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Geneviève Margaret Carr

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Abstract

Periphyton communities are often the dominant primary producers and an important energy source to higher trophic levels in rivers and streams. Empirical models of periphyton biomass (chlorophyll *a*) that have high predictive power are generally lacking. The goal of this research was to assess and improve the predictability of periphyton in rivers. A historical river monitoring data set from Alberta showed that, in general, land use in the drainage basin was a good surrogate for instream nutrient concentrations in regression models of periphyton biomass. Land use explained up to 34% of the variability in chlorophyll *a* whereas models based on instream nutrients explained up to 24% of the variability in chlorophyll *a*. A field study showed that bacterial abundance in periphyton explained an additional 26 to 29 % of residual variance of chlorophyll *a*, after taking nutrients into account. The relationships between algal and bacterial abundance and production estimates were positive, suggesting bacteria and algae coexist in a mutually dependent association. The sampling design for bacteria in the field study was based on the relationships between sample means and variances of published bacterial abundance and production data. The number of replicates needed to sample periphytic bacterial abundance and production was determined from these relationships. A meta-analysis of published periphyton regression models was used to evaluate model predictive power. Once corrected for the number of observations, terms, and sampling replicates in the models, predictive power of periphyton models has not improved over the last 30 years. Geographic extent of the study area and the type of predictor variables used also had almost no effect on predictive power. The theoretical limit of model precision has approximately been reached for models predicting temporally averaged

periphyton biomass. In contrast, residual variances of models predicting instantaneous mean chlorophyll *a* were, on average, 4.5 times higher than theoretical pure error.

Precision of temporal mean models will only be improved by obtaining more precise estimates of mean chlorophyll *a*. Models that predict instantaneous chlorophyll *a* may be made more precise by including variables that better reflect the recent site history.

Résumé

Les communautés périphytiques sont souvent les producteurs primaires dominants et sont une source importante d'énergie pour les niveaux trophiques supérieurs dans les ruisseaux et rivières. Cependant, il n'existe pas de modèles empiriques de la biomasse du périphyton (chlorophylle *a*) qui ont une bonne puissance prédictive. Le but de cette recherche est d'évaluer et d'améliorer la prévisibilité du périphyton en eaux courantes. Un ensemble de données historiques d'Alberta indique que, en général, l'utilisation des terres dans le bassin versant peut remplacer des mesures de la concentration en éléments nutritifs dans les modèles de régression prédisant la biomasse du périphyton. L'utilisation des terres explique jusqu'à 34% de la variabilité en chlorophylle *a* alors que les modèles utilisant les concentrations en éléments nutritifs n'expliquent que 24% de cette variabilité. Une étude sur le terrain indique que l'abondance des bactéries dans le périphyton peut expliquer de 26 à 29% de la variabilité en chlorophylle *a*, corrigée pour l'effet des nutriments. L'abondance et la production des algues et des bactéries sont positivement corrélées, ce qui suggère que les bactéries et les algues coexistent en association mutuellement bénéfique. L'effort d'échantillonnage des bactéries de cette étude sur le terrain a été déterminé suite à une analyse de données publiées sur la variabilité spatiale des abondances bactériennes. Une méta-analyse des modèles de régression publiés a permis d'estimer la prévisibilité du périphyton. Après correction pour l'effet du nombre d'observations, de termes, et de réplicats utilisés, la prévisibilité du périphyton n'a pas augmenté au cours des 30 dernières années. L'étendue géographique de l'aire d'étude et le type de variables indépendantes ont également peu d'effet sur la prévisibilité. Les modèles prédisant la biomasse moyenne pour une saison

ou une année approchent la précision théoriquement atteignable. Cependant, la variabilité résiduelle des modèles prédisant la biomasse pour un instant donné est environ 4.5 fois plus élevée que l'erreur pure de mesure. La précision des modèles prédisant les moyennes pour des périodes de temps ne peut être augmentée à moins de récolter des données plus précises. Les modèles prédisant la biomasse instantanée pourraient potentiellement mener à des prédictions plus précises s'ils intégraient des variables indépendantes reflétant la dynamique récente de chaque site.

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drainage basin (km²); POP: Number of humans living in drainage basin; FARM: Total area of farms in drainage basin (km²); CROP: Total crop area in drainage basin (km²); LU: Number of livestock units in drainage basin; ECOZ: Ecoregion or ecozone of station. MC: montane cordillera ecozone; BP: boreal plains ecozone; PMG: mixed and moist mixed grassland ecoregions; PFG: fescue grassland ecoregion; PAP: aspen parkland ecoregion. Note that ecozone/ecoregion was only determined for stations included in regression models of Chapter 1..... 146

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A Note on Style and Contributions of Collaborators

This thesis is comprised of a series of four research articles that have been prepared for publication in scholarly journals. Each research chapter is, therefore, self-contained, in that it comprises its own abstract, introduction, methods, results, discussion, acknowledgements, references, tables, and figures.

The four research articles that are contained in this thesis have been submitted for publication to or published in scholarly journals, under the joint authorship of myself and my supervisors, Antoine Morin (University of Ottawa) and Patricia Chambers (National Water Research Institute, Environment Canada). Drs. Morin and Chambers funded research expenses and provided supervision to all aspects of this research, from experimental design, analysis, and interpretation, to editorial review of the manuscripts. However, the research articles, analysis and interpretation of results contained within this thesis, were composed entirely by myself.

Because the research articles in this thesis are intended for publication under joint authorship with my supervisors, they have been written in the style of first-person plural. The general introduction and conclusion of this thesis, which are not intended for primary publication, have been written in the style of first-person singular to reflect my personal approach to my chosen research topic.

General Introduction

Scientific prediction in ecology plays a fundamental role in the establishment and refinement of theories related to ecosystem patterns and processes (Pace 2001).

Mechanistic descriptions of ecological processes and patterns have little value if they are not accompanied by scientific predictions (Peters 1991). Predictions also have applied value, by enabling ecosystem managers to estimate responses of a system to external pressures. Currently, the application of scientific predictions to management issues is critical, as funding for pure research becomes more and more limited and there are increased demands from the general public to account for the applicability of pure research to addressing real-world ecological problems (Morin 1997, Pace 2001).

The development of aquatic ecology into a predictive science can largely be attributed to the increased use of empirical models as tools for quantifying relationships between organisms and their environment (Pace 2001). Early predictive success was achieved with the now familiar phosphorus – chlorophyll regression models that demonstrated clear links between nutrient concentrations and phytoplankton biomass in lakes (e.g., Dillon and Rigler 1974). Those empirical models led to experimental manipulations of lake ecosystems that demonstrated the effects of adding (Schindler 1974) or removing (Edmonson and Lehman 1981) phosphorus to lakes and enabled predictions about the amount of planktonic chlorophyll *a* that could be expected under different nutrient scenarios.

In rivers and streams, periphyton communities are often the dominant primary producers and main energy source to higher trophic levels (Stevenson 1996). However, the development of predictive models for river periphyton has lagged behind models for

lake phytoplankton (Biggs 2000). In particular, models that predict periphyton biomass, measured as chlorophyll *a*, on the basis of instream nutrient concentrations typically explain less of the variability in chlorophyll *a* than similar nutrient – chlorophyll models for lake phytoplankton.

The ability to quantify the relationship between periphyton and nutrients in rivers is important, since periphyton is the dominant group that traps nitrogen and phosphorus from the water column and is implicated in the spiralling of nutrients through flowing-water ecosystems (Mulholland 1996). Moreover, because nutrients are the focus of eutrophication management strategies, the ability to predict the response of periphyton to changes in nutrients should assist managers in setting target nutrient concentrations to maintain biomass below nuisance levels (Dodds and Welch 2000).

Some researchers have successfully used land use in the drainage basin as a surrogate for instream nutrient concentrations in predictive models of planktonic chlorophyll *a* in lakes and rivers (Meeuwig and Peters 1996, Lohman and Jones 1999). However, no attempt has been made to model river periphyton biomass as a function of land use in the drainage basin. Nutrients in rivers and streams are variable temporally and, therefore, difficult to estimate precisely (Cattaneo and Prairie 1995, Chételat and Pick 2001). As such, land use variables may provide a better correlate of average instream nutrient concentrations and they could also integrate other factors that may further influence periphyton biomass, such as total suspended solids concentrations and hydrologic regime. In Chapter 1, I make use of a 21-year monitoring data set for Alberta rivers to quantify the relationship between water quality, land use, and periphyton

chlorophyll *a* concentrations. Results from this study enabled me to determine if land use could yield models that more precisely predicted periphyton biomass in rivers.

An often-overlooked biotic component of periphyton communities are the bacteria embedded along with algae in the polysaccharide matrix that makes up the periphyton. Bacteria can be nutrient-limited and have been demonstrated to be more efficient than algae at incorporating nutrients in oligotrophic environments (Currie et al. 1986, Mohamed et al. 1998). In Chapter 3, I conducted a field-survey of periphyton in streams of southern Ontario and southwestern Québec to test the hypothesis that bacteria and algae in benthic biofilms compete for nutrients, and that bacterial abundance and/or production is negatively correlated to the residuals of algal-nutrient regression models. This study made it possible to evaluate if competition for nutrients between algae and bacteria in periphyton is part of the reason for the low precision of models that predict periphyton chlorophyll *a* with respect to nutrients.

As part of the design of the field study of Chapter 3, I quantified sampling variability of bacterial abundance and production in periphyton. This enabled me to determine the optimal number of replicates needed to provide sufficient precision, while minimizing effort, when sampling periphytic bacterial abundance and production. The outcome of the study of sampling variability in bacterial abundance and production in aquatic environments is described in Chapter 2.

The discrepancy between predictive power of lake plankton and river periphyton models is usually attributed to inherent differences between the two types of aquatic ecosystems. In particular, the temporally dynamic hydrologic nature of river ecosystems has often been used to explain the difficulties associated with predicting mean biomass of

periphyton in rivers with respect to nutrients (Biggs 2000). Furthermore, microscale habitat heterogeneity (Cattaneo et al. 1993), intensity of grazing by invertebrates (Anderson et al. 1999), and influence of canopy shading on light availability (Bourassa and Cattaneo 2000) are other factors that have been suggested as possibly obscuring chlorophyll – nutrient relationships. A number of attempts have been made to incorporate these variables, either alone or in combination with nutrients, into regression models of periphyton chlorophyll *a*, with varying degrees of success. My goal in Chapter 4 was to synthesize published periphyton regression models from the last three decades to quantify how the number of model observations and independent terms, geographic scale of the study area, and the independent variables used influenced predictive power. Results of this investigation enabled me to speculate about possible future directions for periphyton regression modelling research.

The research that is laid out in this thesis addresses the issue of the prediction of periphyton biomass in rivers, with a particular emphasis on nutrient – chlorophyll relationships. It is an attempt, first, to develop regression models that have higher predictive power than existing models of periphyton biomass. Second, it synthesizes information about existing regression models and explores reasons for the generally low predictive power of periphyton models.

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Chapter 1: Periphyton, water quality and land use at multiple spatial scales in Alberta rivers

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Abstract

The ability of land use to replace water quality variables in predictive models of periphyton chlorophyll *a* was tested with a 21-year data set for Alberta rivers. Nutrients (total dissolved P (TDP) and $\text{NO}_2 + \text{NO}_3$) explained 23% to 24% of the variability in seasonal chlorophyll *a* whereas land use (human population density) explained 25% to 28% of the variability. The best models included the combination of TDP and population density, explaining 32% to 34% of periphyton chlorophyll *a* variability. However, analysis of variance of chlorophyll *a* by ecoregions and ecozones explained about as much variability (28%–30%), and the inclusion of an ecoregion term into the regression models showed a diminished importance of land use as a predictor of chlorophyll *a*, with best models based upon the combination of nutrients and ecoregion and explaining up to 43%–44% of periphyton chlorophyll *a* variability. Within ecoregions, land use was sometimes a good surrogate for nutrient data in predicting chlorophyll *a* concentrations. Overall, land use is a suitable surrogate for nutrients in regression models for chlorophyll *a*, but its inclusion in general models may reflect regional differences in nutrient-chlorophyll relationships rather than true land use effects on chlorophyll *a*.

Introduction

Periphyton communities are often the dominant primary producers in rivers and in streams, and shifts in their composition and biomass are known to have impacts that reverberate through higher trophic levels within individual ecosystems. However, the development of robust models that predict biomass of periphyton chlorophyll *a* on the basis of water quality in lotic ecosystems has lagged behind the development of similar models for planktonic chlorophyll *a* in lakes (e.g., Dillon and Rigler 1974). Dodds et al. (2002) recently published general models based on total nitrogen and phosphorus concentrations in temperate streams that explained approximately 40% of the variance in both mean and maximum periphyton chlorophyll *a*. The authors' models contrast to phytoplankton models for lakes that often yield coefficients of determination greater than 90% (Dillon and Rigler 1974). The lack of predictability in periphyton models has generally been attributed to high variability in periphyton communities due, in large part, to patchiness in the communities caused by the heterogeneous nature of benthic environments in lake and, in particular, river ecosystems.

There is clear evidence that periphyton biomass is often controlled by nutrient concentrations. Abundant growths of periphyton in nutrient-enriched areas have been documented (Welch et al. 1989) and nutrient-enrichment experiments have shown that periphyton can be P, N, or both N+P-limited (Francoeur 2001). However, other factors have also been shown to influence periphyton biomass, including hydrologic disturbances that cause scouring of periphyton (Biggs 2000), invertebrate grazing of periphyton (Biggs et al. 1998; Anderson et al. 1999), and light availability (Bourassa and Cattaneo 2000). Empirical models that incorporate several of these factors have sometimes yielded higher

coefficients of determination (e.g., Biggs 2000) than models based on nutrients alone, but the application of such models with multiple variables often becomes difficult because of a lack of data.

Several investigators have taken a different approach to predicting chlorophyll *a* concentrations in lakes and rivers by relating chlorophyll *a* concentration at a station to land use within the drainage basin upstream of that station (Meeuwig and Peters 1996; Lohman and Jones 1999). Large temporal variability about true mean values makes it difficult to estimate seasonal average concentrations of nutrients precisely (Cattaneo and Prairie 1995) and land use variables may provide a better correlate of average nutrient concentrations than instream measurements. This is particularly true for forms of N and P that are considered bioavailable, such as inorganic N and soluble reactive P: these are notoriously difficult to estimate precisely and it is not clear that they truly represent bioavailable forms (Dodds 2003). Moreover, because nutrients that wash in from drainage basins may also be associated with factors such as contaminants and suspended particles, the biotic response to diffuse loading is most likely an integrated response to the cumulative effects of multiple stressors (Meeuwig and Peters 1996). Thus, the inclusion of land use variables into chlorophyll models may improve predictions by integrating the effect of more than one independent variable on periphyton biomass. This has been shown to be true for planktonic chlorophyll *a* in lakes (Meeuwig and Peters 1996) and rivers (Lohman and Jones 1999).

Although land use has not been explicitly examined for periphyton at a broad scale, some investigators have recognized its possible effect. Dodds et al. (2002) reported correlation between periphyton chlorophyll *a* and percent urban and agricultural

land use in a drainage basin, but cautioned that anthropogenic effects could not be distinguished from natural geographic variation at the ecoregion level. Sabater et al. (2000) showed how land use and periphyton co-vary along a river system whereas Biggs (1995) showed with a small data set that benthic chlorophyll *a* could be predicted by flood frequency, the proportion of the basin under high intensity agricultural use, and catchment geology. Munn et al. (2002) also showed that periphyton community composition varied with the amount of agriculture in the drainage basin.

The objective of this study was to assess the feasibility of using land use variables as surrogate predictors of periphyton chlorophyll *a* for rivers in Alberta, Canada, using a 21-year historical monitoring data set maintained by the Province of Alberta. Regression models based exclusively on either nutrients or land use were compared and then combined to determine the combination of variables that yielded the best predictive models. The effect of spatial scale (entire province versus ecozones and ecoregions) on modeling outcomes was also compared to evaluate the best scale for developing predictive models for periphyton chlorophyll *a* in rivers. Finally, general trends in chlorophyll-nutrient relationships at the provincial scale were compared to other published chlorophyll-nutrient models.

Methods

Study area

Alberta Environment measured periphyton chlorophyll *a* and water quality data at nearly 400 stations between 1980 and 2000 throughout the province of Alberta. The frequency with which the stations were sampled varied: some stations were sampled at

regular intervals (most often monthly) whereas others were sampled once or only occasionally. The 91 stations that were included in this study were chosen based on two main criteria. First, stations were chosen that had suitable replication of chlorophyll *a* measurements within a season. This decision was based upon examination of average precision about the mean (determined as the standard error divided by the mean) and was an attempt to strike a balance between having high precision in estimates of seasonal means and having sufficient data for analysis. Thus, stations that had at least two replicate measurements of chlorophyll *a* in the spring and fall, and three replicates in the summer were retained in this study. Average precision in seasonal mean chlorophyll *a* estimates retained in this study ranged from 20-28%. Seasons were defined according to the dominant discharge patterns in Alberta rivers, such that spring corresponded to the months of April and May when discharge tends to be low due to persistent cold temperatures in the headwaters. Summer corresponded to the months of June, July and August when discharge tends to be high and variable due to melting in the headwaters. Fall months were September and October, representing the period of freeze-up in the headwaters and generally low flows in the rivers.

The second criterion for inclusion of stations in the study was location of station at or near a watershed boundary, as delineated in the Prairie Farm Rehabilitation Administration (PFRA) Gross Watershed Boundaries for the Canadian Prairies (http://www.agr.gc.ca/pfra/main_e.htm). The PFRA data set defines 879 drainage basins for Alberta and is the most complete dataset available for drainage basins at the provincial level. This final selection yielded 91 stations, with a total of 447 seasonal mean or maximum observations. Stations were spread across seven major drainage

basins in the province (Athabasca, North Saskatchewan, Red Deer, Bow, Oldman, South Saskatchewan, Milk) and three of the five terrestrial ecozones (prairie: 67 stations, 28 observations; montane cordillera: 6 stations, 28 observations; boreal plains: 18 stations, 30 observations), as defined by Alberta Environmental Protection (1994). Because most of the available data were from the prairie ecozone, we examined the distribution of stations across three groups of ecoregions in the prairies (mixed and moist mixed grasslands: 25 stations, 132 observations; fescue grasslands: 25 stations, 171 observations; aspen parkland: 17 stations, 86 observations). Among the stations included in the analysis, the median number of years a station was sampled was one. Four stations on the Bow River were sampled for between 13 and 17 years and accounted for 100 of the total observations. The remaining stations in the study were sampled for between one and eight years (median = 1 year) during the 21-year study period with a median of two observations per year.

Water quality data

Monitoring data for water quality and benthic chlorophyll *a* in Alberta rivers were retrieved from the Alberta Environment surface water quality database (Edmonton, Alberta). Water quality variables included phosphorus (total and total dissolved) and nitrogen (total Kjeldahl and nitrate + nitrite). Total nitrogen was determined by summing total Kjeldahl and nitrate + nitrite. Ammonia was not included in analyses because it was at or below analytical detection limits ~45% of the time it was measured. All other nutrient variables had values that fell below detection limits no more than 20% of the time they were sampled. Measurements that fell below detection limits were replaced with one half the value of the detection limit. There was some variability in analytical

methods over time and across labs for the water quality variables, but all methods approximately followed standard methods set out by the American Public Health Association (1998).

Land use data

Statistics Canada censuses of human population and agriculture from 1981, 1986, 1991, 1996, and 2001 were used to estimate human and animal population and land use practices on a census subdivision (CSD) basis across Alberta. Digital boundary files of census subdivisions for each census year were obtained from Statistics Canada through the Data Liberation Initiative. The number and density of individuals living within a drainage basin was determined from the census of human population. The agricultural censuses were used to determine the area of drainage basins under agricultural land (total farm area and total crop area) and the number of livestock units (cattle, swine, and poultry converted to livestock units based on manure production relative to an average beef cow of 450 kg; Ontario Ministry of Agriculture and Food 1998) within each basin.

Census maps were overlaid onto Alberta drainage basins to extract the subdivisions (or portions thereof) that fell within specific basins. Political boundaries rarely coincided with drainage basin boundaries and so when a CSD overlapped a basin boundary, the percent CSD that fell within the basin was determined, assuming the distribution of land use within the CSD was uniform. Land use in drainage basins in non-census years was estimated as a weighted average of land use in the basins in census years before and after the sampling year.

Data analysis

Data were analysed with SYSTAT (version 10, Systat Software Inc., Richmond, California, <http://www.systat.com>). Where necessary, variables were $\log_{10}$ -transformed to stabilize variance and normalize distribution of residuals. Seasonal mean chlorophyll *a* concentration was determined according to the criteria described above. Seasonal maximum chlorophyll *a* concentration was the highest average daily value for a station collected within any given season. Multiple regressions were used to explore relationships between seasonal mean and maximum epilithic chlorophyll *a*, water quality, and land use. Correlation among independent variables was assessed by examining Pearson correlation coefficients and variables with significant (Bonferonni adjusted $P < 0.05$) coefficients greater than 0.60 were entered into separate models. Multicollinearity among independent variables was further assessed by examining tolerance of each variable, equal to one minus the proportion of variance in each independent variable accounted for by all other independent variables. Low tolerance values (< 0.50) indicated correlation among variables, in which case the models were rerun excluding at least one of the collinear variables. The multiple regression models that had the highest r^2 and lowest residual mean square (RMS) were chosen as the best predictive models of dependent variables.

To examine the influence of the four stations that were sampled most frequently and that comprised 22% of the observations in the full data set, multiple regression models were compared between models run with the entire data set and with a reduced data set that excluded the 100 observations from the four stations.

The influence of distribution of individual sampling stations across Alberta on relationships between periphyton chlorophyll *a* and nutrients and/or land use was also evaluated by modeling chlorophyll *a* as a function of third order polynomials of the latitude and longitude of each station (plus all possible interactions, leading to a total of 15 terms in the model) alone and in combination with nutrient and/or land use predictors.

The effect of season (spring, summer, fall) on periphyton chlorophyll *a* in Alberta rivers was evaluated by analysis of covariance (ANCOVA) with a seasonal term and all possible interactions entered into models that had nutrients and/or land use as predictor variables. A significant interaction between season and the predictor variables indicated a difference in slopes among seasons; a significant main effect of season indicated differences in the y-intercepts of the regression lines among seasons.

The influence of broad geographic patterns, at the scale of ecoregions and ecozones, on periphyton chlorophyll *a* was evaluated with ANCOVA by including a term that identified the ecoregion/ecozone in which a station fell, plus all possible interactions with other predictor variables, into regression models of chlorophyll *a*. Differences in the proportion of variance explained (as determined by the coefficient of variation, r^2) with and without the factorial terms included in the models made it possible to evaluate the benefit of modeling chlorophyll *a* at different geographic scales of analysis.

Results

Chlorophyll and water quality

Periphyton chlorophyll *a* in Alberta rivers ranged from detection limits (0.1 mg•m⁻²) to > 500 mg•m⁻² and averaged ~100 mg•m⁻² across the province (Table 1.1).

Water quality in the rivers studied was, on average, oligotrophic with respect to total N and oligo-mesotrophic with respect to total P (Table 1.1, Figure 1.1), according to the classification scheme proposed by Dodds et al. (1998). Chlorophyll *a* and nutrient concentrations differed ($P < 0.001$, analysis of variance (ANOVA)) among ecozones/ecoregions, such that mean chlorophyll *a*, total N and total P were highest in the prairie fescue grasslands ecoregion, although total P was similar in the fescue and in the mixed and moist mixed grasslands ecoregions of the prairie ecozone. Periphyton chlorophyll *a* was lowest in the boreal plains ecozone, whereas total N and P were lowest in the montane cordillera ecozone (Figure 1.1).

Concentrations of periphyton chlorophyll *a* and total N were fairly stable over the study period, whereas total P declined throughout the 1980s (Figure 1.2). However, chlorophyll *a* differed among seasons, and tended to be highest in fall and equal and lower in spring and summer. Significant differences among seasons were also detected for nutrients ($P < 0.001$, ANOVA), such that nutrient concentrations were highest in spring and lowest in fall. The only exception to this seasonal nutrient trend was $\text{NO}_2 + \text{NO}_3$, which was higher in summer than in fall and differences among seasons were only marginally significant ($P = 0.01$, ANOVA) (Figure 1.2).

Land use

The drainage basins examined in this study were large and ranged from 1180 km² – 283 155 km². Among these basins, human activity upon the landscape varied from intensively farmed agricultural areas (up to 98% of a drainage basin under farmland) to densely populated urban areas (114 individuals•km⁻²) to drainage basins with almost no human activity (population and agricultural density estimates all very low) (Table 1.1).

Human population density was greatest in the fescue grassland ecoregion (prairie ecozone) and lowest in the boreal plains ecozone of the province (Figure 1.3). In contrast, agricultural activities, as measured by density of livestock and proportion of the drainage basin under crops or farmland, were all greatest in the mixed and moist mixed grassland ecoregions and lowest in the montane cordillera ecozone. Average human density exceeded livestock density in the montane cordillera ecozone and the fescue grassland ecoregion, whereas livestock density was greater than human density in the other three terrestrial regions. Significant proportions of variation in all measures of human activity upon the landscape (human and livestock population densities, proportion of basin in crop and farm land) were explained by terrestrial ecoregion following analysis of variance for each variable with ecoregion as the dependent variable ($0.45 < r^2 < 0.78$, $P < 0.001$).

Riverine nutrient concentrations were significantly correlated to land use variables. In particular, estimates of phosphorus (total and dissolved) were positively correlated to estimates of agricultural activity (livestock density and proportion of basin in farm or crop land), whereas nitrogen variables (total and $\text{NO}_2 + \text{NO}_3$) were better correlated to human population density (Table 1.2).

Multiple regression models

Provincial scale models

Examination of the entire data set at a provincial scale, with no seasonal or geographic separation of the data, showed that the best water quality predictors of seasonal mean chlorophyll were the combination of concentrations of total dissolved P and $\text{NO}_2 + \text{NO}_3$, explaining 23% of the variability in mean algal biomass (Table 1.3).

Land use was a better predictor of chlorophyll *a* in Alberta rivers than water quality, explaining 28% of the variability in mean chlorophyll *a*. The best land use predictor of chlorophyll *a* at the provincial level was population density. The combination of water quality (TDP) and land use (Population density) variables provided the best fit to the chlorophyll data at the scale of the entire province, explaining 34% of the variability in mean periphyton chlorophyll *a*. The same regression models performed on a reduced data set yielded virtually identical model coefficients with slightly higher residual mean squares and r^2 values that were between 3.4% and 5.3% less than those for the full data set (Table 1.3).

Models for maximum chlorophyll *a* did not differ considerably from those for mean chlorophyll *a*, although the nutrient-only model yielded slightly better predictions and the land use models yielded slightly worse predictions for maximum as compared to mean chlorophyll *a* (Table 1.3). The differences in r^2 between mean and maximum chlorophyll *a* models were on the order of only 0-1% for nutrient-only models, and 3-4% for land use models. Similar to the mean chlorophyll models, models with the reduced data set yielded equivalent model coefficients and slightly higher residual mean squares and slightly lower r^2 values.

