffuse sources to receiving waters downstream. This has important consequences for meeting water quality targets set by national and international legislation, such as the European Water Framework Directive (European Parliament, 2000).

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