There was a spatial structure to the periphyton chlorophyll *a* data that was detected in multiple polynomial modeling of chlorophyll *a* as a function of the location (latitude and longitude) of sampling stations (Table 1.3). In general, periphyton chlorophyll *a* decreased from south to north and from east to west and location alone explained 33% and 32% of the variability in mean and maximum chlorophyll *a*, respectively. When geographic location was modeled in combination with nutrient

and/or land use predictor variables, a similar pattern emerged for both mean and maximum periphyton chlorophyll *a* as for when location was not taken into account. That is, the combination of nutrients (TDP) and land use (population density) explained the most variability (model $r^2 = 0.44-0.45$) in mean and maximum periphyton chlorophyll *a* when compared to land use or nutrient only models. Nutrient and land use coefficients were similar between models that did and did not include the spatial component of sampling stations. Based on the consistency of modeling results for periphyton, in terms of regression coefficients for nutrients and/or land use and patterns of variance explained among models that did and did not consider the spatial structure of the data, we elected to proceed with regression modeling without including spatial structure of the periphyton data.

A slight seasonal effect was also detected in periphyton chlorophyll *a* after taking into account the effects of nutrients and land use. Inclusion of an additional term to account for seasonal differences in the general models using the entire data set (Table 1.3, plus all possible interactions) yielded only modest improvements to the models ($< 2\%$ increases in r^2), and exclusion of spring data yielded models with non-significant seasonal effects. Analysis of covariance to evaluate differences in slopes and intercepts in the general regression models detected significant differences for intercepts, but not slopes, of the continuous variables, such that spring chlorophyll values were slightly lower ($P < 0.05$) than summer and fall chlorophyll values for any given unit (or combination thereof) of the independent variables in the regression model. Because the effects of season were small, we elected to ignore seasonal effects in subsequent modeling efforts.

Regional scale models

Chlorophyll *a* varied significantly across ecoregions, and ecoregion alone explained approximately the same amount of variability in mean chlorophyll *a* as combined water quality and land use variables at the scale of the entire province (Table 1.4). Inclusion of ecoregion in the regression models as a categorical variable yielded considerable improvements in the amount of variation in chlorophyll *a* explained by the models. An additional 21.5% of the variability in mean chlorophyll was explained when ecoregion and all possible interactions between ecoregion and TDP and $\text{NO}_2 + \text{NO}_3$ were added to the nutrients only model. The improvements to model fit conferred by land use at the provincial scale were essentially eliminated when the effect of ecoregion on nutrient-chlorophyll relationships was taken into account, resulting in the nutrient and ecoregion models being about as precise as the combined nutrient, land use and ecoregions model (44.2% versus 45.4% of the variation in chlorophyll explained by the two models, respectively).

Similar patterns were observed for models of maximum chlorophyll *a* (Table 1.4). Ecoregions alone explained nearly 28% of the variability in chlorophyll *a*, and the inclusion of ecoregion and all possible interactions with nutrients, land use, or the combination of nutrients and land use, yielded models that explained between 38% and 44% of the variability in maximum chlorophyll *a*. Similar to the case for mean chlorophyll *a*, the improvement in precision when nutrients and land use were modeled together at the provincial scale was essentially lost when ecoregion effects on maximum chlorophyll *a* were taken into account.

Significant two and three-way interactions between ecoregion, nutrients, and land use precluded the possibility of developing a general predictive model for chlorophyll *a* (mean or maximum) based on water quality, land use, and ecoregion. To address the relationships at the ecoregion level, individual multiple regressions were run for each ecoregion to identify the best models for predicting periphyton chlorophyll *a* concentrations based on water quality and/or land use within a smaller area of the province. Because of the similarities in model results between mean and maximum chlorophyll *a* at the provincial level, we report here modeling efforts for regional effects on mean chlorophyll *a* only.

In general, models developed for individual ecoregions were similar in terms of the independent variables that were the best predictors of chlorophyll *a* (Table 1.5). Land use (population density or crop density) was a significant predictor of mean chlorophyll *a* in four of the five ecoregions examined, whereas dissolved nutrients (TDP, NO₂+NO₃) were significant predictors in three of the five ecoregions. The combination of nutrients and land use yielded models with lower residual mean squares (and, therefore, higher precision) than province-wide models in the fescue grasslands ecoregion of the prairies and the montane cordillera ecozone. Models for the other three ecoregions, based only on either land use or nutrients, had residual mean squares that were higher than or equal to province-wide models and lower coefficients of determination. Caution should be used in interpreting results of the montane cordillera and boreal parkland ecozone models, since sample sizes in these groups were small ($n = 28$ and 30 , respectively).

Discussion

Models for prediction of mean and maximum chlorophyll *a* in rivers in the Province of Alberta, Canada, were best when based on a combination of nutrients (TDP) and land use (population density). However, when the effects of ecoregion on chlorophyll *a* were taken into account, nutrient-only models explained more variability than land use models and about equal amounts of variability in models that combined nutrients, land use, and ecoregion for the entire province. Biggs (1995) also showed that agricultural land use, in conjunction with bedrock geology and frequency of floods, were good surrogates for nutrient data in predicting chlorophyll *a* concentration. Similarly, Dodds et al. (2002) reported that mean chlorophyll was positively correlated to land use metrics, such as percent urban, crop, and pasture lands, as well as drainage area. However, neither of the above studies explicitly compared regression models developed with nutrients to those developed with land use, as we have done here.

The fact that predictions of chlorophyll *a* based on land use were about as good as, or better than, predictions based solely on nutrients is notable, especially given the fact estimates of land use in Alberta were relatively coarse when compared to the more intensively collected water quality data. Although satellite imagery may have improved estimates of land use for Alberta, census data are readily available, inexpensive, and updated every five years (in Canada) and this makes them appealing as a means to derive rough predictions of how much benthic chlorophyll *a* can be expected in any one location.

Human population density, which was the best overall land use predictor of chlorophyll *a* at the provincial level, was well correlated to nitrite + nitrate

concentrations, whereas agricultural activities were well correlated to phosphorus concentrations. These patterns were consistent with human activities upon the Alberta landscape. First, efforts to curb eutrophication through phosphorus reductions have led to general increases in the N:P ratio of sewage to and situations where nitrogen, but not phosphorus, tends to be found in high concentrations in effluents from many municipal wastewater treatment plants (Chambers et al. 1997). Thus, in areas where human population density is high in Alberta, nitrogen concentrations also tend to be high. In agricultural landscapes in Alberta, the application of livestock manure as fertilizer to cropland has, until recently, been done to meet plant nitrogen requirements. However, because N:P in manure is low ($\sim 5:1$, USDA 1992) relative to plant requirements ($15:1$), there has tended to be an over-application of P on the landscape. The excess P could then potentially move into surface waters, leading to a correlation between agricultural land use and phosphorus concentrations. Modeling results for chlorophyll *a* reflected the correlations between land use and water chemistry: when more than one variable was included in a model, these consisted of a form of phosphorus or a land use variable that was correlated to phosphorus (i.e., livestock, farm or crop density) and a form of nitrogen or a land use variable correlated to nitrogen (i.e., human population density).

The fact that inclusion of an ecoregion term into the general province-wide nutrient models yielded as good predictions as models that combined land use, nutrients and ecoregions, suggests that the improvements in models when land use, but not ecoregion, was included, were probably due to a covariance between ecoregion and land use. Land use patterns did vary significantly among ecoregions in this study: population density was greatest in the fescue grassland ecoregion, agricultural activity was greatest

in the mixed and moist mixed grassland and aspen parkland ecoregions, and human activities were generally low in the boreal plains and montane cordillera ecoregions. These patterns are not surprising, as some ecoregions will naturally be more readily inhabited than others (Smith et al. 2003).

Spatial patterns in the Alberta data set were also detected when periphyton chlorophyll was modeled as a function of geographic location of sampling stations: periphyton biomass was, on average, highest in the southern and eastern portions of the province, corresponding to areas of high agricultural activity and warmer climates. However, taking into account the spatial structure of the data did not eliminate relationships between chlorophyll and nutrients and/or land use. In fact, models that included both the spatial component of the data and nutrients and/or land use as predictor variables had coefficients for the nutrient and land use variables that were very similar to models that did not include location of sampling stations.

Dodds et al. (2002) cautioned against the ecoregion modeling approach because of the problems of covariance between water quality, land use, and ecoregion and the general lack of suitably pristine reference stations within some ecoregions. However, it is our opinion that, in the presence of correlations between land use and ecoregion, the question becomes one of whether predictive models can be enhanced by looking at chlorophyll-nutrient (or land use) relationships within an ecoregion, rather than across many ecoregions. In our study, land use was well-correlated to chlorophyll *a* within some ecoregions and estimates of anthropogenic activities (human density, proportion of basin under crops) yielded the best models for chlorophyll *a* in the mixed and moist mixed grassland and aspen parkland ecoregions and the combined effects of land use and

nutrients yielded best models for chlorophyll in the fescue grasslands and montane cordillera ecoregions. These patterns support the hypothesis that land use can be a good surrogate for nutrient data in predicting periphyton chlorophyll *a* concentrations.

Although we advocate the ecoregion modeling approach in this study, we acknowledge that caution must be exercised when interpreting results from one ecoregion and applying these to another ecoregion that may have very different chlorophyll – nutrient – land use patterns.

Many published nutrient-chlorophyll models rely on total, rather than dissolved forms of nutrients. Although dissolved nutrients may not be ideal for indicating nutrient status of surface waters because of high sampling variability and rapid turnover (Dodds 2003), their use in empirical modeling exercises is justified since they are usually highly correlated to total forms of the same nutrients. In the case of the Alberta dataset, total and dissolved forms of phosphorus and nitrogen were well correlated on a logarithmic scale (Pearson's $r = 0.84$ and 0.55 for P and N forms, respectively) and there were more observations of dissolved nutrients available for modeling, thereby increasing statistical power by increasing sample size.

Total nitrogen and phosphorus were also significant predictors of periphyton chlorophyll *a* in this study at the scale of the entire province (Table 1.6), but the best models based on total nutrients had lower r^2 and higher residual mean squares than those based on dissolved forms of the nutrients. We compared models based on total N and total P developed with the Alberta data to models published by Dodds et al. (2002) for a literature data set consisting mostly of sites in North America and New Zealand and found that in all cases the coefficients of the models developed with Alberta data were

significantly different from the published models. In general, models with Alberta data had slightly higher intercepts (indicating, on average, more chlorophyll per unit nutrient in Alberta rivers) and slightly shallower slopes, such that published models tended to under-predict chlorophyll in Alberta rivers (Figure 1.4). However, the coefficients for the slopes for the total N models in particular are quite close (0.63 for Alberta vs 0.72 for published data), suggesting a generality in chlorophyll-nutrient relationships that requires only minor adjustment for different regions.

Our results indicate that scale of analysis impacts the predictability of chlorophyll models and there are several lines of evidence within the data examined to support this conclusion. Although there was good correspondence between the province-wide models developed here and other, published models for temperate streams, the predictability of these models was weak. In the case of the Alberta data, a simple analysis of variance on chlorophyll among ecoregions explained as much variability as the more complex multiple regression models at the scale of the province. Thus, for the province as a whole, it is possible to get as good a prediction for chlorophyll at a station simply by knowing in which ecoregion it falls as it is by knowing land use characteristics of the drainage basin or instream nutrient concentrations. However, the inclusion of a term to account for ecoregion into the regression models, as well as multiple regression analysis on ecoregion subsets of the data showed improvements in terms of modeling capacity for chlorophyll *a*. At the provincial level, models for mean and maximum chlorophyll *a* explained between 37% and 45% of the variability based on different combinations of independent variables, and within individual ecoregions, reductions in residual mean squares and improvements in r^2 values, relative to the province-wide models, were

detected. The empirical models developed here for ecoregions could be used as reference points for the development of predictive models for chlorophyll that are more specific to the different regions of the province: in some cases this might imply a more detailed land use analysis within an ecoregion and in others it might imply the gathering of more specific water quality data.

Although an understanding of the factors that control periphyton biomass is important from an ecological perspective, these same factors make implementation of general models for periphyton difficult, from a management perspective: it is uncommon that all factors needed to predict chlorophyll *a* are measured in routine monitoring programs, leaving predictions of chlorophyll *a* subject to considerable uncertainty. The issue of predictability based on regression models is not a new one and, in fact, has been a key criticism of empirical regression models for chlorophyll, even in lakes (Prairie 1996). The results of this study indicate that estimates of land use are about equal to nutrients in terms of their predictive capabilities for periphyton chlorophyll in Alberta rivers. The implications of these observations are that monitoring water quality in the hopes of predicting periphyton biomass is somewhat futile. If the goal of the monitoring program was to ultimately manage periphyton chlorophyll, management authorities would be wise to expend resources in localized areas and focus on collecting land use and water quality data specific to the region rather than looking for broad patterns. Over a broad geographic area, land use estimates will do as suitable a job as nutrients in predicting chlorophyll concentration in a river, and probably at considerably less expense.

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Table 1.1. Summary statistics of variables used in the analysis. Data are for all seasons, all years, and all stations. Land use data are averaged by drainage basin, not individual observations, since multiple observations may correspond to the same land use data. "se" = standard error, n = number of observations, TP = total phosphorus, TDP = total dissolved phosphorus, TN = total nitrogen, $\text{NO}_2 + \text{NO}_3$ = nitrite + nitrate.

	mean (se)	median	minimum	maximum	n
Epilithic chlorophyll <i>a</i> ($\text{mg}\cdot\text{m}^{-2}$)	Mean 112 (5)	76.3	0.111	514	447
	Maximum 165 (7)	121	0.152	988	447
TP ($\text{mg}\cdot\text{L}^{-1}$)	0.049 (0.005)	0.024	0.001	1.22	413
TDP ($\text{mg}\cdot\text{L}^{-1}$)	0.027 (0.003)	0.008	0.001	0.938	447
TN ($\text{mg}\cdot\text{L}^{-1}$)	0.575 (0.026)	0.416	0.089	3.31	340
$\text{NO}_2 + \text{NO}_3$ ($\text{mg}\cdot\text{L}^{-1}$)	0.255 (0.016)	0.069	0.001	1.63	447
Population density ($\text{individuals}\cdot\text{km}^{-2}$)	16.6	5.61	0.06	114	226
Livestock density ($\text{LU}\cdot\text{km}^{-2}$)	11.2	9.29	0.1	39.4	226
Farm land (% of basin)	41.6	48.5	0.1	98.0	226
Crop land (% of basin)	18.1	19.0	0.1	48.2	226
Basin area (km^2)	20 209	6489	1180	283 155	74

Table 1.2. Pearson correlation coefficient matrix of nutrient and land use variables. All variables $\log_{10}$ -transformed. Correlation coefficients followed by ‘*’ are not significant (Bonferroni-adjusted $P > 0.05$). Correlations based on 340 records that are complete for all variables. TP = total phosphorus, TDP = total dissolved phosphorus, TN = total nitrogen, $\text{NO}_2 + \text{NO}_3$ = nitrite + nitrate.

	TP ($\text{mg}\cdot\text{L}^{-1}$)	TDP ($\text{mg}\cdot\text{L}^{-1}$)	TN ($\text{mg}\cdot\text{L}^{-1}$)	$\text{NO}_2 + \text{NO}_3$ ($\text{mg}\cdot\text{L}^{-1}$)
Basin area (km^2)	0.306	0.290	0.265	0.191
Population density (individuals $\cdot\text{km}^2$)	0.107*	0.177	0.405	0.515
Livestock density ($\text{LU}\cdot\text{km}^2$)	0.439	0.363	0.297	-0.141*
Farm land (% of basin)	0.482	0.402	0.349	-0.117*
Crop land (% of basin)	0.484	0.409	0.358	-0.104*

Table 1.3. Comparison of regression models predicting seasonal mean and maximum periphyton chlorophyll *a* in Alberta rivers. Coefficients (and standard errors, SE) of nutrient and/or land use terms and regression statistics (residual mean square, RMS, and r^2) for each category of predictor variables are shown for all data (447 observations), for a reduced data set that excludes the four most frequently sampled stations (347 observations), and for models based on the entire data set that include 3rd order polynomial terms (plus all interactions, for a total of 15 model terms) to describe location (latitude and longitude, in decimal degrees) of each sampling station. Regression statistics for models based solely on the 3rd order polynomial terms to describe location are also shown. Chlorophyll, nutrient and land use variables were log₁₀-transformed. TDP = total dissolved phosphorus, NO₂+NO₃ = nitrite + nitrate. Units according to Table 1.1.

Predictor variables	Model number / constraints	Constant	TDP	NO ₂ +NO ₃	Population Density	RMS	r^2
<i>Mean chlorophyll</i>							
Nutrients	1. All data	2.58[0.08]	0.28[0.04]	0.17[0.03]		0.234	0.227
	2. Reduced	2.49[0.10]	0.27[0.05]	0.13[0.04]		0.259	0.174
	3. Spatial		0.18[0.04]	0.12[0.03]		0.186	0.401
Land use	4. All data	1.39[0.04]			0.43[0.03]	0.219	0.276
	5. Reduced	1.42[0.04]			0.40[0.04]	0.237	0.242
	6. Spatial				0.36[0.05]	0.183	0.410
Nutrients and land use	7. All data	1.97[0.10]	0.24[0.04]		0.36[0.03]	0.201	0.337
	8. Reduced	1.93[0.11]	0.22[0.04]		0.33[0.04]	0.221	0.296

Predictor variables	Model number / constraints	Constant	Model coefficients [SE]			RMS	r^2
			TDP	NO ₂ +NO ₃	Population Density		
Latitude and longitude	9. Spatial		0.21[0.04]		0.33[0.04]	0.170	0.451
	10. Spatial					0.208	0.326
<i>Maximum chlorophyll</i>							
Nutrients	11. All data	2.77[0.08]	0.29[0.04]	0.16[0.03]		0.224	0.239
	12. Reduced	2.68[0.09]	0.28[0.05]	0.13[0.03]		0.252	0.186
	13. Spatial		0.19[0.04]	0.12[0.03]		0.180	0.405
Land use	14. All data	1.59[0.04]			0.40[0.03]	0.221	0.249
	15. Reduced	1.62[0.04]			0.37[0.04]	0.242	0.214
	16. Spatial				0.32[0.05]	0.185	0.388
Nutrients and land use	17. All data	2.22[0.10]	0.27[0.04]		0.32[0.03]	0.200	0.323
	18. Reduced	2.18[0.11]	0.24[0.04]		0.30[0.04]	0.223	0.280
	19. Spatial		0.23[0.04]		0.29[0.04]	0.170	0.437
Latitude and longitude	20. Spatial					0.205	0.320

Table 1.4. Variance partitioning among general linear models for mean and maximum chlorophyll *a* in Alberta rivers. Model numbers refer to the models in Table 1.3 based on the full data set (447 observations). “Full model” is the combination of the model terms from Table 1.3 plus an ecoregion term and all possible interaction. RMS = residual mean square of the models, ANOVA = analysis of variance. All variables log₁₀-transformed.

Model/constraint	RMS	r^2
<i>Mean chlorophyll</i>		
Ecoregions only (ANOVA model)	0.213	0.301
Nutrients only (model 1)	0.234	0.227
Nutrients and Ecoregions (full model)	0.176	0.442
Land use (model 4)	0.219	0.276
Land use and Ecoregions (full model)	0.183	0.406
Nutrients and Land use (model 7)	0.201	0.337
Nutrients, Land use, and Ecoregions (full model)	0.172	0.454
<i>Maximum chlorophyll</i>		
Ecoregions (ANOVA model)	0.214	0.278
Nutrients only (model 11)	0.224	0.239
Nutrients and Ecoregions (full model)	0.175	0.429
Land use (model 14)	0.221	0.249
Land use and Ecoregions (full model)	0.187	0.377
Nutrients and Land use (model 17)	0.200	0.323
Nutrients, Land use, and Ecoregions (full model)	0.171	0.443

Table 1.5. Regional models of mean periphyton chlorophyll *a* based on water quality, land use, or the combination of water quality and land use. All variables were log₁₀-transformed. Values in [] are standard errors. RMS = residual mean square, TDP = total dissolved phosphorus, NO₂+NO₃ = nitrite + nitrate. Units are according to Table 1.1.

Region	Equation	RMS	<i>r</i> ²
Fescue grasslands (prairie ecozone)	1.93[0.09]+0.11[0.03]•TDP+0.31[0.04]• Population density	0.083	0.296
Mixed and moist mixed grasslands (prairie ecozone)	1.44[0.08]+0.31[0.07]•Population density	0.170	0.125
Aspen parkland (prairie ecozone)	0.65[0.21]+0.86[0.19]•Crop land	0.296	0.197
Montane cordillera ecozone	4.09[0.68]+1.00[0.26]•TDP+0.34[0.10]• Population density	0.095	0.398
Boreal plains ecozone	1.86[0.35]+0.49[0.21]•NO ₂ +NO ₃	0.262	0.156

Table 1.6. Comparison of models that predict mean periphyton chlorophyll *a* based on TN (total nitrogen) and TP (total phosphorus) for Alberta data and for a literature data set published by Dodds et al. (2002). Slight variations from published models reflect corrections made to models after publication (W.K. Dodds, Biology, Kansas State University, Manhattan, KS, 66506, personal communication). Chlorophyll *a*, TN, and TP were log₁₀-transformed in all models. Chlorophyll *a* is expressed in mg·m⁻²; TN and TP are in mg·m⁻³. ‘RMS’ denotes the residual mean square of the models. Two tests of significance for regression models with Alberta data are shown: a test of the hypothesis of no difference from zero for all coefficients, including the intercept (H_0 : coefficients = 0), and a test of the extrinsic hypothesis of no difference to the models of Dodds et al. (2002) (H_0 : coefficients = Dodds et al. 2002). Models for Alberta include data from all seasons and all stations in the province (i.e., no geographic limitation on selection of data, as explained in the methods).

TN models				
<i>Data source</i>	<i>Model</i>	<i>n</i>	<i>r</i> ²	<i>RMS</i>
Dodds et al. 2002	-0.40 + 0.72 (TN)	198	0.30	0.215
Alberta	0.06 + 0.63 (TN)	340	0.14	0.282
	<i>Significance tests</i>	<i>F</i> <i>df1, df2</i>	<i>P</i>	
	H_0 : Coefficients = 0	1790 2, 338	< 0.001	
	H_0 : Coefficients = Dodds et al. 2002	28.9 2, 338	< 0.001	
TP models				
<i>Data Source</i>	<i>Model</i>	<i>n</i>	<i>r</i> ²	<i>RMS</i>
Dodds et al. 2002	0.89 + 0.37 (TP)	254	0.13	0.260
Alberta	1.39 + 0.28 (TP)	413	0.07	0.287
	<i>Significance tests</i>	<i>F</i> <i>df1, df2</i>	<i>P</i>	
	H_0 : Coefficients = 0	2274 2, 411	< 0.001	
	H_0 : Coefficients = Dodds et al. 2002	104.4 2, 411	< 0.001	
TN + TP models				
<i>Data Source</i>	<i>Model</i>	<i>n</i>	<i>r</i> ²	<i>RMS</i>
Dodds et al. 2002	-0.41 + 0.59 (TN) + 0.20 (TP)	193	0.38	0.184
Alberta	-0.03+0.70 (TN) -0.08 (TP)	340	0.14	0.282
	<i>Significance tests</i>	<i>F</i> <i>df1, df2</i>	<i>P</i>	
	H_0 : Coefficients = 0	1194 3, 337	< 0.001	
	H_0 : Coefficients = Dodds et al. 2002	44.9 3, 337	< 0.001	

Figure 1.1. Box and whisker plots of nutrient (total P (a) and N (b)) and periphyton chlorophyll *a* (c) concentrations in Alberta rivers, with observations separated by major terrestrial ecoregion and ecoregion. 'MC' corresponds to the montane cordillera ecoregion and 'BP' corresponds to the boreal plains ecoregion. 'PMG', 'PFG' and 'PAP' are located in the prairie ecozone and correspond to the mixed and moist mixed grassland ecoregions (PMG), the fescue grassland ecoregion (PFG), and the aspen parkland ecoregion (PAP), respectively. Dashed lines represent oligo-mesotrophic (left dashes) and meso-eutrophic (right dashes) boundaries for TN, TP, and chlorophyll *a*, proposed by Dodds et al. (1998).

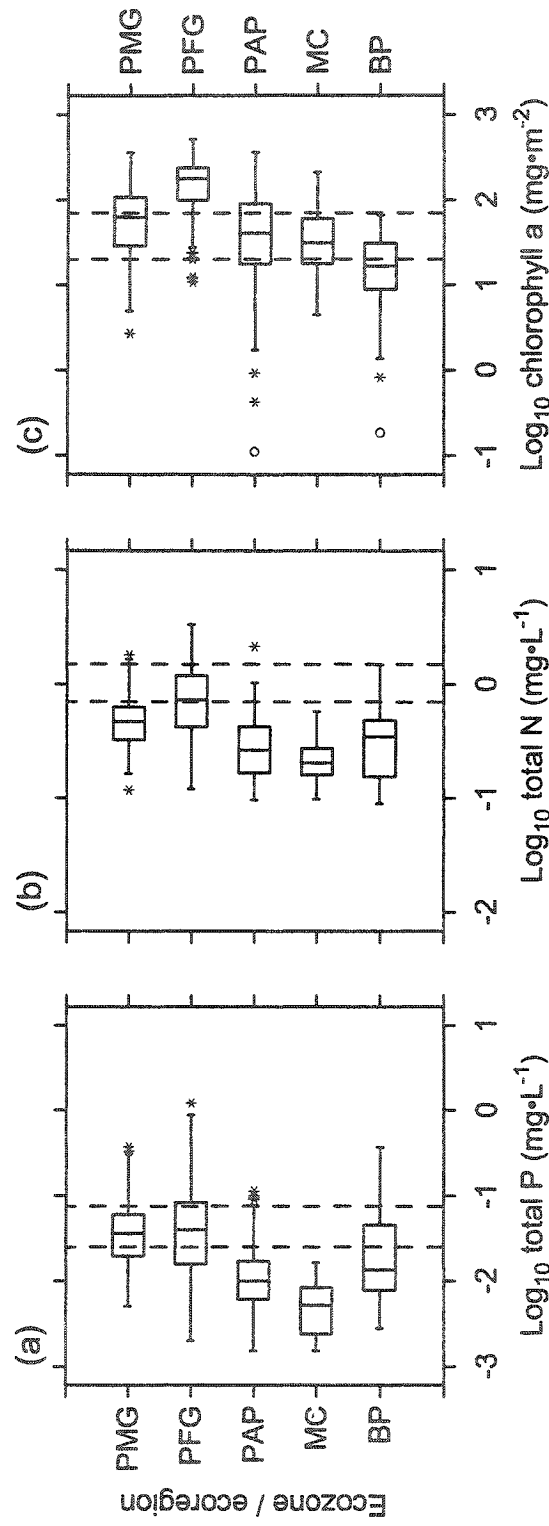


Figure 1.2. Temporal patterns in total P ($\text{mg}\cdot\text{L}^{-1}$, (a)), total N ($\text{mg}\cdot\text{L}^{-1}$, (b)), and periphyton chlorophyll a ($\text{mg}\cdot\text{m}^{-2}$, (c)). Symbols are annual means ± 1 standard error averaged across all stations. Curves are locally weighted regressions based on seasonal means such that spring = solid, summer = dashed, fall = stippled. Note different scales on y-axes.

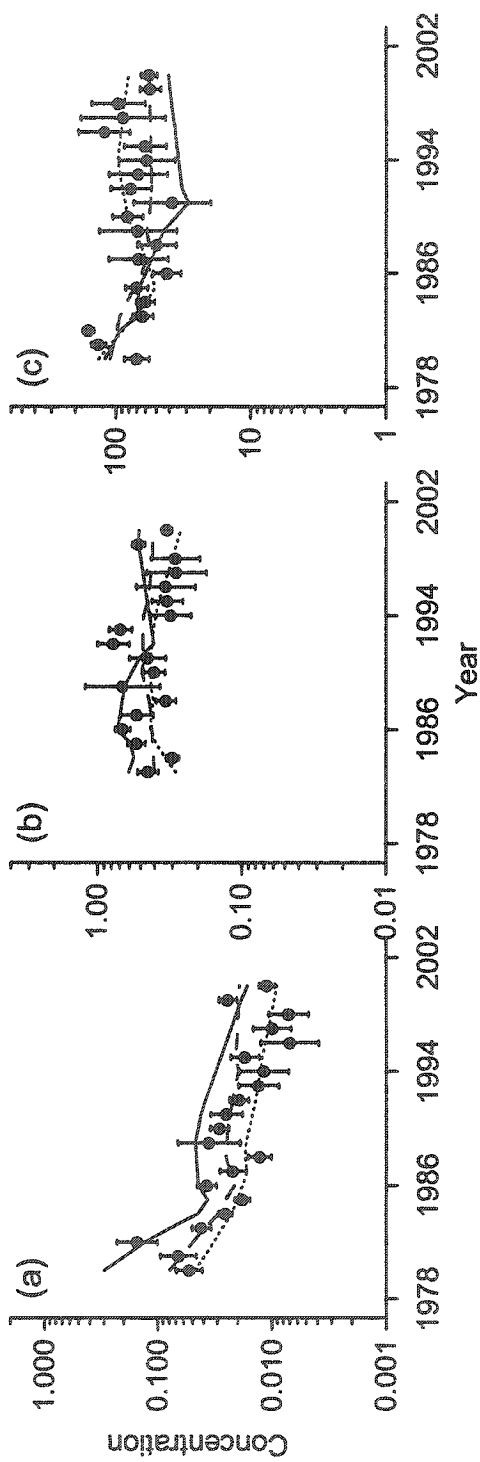


Figure 1.3. Land use metrics across major ecozones and ecoregions in Alberta. Human density (white bars) is expressed as individuals $\cdot$ km $^{-2}$ and livestock densities (grey bars) are expressed as LU $\cdot$ km $^{-2}$; proportion of land in crops (black bars) and farms (hatched bars) are dimensionless. 'MC' corresponds to the montane cordillera ecozone and 'BP' corresponds to the boreal plains ecozone. 'PMG', 'PFG' and 'PAP' are located in the prairie ecozone and correspond to the mixed and moist mixed grassland ecoregions (PMG), the fescue grassland ecoregion (PFG), and the aspen parkland ecoregion (PAP), respectively. Data are mean $\pm$ 1 standard error.

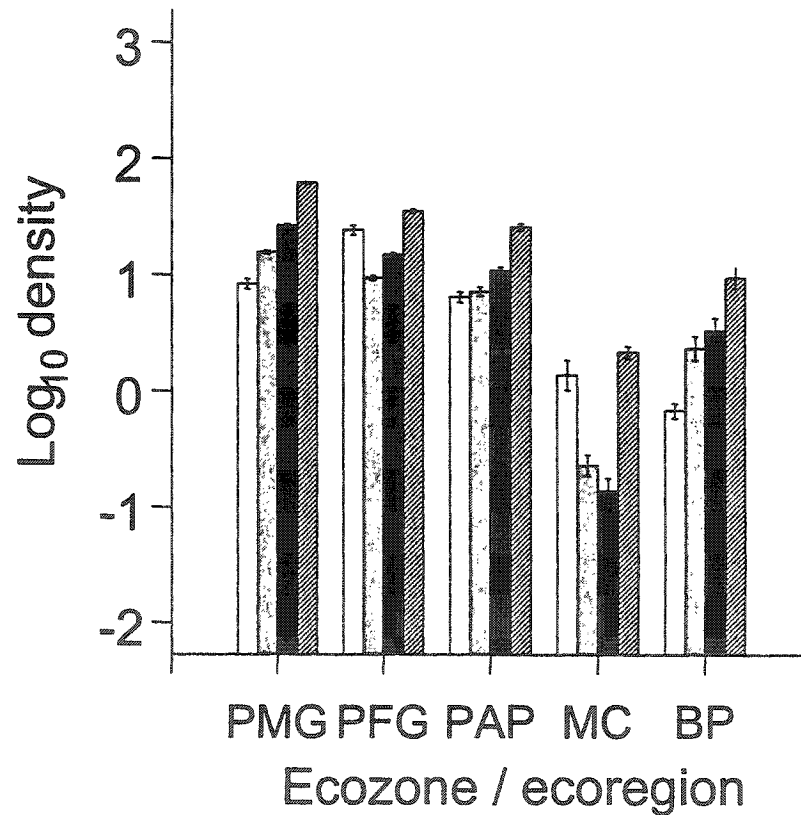
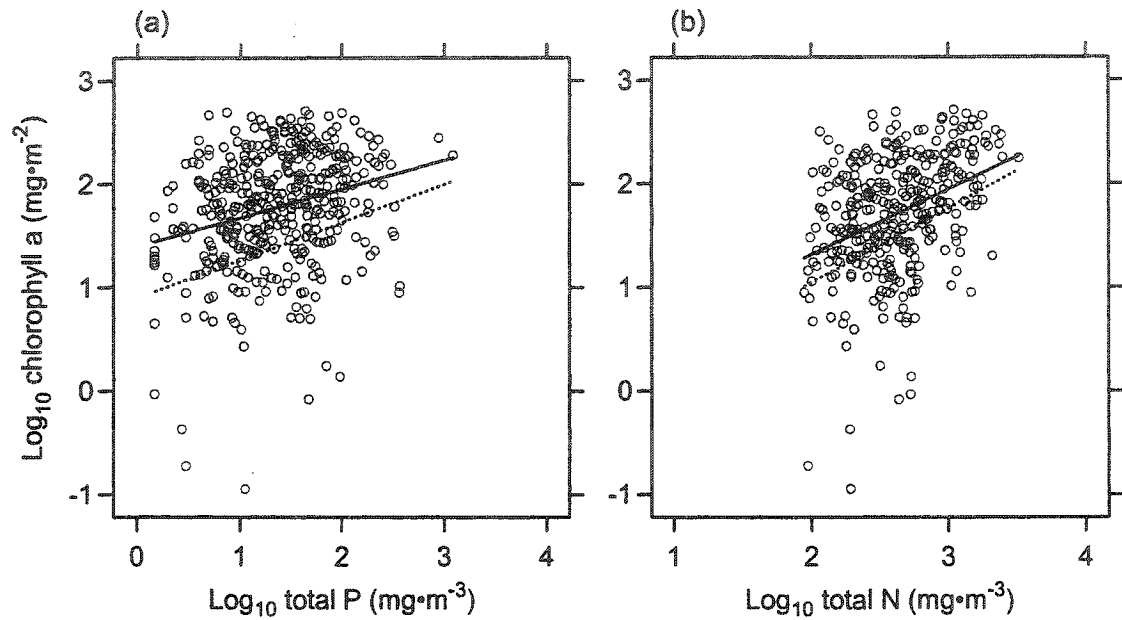


Figure 1.4. Relationship between periphyton chlorophyll *a* and total P (a) and total N (b) in Alberta rivers. Solid lines correspond to chlorophyll-nutrient models fit with Alberta data; dashed lines are regression models of Dodds et al. (2002).



Chapter 2: Sampling variability and the design of bacterial abundance and production studies in aquatic environments

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Abstract

Published data for aquatic bacterial abundance and production in benthic and planktonic environments were collected from the literature to describe relationships between sample means and variances, to explore the factors that affect these relationships, and to estimate the number of samples needed to detect specified differences among means with adequate power. Between 75 and 94% of sample $\log_{10}(\text{variance})$ was explained by $\log_{10}(\text{mean})$ for both bacterial abundance and production. Differences in mean–variance relationships of bacterial abundance and production due to habitat (river, lake, marine), quantification method, and experimental manipulation (planktonic bacteria) or substrate type (benthic bacteria) were negligible (less than 11% of residual variance from regressions explained). Between 12 and 69 replicates are necessary to detect a 20% difference in means for bacterial abundance and production with a power of 80%. Given the median rate of replication of 3 to 4, the majority of published studies reviewed here are, at best, able to detect differences in means of 50% (planktonic bacterial abundance) or 100% (planktonic production and benthic abundance and production) with 80% power. If effect sizes less than these values are deemed biologically meaningful, then future studies will have to increase sampling effort to enable detection of such differences.

Résumé

Des données sur l'abondance et la production de bactéries benthiques et planctoniques ont été récoltées dans la littérature et analysées pour décrire la relation entre la moyenne et la variance d'échantillonnage, pour examiner les facteurs affectant cette relation, et pour estimer le nombre d'échantillons requis pour détecter une différence entre deux moyennes avec une puissance statistique donnée. Entre 75 % et 94 % de la variabilité du $\log_{10}$ variance peut être attribuée au $\log_{10}$ de la moyenne pour l'abondance et la production des bactéries. Les différences dans les relations entre la moyenne et la variance de l'abondance et la production bactérienne attribuées aux habitats (rivières, lacs, océans), la méthode de quantification et les manipulations expérimentales (bactéries planctoniques) ou le type de substrat (bactéries benthiques) sont négligeables et expliquent moins de 11 % de la variabilité. Les analyses de puissance indiquent que entre 12 et 69 échantillons sont nécessaires pour détecter une différence de 20 % entre deux moyennes d'abondance ou de production bactérienne avec une puissance de 80 %.

Puisque la médiane du nombre d'échantillons dans les études utilisées dans cette analyse se situe entre 3 et 4, la majorité de ces études pouvaient au mieux détecter une différence entre les moyennes de 50 % (pour l'abondance de bactéries planctoniques) ou de 100 % (production bactérienne planctonique ou abondance et production bactérienne benthique) avec une puissance de 80%. Il semble donc que si des tailles d'effet plus petites que 50 % sont jugées écologiquement significantes, alors les études futures devront utiliser un nombre plus élevé d'échantillons pour les détecter statistiquement.

Introduction

Interest in the role of bacteria in mediating fluxes of organic matter and minerals in aquatic environments has mounted in the last three decades as our ability to detect their presence and quantify production has improved (Cole 1999). Recent studies have demonstrated that planktonic bacteria contribute, among other things, to the metazoan food web in pelagic systems (Sherr and Sherr 1988), whereas when attached to benthic surfaces, bacteria play a role in the physical development of complex biofilm communities and also in the cycling of nutrients through these communities (Lock et al. 1984; Stock and Ward 1989). However, because of sampling variability and methodological constraints, field studies of bacteria in aquatic systems require considerable effort that could be minimized by optimizing study designs.

Spatial and temporal variability of bacteria is the most important factor affecting the design of any study that quantifies bacteria in the natural environment. Organisms that are highly variable require large sampling effort to estimate population parameters in space or time. Knowledge of the variability of a population is necessary to design adequate sampling programs that can detect biologically meaningful differences among samples with sufficient power (Peterman 1990). Organisms living in aquatic environments are notoriously variable both in their distribution and in their abundance (Downing 1979; Morin and Cattaneo 1992). To date, there have been no surveys of the variability of abundance and production of aquatic bacteria in either planktonic or benthic environments, despite the increased interest in the role of bacteria in trophic and biogeochemical studies of aquatic ecosystems.

Here, we report on the results of a meta-analysis of published bacterial abundance

and production data in benthic and planktonic environments. The goals of this study were (i) to quantify the relationship between spatial variance and mean of bacterial measures and (ii) to use these relationships to estimate the minimum number of replicates in space necessary to detect differences among means for samples of bacterial abundance and production with adequate power. We report on differences in mean–variance relationships for bacterial abundance and production in marine and freshwater environments, lotic and lentic systems, and benthic versus planktonic habitats. We also examine the effect of quantification techniques and whether experimental manipulation influences mean–variance relationships for bacterial abundance.

Materials and methods

The published literature was searched systematically for values of bacterial cell abundance and production in benthic and planktonic environments of aquatic ecosystems. Because we rely here on the relationship between mean and variance of a sample to describe variability in bacterial populations, we only used estimates of abundance and production that were accompanied by some estimate of variability about the mean (standard deviation, standard error, coefficient of variation, confidence limits). We were specifically interested in estimates of means and variances describing an observation at a single place and time to evaluate spatial variability. Thus, estimates of means and variances that were summaries of multiple sites or multiple sampling efforts over time were not included in this analysis. Studies that collected only one sample from a location and replicated bacterial measures by subsampling were also excluded because the replication technique made it impossible to distinguish between analytical and spatial variability. Abundance and production of planktonic bacteria were expressed

volumetrically, whereas estimates for attached bacteria were expressed aerielly. In the case of benthic bacteria, we only used estimates of abundance and production that were reported aerielly and so in most cases corresponds to attached or periphytic bacteria.

For each study, we recorded the methods used to quantify production and abundance. Production methods consisted of determining incorporation rates of either thymidine (Findlay et al. 1984) or leucine (Smith and Azam 1992). The dominant methods to enumerate bacterial abundance consisted of cell staining and microscopic examination according to the acridine orange direct count (AODC; Hobbie et al. 1977) or 4',6-diamidino-2-phenylindole (DAPI; Porter and Feig 1980) methods. We also recorded the habitat from which samples were drawn (lake, river, marine) and whether the samples underwent any form of experimental manipulation (planktonic bacteria) or were grown on natural or artificial substrata (benthic bacteria).

The relationship between variance and mean was described by linear regression on $\log_{10}$ -transformed variables. Residuals of bacterial abundance relationships were examined by analyses of variance (ANOVAs) for deviations attributable to quantification technique, habitat, and whether the samples had been experimentally manipulated (planktonic bacteria) or whether they were grown on natural or artificial substrata (benthic bacteria).

We quantified the number of replicates per sample needed to detect a difference between two means with an acceptable level of type I (α) and type II (β) error with SYSTAT (version 10, Systat Software Inc., Richmond, Calif., <http://www.systat.com>). For this, we assumed that statistical comparisons by Student's *t*-tests would be performed using the log-transformed data, and thus, estimated the variance (s^2) of a lognormal

distribution as a function of the arithmetic means ($\bar{x}$) for bacterial measures according to the method of Hines and Montgomery (1980), such that

$$s^2 = \ln(10^a \bar{x}^{b-2} + 1)$$

where a is the y intercept and b is the slope of $\log_{10}(\text{mean}) - \log_{10}(\text{variance})$ relationships for each bacterial measure. We pooled the variances for the different means and computed the number of replicates needed to achieve 50 and 80% power when type I error is set at 5%.

Results

Our literature search yielded 29 planktonic bacteria studies and 16 benthic bacteria studies. Of these, 22 and 12 studies reported abundance and 11 and 5 studies reported production for planktonic and benthic bacteria, respectively (Table 2.1). The benthic studies were restricted entirely to river environments; there were some studies that reported bacterial abundance in sediments of other environments (mostly marine) but abundance was expressed volumetrically rather than aerially, and thus could not be compared to other benthic studies. Publication dates for the data collected ranged from 1976 to 2001. Bacterial abundances spanned five orders of magnitude in both planktonic and benthic systems, whereas production spanned four to five orders of magnitude for the same systems. Abundance and production means and variances were all heavily right-skewed; skewness was eliminated by $\log_{10}$ transformations. Median number of replicates for all measures was between three and four (Table 2.1).

$\log_{10}(\text{variance})$ increased linearly with $\log_{10}(\text{mean})$ for abundance and production in benthic and planktonic environments (Figure 2.1). Mean bacterial abundance and production explained between 75 and 94% of the variability in variance of a sample with

regressions for benthic bacteria explaining more of the variability than planktonic bacteria (Table 2.2). With the exception of benthic bacterial production, the slopes of the mean–variance relationships were less than two and these differences were statistically significant (Table 2.2). The slope for benthic bacterial production was not significantly different from two. A slope of two for a mean–variance relationship on a log–log scale indicates the coefficient of variation (CV, standard deviation/mean) is independent of the mean, whereas a slope of less than two indicates that the CV decreases with the mean and a slope of greater than two indicates that the CV increases with the mean.

Coefficients of variation for all bacterial measures varied from a mean of 20.6% (planktonic abundance) to 48.3% (benthic production) (Table 2.1). Since the slopes of mean–variance relationships were near two, we assumed that the CV was approximately independent of the mean. Following this assumption, a two-way ANOVA showed that $\log_{10}$ -transformed CVs for benthic bacteria were higher than for planktonic bacteria ($P < 0.001$), that CVs for production estimates were higher than those for abundance estimates ($P < 0.001$), and that there was no interaction between type of bacteria and type of measurement ($P = 0.52$). The effects on CV were small and the ANOVA model explained only 12.7% of the variability in CV. This is evident in Figure 2.2, where the scatter of CVs for benthic and planktonic abundance and production measurements is roughly the same, with almost complete overlap of points where the values for the means are of the same order of magnitude.

One-way ANOVAs of the residuals of the mean–variance relationships yielded significant differences among some of the factors examined, but these were mostly negligible in terms of the amount of variation explained. Residuals of mean–variance

relationships for bacterial abundance in the plankton differed according to enumeration method (AODC, DAPI; $P = 0.002$; Figure 2.3), but this difference explained only 2% of the residual variance and was not significant for benthic bacterial abundance. Thymidine production methods yielded estimates with higher variances than leucine production methods ($P \leq 0.028$) and these differences accounted for 11 and 9% of residual variance for planktonic and benthic bacteria, respectively (Figure 2.3). It should be noted that only one study used the leucine incorporation method for benthic production estimates and so this result should be interpreted cautiously. Experimental manipulation of planktonic samples and substrate type (natural or artificial) for benthic samples had no effect on variability of production and abundance estimates ($0.45 \leq P \leq 0.06$; Figure 2.3). Habitat explained 2.3 and 6.3% of the residual variance for planktonic abundance and production, respectively ($P \leq 0.005$; Figure 2.3). In the case of planktonic abundance, river samples had higher variance than lake and marine samples, whereas marine samples had higher variance than lake samples for planktonic production (rivers could not be evaluated for planktonic production because of a lack of data). We were not able to assess habitat effects for benthic bacteria because all data retrieved from the literature were from river systems.

The number of replicates needed to detect a difference among means with a specific power differed with bacterial measures, such that more samples, on average, would be needed for benthic than planktonic bacteria and for production than abundance measures (Figure 2.4). To detect a difference in means of 20% (i.e., $\bar{x}_2/\bar{x}_1 = 1.2$) with a power of 80%, 12 and 23 replicates would be needed for planktonic abundance and production measures, and 42 and 69 replicates would be needed for benthic abundance

and production measures, respectively. The number of replicates needed to detect a doubling of means dropped to between three and seven replicates for all bacterial measures (Figure 2.4).

Discussion

The relationship between $\log_{10}(\text{variance})$ and $\log_{10}(\text{mean})$ for aquatic bacteria was linear for both benthic and planktonic abundance and production measures. Similar relationships have been observed for other aquatic biotic variables, including benthic invertebrates in lakes and rivers, freshwater measures of periphyton, lake chlorophyll, and macrophyte biomass (Table 2.3). Most of these relationships have slopes near to or just below 2, indicating that the CV is independent of the mean or decreases slightly with increasing means (Table 2.3). This pattern suggests a nearly universal feature of biotic populations that as measured values increase for a population, the populations become more stable (or less variable).

Several of the above studies included additional factors that improved variance–mean relationships (size of sampler for benthic studies, discharge for river studies), but the improvements to model fit were small relative to the strength of these relationships. We also assessed the influence of several factors on variance–mean relationships for bacterial abundance and production estimates and found that only small amounts of the residual variance could be explained by quantification techniques and habitat. In particular, thymidine incorporation techniques yielded more variable production estimates than leucine in the plankton and the trend was supported with benthic data, despite limited data. The AODC enumeration technique also yielded more variable estimates than DAPI in the plankton, but these differences were very small and not

significant for benthic bacteria. Only one study enumerated bacterial abundance by flow cytometry, so we were unable to evaluate if this relatively new technique offers any advantages over traditional microscopic techniques in terms of reducing variance in abundance estimates. Residual variance was not affected by experimental manipulation (planktonic bacteria) or substrata on which the samples were grown (benthic bacteria).

Peterman (1990) highlighted the fact that most studies in the aquatic sciences fail to consider the power of their analyses when a null hypothesis is not rejected, and others have echoed these comments (Osenberg et al. 1994; Steidl et al. 1997). The mean–variance relationships presented here for bacteria are useful in the planning stage of studies where decisions need to be made about sampling effort required to detect significant trends with sufficient power. Our analyses show that between three and seven replicates are usually sufficient to detect a doubling of means for abundance and production in both benthic and planktonic environments with a power of 80%; however, replication rate would need to be increased to detect even a 50% difference in means with the same power. Production estimates need slightly more replicates to detect a specific difference among means than abundance estimates, whereas benthic bacteria need more replication than planktonic bacteria.

Among the studies examined here, the median replication rates for the different bacterial measures would be able to detect, with 80% power, a ratio of means equivalent to approximately 1.6 and 2.0 in the case of planktonic abundance and production and 2.4 and 2.6 in the case of benthic abundance and production, respectively. Thus, approximately half of the planktonic bacteria studies reviewed here would have been unable to detect a 50% difference in mean abundances, and a 100% difference, or

doubling, in means could not be detected by approximately half of the benthic bacteria studies and also half the planktonic production studies. Clearly, the power of most studies to detect small differences in means is low and the ability of investigators to detect biologically meaningful trends in the data may be limited by the lack of power of many studies. Failure to consider sampling variance and the power to detect differences in means in the design of studies will inevitably lead to difficulties in interpretation of results.

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Table 2.1. Summary statistics of bacterial production and abundance measures retrieved from literature and used in this study.

Parameter	Planktonic bacteria		Benthic bacteria	
	Abundance (cells·L ⁻¹)	Production (μg C·L ⁻¹ ·h ⁻¹)	Abundance (cells·cm ⁻²)	Production (mg C·m ⁻² ·h ⁻¹)
Mean	4.50 × 10 ¹⁰	2.67	2.39 × 10 ⁹	23.8
Median	1.68 × 10 ⁹	0.579	3.69 × 10 ⁷	3.26
Minimum	1.60 × 10 ⁷	0.008	6.25 × 10 ⁵	0.259
Maximum	6.24 × 10 ¹²	38.4	5.51 × 10 ¹⁰	140
<i>n</i> (observations)	469	199	235	54
Coefficient of variation (mean %)	20.6	35.4	34.5	48.3
Median no. replicates	3	3	3	4
Range of replication	2-16	2-14	2-8	3-5
No. studies	22	11	12	5

Data sources: *Planktonic bacteria:* Alldredge et al. (1986); Benner and Biddanda (1998); Benner et al. (1995); Bertilsson and Tranvik (1998); Boon (1994); Bouvy et al. (1998); Bunte and Simon (1999); Carlsson and Caron (2001); Cochlan (2001); Cole and Pace (1995); Edwards (1987); Eisenmann et al. (1999); Ferguson and Rublee (1976); Findlay et al. (1986); Kirchman et al. (2000); Kroer (1993); Langenheder and Jürgens (2001); Lind and Dávalos-Lind (1991); Lindell et al. (1995); Moeseneder and Herndl (1995); Palumbo et al. (1987); Rich et al. (1996); Scavia and Laird (1987); Scavia et al. (1986); Seitzinger and Sanders (1999); Suzuki et al. (1993); Tapper and Hicks (1998); Theil-Nielsen and Søndergaard (1999); Tranvik (1994). *Benthic bacteria:* Findlay et al. (1993); Freeman and Lock (1995); Geesey et al. (1978); Hudson et al. (1990); Hudson et al. (1992); Kaplan and Bott (1989); Ledger and Hildrew (1998); Lock et al. (1984); Mohamed et al. (1998); Neely and Wetzel (1995); Romaní and Sabater (1997); Romaní and Sabater (1999a); Romaní and Sabater (1999b); Rosenfeld and Hudson (1997); Sabater and Romaní (1996); Stock and Ward (1989).

Table 2.2. Regression statistics for mean ($\bar{x}$) - variance (s^2) relationships for benthic and planktonic bacterial measures (abundance and production).

Dependent variable	Model	r^2	RMS	n	$P_{\beta=2}$
Planktonic bacteria					
$\log_{10}(s^2_{\text{abundance}})$	$-0.235 [0.470] + 1.848[0.050] \times \log_{10}(\bar{x}_{\text{abundance}})$	0.746	0.612	469	0.002
$\log_{10}(s^2_{\text{production}})$	$-1.279[0.063] + 1.856[0.068] \times \log_{10}(\bar{x}_{\text{production}})$	0.790	0.716	199	0.036
Benthic bacteria					
$\log_{10}(s^2_{\text{abundance}})$	$0.387[0.233] + 1.811[0.029] \times \log_{10}(\bar{x}_{\text{abundance}})$	0.943	0.274	235	< 0.001
$\log_{10}(s^2_{\text{production}})$	$-0.951[0.148] + 2.247[0.134] \times \log_{10}(\bar{x}_{\text{production}})$	0.843	0.620	54	0.072

Note: Values in square brackets are standard errors (SE) of coefficients. RMS denotes the residual mean square of the model. All mean-variance relationships are significant ($P < 0.001$). $P_{\beta=2}$ denotes the probability that slopes (β) are different from 2 as determined by a t -test, where $t = |\beta - 2|/\text{SE}_{\beta}$ and degrees of freedom = $n - 2$.

Table 2.3. Published models predicting variance (s^2) based on means ($\bar{x}$) for different measures of aquatic biota. Models are separated according to those predicting spatial variability (as in this study) and those predicting temporal variability.

Parameter	Model of $\log(s^2)$	r^2	n	Source
Spatial variance				
Abundance, lake benthos	$1.38 + 1.61 \log \bar{x}$	0.97	69	(1)
Abundance, river benthos	$0.482 + 1.386 \log \bar{x} + 0.047 (\log \bar{x})^2 - 0.384 \log(\text{sampler size})$	0.93	1461	(2)
Abundance, marine benthos	$0.262 + 1.22 \log \bar{x}$	0.86	3015	(7)
Abundance, freshwater periphyton	$5.48 + 1.31 \log \bar{x} - 0.26 \log(\text{sampler size})$	0.89	55	(3)
Abundance, benthic bacteria	$0.39 + 1.81 \log \bar{x}$	0.94	235	This study
Abundance, planktonic bacteria	$-0.24 + 1.85 \log \bar{x}$	0.75	469	This study
Production, freshwater periphyton	$-1.06 + 1.88 \log \bar{x}$	0.83	200	(3)
Production, benthic bacteria	$-0.95 + 2.25 \log \bar{x}$	0.84	54	This study
Production, planktonic bacteria	$-1.28 + 1.86 \log \bar{x}$	0.79	199	This study
Ash-free dry mass, freshwater periphyton	$-1.56 + 1.91 \log \bar{x} + 0.47 \log(\text{sampler size})$	0.80	187	(3)
Biovolume, freshwater periphyton	$-0.78 + 1.72 \log \bar{x}$	0.76	94	(3)
Chlorophyll, freshwater periphyton	$-1.68 + 2.07 \log \bar{x} + 0.45 \log(\text{sampler size})$	0.84	1193	(3)
Dry mass, freshwater periphyton	$-0.75 + 1.81 \log \bar{x} + 0.26 \log(\text{sampler size})$	0.92	57	(3)
Biomass, macrophytes, lakes	$0.76 + 1.57 \log \bar{x} - 0.16 \log(\text{sampler size})$	0.95	1200	(8)
Biomass, macrophytes, rivers	$0.30 + 1.92 \log \bar{x}$	0.94	48	(4)

Parameter	Model of $\log(s^2)$	r^2	n	Source
Temporal variance				
Chlorophyll, seasonal, lakes	$-1.03 + 2.50 \log \bar{x}$	0.94	68	(5)
Chlorophyll, annual, lakes	$-0.53 + 2.10 \log \bar{x}$	0.93	47	(5)
Chlorophyll a , seasonal, river	$-1.44 + 2.13 \log \bar{x}$	0.54	12	(6)

Sources: (1) Downing (1979); (2) Morin (1985); (3) Morin and Cattaneo (1992); (4) G.M. Carr, unpublished data; (5) Marshall et al. (1988); (6) Cattaneo and Prairie (1995); (7) Vézina (1988); (8) Downing and Anderson (1985).

Figure 2.1. Mean-variance relationships of bacterial abundance (a and b) and production (c and d) for planktonic and benthic bacteria. Units for abundance and production are as in Table 2.1. Fitted lines are linear regressions and correspond to equations in Table 2.2. Note difference in axis scales between top and bottom panels.

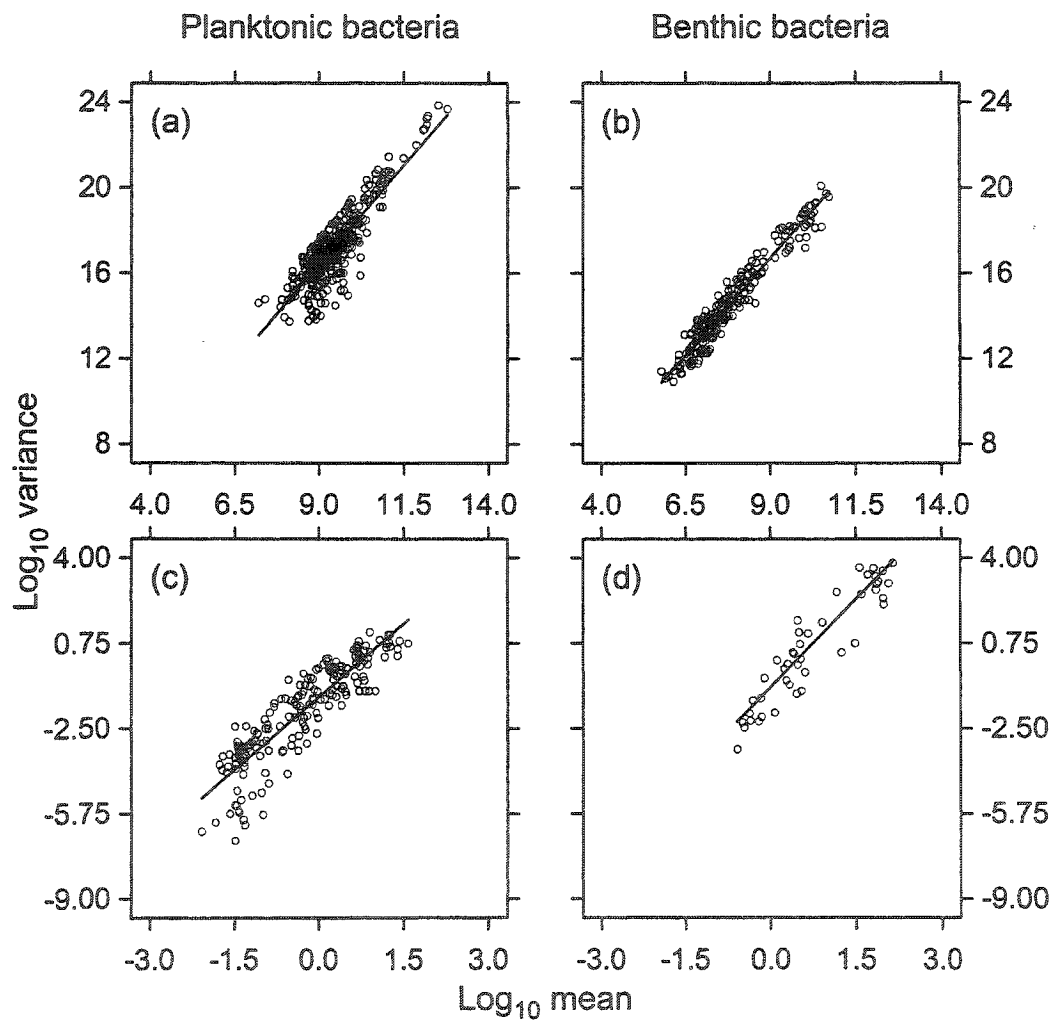


Figure 2.2. Coefficient of variation as a function of mean for (a) bacterial production and
(b) abundance in benthic (closed symbols) and planktonic (open symbols)
bacteria. Units for mean production and abundance are as in Table 2.1.

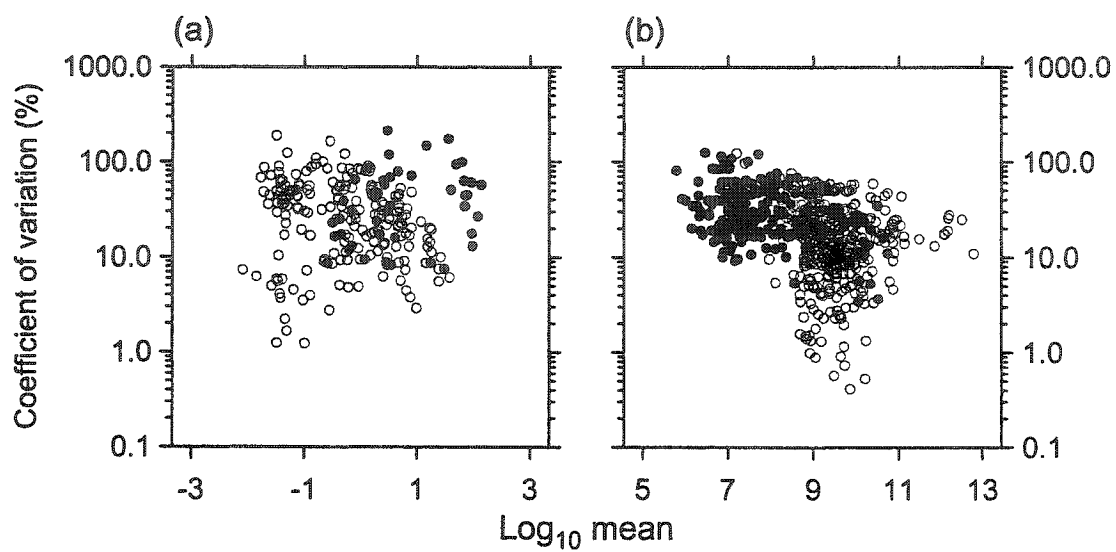


Figure 2.3. Mean (± 2 standard errors) of residuals of variance-mean models for benthic (solid symbols) and planktonic (open symbols) bacterial production and abundance. Residuals are grouped according to quantification technique (production: thymidine or leucine incorporation rates; abundance: acridine orange direct count (AODC) or 4'6-diamidino-2 phenylindole (DAPI) enumeration methods), whether the samples underwent any form of manipulation (planktonic bacteria) or were grown on natural or artificial substrata (benthic bacteria), and habitat from which the samples were taken (river, lake, or marine).

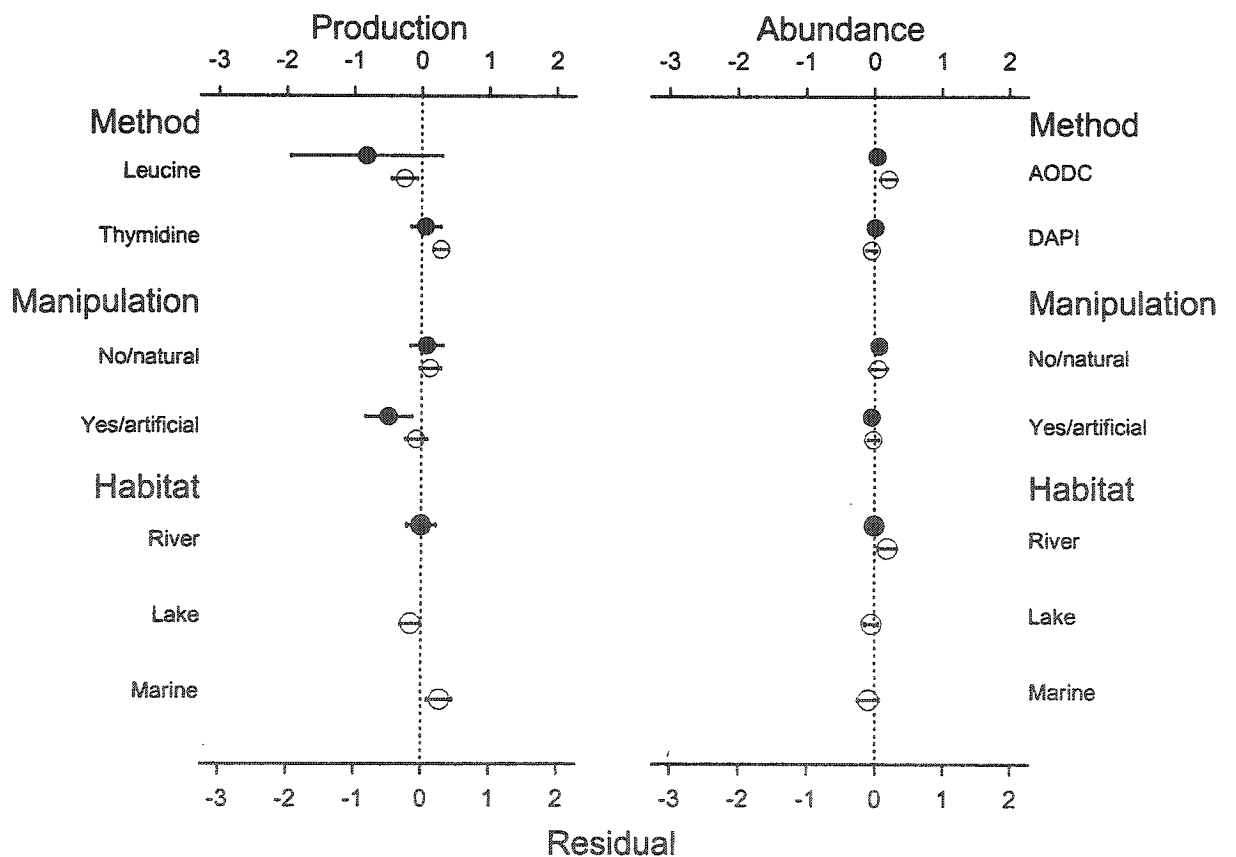
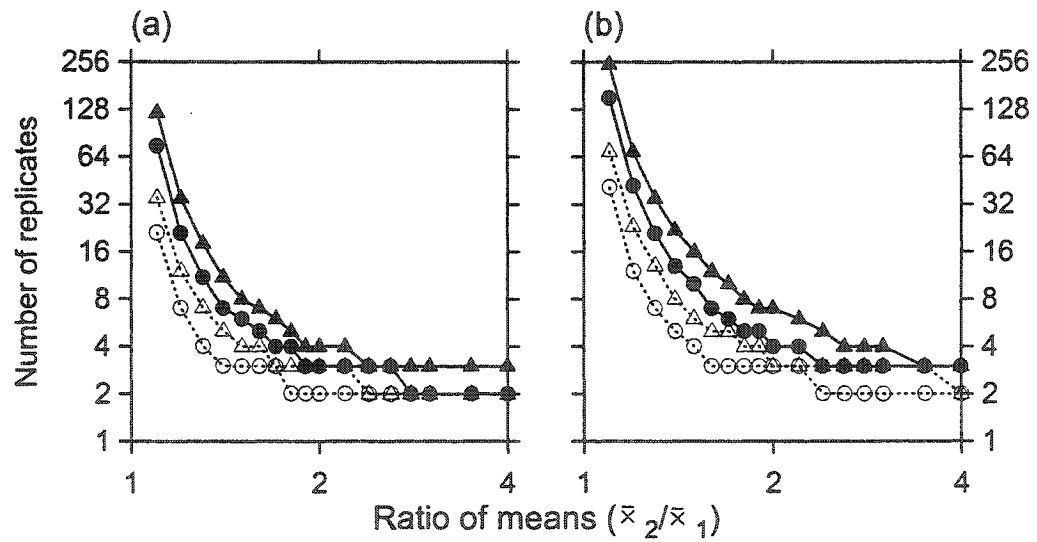


Figure 2.4. Number of replicates required per sample to detect predetermined differences between means with a power of (a) 50% and (b) 80% for planktonic (open symbols) and benthic (solid symbols) bacterial abundance (circles) and production (triangles). The denominator in the ratio of means, $\bar{x}_1$, was set as the median of all published observations for each measure (Table 2.1). Note scale of x - and y -axes to maximize separation among points. Between $\bar{x}_2/\bar{x}_1 = 1$ and 2, number of replicates was evaluated for increments of 0.1.



Chapter 3: Bacteria and algae in stream periphyton along a nutrient gradient

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Abstract

Stream riffles in southern Ontario and western Québec were sampled for biomass (58 stations from 51 streams) and production (22 stations from 21 streams) of algae and bacteria in periphyton to test the hypothesis that bacteria in benthic biofilms compete with algae for nutrients. Algae and bacteria were, in general, positively correlated. The ratio of algal to bacterial biomass did not vary with nutrients whereas algal production tended to increase with nutrients more rapidly than bacterial production. Algal production and biomass were most strongly correlated to instream nitrogen concentrations, which explained 38-58% of the variability in biomass and production. Bacterial abundance explained an additional 9 – 29% of the residual variance in algal production and biomass, once nutrients were taken into account. However, the sign of the relationship between bacterial abundance and algal production and biomass, once nutrients were taken into account, was positive, which is opposite to what would be predicted under a competition scenario. Thus, we rejected our hypothesis that bacteria in biofilms compete with algae for nutrients. Instead, our data suggested that bacteria and algae in biofilms coexist in an association that offers space and resources to sustain production of both groups of organisms.

Introduction

Empirical models that predict periphyton biomass in rivers from instream nutrient concentrations have yielded consistent but weak relationships that generally explain little more than half of the variability in chlorophyll *a* over broad geographic regions (e.g., Chapter 1; Dodds et al. 2002). Similar chlorophyll-nutrient models for phytoplankton in lakes account for a higher proportion of natural variability and typically explain 70-90% of the variance in chlorophyll *a* (Currie 1990). Factors such as high spatial variability, light availability, and grazing by benthic invertebrates have often been cited as reasons behind the weaker relationships for river periphyton, but attempts to include these variables in empirical models have been inconsistent in terms of improved predictions.

Epilithic periphyton in rivers is really a biofilm community composed primarily of algae and bacteria embedded in a polysaccharide matrix (Lock et al. 1984). Early research on benthic biofilms demonstrated that biofilm bacterial production was coupled to algal production as a result of organic compounds excreted during photosynthesis and after algal cell death (Haack and McFeters 1982a, b). The view that bacterial production is directly coupled to algal production has remained dominant in the literature to the present day (Rier and Stevenson 2001, Niyogi et al. 2003) despite the fact that some studies have shown little or no relationship between bacterial and algal biomass and production (Jones and Lock 1993, Findlay et al. 1993, Sobczak and Burton 1996).

Bacterial abundance and production may, in fact, be limited by inorganic nutrient availability rather than by availability of dissolved organic carbon excreted by algae. And, if bacteria are nutrient-limited, they might compete with algae for inorganic nutrients. Mohamed et al. (1998) demonstrated phosphorus-limitation for bacteria in

biofilms from the Fraser River, British Columbia. Currie et al. (1986) showed that planktonic bacteria in lakes were responsible for most of the uptake of inorganic phosphorus at low nutrient concentrations. However, Currie (1990) also demonstrated for plankton in lake systems that bacteria were positively correlated to the residuals of phosphorus-chlorophyll regression models, which is opposite to what would be expected if bacteria simply competed with algae for inorganic nutrients.

Rier and Stevenson (2001) evaluated the relationship between bacteria and algae in periphyton and instream nutrient concentrations with path analysis and concluded that bacteria were most likely to be dependent on algae for production, rather than nutrients in the water column. Niyogi et al. (2003) also used path analysis to evaluate periphytic algal-bacterial relationships in acid-stressed systems and similarly concluded that bacteria were more strongly correlated to algae than external water chemistry variables. However, Currie (1990) evaluated 7 different possible path models to describe the relationship between planktonic algae, bacteria, and nutrients in lakes, and speculated that the positive relationship between algae and bacteria in planktonic systems was probably the result of a mutualistic relationship, rather than simply a dependence relationship, where additional external factors also limit bacterial production. Rier and Stevenson (2002) experimentally manipulated nutrient and organic carbon conditions and speculated that positive associations between bacteria and algae in biofilms were the result of a co-dependence between the two for space rather than competition or simple dependence. The possibility of a mutual dependence, rather than simply a competitive or direct dependence relationship, between algae and bacteria has not yet been evaluated for stream periphyton along a nutrient gradient.

In this study, we test the hypothesis that bacteria compete with algae for nutrients in river periphyton. We predict that estimates of bacterial abundance will be negatively correlated to the residuals of algal production – nutrient regression models. Assuming that algal biomass and production are positively correlated, then we also predict that bacterial abundance will be negatively correlated to algal abundance, once nutrient effects are taken into account. In addition, we quantify how the relationship between algae and bacteria varies along a nutrient gradient for both biomass and production and evaluate the most likely relationships between algae, bacteria and nutrients in stream periphyton.

Methods

Fifty-eight stations located on 51 rivers and streams in southern Ontario and western Québec were chosen for sampling. Twenty-three stations located in the National Capital Region (NCR) and corresponding to City of Ottawa water quality monitoring stations were sampled for periphyton chlorophyll *a*, bacterial abundance, and ash free dry mass (AFDM) from July 11 – 19, 2001. An additional 30 stations, located in the Waterloo region, west of Toronto, and corresponding to Ontario Ministry of the Environment water quality monitoring stations were sampled for the same parameters from August 7 – 12, 2001. Eighteen City of Ottawa monitoring stations plus 4 additional NCR stations located in western Québec were sampled from August 6 – 11, 2002, for chlorophyll *a*, bacterial abundance, AFDM and algal and bacterial production (Figure 3.1).

At each station, 6 replicate rocks that ranged in size from 30 – 260 cm² were chosen haphazardly from the stream bottom, in riffle-run zones, and immediately

transferred into separate whirlpak bags, each filled with a known volume of ethanol, and placed in a cooler in the dark until return to the lab for analysis of chlorophyll *a*. An additional three samples were collected at each station for ash-free dry mass, by removing a known area of periphyton from the surface of each rock with a scalpel and storing this in a test tube filled with 10 ml of river water, on ice, until return to the lab. Three replicate samples were also collected for determination of bacterial abundance by removing a known area of periphyton from a rock with a scalpel and placing this in a test tube filled with river water. Upon return to the lab and usually within less than 6 hours, the samples were processed and stored appropriately. Samples for chlorophyll were stored at 4 °C for a 24-hour extraction in ethanol. Samples for ash-free dry mass were frozen until later processing. Samples for bacterial abundance were preserved in a final concentration of 1-2% glutaraldehyde or 1% Lugol's solution and stored at 4 °C until counting.

Chlorophyll *a*, following a 24-h extraction in 95% ethanol, was determined spectrophotometrically according to methods described by Ostrofsky and Rigler (1987). Samples for AFDM were thawed, filtered onto glass fibre filters (GF/C, equivalent pore size = 1.2µm), dried to constant mass at 105 °C, then combusted at 550 °C for 1 hour. AFDM was calculated as the difference in weights between dried and combusted filters, standardized to the area of rock scraped.

Bacteria were stained with DAPI and enumerated on an epifluorescent microscope according to methods described by Porter and Feig (1980). Samples were shaken, subsampled, diluted with water, sodium thiosulphate (in the case of samples preserved in Lugol's only), and sodium pyrophosphate, and sonicated for 5 minutes to

disperse bacteria in the sample (Velji and Albright 1993). Samples were then stained with DAPI (Sigma Chemicals D8417) for 5 minutes in the dark and examined in oil-immersion at $1250\times$ magnification under an Leitz Ortholux II Epifluorescence microscope equipped with a broad band pass filter block with excitation from 340-380 nm and suppression at 430 nm. A minimum of 10 fields and 200 cells were counted for each sample.

Production of bacteria and algae was measured on stones collected from 22 stations in the NCR from August 6 – 11, 2002. Stations were visited in the mornings and small cobbles (surface area range from 10 – 100 cm²) were haphazardly chosen from each station and kept in river water in the dark until return to the laboratory where production measurements were made (usually within 1-2 hours of collection).

Bacterial production in biofilms was measured in the laboratory with ³H-thymidine (³H-TdR) following methods modified from Findlay (1993) and Hudson et al. (1990). Rate of incorporation of thymidine into bacterial DNA was measured by incubating five replicate rocks (4 live and 1 killed control) per station for 1 hour in small whirlpak bags containing 30 mL river water and 1.5 MBq of ³H-TdR (Sigma T4938, 0.925 MBq/nmol). Samples were incubated in the dark, at ~21 °C (*in situ* stream water temperatures ranged from 11 to 27.5 °C). Controls were killed with 10% formalin at the outset of the incubation and the same was used to stop incubation of live samples after one hour. Rocks were rinsed twice with formalin and then frozen in their incubation bags until later processing, which occurred within 6 weeks of sampling. Upon processing, DNA on rocks was extracted with 0.3N NaOH, 0.1% SDS, and 25 mM EDTA for 18 hours under continuously mixed conditions at 21 °C. Rocks were removed from the bags

and wrapped in aluminum foil, which was then used to determine surface area by gravimetric methods. The remaining DNA extract was cooled on ice and neutralized with 1 ml 3N HCl. DNA and protein matter were then precipitated by acidification with 2ml cold 50% TCA. After ~30 minutes on ice, samples were filtered through 0.2 μ m nitrocellulose membrane filters. The filters were transferred to test tubes, filled with 10% TCA, and heated at 95 °C for 30 minutes to hydrolyse DNA. The tubes were then centrifuged for 5 minutes and the supernatant assayed for radioactivity. The rate of incorporation of thymidine into DNA was standardized to total rock area and calculated as a daily rate by assuming constant production over 24 hours.

Algal production was measured in the laboratory with sodium ^{14}C -bicarbonate following methods outlined by Findlay et al. (1993). Seven replicate rocks (five light samples and two dark controls) for algal production were transferred to plastic bags filled with 100 ml of river water and ~0.18 MBq ^{14}C - NaHCO_3 , and incubated for two hours at ~21 °C. Total activity added to the stream water was measured at the outset of incubation and dissolved inorganic carbon concentration was measured for a sample of water from each stream. Incubations were conducted indoors, with the light replicates under a fluorescent light box, where photosynthetically active radiation (PAR) was approximately 2% of outdoor, incident PAR. Dark controls were incubated under the same laboratory conditions in the absence of light. Incubations were stopped by washing the rocks with stream water and freezing the rocks in their incubation bags, until processing, which occurred within 6 weeks of sampling. Upon processing, the biofilm was scraped from the rocks with a scalpel and collected on a Gelman GN-6 filter (pore size: 0.45 μ m). The filter was acidified, dissolved in ethylene glycol monomethylether, placed in scintillation

fluor, and then assayed for ^{14}C radioactivity. Radioactivity was standardized to rock area, which was determined in the same manner as for bacterial production. Primary production on the rocks was determined based on the total available ^{14}C relative to assimilated ^{14}C and total available dissolved inorganic carbon, according to the methods outlined in Wetzel and Likens (2000). Algal production measured at one station was negative after correcting for dark-uptake of ^{14}C and so we elected to remove this station from our analysis.

To compare biomass and production of algae and bacteria in benthic biofilms, all biotic measures of the biofilm were expressed as carbon standing stock (mg C m^{-2}) or production rates ($\text{mg C m}^{-2} \text{ d}^{-1}$). Epilithic chlorophyll *a* was converted to algal carbon standing stock by assuming the ratio of carbon to chlorophyll = 27 (Gosselain et al. 2000). Bacterial abundance was converted to bacterial carbon biomass by assuming the carbon content per cell = 20 fg (20×10^{-15} g; Whitman et al. 1998). Bacterial production, measured as the rate of incorporation of thymidine into DNA, was converted to rate of production of carbon using a conversion factor of $0.544 \text{ mg C nmol TdR}^{-1}$ (Coveney and Wetzel 1995). The technique used here to quantify algal production directly measured carbon incorporation and so no conversion was necessary. Daily algal production was estimated by assuming a 14-hour light period for the NCR in August 2001. Daily bacterial production was estimated assuming constant production throughout a 24-hour day.

Water quality data were obtained from the Ontario Ministry of Environment (30 stations in 2001, west of Toronto) and from the City of Ottawa (23 stations in 2001, 18 stations in 2002). Samples were collected monthly by all agencies during the ice-free

period. We sampled data for the 4 Québec stations located within the NCR monthly and samples were analysed at the City of Ottawa lab using the same protocols as for the regular city samples. We retrieved data for phosphorus (total [TP], reactive [RP]), nitrogen (nitrate+nitrite [NO_2+NO_3], ammonia [NH_3], total kjeldahl [TKN]), pH, alkalinity, conductivity, and total suspended solids (TSS). Dissolved organic carbon (DOC) was measured at all NCR stations and one Ministry of Environment station. RP, NH_3 , and TSS were not measured at the 4 Québec stations. Analytical protocols followed standard methods set out by the American Public Health Association (1998). Total N (TN) was determined by summing NO_2+NO_3 and TKN. Mean summer water quality conditions were determined for each station by averaging May-August measurements.

Data were analysed with SYSTAT (version 10, Systat Software Inc., Richmond, Calif., <http://www.systat.com>). Logarithmic transformations were applied when necessary to meet parametric assumptions of normality and homogeneity of variances. Correlations matrices and regression analysis were used to quantify relationships between the bacterial and algal communities and water quality.

Path analysis was used to test the following hypotheses about the relationships between nutrients, algae and bacteria: 1) Nutrients limit algal biomass, which, in turn, limits bacterial biomass, 2) Nutrients limit both algal and bacterial biomass, and bacterial biomass limits algal biomass, 3) Nutrients limit both algal and bacterial biomass, and algae and bacteria co-vary after accounting for nutrients. Principal components analysis was used to reduce phosphorus and nitrogen variables into one single “nutrient” component that was subsequently used in path analysis to evaluate the most likely relationships between algae, bacteria, and nutrients.

Results

The streams in the study were, for the most part, mesotrophic with respect to epilithic chlorophyll *a* and total P and N, according to the classification scheme proposed by Dodds et al. (1998) (Figure 3.2). There were some differences in water quality among regions and years, most notably that all forms of N were significantly higher at stations in the Waterloo region than at stations in the NCR in either 2001 or 2002. TP did not differ among the 3 groups of stations ($P = 0.24$; ANOVA). P and N variables were significantly and positively correlated ($0.48 \leq \text{Pearson's } r \leq 0.89$; $P < 0.001$) and a principal component analysis of TP, TN and $\text{NO}_2 + \text{NO}_3$ yielded one 'nutrient' component that explained 76% of the variability in the nutrients variables. This nutrient component was subsequently used in path models as a surrogate for the three nutrient variables.

Mean benthic chlorophyll *a* ranged from 4 to 214 mg m^{-2} across regions and years and samples collected in 2002 had significantly less chlorophyll than samples collected in 2001 (Table 3.1). Bacterial abundance spanned approximately 2.5 orders of magnitude, from 4.8×10^6 to $1.2 \times 10^9 \text{ cells cm}^{-2}$ and was lowest in the NCR in 2002 and highest in Waterloo in 2001, although differences among regions and years were not significant. AFDM was significantly higher in the Waterloo region compared to the two groups of NCR stations. Bacterial carbon was between 0.3 and 17 % and averaged 2 % of the carbon mass of algae. Assuming 50% of AFDM is organic carbon (Cole et al. 1988), algal carbon was approximately 10% of the biofilm carbon and bacterial carbon was <1% of the biofilm carbon. Bacterial production was generally less than the empirically estimated algal production and made up between 5 and 167 %, averaging 38 % of algal production.

Bacterial and algal carbon standing stocks were positively correlated in the entire data set and in the reduced data set from 2002 (Table 3.2). Measured algal production was positively correlated to both algal and bacterial carbon standing stocks and weakly correlated to bacterial carbon production. Bacterial production was not significantly correlated to either algal or bacterial biomass, although the sign of both correlations was positive.

Preliminary examination of laboratory results revealed that algal production estimates were low ($0.35 - 36.5 \text{ mg C m}^{-2} \text{ d}^{-1}$) in comparison to values reported in the published literature ($0.6 - 2510 \text{ mg C m}^{-2} \text{ d}^{-1}$, Morin and Cattaneo 1992). We attributed the low production estimates to experimental conditions where light levels in the laboratory were $\sim 1 - 2 \%$ incident PAR (measured at peak daylight in the absence of cloud cover) and much below typical saturation light levels for periphyton ($\sim 20 - 30 \%$ PAR, Boston and Hill 1991, Dodds et al. 1999). However, the patterns observed in the measured algal production were consistent with expectations: that is, production was well correlated to chlorophyll *a* (Pearson's $r = 0.85$, $P < 0.001$) and slightly less well correlated to AFDM (Pearson's $r = 0.65$, $P = 0.001$). As such, we elected to include the measured algal production values in our analyses in situations where the pattern of the relationships (e.g. production versus water quality) was important but the magnitude of production values was not critical. In situations where we wished to compare magnitude of carbon production rates among algal and bacterial populations, or production rates to standing stock, we estimated algal production from chlorophyll *a* concentration based on an empirical model developed by Morin et al. (1999), such that:

$$\log_{10}(\text{algal production, mg C m}^{-2} \text{ d}^{-1}) = 1.23 + 0.79 * \log_{10}(\text{chlorophyll } a, \text{ mg m}^{-2}).$$

Biomass and production of bacteria and algae in the biofilms studied here increased with increasing nutrient concentrations (Figure 3.3). The relationships were strongest for nitrogen concentrations (total or $\text{NO}_2 + \text{NO}_3$) but the same trends were also evident with total phosphorus (Table 3.3). The relationship between bacterial production and nutrients was weak, but the trend with respect to nutrients was the same as for other measures. There was no change in the ratio of algal to bacterial biomass with nutrient concentrations, but the ratio of algal to bacterial production increased significantly with nitrogen and phosphorus concentrations, such that algal production, relative to bacterial production, was higher at higher nutrient concentrations (Figure 3.4). Algal production, estimated empirically from chlorophyll *a*, was consistently greater than bacterial production (production ratio > 1), with the exception of two stations where bacterial production was greater than algal production (Figure 3.3).

Total nitrogen was the best predictor of algal production (laboratory measurements), explaining 52% of the variability in production (Table 3.4). Once the effects of nutrients were taken into account for both algal production and bacterial biomass, there was a weak positive relationship algal production and bacterial biomass. As such, the inclusion of bacterial abundance in regression models for algal production yielded modest improvements in the amount of variability explained (60% for the combination of total N and bacterial abundance).

The best nutrient predictor of chlorophyll *a* was $\text{NO}_2 + \text{NO}_3$, which explained 38% of the variability in chlorophyll *a* (Table 3.4). A quadratic relationship between residuals of the bacterial biomass - $\text{NO}_2 + \text{NO}_3$ relationship and residuals of chlorophyll-nutrient models was evident, after taking into account correlations to nutrients (Figure 3.5). Thus,

the best model for chlorophyll *a* included NO₂+NO₃ and linear and quadratic terms for bacterial abundance, and these models explained 66% of the variation in chlorophyll *a* from streams in southern Ontario and western Québec (Table 3.4). Similar results were obtained between the entire data set and only the 2002 data, except that correlations for 2002 were stronger and nutrients and bacteria were better predictors of chlorophyll *a* (Table 3.4).

Path analysis supported the first hypothesis that nutrients limit algae, which in turn limits bacteria: significant positive correlations between nutrients and algae, and between algae and bacteria, were detected (Figure 3.6a). The second hypothesis that algae and bacteria were limited by nutrients and that bacteria subsequently influenced algae was partially supported: path analysis revealed significant correlations for all possible paths examined in this model, but the sign of the relationship between algae and bacteria was positive and not negative, as we would have expected (Figure 3.6b). Finally, our third hypothesis that algae and bacteria co-vary after taking nutrients into account was also supported by significant positive correlations between nutrients and algae and bacteria and between the residuals of algae and bacteria after taking nutrients into account (Figure 3.6c).

Discussion

The primary objective of this study was to test the hypothesis that bacteria in benthic biofilms compete with algae for nutrients in river periphyton. We predicted that competition for nutrients would yield a negative relationship between algal production and bacterial abundance in biofilms, after statistically accounting for the positive effect of nutrients on both groups. Given that algal production and biomass are positively

correlated (Table 3.2, Morin et al. 1999), we also predicted that a negative relationship between algal biomass and bacterial abundance would be detected. Our results showed that bacterial abundance was significantly correlated to algal production and algal biomass and explained an additional 8 – 29 % of residual variation. However, contrary to our predictions, the sign of the relationship was positive: chlorophyll *a* tended to increase with increasing bacterial abundance, rather than decrease. Path analysis of abundance and nutrient data revealed a similar observation: the relationship between algae and bacteria was positive and not negative.

Currie (1990) reported similar observations to ours in his empirical study of lake phyto- and bacterioplankton and postulated that the positive correlation was the result of a mutually beneficial relationship between algae and bacteria rather than a competitive relationship. Furthermore, Currie (1990) proposed that estimates of bacterial activity were more strongly correlated to chlorophyll *a* concentrations in lake plankton than estimates of bacterial abundance. Our data did not support this second assertion as bacterial production was neither correlated to chlorophyll *a* (Pearson's $r = 0.32$, $P = 0.15$) nor was it a significant predictor of chlorophyll *a* in regression models with nutrients. Rier and Stevenson (2002) also found a positive association between algal and bacterial biomass under experimentally manipulated nutrient, organic carbon, and light conditions in an oligotrophic stream in Kentucky and could find no support for the hypothesis that algae and bacteria competed for nutrients in biofilms.

Associations between algae and bacteria in river biofilms have not consistently been detected. Jones and Lock (1993) reported a correlation between bacterial and algal communities in a well-lit oligotrophic river, but the correlation was not as strong in a

eutrophic river. Findlay et al. (1993) did not detect strong correlations between algal and bacterial productivity in two streams of the Hubbard Brook Experimental Forest and Sobczak and Burton (1996) found no correlation between bacterial biomass and chlorophyll *a* in a third-order Michigan stream. Finally, the correlation between biomass of algae and bacteria that was detected by Rier and Stevenson (2001) was only evident when algal biomass was high ($>50 \text{ mg chl } a \text{ m}^{-2}$).

DOC in the water column has often been considered a factor likely to limit bacterial growth in biofilms and has sometimes been used to explain the failure to detect a correlation between algae and bacteria (Sobczak and Burton 1996, Findlay et al. 1993). However, the study by Rier and Stevenson (2001) found no link between water column DOC and bacterial abundance. DOC, as glucose, was not sufficient to elicit an increase in bacterial biomass in nutrient diffusing substrata experiments: only the combination of DOC and nutrients yielded increased bacterial biomass (Rier and Stevenson 2002). DOC collected in 2002 as part of this study was correlated to neither bacterial abundance nor production ($|\text{Pearson's } r| < 0.1, P > 0.70$).

Bacteria in biofilms have been shown to be very flexible with respect to the sources upon which they rely for organic carbon. As such, bacteria in biofilms are able to consume organic matter from algal exudates and lysed algal cellular products (Haack and McFeters 1982a, b, Coveney and Wetzel 1989) and this fact is often used to explain positive correlations between algae and bacteria (Rier and Stevenson 2001, Romani and Sabater 1999). Bacteria have also been shown to respond in terms of abundance and/or production to organic carbon additions to the water column (Kaplan and Bott 1989) and this response has often been used to explain a lack of correlation between algae and

bacteria (Findlay et al. 1993). Finally, Freeman and Lock (1995) showed that bacteria were able to use the polysaccharide matrix and any adsorbed organic matter as a carbon source under situations where organic carbon in the water column was heavily depleted. Thus, biofilm bacteria appear to be able to adapt to any organic carbon supply scenario and it seems unlikely that organic carbon in the water column is the true reason behind a lack of correlation between algae and bacteria.

Rier and Stevenson (2002) also documented a positive correlation between algal and bacterial biomass under varying light, nutrient, and organic carbon conditions. The authors suggested the correlation might be the result of bacterial reliance on algae for resources or the result of a reliance of both algae and bacteria on the associated polysaccharide matrix in low-resource conditions (Rier and Stevenson 2002). In our study, microscopic enumeration of bacterial cells in the periphyton revealed that many bacterial cells were directly adhered to algal cells, even after cells in the periphyton were dispersed by the addition of sodium pyrophosphate and subsequent sonication (G. Carr, personal observation). Furthermore, algal and bacterial biomass increased with nutrients at equal rates (i.e., the ratio of algal to bacterial biomass did not vary along a nutrient gradient). These two observations would seem to support the possibility that bacteria were directly dependent on algae for resources. However, the possibility of a separate factor, such as hydrologic regime or invertebrate grazing, limiting production and, hence, biomass of both algae and bacteria, cannot be discounted in our study.

Bacterial production in this study changed very little, compared to algal production that increased linearly, with increasing N or P in the water column. Our results suggest that bacteria rely on an alternative source of inorganic nutrients for

production. Rier and Stevenson (2002) proposed that bacteria might rely on the polysaccharide matrix as a source of inorganic nutrients, particularly when water column nutrients are scarce. In this study, algae within the biofilm made up an average of approximately 10% of the organic carbon contained within benthic biofilms and bacteria consisted of less than 1% of the total organic carbon. The remaining ~90% of biofilm carbon, then, must consist of extracellular polysaccharides and detrital matter that is adhered to the biofilms. Couch and Meyers (1992) estimated for epixylic biofilms (i.e., biofilms attached to wood substrata) that 9 times more carbon was in extracellular polysaccharides than in biofilm bacteria and Geesey et al. (1978) reported that carbohydrates contributed nearly 10 times more carbon than epilithic algae. Given that bacteria are efficient at relying on the polysaccharide matrix for DOC to sustain production (Freeman and Lock 1995), and also that the matrix is a nutrient rich substance (Couch et al. 1996), we think it is likely that bacteria are able to compensate for changes in algal production by relying on the polysaccharide matrix when algal products are limiting.

Morin et al. (2001) showed that in some eutrophic systems, invertebrate grazing rates were higher than primary production, leading to the speculation that heterotrophic production supplemented the diets of grazers in eutrophic environments. Our data did not support this hypothesis: bacterial production, relative to algal production, was proportionately higher in low nutrient environments than in high nutrient environments. If bacterial production supplemented invertebrate diets in high nutrient environments, we would have expected to observe the opposite trend.

The use of path analysis to quantify relationships between algae and bacteria in benthic biofilms is attractive because it purports to elucidate the mechanism behind observed correlations. However, it is critical that all possible relationships be evaluated in path models. If we had chosen to test only the hypothesis that bacteria are dependent on algae and indirectly dependent on nutrient concentrations, we would have observed results that are very similar to those of Rier and Stevenson (2001, Figure 3.6a). However, our data equally supported the alternative hypothesis of a covariance between algae and bacteria biomass once nutrient effects were taken into account (Figure 3.6c). The covariance between algae and bacteria is probably the result of another variable that is independent of nutrients but that was not measured in this study (e.g., hydrologic regime, invertebrate grazing). Our observations are consistent with those of Currie (1990), who used several empirical data sets to evaluate multiple path models for planktonic algae and bacteria in lakes, and showed that the most complex path models were the most likely to be true for plankton in lakes. We suspect that examination of all possible path relationships in the studies of Rier and Stevenson (2001) and Niyogi et al. (2003) might have showed relationships that were similar to ours: that is, that covariance between algae and bacteria was stronger than correlations to nutrients. Although we do not contend that the path models of Rier and Stevenson (2001) and Niyogi et al. (2003) are incorrect, per se, we echo concerns of Shipley (1997) and caution instead that alternative path models may yield results that support alternative theories as well as the presented path models support current theories. Furthermore, because path analysis is based explicitly on linear correlations, its application and optimization is difficult in

situations where non-linear relationships are present, as was the case in this study between algal biomass and bacterial abundance.

In summary, bacterial abundance explained a significant component of the residual variance in stream periphyton algal production and chlorophyll-nutrient models. However, the direction of the relationship was positive, refuting our hypothesis that bacteria and algae in biofilms compete for resources. Instead, our data suggest that bacteria and algae in biofilms generally coexist in a mutually dependent association that offers space and resources to sustain growth in both groups of organisms. These data support the findings of the recent study of Rier and Stevenson (2002) for benthic biofilms and the study by Currie (1990) for planktonic bacterial-algal associations.

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Table 3.1. Summary statistics (mean $\pm$ 1 SE; range) of biotic variables measured in 2001 and 2002, separated according to region and year (Waterloo 2001, National Capital Region [NCR] 2001, NCR 2002). Measured algal production values are based on only 21 stations and correspond to laboratory measurements. Estimated algal production values (22 stations from 2002) were based on the empirical relationship to chlorophyll *a* described by Morin et al. (1999).

	Waterloo 2001 (n=30)		NCR 2001 (n=23)		NCR 2002 (n=22)	
	mean $\pm$ 1 SE	range	mean $\pm$ 1 SE	range	mean $\pm$ 1 SE	range
Benthic chlorophyll (mg chl <i>a</i> m ⁻²)	105 $\pm$ 8	42.7 – 214	87.3 $\pm$ 9.7	16.7 – 175	64.1 $\pm$ 9.0	4.2 – 146
Algal biomass (mg C m ⁻²)	2845 $\pm$ 206	1152 – 5782	2358 $\pm$ 263	451 – 4724	1731 $\pm$ 244	113 – 3951
Bacterial abundance ($\times 10^8$ cells cm ⁻²)	3.58 $\pm$ 0.45	0.49 – 11.8	2.56 $\pm$ 0.48	0.76 – 12.2	1.04 $\pm$ 0.18	0.05 – 3.06
Bacterial biomass (mg C m ⁻²)	71.5 $\pm$ 9.1	9.73 – 237	51.2 $\pm$ 9.7	15.2 – 244	20.7 $\pm$ 3.5	0.97 – 61.2
AFDM (mg m ²)	59.1 $\pm$ 7.5	13.2 – 186	26.3 $\pm$ 4.1	9.9 – 106	29.1 $\pm$ 4.0	0.99 – 69.8
Algal production measured (mg C m ⁻² d ⁻¹)					8.35 $\pm$ 1.88	0.35 – 36.6
Algal production estimated (mg C m ⁻² d ⁻¹)					435 $\pm$ 52	52.7 – 872
Bacterial production (mg C m ⁻² d ⁻¹)					109 $\pm$ 13	27.6 – 286

Table 3.2. Pearson correlation coefficients between algal and bacterial biomass (mg C m^{-2}) and production ($\text{mg C m}^{-2} \text{ d}^{-1}$) for all data and for the subset of data collected in 2002 from the NCR. All variables $\log_{10}$ transformed. Algal production data are from laboratory measurements. Correlations for the empirically derived algal production are the same as those for algal carbon standing stock, since both were estimated from chlorophyll *a* concentrations. Sample sizes (*n*) and probabilities indicated in brackets next to each correlation.

	Algal biomass	Bacterial biomass	Bacterial production
Entire data set (numbers of pairs in brackets)			
Bacterial biomass	0.674 (75, <0.001)		
Bacterial production	0.321 (22, 0.15)	0.234 (22, 0.29)	
Algal production (measured)	0.849 (21, <0.001)	0.716 (21, <0.001)	0.449 (21, 0.04)
NCR 2002 (<i>n</i> = 21)			
Bacterial biomass	0.819 (<0.001)		
Bacterial production	0.276 (0.23)	0.200 (0.38)	
Algal production (measured)	0.849 (<0.001)	0.716 (<0.001)	0.449 (0.04)

Table 3.3. Pearson correlation coefficients between nutrients and algal and bacterial biomass (mg C m^{-3}) and production ($\text{mg C m}^{-2} \text{d}^{-1}$) for all data and for the subset of data collected in 2002. All variables $\log_{10}$ transformed. Algal production correlations are based on data from laboratory measurements. Sample sizes (n) are as indicated except for algal production correlations, which are based on 21 observations.

	Total P (mg L^{-1})			Total N (mg L^{-1})			NO ₂ +NO ₃ (mg L^{-1})		
	r	P		r	P		r	P	
	All data ($n=75$)			2002 data ($n=22$)			All data ($n=75$)		
Algal biomass	0.39	<0.001	0.69	<0.001	0.57	<0.001	0.76	<0.001	0.76
Algal production			0.51	0.020		<0.001	0.62	<0.001	0.76
Bacterial biomass	0.34	0.003	0.63	0.002	0.48	<0.001	0.73	<0.001	0.63
Bacterial production			0.14	0.523		0.068	0.40	0.068	0.43
									0.047

Table 3.4. Summary of regression models relating benthic algal production (AP, mg C m⁻² day⁻¹) and biomass (as chlorophyll *a*, chl *a*, mg m⁻²) to nutrients (mg L⁻¹) and bacterial abundance (Bact, cells cm⁻²). Algal production relationships are based on measured production values. Models of algal biomass are shown for the entire data set and the reduced 2002 data set.

Model	Equation	r ²	RMS
Algal production (measured)			
<i>2002 data only (n = 21)</i>			
(1)	$\log_{10}(\text{AP}) = 0.63 + 1.06\log_{10}(\text{TN})$	0.521	0.108
(2)	$\log_{10}(\text{AP}) = -2.24 + 0.63\log_{10}(\text{TN}) + 0.34\log_{10}(\text{Bact})$	0.600	0.095
Algal biomass (chlorophyll <i>a</i>)			
<i>All data (n = 75)</i>			
(3)	$\log_{10}(\text{chl } a) = 1.90 + 0.25\log_{10}(\text{NO}_2 + \text{NO}_3)$	0.378	0.068
(4)	$\log_{10}(\text{chl } a) = -19.7 + 0.14\log_{10}(\text{NO}_2 + \text{NO}_3) + 5.05\log_{10}(\text{Bact}) - 0.29\log_{10}(\text{Bact})^2$	0.664	0.038
<i>2002 data only (n = 22)</i>			
(5)	$\log_{10}(\text{chl } a) = 1.88 + 0.42\log_{10}(\text{NO}_2 + \text{NO}_3)$	0.575	0.090
(6)	$\log_{10}(\text{chl } a) = -27.6 + 0.23\log_{10}(\text{NO}_2 + \text{NO}_3) + 7.24\log_{10}(\text{Bact}) - 0.44\log_{10}(\text{Bact})^2$	0.838	0.038

Figure 3.1. Distribution of sampling locations in 2001 and 2002. Waterloo region is bounded according to major drainage basins (Credit, Grand, Thames, Maitland). The National Capital Region is delineated by geo-political boundaries. Note differences in scales of two regions.

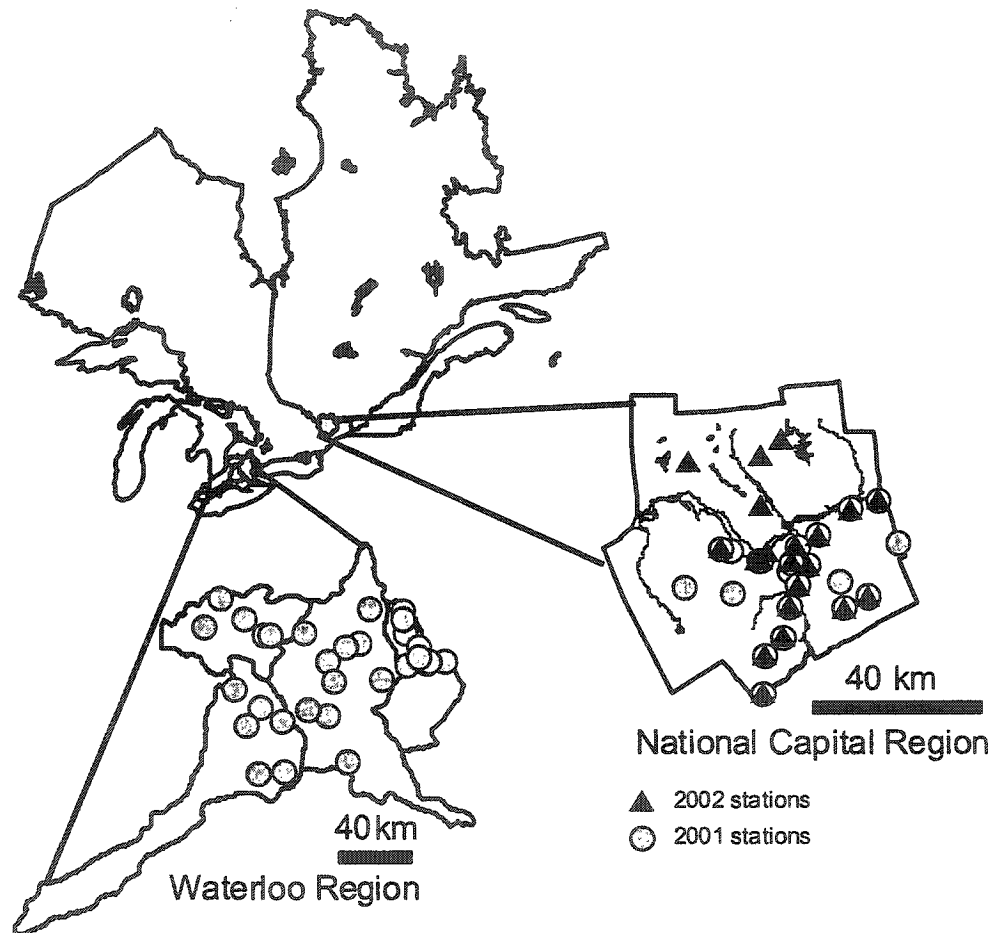


Figure 3.2. Box and whisker plots of nutrient concentrations (total P and N), periphyton chlorophyll *a*, and bacterial abundances separated according to sampling region and study year. 'NCR' corresponds to the National Capital Region and includes stations sampled in the Ottawa area and western Québec. Dashed lines represent oligo-mesotrophic (left dashes) and meso-eutrophic (right dashes) boundaries for TN, TP, and chlorophyll *a*, proposed by Dodds et al. (1998).

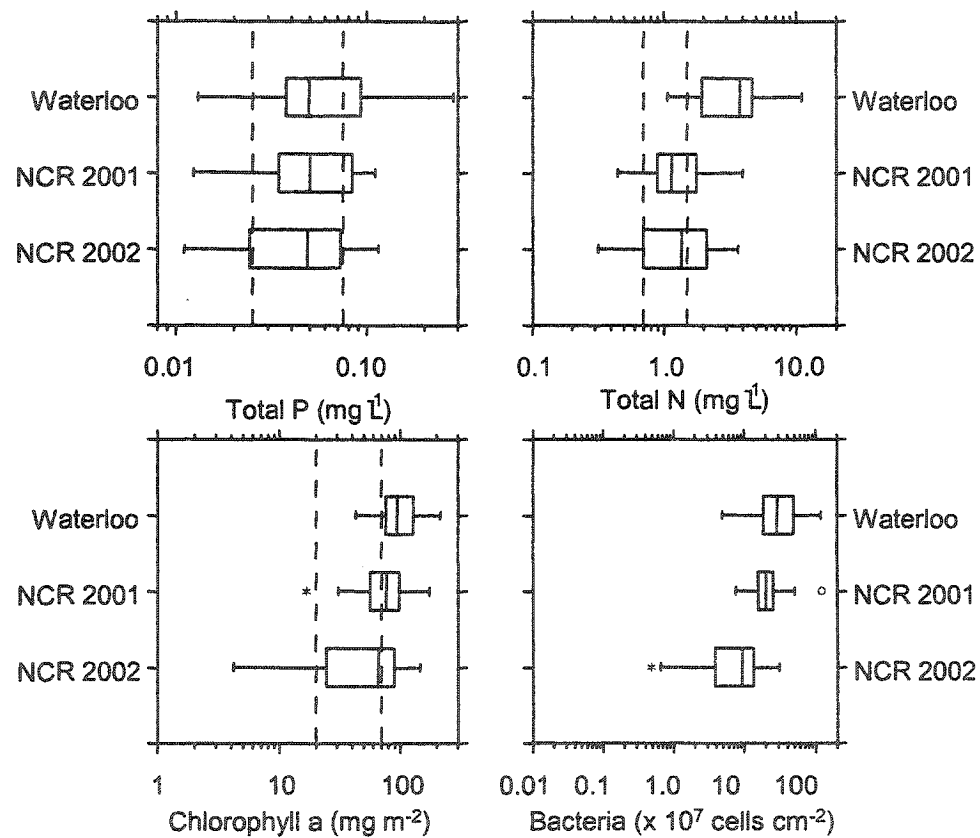


Figure 3.3. Relationship between algal (circles) and bacterial (triangles) biomass (top panels) and production (bottom panels) and total P (left panels) and N (right panels). Open and solid symbols correspond to data collected in 2001 and 2002, respectively. Solid and dashed lines are locally weighted regression curves (LOESS) for algae and bacteria, respectively, and based upon all data in each panel. Algal production was estimated empirically, based on chlorophyll *a*, according to the model of Morin et al. (1999).

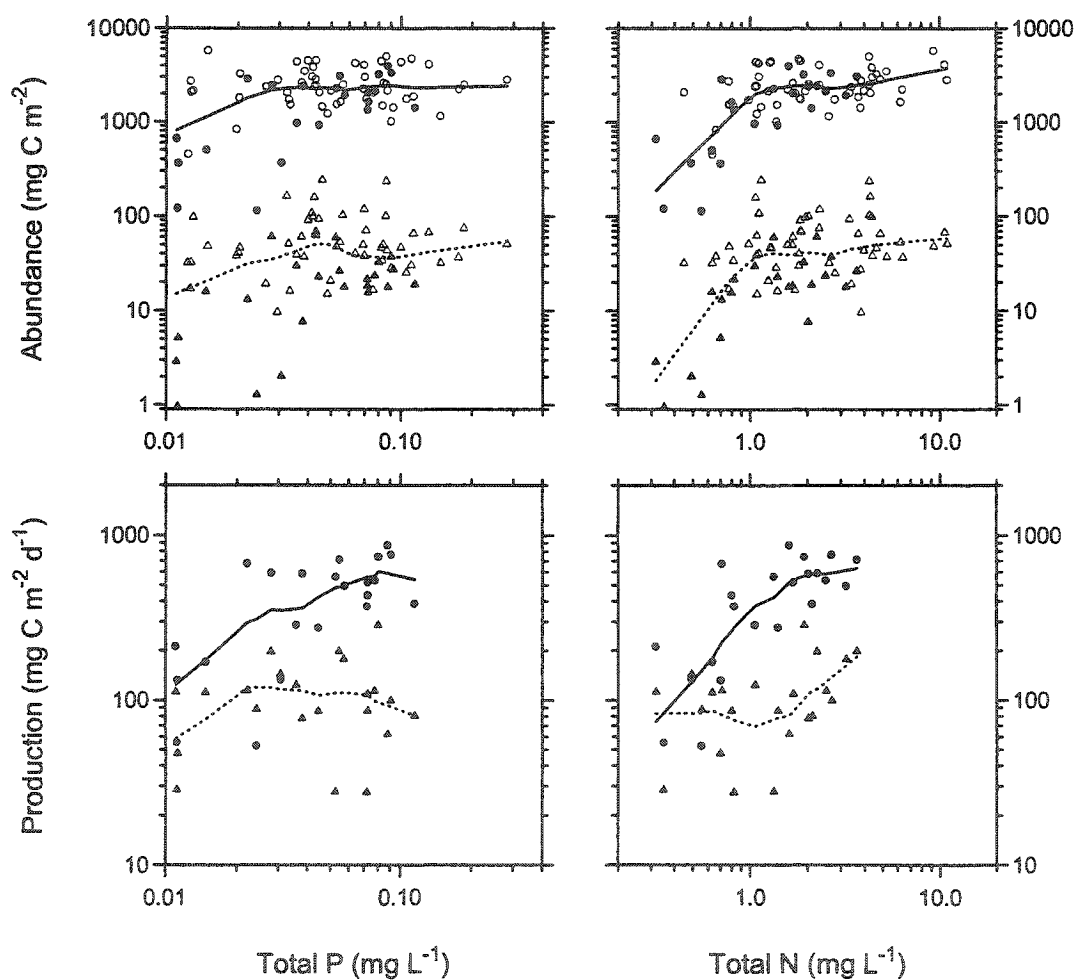


Figure 3.4. Relationship between ratios of algal:bacterial biomass (top panels) and production (bottom panels) with total P (left panels) and total N (right panels). Biomass ratios are based on the biomass expressed in carbon units for the two groups. Algal production was estimated empirically from chlorophyll *a* concentrations and production ratios are based on the daily carbon production for the two groups. Open and solid symbols correspond to data collected in 2001 and 2002, respectively. Fitted lines are linear correlations based on entire data sets. Only the correlations for production ratios are significant (Pearson's $r = 0.55, 0.43, P = 0.008, 0.045$ for TP, TN, respectively).

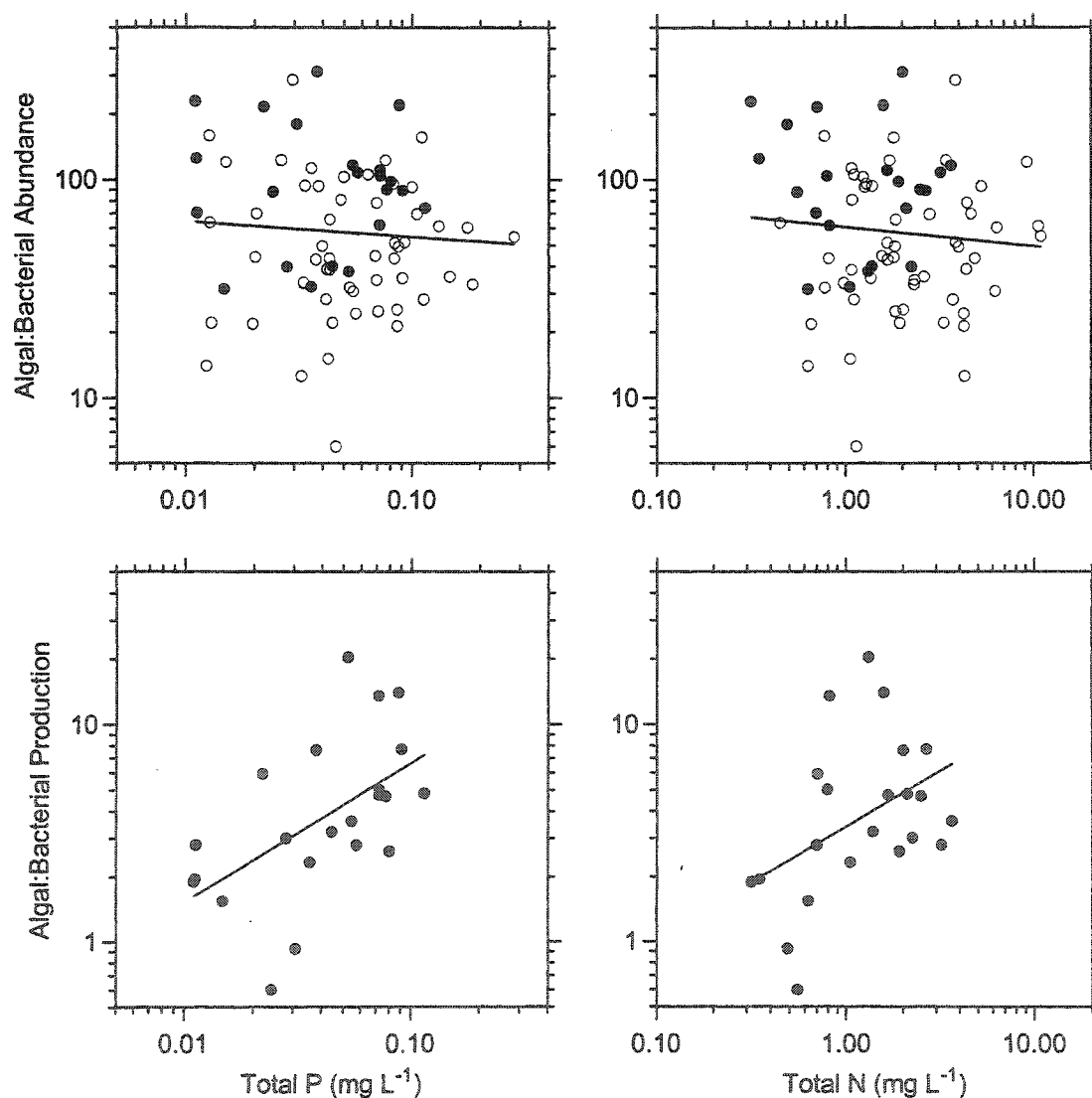


Figure 3.5. Relationship between residuals of algal production (AP) - total N (TN) regression and residuals of bacterial abundance (Bact) - TN regression (left panel) and between residuals of chlorophyll *a* (chl *a*) - NO₂+NO₃ regression and residuals of bacterial abundance - NO₂+NO₃ regression (right panel). Open and solid symbols correspond to 2001 and 2002 data, respectively. Fitted lines are locally weighted regression (LOESS) curves depicting relationships between residuals, and are fit to the entire data set. Units of abundance and production are the same as Table 3.1. All variables were log₁₀-transformed in regressions used to generate residuals.

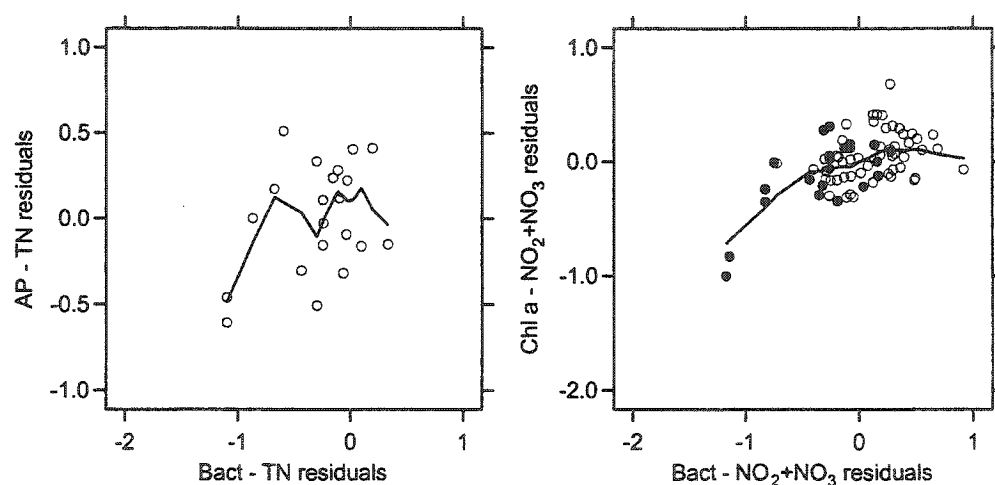
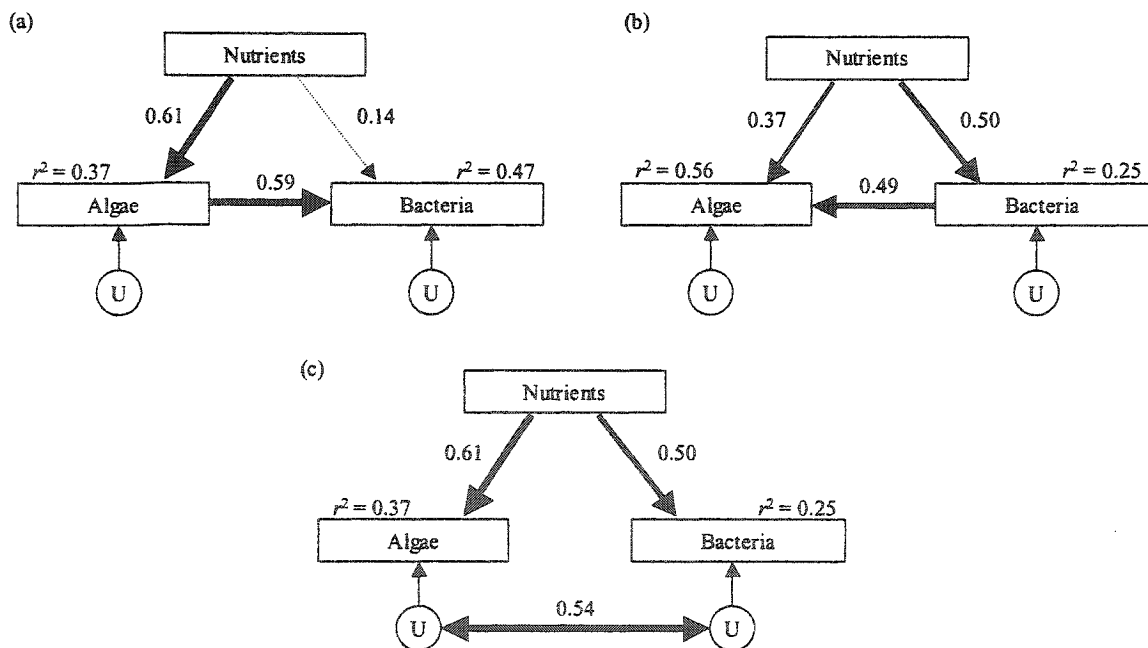


Figure 3.6. Path diagrams evaluating three possible models between nutrients (mg L^{-1}), algae (chlorophyll *a*, mg m^{-2}), and bacteria (abundance, cells cm^{-2}) with the entire data set. The ‘nutrients’ variable is the first factor from the principal components analysis of $\log_{10}(\text{TP})$, $\log_{10}(\text{TN})$, and $\log_{10}(\text{NO}_2 + \text{NO}_3)$. (a) Model 1: nutrients limit algae that, in turn, limit bacteria. (b) Model 2: nutrients limit both algae and bacteria and bacteria additionally limit algae through competition for nutrients. (c) Model 3: nutrients limit both algae and bacteria, and algae and bacteria co-vary after accounting for nutrients. Standardized partial regression coefficients are shown for causal relationships (single headed arrows). Relative width of each arrow indicates the strength of the interaction. Solid and dashed lines indicate significant and non-significant coefficients, respectively ($\alpha = 0.05$). Correlation coefficients are shown for covariance relationships. “U” represents the unknown or residual variance after taking into account causal relationships. Squared multiple correlations (r^2) for algae and bacteria indicate the variance explained by the path models for each variable.



Chapter 4: Prediction of periphyton in rivers: the more we look, the less we know?

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Abstract

A meta-analysis of 67 published models from the last 30 years that predict periphyton chlorophyll *a* in rivers was used to evaluate predictive power as a function of year of the study, geographic extent of the study area, and the type of predictor variables used. Model r^2 and residual mean square (RMS) values did not change over time, indicating no net improvement in our ability to predict periphyton chlorophyll *a* in rivers. Regression statistics (r^2 and RMS) did not differ among models that included physical, chemical, or both predictor variables or with type of physical (hydrology, drainage basin, light) or nutrient (total versus dissolved) variable. Models that included nitrogen had slightly higher r^2 values than models that included only phosphorus. The theoretical limit of model precision, determined from estimates of pure error due to instantaneous, spatial heterogeneity and also due to temporal variability, appears to have been reached for models predicting temporally averaged chlorophyll *a* concentrations. The implication for temporal mean models is that higher predictive power is not likely to be achieved until more effort is expended obtaining precise estimates of temporal means. In contrast, RMS values of models predicting instantaneous mean chlorophyll *a* were, on average, 4.5 times higher than theoretical pure error. We suggest that models predicting instantaneous chlorophyll *a* could be made more precise by including variables that better reflect the recent site history, such as the time since last flood or accumulated irradiance prior to the sampling date.

Introduction

Empirical regression models have been widely accepted among aquatic scientists, and ecologists in general, as being useful tools for providing insight into ecosystem functioning, and in guiding scientific research and management practices (Morin 1997, Pace 2001). However, the development of regression models for river ecosystems that have good predictive power has lagged behind models developed for lakes (Dodds et al. 2002). In particular, models for periphyton, the dominant primary producers of many river ecosystems, have failed to achieve similar levels of precision as models for lake phytoplankton. It is important from a management perspective to derive accurate predictions of periphyton in rivers since regulatory agencies worldwide are attempting to define science-based criteria for maintaining algal biomass in rivers, as well as lakes, below nuisance levels (Chambers et al. 2001). The ability to accurately predict river periphyton abundance is equally important from a scientific perspective, because of the contribution of benthic algae to food web dynamics in rivers (Dodds et al. 2002).

The spatially heterogeneous nature of periphyton communities is one of the factors attributed to the low predictive power of periphyton regression models (Morin and Cattaneo 1992). Periphyton communities are also variable through time and may be influenced by daily, seasonal and annual fluctuations in factors such as discharge, light, and temperature regimes. The inherent understanding that river ecosystems are dynamic temporally and that periphyton habitat is spatially patchy has to some extent guided how river ecologists have attempted to model periphyton abundance. Specifically, Cattaneo et al. (1993) advocated including elements of microscale variation at a site to improve precision of regression models predicting chlorophyll *a* at a single point in time by

accounting for some of the variability that can be attributed to habitat patchiness. Similarly, Biggs and colleagues (Biggs and Close 1989, Biggs 1995, Biggs et al. 1998) attempted to account for some of the temporal variability in periphyton abundance by including elements of the hydrologic regime (e.g., flood frequency and percent time in flood) in models of temporal mean chlorophyll *a*. Light availability (Rosemond 1994), water temperature (Uehlinger 1991), drainage basin characteristics (Biggs 1995, Chapter 1), and biotic variables (Chapter 3) are among some of the other independent variables that have been used to predict either instantaneous or temporal mean periphyton abundance in rivers, with varying levels of success.

One of the difficulties in having many published models that predict periphyton abundance as a function of a suite of independent variables, is that the models are not easily generalized to other regions or systems (Morin 1997). Probably the most geographically extensive empirical regression studies of river periphyton are the chlorophyll – nutrient models of Dodds et al. (1997, 2002), but the periphyton models were considerably less precise than typical lake phytoplankton models ($r^2 \approx 0.40$ versus ≈ 0.90). It is not immediately obvious to the novice periphyton researcher or manager which independent variables should be examined to best predict periphyton abundance in rivers. It is also not clear whether emphasis should be placed in characterizing spatial or temporal variability in periphyton communities.

The goal of this study was to synthesize information about the predictive power of published empirical regression models for periphyton abundance. We examined the relationship between predictive power of regression models, measured as model r^2 and residual variance, as a function of publication year to determine if models have improved

with time as scientific understanding of the factors that limit periphyton growth has also, presumably, increased. We examined if predictive power of regression models varied with the types of independent variables included in the models and specifically whether the inclusion of physical or chemical variables yielded improved predictability. We quantified the minimum expected residual variance, or pure error, for periphyton chlorophyll *a* models that could be attributed to either *in situ*, spatial variability, or temporal variability and compared the differences between observed and expected minimum residual variances to assess the relative lack of fit of current models for periphyton in rivers.

Methods

The published literature was searched systematically for statistically significant regression models predicting instantaneous mean (i.e., the average of several sampling replicates taken from one location) or temporal mean (i.e., the average of samples collected from one location over several dates) biomass of benthic chlorophyll *a* in rivers. For each model, we recorded the year the model was published, the number of observations that contributed to model development, the geographic extent of sampling sites (determined approximately based on descriptions in text or maps of the study area), the number and type of independent variables in the model, the number of chlorophyll *a* sampling replicates (for instantaneous means) or dates (for temporal means), and the coefficient of determination (r^2) and residual mean square (RMS) for each model, when available. Regression models were not always explicitly stated: in some cases, correlation coefficients (r) were reported, from which we calculated the r^2 for a simple linear regression. In other cases, raw data were provided in tables from which we built

linear regression models to predict chlorophyll *a* concentrations. RMS values were also not always reported: where possible, models were rebuilt based on data in figures or tables and the RMS was calculated. Most regression models predicted the log₁₀-transformed chlorophyll *a* concentrations; when other transformations were used we converted the RMS values to log₁₀ units by rebuilding models with log₁₀-transformed chlorophyll *a* concentrations.

Independent variables were classified according to three main categories: 1) physical variables that usually represented some form of hydrologic variable (mean annual or monthly discharge, days since last flood, current velocity, etc), drainage basin characteristics (drainage area, stream slope, underlying geology), light availability, or temperature, 2) chemical variables that we separated into nutrients (nitrogen or phosphorus) or other chemical constituents (conductivity), and 3) other variables that included estimates of land use in the drainage basin, bacterial abundance in biofilms, and cellular nitrogen composition of periphyton (Table 4.1). In the case of models that included nutrients, we recorded whether total or dissolved nutrients were used.

In several cases, more than one regression model for chlorophyll *a* was reported in a study. In cases where the models were developed with independent data (e.g., data from different years, or different locations), all models were included in this study. In cases where multiple models were reported using the same chlorophyll data but different independent variables, the best model (i.e., highest r^2 and lowest RMS) for each class of independent variables was reported (e.g., the best model based on physical data such as discharge and land use, and the best model based on chemical data such as nutrient concentrations). Sometimes, models were reported using different subsets of the

chlorophyll data that differed according to temporal or spatial categories. In these cases, the best model based on the entire data set as well as the best models based on subsets of the data were included in this study.

Data were analysed with SYSTAT (version 10, Systat Software Inc., Richmond, California, <http://www.systat.com>). General linear models were used to quantify the relationship between model statistics (r^2 and RMS) and model sample size, number of terms in the model, and number of sample replicates used to estimate chlorophyll *a* concentrations in each study. Complete models were fit for each model statistic (i.e., each term plus all possible interactions) and non-significant terms were removed one by one, beginning with the highest-order interactions, until a model with only significant terms remained. The residuals from the final models for r^2 and RMS were then used in regression analyses to examine differences in predictability over time (i.e., model publication year) and geographic extent of the study area for each model. The influence of type of variable used to predict chlorophyll *a* concentration (i.e., physical or chemical, nitrogen or phosphorus, total or dissolved nutrients) on residuals of r^2 and RMS values was evaluated with analysis of variance (ANOVA). When necessary, independent variables were $\log_{10}$ -transformed to meet assumptions of normality and homogeneity of variance.

In order to determine the theoretical minimum residual variability given levels of sampling effort, we used empirical relationships relating sampling variance to mean chlorophyll *a*. For spatial variance, we used the relationship between sampling variance (s^2) and observations of instantaneous mean periphyton chlorophyll *a* (M) and sampler area, published by Morin and Cattaneo (1992) such that:

$$\log_{10}(s^2_{\text{instantaneous}}) = -1.68 + 2.07\log_{10}M_{\text{instantaneous}} + 0.45\log_{10}(\text{sampler area}) \quad (1)$$

Variance – mean relationships have not been published for temporal estimates of mean periphyton chlorophyll *a* concentrations. As such, we quantified temporal variance – mean relationships for periphyton using a 21-year monitoring dataset from Alberta rivers with > 500 mean annual observations (Carr, unpublished data), such that:

$$\log_{10}(s^2_{\text{annual}}) = -0.14 + 1.87\log_{10}M_{\text{annual}} \quad (2)$$

Using the coefficients of the equation in (1) for instantaneous mean chlorophyll models and those of equation (2) for temporally averaged mean chlorophyll models, we estimated the theoretical minimum observational sampling variance (s^2) for a lognormal distribution as a function of the arithmetic mean (M) chlorophyll *a* concentration, according to the method of Hines and Montgomery (1980), such that:

$$s^2 = \ln(10^a M^{b-2} + 1) \quad (3)$$

where a is the y intercept and b is the slope of the $\log_{10}(\text{variance}) - \log_{10}(\text{mean})$ relationships. In the case of instantaneous means, we solved the relationship in (1) for a sampler area of 20 cm² (the median sampler area of published studies reviewed by Morin and Cattaneo 1992) such that $a = -1.09$. We estimated sampling variances for the minimum and maximum reported mean chlorophyll *a* concentrations (M) in each study and then averaged these values. To estimate the variance expected for a population of means (used in regression models to predict chlorophyll *a* abundance), we divided the average sampling variance by the number of instantaneous or temporal replicates used in each published study (or the median number when sample replicates varied in number within an individual study). The resulting variances corresponded to estimates of the minimum residual variance in regression models that could be attributed to ‘pure error’

caused by spatial (i.e., instantaneous) or temporal variability in periphyton chlorophyll *a* concentrations.

Results

A total of 67 predictive models were retrieved from 28 sources in the published literature from 1976 to 2004 and from 2 of the authors' (as yet) unpublished studies (Table 4.1). Most studies reported only one model predicting abundance of periphyton chlorophyll *a* in rivers, but some reported up to 11 (Chapter 1). Ten of the studies reported models based only on physical characteristics (hydrology, basin characteristics, etc.) and 13 studies reported models based only on chemical characteristics of the overlying water. Seven studies reported models that combined physical, chemical, and/or 'other' predictor variables in the models. Six of the models predicted maximum periphyton biomass (i.e., peak biomass in a season), 29 models predicted mean biomass (i.e., average biomass over a set time period, usually a growing season or one year), and 38 models predicted instantaneous (i.e., one-time sampling) biomass. Residual mean squares were obtained for 22 of the 30 studies and 46 of the 67 predictive models; the RMS often had to be generated by recalculating the regressions based on raw data presented in the tables and figures in the original publications.

Published regression models of chlorophyll *a* explained between 8 and 99% and averaged 48% of the variability in chlorophyll (Table 4.2). Residual variances of published models ranged from 0.0006 to 0.415 and averaged 0.128. Models were based on between 4 and 447 observations, and averaged 84 observations per model. Replication rate for spatial or temporal estimates of chlorophyll ranged from 1 to 29 replicates with a mean of 7 and median of 3 replicates per estimate. Between 1 and 6

terms were included in the published models, with a median of 1 and mean of 1.8 terms per regression model. Studies ranged from local studies of periphyton in one river reach to large-scale, global studies, with the geographic extent of models averaging 15,000 km².

Over the last 28 years, there was a significant decrease in the proportion of variation explained by regression models (r^2) and an increase in the residual variance (RMS) of regression models for periphyton chlorophyll *a* (Figure 4.1). A corresponding increase in the geographic extent of study sites and number of observations used to build regression models was also detected.

Model r^2 values were negatively correlated to model sample size and positively correlated to the number of model terms (Table 4.3). The best relationship between r^2 and sample size (log₁₀-transformed) was quadratic. The number of sampling replicates used to estimate chlorophyll *a* concentration was not significantly correlated to model r^2 . By comparison, model RMS values were positively and linearly correlated to model sample size (log₁₀-transformed) and negatively correlated to the number of sampling replicates used to estimate chlorophyll *a* concentrations.

Once corrected for the effect of sample size and number of replicates, r^2 and RMS values did not vary with year (Figure 4.2). There also was no relationship between model statistic residuals and geographic extent of the study area, although RMS residuals tended to increase with increasing study area (Pearson's $r = 0.28$, $P = 0.07$).

Predictions of chlorophyll *a* were not significantly different between models that included physical, chemical, both physical and chemical variables, or other variables (1-way ANOVA of r^2 and RMS residuals versus model type, $P \geq 0.64$; Table 4.4). Among

the models that included physical variables, there was no difference between models based on hydrology, on drainage basin characteristics, or on light variables (1-way ANOVA, $P \geq 0.95$ for both r^2 and RMS residuals; Table 4.4). All but one of the models that included chemical terms used nutrients as the predictor. Among the nutrient models, there was no effect on r^2 residuals of using total versus dissolved nutrients but r^2 residuals were significantly higher for models that included nitrogen variables (2-way ANOVA with model type (P, N, P+N) and form of nutrient (total or dissolved), $F_{2, 41} = 3.42$, $P = 0.04$). No differences were detected among model types or nutrient forms for RMS residuals (2-way ANOVA, $P \geq 0.20$).

Reported RMS values for instantaneous mean chlorophyll models were, on average, 4.5 times higher and were positively correlated to the pure error estimates (Pearson's $r = 0.56$, $P = 0.02$, Figure 4.3). Reported RMS values for temporal mean chlorophyll a values were much closer to pure error estimates and also were correlated to theoretical values (Pearson's $r = 0.82$, $P < 0.001$, Figure 4.3). Theoretical minimum pure error (expressed as RMS) was, on average, 17 (median = 10) times greater for temporal than for instantaneous mean chlorophyll models.

Discussion

Published regression models from the last 30 years that predict abundance of periphyton chlorophyll a have varied in terms of the number of observations, the geographic extent of the sampling sites and the type of independent variables included in the models. However, virtually no improvements in the amount of variation explained by independent variables or decreases in the amount of residual variance after fitting models were detected over the 30-year publishing record. If the goal of empirical modelling is to

generate predictions for a variable that improve as a better understanding of system processes and mechanisms develops (Pace 2001), then empirical models for periphyton chlorophyll *a* have not been very successful.

Model synthesis

The models used in this study ranged from local studies on one river reach that was sampled repeatedly over time (e.g. Uehlinger 1991, Mosisch and Bunn 1997) to continental and global studies that combined chlorophyll *a* and water quality data from published sources to examine large-scale patterns in chlorophyll *a* – nutrient relationships (e.g., Dodds et al. 1997, 2002). Study area and number of observations used in regression models tended to increase over time, probably as a result of more extensive regional monitoring programs (e.g., Chapter 1) and also because more recent studies made use of data collected from previous studies to build larger, more general models (e.g., Dodds et al. 1997, 2002).

The number of model observations influenced model r^2 and RMS values, since the power to detect significant relationships increases with sample size. The number of model terms and sampling replication rates also influenced model r^2 and RMS values, respectively. Once corrected for the effects of numbers of model observations, terms, and sampling replicates, there was no relationship between r^2 and geographic extent of the study area but a weak relationship for RMS was detected such that residual variance increased with study area. The increase in residual variance with study area was not surprising, when considering the myriad features of the landscape and climate that may alter growing conditions for attached algae in streams.

Independent variables

Cattaneo et al. (1993) suggested that periphyton modelling could be improved by measuring physical and biotic factors in addition to nutrient variables. Our results showed that physical variables, either alone or in combination with chemical variables, yielded models that did not differ in terms of precision. Moreover, the study in Chapter 3 included estimates of bacterial abundance in periphytic biofilms as biotic predictors of mean instantaneous chlorophyll *a* and, although bacterial abundance estimates yielded a decrease in residual variance by nearly two-fold from a nutrient-only model, residual variance remained approximately 2.4 times higher than the theoretical minimum variance. It has been well established that top-down control of periphytic algae by grazing invertebrates is also important in determining abundance of benthic algae (Hillebrand 2002) and so the inclusion of invertebrate abundance in periphyton models may yield more precise models. However, we found no studies that reported results of empirical modelling of the relationship between invertebrate abundance and periphyton chlorophyll *a*.

There was only one small effect detected that suggested that the independent variables included in regression models for periphyton might influence predictive power: models that included nutrients as predictor variables had slightly higher r^2 values when nitrogen was included than when only phosphorus was included. The observation that nitrogen might have a small effect on predictive power adds to the growing body of evidence suggesting that nitrogen is an important factor in regulating periphyton biomass in stream ecosystems (Francoeur 2001, Tank and Dodds 2003).

Theoretical limits to precision

Pure error for instantaneous mean chlorophyll models is due to spatial variability in periphyton among replicates. By comparison, pure error attributed to temporal mean chlorophyll *a* concentrations includes not only spatial but also temporal variability in chlorophyll *a*. Consequently, it was no surprise that the theoretical minimum pure error (expressed as RMS) was, on average, 17 times greater for temporal than for instantaneous mean chlorophyll models. The estimates of pure spatial error indicated that RMS of published regression models for instantaneous chlorophyll *a* were much greater than theoretical minima, whereas published temporal regression models approached minimum expected residual variances and nearly 60% of the models had observed RMS values that were below the theoretical minima. At the same time, the instantaneous models had the potential to achieve much higher precision, since variation expected as a result of pure spatial error was much lower than for temporal models.

Pure error in the independent variables of ordinary least-squares regression models also has the potential to influence precision (Prairie et al. 1995). As such, residual variance of the regression models in this study may, in part, be influenced by pure error in the predictor variables. This is important to consider when evaluating differences in precision of temporal and instantaneous mean models. We know of no study that compares pure error between temporal and spatial estimates of the physical and chemical predictors used in the published regression models of this study. However, pure error due to temporal variability in water chemistry variables has been evaluated for rivers and is generally less than pure error due to temporal estimates of river periphyton biomass (Cattaneo and Prairie 1995, Chételat and Pick 2001). In this study, there was

very little difference among instantaneous and temporal mean models with respect to the predictor variables used: 24% of both model types included physical variables as predictors; and 74% of instantaneous models and 86% of temporal mean models used chemical variables as predictors. Thus, although the pure error from predictor variables likely contributes to the residual variance of published periphyton regression models, we expect the effect of this pure error to be similar among both the instantaneous and temporal mean models examined here, because there was no difference in usage of the variables among the two model types.

We suggest that the residual variability in instantaneous models, above and beyond pure error that is unaccounted for by spatial variability is, in fact, a reflection of temporal legacies (*sensu* Strayer et al. 2003) of events that occurred prior to the sampling date but that were not taken into account in regression modelling. Thus, an approach to reducing the residual variance of instantaneous models may be to include variables that reflect the recent temporal history of the study site rather than the immediate microscale variation at the site, which was suggested by Cattaneo et al. (1993). Factors that quantify the length of time since an event, such as the number of days since the last flood or canopy leaf out, the number of growing degree-days, or the amount of accumulated irradiance prior to the sampling date, may improve precision of instantaneous periphyton chlorophyll *a* models. Biggs and colleagues (Biggs and Close 1989, Biggs 1995, Biggs et al. 1995) and Uehlinger (1991) modelled chlorophyll *a* as a function of variables related to discharged regime of the system (e.g., percent time in flood, days since last flood, flood frequency). However, all of these studies used temporally averaged estimates of

chlorophyll *a* so that the independent variables reflected only an average discharge condition rather than the immediate history of a particular site at a particular time.

Hakanson (1999) reported that calculations of maximum theoretical r^2 as a function of the coefficients of variation (CV) of observations should guide the development of empirical models. A high estimate for the CV of instantaneous mean chlorophyll is 0.3 (estimated from Figure 2 of Morin and Cattaneo 1992), which, according to Hakanson (1999) should yield an upper limit to the r^2 of models of 0.94. Assuming a high CV for temporally averaged data of 0.75 (estimated based on annual mean – variance relationships from Alberta), the upper limit to the r^2 of regression models predicting temporally averaged chlorophyll *a* would be 0.63. Although the mean r^2 values of instantaneous models in this study (0.47) was not close to the maximum possible r^2 value, the mean r^2 of temporal regression models (0.49) was closer to the theoretical maximum and 10 of the 29 models predicting mean chlorophyll were above the theoretical maximum. Only 1 of the 38 models reporting instantaneous mean chlorophyll *a* had an r^2 greater than the theoretical maximum. These results further indicate that instantaneous models of chlorophyll *a* have the potential to achieve much higher precision than observed here and that temporal models have approximately reached the limit of precision.

RMS values were seldom reported along with regression model r^2 values, and this is unfortunate because they represent a better estimate of model precision than r^2 values. Model r^2 values were dependent on the number of terms included in a model, whereas RMS values were not. Additional terms in models probably serve to explain differences among disparate groups of observations that are highly variable (and therefore have a

high variance), but they do not reduce RMS values to the minimum variance expected due to pure error. The significance of regression models and model r^2 values may also be influenced by the range of independent variables included in the model, such that a correlation might not be detected over a narrow range of an independent variable, due to the highly variable nature of chlorophyll *a* estimates, but a larger range of the same variable might lead to a detectable trend, despite similar residual variability in chlorophyll *a*. In the first case, the independent variable in question would not be significant and the r^2 value would be very low; in the second case, the independent variable would be significant and the r^2 value would be higher. In both cases, no change in the residual variance would be expected.

This study included only those models that were statistically significant and was therefore biased towards models that sampled large ranges of independent variables. The decision to include only significant models was deliberate, since a preliminary survey of the literature revealed that there were not many cases of reported models of periphyton chlorophyll *a* that were non-significant and, among those that were reported (e.g., Jones et al. 1984), the only obvious difference between significant and non-significant models was the range of the independent variables used in the study. Since this range affects only r^2 and not RMS values, we suspected that the bias that we deliberately chose to include in our study was better than the publication bias toward only significant models that we could not quantify.

Variance – mean relationships for temporal estimates were based on data from Alberta and, although the data were limited in geographic scope, the large sample size (535 annual mean and variance estimates) should be sufficiently robust to describe

general patterns in temporally averaged chlorophyll *a* values. Not all of the published temporal mean regression models used in this study reported relationships for annual means; some reported means for only a few sampling dates that spanned only several weeks. The data from Alberta also were divided seasonally, and the variance – mean relationship for seasonal chlorophyll estimates yielded variance estimates that were intermediate between instantaneous (spatial) sampling variability and annual (temporal) sampling variability. Thus, the annual variance estimates used here to predict minimum expected RMS values were conservative.

Variance-mean relationships in phytoplankton chlorophyll *a* followed patterns similar to those of periphyton in that seasonal averages were less variable than annual averages (Marshall et al. 1988; Cattaneo and Prairie 1995). Although published models of instantaneous variance – mean relationships for phytoplankton chlorophyll *a* were not found, we assumed that a similar pattern would hold and that instantaneous estimates of mean phytoplankton would be less variable than temporally averaged estimates. However, in the case of phytoplankton, the intercepts of seasonal and annual variance – mean relationships were lower than for periphyton chlorophyll *a*, indicating phytoplankton is less variable than periphyton. The implications of this observation are that coefficients of variation should be lower, theoretical maximum r^2 values should be higher, and minimum RMS values should be lower for phytoplankton than periphyton. This probably explains the discrepancy between periphyton and phytoplankton models in the published literature, where many studies that predicted planktonic chlorophyll *a* reported r^2 values in the range of 0.8 – 0.9, compared to reported r^2 values for periphyton that average less than 0.5.

Conclusions

This study of published periphyton models revealed that there were almost no differences in terms of model predictability between types of independent variables examined in regression models, study area, or year of study. The theoretical limit of model precision for periphyton models appears to have been reached for estimates of chlorophyll *a* averaged over time, but not space. Models for temporal mean chlorophyll *a* will only become more precise by sampling more dates to better capture the true mean chlorophyll value and reduce variance around the true mean. Future efforts to improve precision of instantaneous mean chlorophyll *a* models will be well served by including estimates of the recent site history as predictor variables. Better capturing the dynamic nature of stream ecosystems should increase predictive power of instantaneous periphyton chlorophyll models.

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Table 4.1. Independent variables used to predict chlorophyll *a* concentrations from published regression models with reference to studies from which models were retrieved. Numbers in brackets under references column refer to the number of models used in the meta-analysis from the particular study that contain the variable in question.

Variable Type		Reference
Physical variables		
Hydrology	Water velocity	7, 14(6), 20
	Time in flood	4(2)
	Flood frequency	3, 6
	Time since last flood	28, 29
	Average discharge	29
	Maximum discharge	28
	Discharge at sampling time	4(2)
	Water depth	5, 7, 19
	Size of rock sampled	4
	Total suspended solids	4(2)
Drainage basin	Distance from headwaters	10(3)
	Surface area of upstream lakes	10(2)
	Distance d/s from lakes	10(2)
	Percent alkaline rocks in basin	3
Light	Irradiance	24
	Cumulative irradiance	25
	Riparian cover / % penetration	20, 27
Temperature		28
Chemical variables		
Phosphorus	Total	11, 12(2), 13(2), 16(2), 18, 22(2)
	Dissolved	1(2), 4(2), 8(4), 13, 14(6), 15, 21, 23, 26
Nitrogen	Total	11, 12(2), 13(3), 16(2), 22
	Dissolved	1, 2, 4(2), 8(2), 9(2), 10(2), 13, 17, 23, 26(2)

Variable Type	Reference
Conductivity	11
Other variables	
High intensity agricultural land use in drainage basin (%)	3
Human population density in drainage basin	8(4)
Crop density in drainage basin	8
Accrual time (for artificial substrata)	14(6)
Cellular N content of periphyton	6
Bacterial abundance in biofilms	9

References: Unless indicated in brackets, 1 model per study was used in the meta-analysis. (1) Aizaki and Sakamoto 1988 (3 models), (2) Bernhardt and Likens 2004, (3) Biggs 1995, (4) Biggs and Close 1989 (3 models), (5) Biggs and Hickey 1995, (6) Biggs et al. 1998, (7) Bourassa and Cattaneo 1998, (8) Carr et al. Alberta (11 models), (9) Carr et al. Bacteria (2 models), (10) Cattaneo 1996 (4 models), (11) Chételat et al. 1999 (3 models), (12) Dodds et al. 1997 (2 models), (13) Dodds et al. 2002 (5 models), (14) Horner and Welch 1981 (6 models), (15) Kjeldsen 1994, (16) Lohman et al. 1992 (4 models), (17) Marcus 1980, (18) Morin et al. 2001, (19) Mosisch and Bunn 1997, (20) Mosisch et al. 2001, (21) Mulholland and Rosemond 1992, (22) Pan et al. 1999 (3 models), (23) Rier and Stevenson 2001 (2 models), (24) Rosemond 1994, (25) Sand-Jensen et al. 1988, (26) Scrimgeour and Chambers 2000 (2 models), (27) Stockner and Shortreed 1976, (28) Uehlinger 1991, (29) Uehlinger et al. 1996, (30) Welch et al. 1988.

Table 4.2. Summary (mean, median, range) of regression model statistics retrieved from published models, including the r^2 and RMS values, the number of observations in the model, the number of terms in the model, the number of replicates used for sampling spatial or temporal mean chlorophyll, and the geographic extent of the study area (km²). Summaries are based on 67 observations, except for the RMS values that are based on 46 models.

	Mean	Median	Range
r^2	0.48	0.47	0.084 – 0.989
RMS	0.128	0.100	0.0006 – 0.415
N observations	83.8	29	4 – 447
Model terms	1.75	1	1 - 6
Sampling replicates	7	3	1 – 29
Study area (km ²)	3.9×10^6	1.5×10^4	1 - 3.9×10^6

Table 4.3. Generalized linear models quantifying statistical relationships between regression model statistics (r^2 and RMS) and model sample size (Model n), number of terms in the models (Model terms), and number of sample replicates (Sample n) used to estimate chlorophyll a concentrations. Probabilities for independent variables are one-tailed. Generalized linear models based on 67 r^2 and 46 RMS observations.

	Independent variable	Coefficient	SE	P	r^2	RMS
r^2	Intercept	1.152	0.181			
	Log_{10} Model n	-0.744	0.221	0.001		
	$(\text{Log}_{10} \text{ Model } n)^2$	0.140	0.064	0.016		
	Model terms	0.059	0.020	0.023	0.515	0.028
RMS	Intercept	0.003	0.048			
	Log_{10} Model n	0.105	0.028	0.001		
	Sample n	0.013	0.007	0.034		
	Sample $n \times \text{Log}_{10}$ Model n	-0.015	0.006	0.011	0.414	0.006

Table 4.4. Summary of r^2 and RMS residuals of different models, separated by independent categorical variables. Note that some models are represented more than once in this table, because they include combinations of different types of physical variables.

	r^2 residuals			RMS residuals		
	mean	SE	<i>n</i>	mean	SE	<i>n</i>
Physical variables						
Hydrology	-0.0141	0.0447	16	0.0015	0.0130	7
Light	-0.0125	0.1302	4	-0.0004	0.0325	3
Basin	0.0141	0.0869	4	-	-	0
Chemical variables						
Nutrients	-0.0089	0.0231	47	0.0004	0.0097	29
Phosphorus – Total	-0.0143	0.0427	10	0.0085	0.0117	8
Phosphorus – Dissolved	-0.0728	0.0306	21	-0.0091	0.0155	11
Nitrogen – Total	0.0219	0.0435	9	-0.0027	0.0053	7
Nitrogen – Dissolved	0.0624	0.0418	16	0.0160	0.0204	11
Conductivity	0.2660	-	1	-0.0378	-	1
Other variables	-0.0381	0.0472	4	0.0062	0.0124	4

Figure 4.1. Relationship between regression model statistics (r^2 , residual mean square (RMS), geographic extent of study area, and number of points in model) and publication year of each study. Pearson correlations (r) between models and statistics and publication year are shown for each panel and correspond to the lines fitted to the points. The dashed line in the RMS panel corresponds to the correlation excluding the models from the study of Aizaki and Sakamoto (1988; solid symbols). Correlations are significant ($P \leq 0.002$), except for the RMS correlation that includes models from the study of Aizaki and Sakamoto ($P = 0.222$).

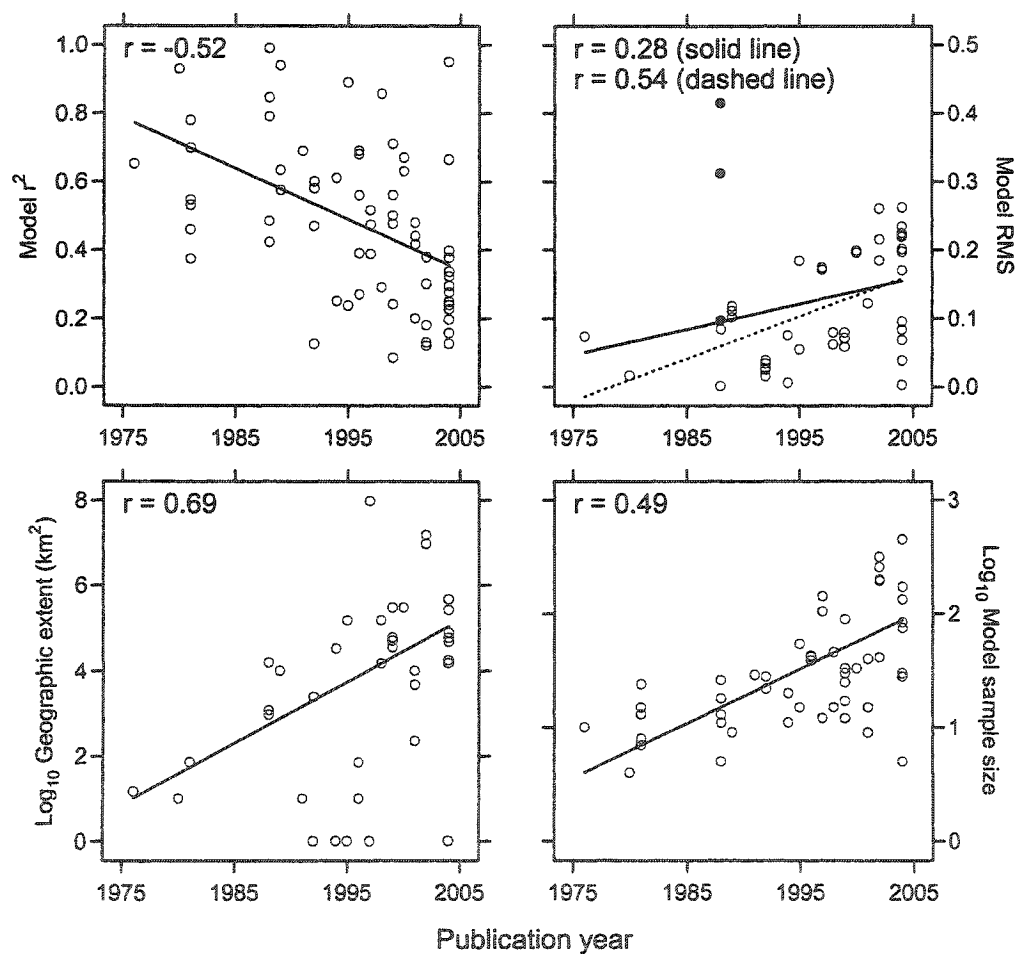


Figure 4.2. Relationships between r^2 and RMS residuals plotted versus publication year (top panels) and geographic extent of study area (bottom panels). Pearson correlations (r) between residuals and publication year and study area are shown and correspond to the lines fitted to the points. None of the correlations are significant ($P \geq 0.10$).

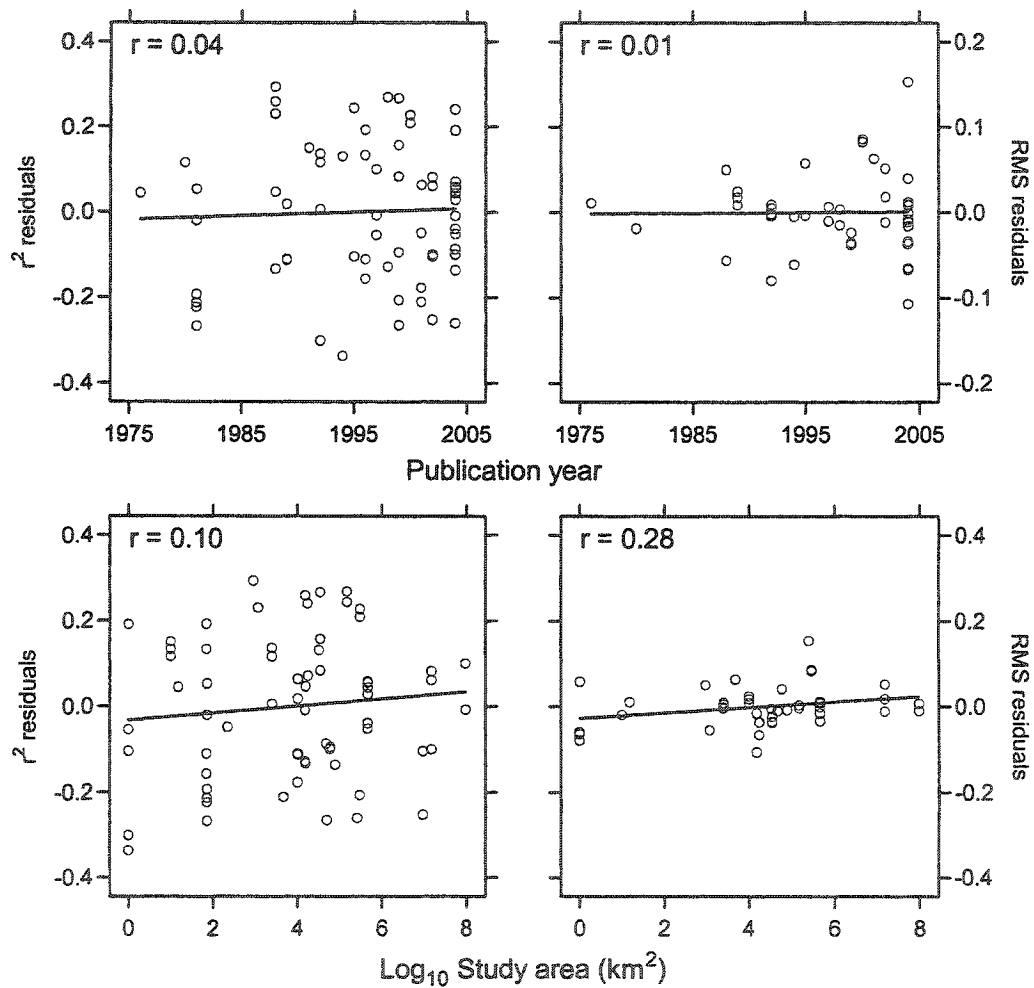
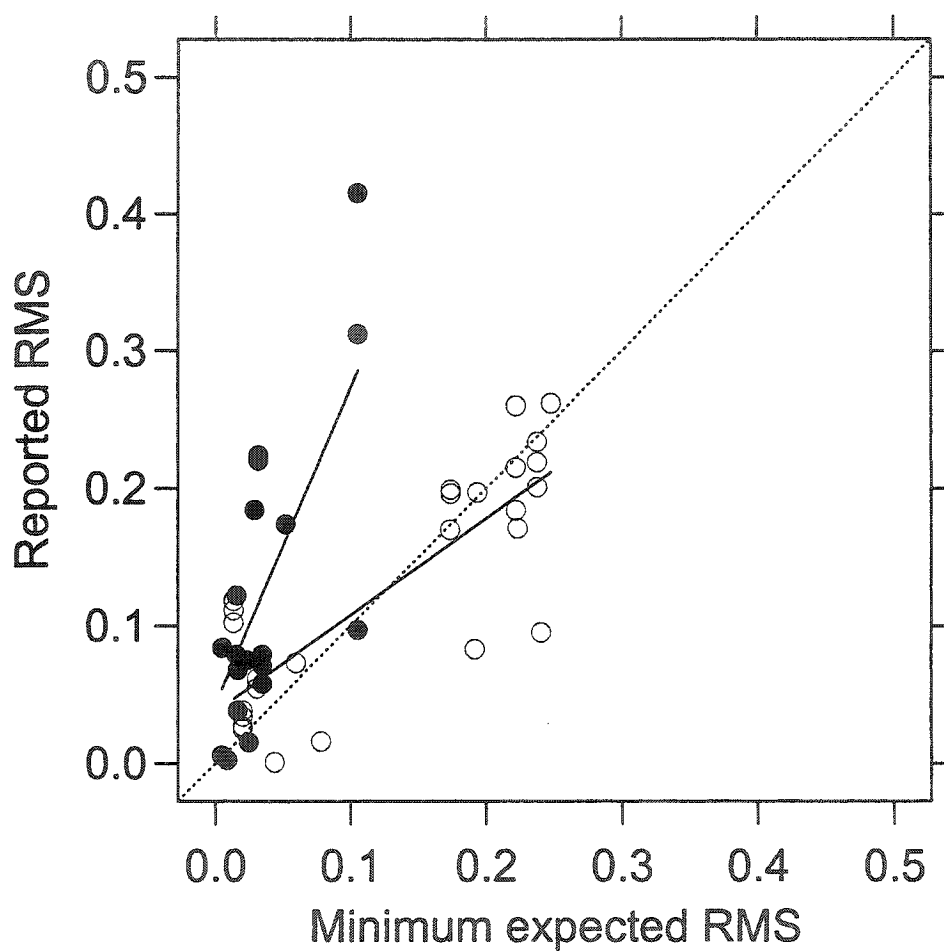


Figure 4.3. Relationship between reported RMS and minimum expected RMS for models predicting instantaneous (solid symbols) and mean (open symbols) chlorophyll *a* values. Solid lines are linear regressions for each group. Dashed line is the 1:1 line.



General Conclusion

The overall goal of this research was to address the issue of the prediction of periphyton biomass in rivers. In Chapter 1, I examined the predictability of periphyton chlorophyll *a* at a large geographic scale by quantifying the relationship between chlorophyll *a*, nutrients and land use in drainage basins with a historical data set from Alberta. Results showed that at the scale of the entire province, land use, and population density in particular, was about as good as nutrients at predicting periphyton chlorophyll *a* concentrations. Nutrients explained between 23 and 24% of the variability in chlorophyll *a*, whereas land use explained 25 to 28% of the same variability. The combination of nutrients and land use yielded the best predictions of chlorophyll *a*, explaining 32 to 34% of chlorophyll *a* variability. However, simply grouping monitoring stations according to their ecoregion and quantifying differences in chlorophyll *a* among regions explained about equal amounts of variability in chlorophyll *a* (28 – 30%) as the best regression models. Moreover, up to 43 to 44% of the total variability in chlorophyll *a* could be explained by the inclusion of an ecoregion categorical term in regression models (plus all possible interactions), indicating a strong regional effect on chlorophyll – nutrient and/or land use relationships. Within ecoregions, regression analysis revealed that land use was sometimes a suitable surrogate for nutrient concentrations but the pattern was not consistent. I concluded from this investigation that land use could act as a surrogate for nutrients in general regression models of chlorophyll *a*, but that land use did not account for the large amount of unexplained variability common in empirical models of periphyton abundance.

In an attempt to isolate factors that might yield improved predictions of chlorophyll *a* along a nutrient gradient, I then examined how bacteria in periphytic biofilms co-vary with algae in terms of abundance and production. This second component of my research consisted of a field study where I sampled bacterial and algal abundances and production in streams of southern Ontario and southwestern Québec (Chapter 3). To this end, I first conducted a meta-analysis of the sampling variability for bacterial abundance and production to enable me to design a field study with levels of replication that adequately described mean bacterial abundance and production at sites and that would enable detection of differences among sites (Chapter 2). There were strong positive correlations between the variances and means of bacterial abundance and production in both planktonic and benthic environments. The mean-variance relationships that were generated for benthic environments led me to conclude that 3 (bacterial abundance) and 4 (bacterial production) replicates would make it possible to detect an approximate doubling of means among stations.

Results of the field study that quantified the relationship between periphytic algae and bacteria along a nutrient gradient are outlined in Chapter 3. Bacterial abundance was a significant predictor of chlorophyll *a* concentration and explained an additional 26-29% of the residual variance in chlorophyll *a* (r^2 of full model = 0.66 – 0.84). However, the results did not support my initial hypothesis that bacteria compete with algae for nutrients because the sign of the correlation was positive. Instead, the results supported an alternative hypothesis that bacteria and algae in biofilms coexist in an environment where factors other than nutrients, such as hydrologic regime or invertebrate grazing, control biomass and production of both groups of organisms.

The study of historical monitoring data for Alberta rivers in Chapter 1 and the field study of Chapter 3 yielded results that were interesting in terms of addressing whether additional or different variables can improve predictions of periphyton chlorophyll *a*, but they failed to resolve the issue of the low predictive power of river periphyton models. The meta-analysis of published regression models that predicted chlorophyll *a* concentrations in Chapter 4 was an attempt to address this issue. I quantified predictive power of regression models in terms of model r^2 and residual mean squares (RMS) and examined how these varied with publication year of the study, geographic extent of the study area, and the type of predictor variables used. Once corrected for the statistical effects of number of model observations, number of terms in the model, and the number of sampling replicates used to estimate chlorophyll *a*, there was no evidence that predictive power of published regression models has improved over time. Moreover, geographic extent of the study area had almost no influence on the predictive power of regression models, except for a slight increase in RMS with increasing study area. There were no differences in regression statistics among models that included chemical, physical or combined chemical and physical predictor variables. The only small effect that could be detected due to the type of independent variables used was that chlorophyll – nutrient models that included nitrogen had slightly higher r^2 values than models that included only phosphorus.

The observation that very little progress has been made over the last 3 decades in terms of finding general models for periphyton abundance that yielded precise predictions of chlorophyll *a* led me to quantify pure error attributable to spatial and temporal estimates of chlorophyll *a*. I then compared the observed RMS to theoretical

minimum RMS values for models that predicted instantaneous and temporally averaged chlorophyll *a*. The theoretical limit of model precision had approximately been reached for temporal mean models but not for instantaneous mean models. Instantaneous mean periphyton models had the potential to achieve RMS values that were, on average, 17 times less than temporal mean models, but observed RMS values for instantaneous models were, on average, 4.5 times higher than the theoretical minima. Thus, I concluded that temporal mean chlorophyll *a* models were unlikely to become more precise with further modelling because they have, more or less, reached the limits of pure error. However, increasing sampling effort of periphyton biomass through time could reduce pure error of temporal mean models and, therefore, increase model precision. In contrast, instantaneous mean chlorophyll models have the potential to achieve much higher levels of precision and may be improved by incorporating independent variables into the models that represent the recent history of the site, such as the time since last flood or accumulated irradiance prior to the sampling date.

The fact that models predicting mean chlorophyll *a* over time have approximately reached their limit of precision and that the independent variables used have little influence on predictive power leads to questions about the value of further developing regression models for periphyton chlorophyll *a*. If the reason for developing a regression model is to have a tool that can be used in the management of periphyton chlorophyll *a*, then existing models are probably sufficient. By far the greatest interest among management agencies is in the prediction of periphyton chlorophyll *a* with respect to nutrient concentrations, because these are among the only variables that are likely to limit periphyton growth and that may also respond to different management strategies. One of

the main conclusions that could be drawn from the Alberta study (Chapter 1) was that periphyton generally increases with nutrients, and with nitrogen in particular. However, the magnitude of change that might be expected due to changes in nutrient concentrations is difficult to predict precisely, because of the high residual variance of the periphyton models.

Management strategies may be targeted more directly toward maintaining maximum periphyton biomass below nuisance levels. If maximum chlorophyll *a* is simply the average of several replicate samples collected at the time of peak biomass (as it was in the Alberta study), then models predicting maximum chlorophyll have the potential to achieve much lower residual variance. As discussed in Chapter 4, further study into the factors that may reflect the temporal history of a site prior to achieving peak biomass may yield improved predictions. For example, if a model was developed that predicted maximum periphyton chlorophyll *a* as a function of nutrient concentrations and the accumulated irradiance over the growing season, it might be possible to predict more precisely peak biomass under different nutrient and light scenarios. Thus, nutrient management may be targeted toward maintaining peak periphyton biomass below some level in the sunniest of seasons, with the understanding that higher chlorophyll levels would be unlikely to develop.

If the reason for developing regression models of periphyton chlorophyll *a* is to better understand ecological relationships and ecosystem functioning, then further modelling may be fruitful. My investigation of the relationship between algae and bacteria in periphyton along a nutrient gradient (Chapter 3) showed that, although the sign of the relationship was opposite to what I predicted, bacterial abundance did improve

predictions of instantaneous chlorophyll a . The positive association I observed between abundance and production of algae and bacteria may reflect a co-dependency between the two groups of organisms that could have implications to ecosystem productivity. Further investigations into algal-bacterial relationships in periphyton may find that the association between the two is also a function of diversity of one or both groups. Such an investigation could corroborate experimental mesocosm studies by Naeem et al. (2000) that found that total productivity and biomass were a function of the diversity of both algal and bacterial communities. Thus, although the regression model I developed to predict algal biomass based on nutrients and bacteria did not reach the theoretical limits of model precision, it may be a useful step toward better understanding productivity and diversity relationships in river periphyton.

Several studies have recently been published that highlight the importance of understanding the ecological implications of high versus low periphyton biomass. In particular, a recent study by Berglund (2003) demonstrated that organochlorine concentrations in fish were well correlated to biomass and organochlorine concentrations of periphyton in ten Swedish rivers. Thus, being able to more precisely predict periphyton biomass could lead to better models of contaminant transport and exposure to local biota. Huggins et al. (2004) recently observed that community structure of lake biofilms created differences in nutritional status for grazers such that when biofilm biomass was high, nutritional quality tended to be low. If the patterns observed by Huggins et al. (2004) are also found to be true for river periphyton, then there may be nutritional implications of high periphyton biomass for grazing invertebrates and their predators. Once again, models that more precisely predict periphyton biomass could

eventually be used to better understand the nutritional contributions of periphyton to higher trophic levels.

In summary, the predictive power of periphyton regression models will always be low in comparison to phytoplankton models, largely because of the high spatial heterogeneity in periphyton communities relative to phytoplankton communities.

Although additional modelling efforts may yield improved predictions of instantaneous periphyton biomass, and increased sampling effort may reduce pure error of temporal mean periphyton models, the effort involved in doing so may not be considered worthwhile from a management perspective. Periphyton is sometimes unsightly, smelly, and may discourage recreational use of waterways, but it seldom causes economic hardships, which means that it is seldom the driving force behind management actions. This does not mean that periphyton is unimportant from an ecological perspective, only that, historically, humans tend not to be particularly adept at dealing with issues that do not directly influence their lives. In fact, I believe strongly that continued effort to develop models that better predict instantaneous periphyton biomass will be useful in elucidating ecological relationships that have implications for, among other things, investigations into effects of biodiversity on ecosystem productivity, trophic level dynamics, and movement of contaminants in ecosystems.

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**Appendix A. Alberta Rivers: Periphyton Chlorophyll,
Water Quality, and Land Use Data**

Table A.1. Periphyton chlorophyll *a*, water quality and land use in Alberta rivers. Station_No: Unique Alberta Environment station identifier; Year: Year in which samples were collected; Season: Season in which samples were collected (spring, summer, and fall only); ACMe: Annual mean periphyton chlorophyll *a* (mg chl *a* m⁻²); ACVa: Variance of annual mean periphyton chlorophyll *a*; ACN: Number of daily means used to calculate annual mean periphyton chlorophyll *a*; SCMe: Seasonal mean periphyton chlorophyll *a* (mg chl *a* m⁻²); SCVa: Variance of seasonal mean periphyton chlorophyll *a*; SCN: Number of daily means used to calculate seasonal mean periphyton chlorophyll *a*; SCMa: Maximum mean daily chlorophyll *a* measured in a season (mg chl *a* m⁻²); TKN: Total Kjeldahl nitrogen (mg L⁻¹), seasonal mean; NOX: NO₂+NO₃ (mg L⁻¹), seasonal mean; TN: Total nitrogen = TKN + NOX (mg L⁻¹), seasonal mean; TP: Total phosphorus (mg L⁻¹), seasonal mean; TDP: Total dissolved phosphorus (mg L⁻¹), seasonal mean; BAS: Area of drainage basin (km²); POP: Number of humans living in drainage basin; FARM: Total area of farms in drainage basin (km²); CROP: Total crop area in drainage basin (km²); LU: Number of livestock units in drainage basin; ECOZ: Ecoregion or ecozone of station. MC: montane cordillera ecozone; BP: boreal plains ecozone; PMG: mixed and moist mixed grassland ecoregions; PFG: fescue grassland ecozone; PAP: aspen parkland ecozone. Note that ecozone/ecoregion was only determined for stations included in regression models of Chapter 1.

STATION_NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB05AA0050	1984	Fall	23	201	14	28	189	2	37	0.210	0.006	0.216	0.005	0.002	159959	133	10593	2269	2467	MC
AB05AA0050	1984	Spring	23	201	14	17	65	4	28	0.100	0.004	0.104	0.007	0.004	159959	133	10593	2269	2467	MC
AB05AA0050	1984	Summer	23	201	14	21	292	6	52	0.247	0.009	0.256	0.015	0.007	159959	133	10593	2269	2467	MC
AB05AA0050	1985	Fall	43	1334	12	41	1342	3	80	0.193	0.010	0.203	0.008	0.005	159959	136	9401	2215	2096	MC
AB05AA0050	1985	Spring	43	1334	12	27	545	3	45	0.485	0.005	0.490	0.016	0.009	159959	136	9401	2215	2096	MC
AB05AA0050	1985	Summer	43	1334	12	59	2100	5	126	0.569	0.003	0.572	0.010	0.005	159959	136	9401	2215	2096	MC
AB05AA0050	1991	Fall	6	9	4	5		1												
AB05AA0050	1991	Spring	6	9	4	6		1												

STATION NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB05AA0050	1991	Summer	6	9	4	7	25	2												
AB05AA0050	1992	Fall	12	124	4	27		1												
AB05AA0050	1992	Spring	12	124	4	1		1												
AB05AA0050	1992	Summer	12	124	4	10	20	2												
AB05AA0070	2000	Fall	12	32	9	10	24	4												
AB05AA0070	2000	Summer	12	32	9	13	43	5												
AB05AA0220	1991	Fall	69	837	4	32		1												
AB05AA0220	1991	Spring	69	837	4	59		1												
AB05AA0220	1991	Summer	69	837	4	92	2	2												
AB05AA0220	1992	Fall	87	6905	4	208		1												
AB05AA0220	1992	Spring	87	6905	4	19		1												
AB05AA0220	1992	Summer	87	6905	4	61	261	2												
AB05AA0270	1985	Fall	279	10582	11	234	6229	3	317	0.253	0.169	0.423	0.015	0.006	92708	7142	14405	4428	3452	PFG
AB05AA0270	1985	Spring	279	10582	11	253	23595	3	421	0.740	0.090	0.830	0.056	0.015	92708	7142	14405	4428	3452	PFG
AB05AA0270	1985	Summer	279	10582	11	321	7332	5	438	0.583	0.030	0.612	0.021	0.009	92708	7142	14405	4428	3452	PFG
AB05AA0400	1991	Fall	9	63	4	3		1												
AB05AA0400	1991	Spring	9	63	4	19		1												
AB05AA0400	1991	Summer	9	63	4	6	38	2												
AB05AA0400	1992	Fall	29	1343	4	6		1												
AB05AA0400	1992	Spring	29	1343	4	2		1												
AB05AA0400	1992	Summer	29	1343	4	53	1600	2												
AB05AA0410	1985	Fall	101	4127	10	160	225	3	174	0.153	0.043	0.197	0.012	0.005	127834	1600	39121	12238	9368	PFG
AB05AA0410	1985	Spring	101	4127	10	11	68	2	17	0.555	0.052	0.607	0.030	0.005	127834	1600	39121	12238	9368	PFG
AB05AA0410	1985	Summer	101	4127	10	102	2507	5	166	0.453	0.020	0.473	0.006	0.003	127834	1600	39121	12238	9368	PFG
AB05AB0040	1984	Fall	27	171	14	20	20	2	23	0.210	0.005	0.215	0.005	0.003	469885	10317	147123	44780	35668	PFG
AB05AB0040	1984	Spring	27	171	14	24	158	4	35	0.115	0.010	0.125	0.010	0.004	469885	10317	147123	44780	35668	PFG
AB05AB0040	1984	Summer	27	171	14	33	262	6	56	0.191	0.008	0.199	0.016	0.008	469885	10317	147123	44780	35668	PFG
AB05AB0040	1985	Fall	39	445	10	67		1												
AB05AB0040	1985	Spring	39	445	10	24	333	3	42	0.550	0.018	0.568	0.035	0.004	469885	10256	143122	44941	34037	PFG
AB05AB0040	1985	Summer	39	445	10	39	385	5	61	0.465	0.005	0.470	0.009	0.004	469885	10256	143122	44941	34037	PFG
AB05AB0040	1991	Fall	66	4765	5	50	1331	2	75	0.240	0.104	0.344	0.021	0.009	469885	9765	140876	46215	44501	PFG

STATION NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB05AB0040	1991	Spring	66	4765	5	44		1												
AB05AB0040	1991	Summer	66	4765	5	94	15121	2												
AB05AB0040	1992	Fall	117	14355	8	238	35698	2	372	0.340	0.018	0.358	0.013	0.002	469885	9759	171785	48589	51069	PFG
AB05AB0040	1992	Spring	117	14355	8	21	2	2	22	0.270	0.048	0.318	0.015	0.002	469885	9759	171785	48589	51069	PFG
AB05AB0040	1992	Summer	117	14355	8	113	7678	3	167	0.487	0.024	0.511	0.010	0.002	469885	9759	171785	48589	51069	PFG
AB05AB0070	2000	Fall	65	1233	11	83	701	4	119	0.063	0.058	0.120	0.006	0.002	469885	9648	286141	57793	81903	PFG
AB05AB0070	2000	Summer	65	1233	11	55	1366	7	102	0.190	0.065	0.255	0.009	0.003	469885	9648	286141	57793	81903	PFG
AB05AB0130	1984	Fall	36	1222	14	77	3851	2	121	0.170	0.002	0.262	0.005	0.003	589904	14552	223025	72217	53734	PMG
AB05AB0130	1984	Spring	36	1222	14	23	177	4	32	0.135	0.034	0.169	0.013	0.003	589904	14552	223025	72217	53734	PMG
AB05AB0130	1984	Summer	36	1222	14	33	1145	6	84	0.220	0.005	0.217	0.036	0.008	589904	14552	223025	72217	53734	PMG
AB05AB0130	1985	Fall	61	2304	9	61		1												
AB05AB0130	1985	Spring	61	2304	9	27	504	3	52	0.500	0.010	0.510	0.067	0.005	589904	14226	218654	72703	51648	PMG
AB05AB0130	1985	Summer	61	2304	9	81	2978	5	168	0.540	0.004	0.544	0.011	0.004	589904	14226	218654	72703	51648	PMG
AB05AB0130	1991	Fall	8	63	4	5		1												
AB05AB0130	1991	Spring	8	63	4	4		1												
AB05AB0130	1991	Summer	8	63	4	11	150	2												
AB05AB0130	1992	Fall	18	344	4	46		1												
AB05AB0130	1992	Spring	18	344	4	6		1												
AB05AB0130	1992	Summer	18	344	4	10	7	2												
AB05AB0130	2000	Fall	4	12	9	3	3	4	5	0.180	0.002	0.182	0.011	0.002	589904	14776	354842	82352	107938	PMG
AB05AB0130	2000	Summer	4	12	9	5	19	5												
AB05AB0170	1990	Fall	101	1162	7	114	1002	3												
AB05AB0170	1990	Summer	101	1162	7	91	1366	4												
AB05AB0200	1990	Fall	26	95	7	33	7	3												
AB05AB0200	1990	Summer	26	95	7	21	107	4												
AB05AB0220	1990	Fall	14	333	7	12	31	3	18	0.253	0.006	0.260	0.020	0.004	114384	562	52425	21342	12989	PMG
AB05AB0220	1990	Summer	14	333	7	16	638	4	53	0.370	0.003	0.373	0.030	0.003	114384	562	52425	21342	12989	PMG
AB05AB0220	1999	Fall	13	68	6	22	70	2	28	0.185	0.004	0.189	0.044	0.014	114384	627	80915	22228	21852	PMG
AB05AB0220	1999	Summer	13	68	6	9	16	4	15	0.323	0.003	0.326	0.026	0.004	114384	627	80915	22228	21852	PMG
AB05AB0250	1990	Fall	68	467	7	73	386	3	88	0.280	0.004	0.284	0.020	0.003	198688	4584	120600	49802	30189	PMG
AB05AB0250	1990	Summer	68	467	7	64	622	4	84	0.405	0.003	0.408	0.038	0.003	198688	4584	120600	49802	30189	PMG

STATION NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOA
AB05AB0260	1990	Fall	66	460	7	75	159	3	90	0.247	0.003	0.250	0.015	0.004	227248	5224	148668	61520	37270	PMG
AB05AB0260	1990	Summer	66	460	7	59	662	4	88	0.425	0.005	0.430	0.045	0.005	227248	5224	148668	61520	37270	PMG
AB05AB0260	1999	Fall	37	89	6	31	36	2	35	0.235	0.081	0.316	0.013	0.002	227248	5647	183997	63312	58446	PMG
AB05AB0260	1999	Summer	37	89	6	40	97	4	48	0.397	0.004	0.401	0.020	0.004	227248	5647	183997	63312	58446	PMG
AB05AB0260	2000	Fall	29	279	4	44		1												
AB05AB0260	2000	Summer	29	279	4	24	255	3	40	0.257	0.003	0.259	0.022	0.008	227248	5712	184802	63117	58070	PMG
AB05AB0770	1999	Fall	14	24	7	12	61	2												
AB05AB0770	1999	Summer	14	24	7	15	19	5												
AB05AB0770	2000	Fall	28	194	4	17	28	2												
AB05AB0770	2000	Summer	28	194	4	38	116	2												
AB05AB0780	1999	Fall	26	228	7	26	0	2												
AB05AB0780	1999	Summer	26	228	7	26	342	5												
AB05AB0780	2000	Fall	85	994	4	100	89	2												
AB05AB0780	2000	Summer	85	994	4	70	1990	2												
AB05AB0790	1999	Fall	15	356	7	29	1202	2												
AB05AB0790	1999	Summer	15	356	7	9	95	5												
AB05AB0790	2000	Fall	78	701	4	104		1												
AB05AB0790	2000	Summer	78	701	4	69	594	3												
AB05AB0970	2000	Fall	12	52	9	16	69	4												
AB05AB0970	2000	Summer	12	52	9	9	26	5												
AB05AC0010	2000	Fall	28	107	9	34	151	4	46	0.170	0.002	0.172	0.009	0.009	882647	24564	618102	182154	210389	PMG
AB05AC0010	2000	Summer	28	107	9	24	49	5												
AB05AC0066	1999	Fall	24	400	7	39	35	2												
AB05AC0066	1999	Spring	24	400	7	13	10	2												
AB05AC0066	1999	Summer	24	400	7	21	830	3												
AB05AC0066	2000	Fall	29	396	7	30	331	2												
AB05AC0066	2000	Spring	29	396	7	27	66	2												
AB05AC0066	2000	Summer	29	396	7	28	986	3												
AB05AC0080	1990	Fall	158	6800	7	227	4566	3												
AB05AC0080	1990	Summer	158	6800	7	107	2207	4												
AB05AC0080	1999	Fall	168	9778	7	260	18487	2												

STATION_NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB05AC0080	1999	Spring	168	9778	7	72	444	2											
AB05AC0080	1999	Summer	168	9778	7	171	2294	3											
AB05AC0080	2000	Fall	180	4898	7	257	827	2											
AB05AC0080	2000	Spring	180	4898	7	131	23	2											
AB05AC0080	2000	Summer	180	4898	7	160	5371	3											
AB05AC0089	1999	Fall	22	559	7	41	1485	2											
AB05AC0089	1999	Spring	22	559	7	18	639	2											
AB05AC0089	1999	Summer	22	559	7	12	81	3											
AB05AC0089	2000	Fall	33	412	7	37	677	2											
AB05AC0089	2000	Spring	33	412	7	28	432	2											
AB05AC0089	2000	Summer	33	412	7	35	641	3											
AB05AC0093	1999	Fall	76	854	7	102	211	2											
AB05AC0093	1999	Spring	76	854	7	42	14	2											
AB05AC0093	1999	Summer	76	854	7	83	521	3											
AB05AC0093	2000	Fall	142	12859	7	271	20289	2											
AB05AC0093	2000	Spring	142	12859	7	79	3804	2											
AB05AC0093	2000	Summer	142	12859	7	98	3082	3											
AB05AC0100	1990	Fall	224	9441	9	232	5560	3											
AB05AC0100	1990	Summer	224	9441	9	194	17071	4											
AB05AC0100	1998	Fall	174	21099	6	206	1386	2											
AB05AC0100	1998	Spring	174	21099	6	423		1											
AB05AC0100	1998	Summer	174	21099	6	70	3688	3											
AB05AC0100	1999	Fall	201	27500	7	425	15040	2											
AB05AC0100	1999	Spring	201	27500	7	73	12	2											
AB05AC0100	1999	Summer	201	27500	7	138	2223	3											
AB05AC0100	2000	Fall	130	891	7	130	172	2											
AB05AC0100	2000	Spring	130	891	7	115	1	2											
AB05AC0100	2000	Summer	130	891	7	139	2221	3											
AB05AC0110	1998	Fall	13	230	4	15		1											
AB05AC0110	1998	Spring	13	230	4	0		1											
AB05AC0110	1998	Summer	13	230	4	18	478	2											

STATION_NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	EC0Z
AB05AC0110	1999	Fall	38	603	7	32	203	2												
AB05AC0110	1999	Spring	38	603	7	26	160	2												
AB05AC0110	1999	Summer	38	603	7	49	1252	3												
AB05AC0110	2000	Spring	26	962	3	8	7	2												
AB05AC0110	2000	Summer	26	962	3	62		1												
AB05AC0120	1999	Fall	40	740	7	53	1811	2												
AB05AC0120	1999	Spring	40	740	7	44	1101	2												
AB05AC0120	1999	Summer	40	740	7	28	342	3												
AB05AC0120	2000	Fall	64	3128	7	72	380	2												
AB05AC0120	2000	Spring	64	3128	7	16	445	2												
AB05AC0120	2000	Summer	64	3128	7	90	5520	3												
AB05AC0130	1999	Fall	126	4904	6	81		1												
AB05AC0130	1999	Spring	126	4904	6	126	13694	2	209	0.820	0.094	0.914	0.069	0.019	11800	137	11565	4967	4351	PFG
AB05AC0130	1999	Summer	126	4904	6	141	4032	3	203	1.062	0.018	1.080	0.089	0.033	11800	137	11565	4967	4351	PFG
AB05AC0130	2000	Spring	63	3819	3	30	1013	2	53	0.771	0.007	0.778	0.139	0.031	11800	138	11534	4956	4304	PFG
AB05AC0130	2000	Summer	63	3819	3	130		1												
AB05AC0140	1998	Fall	62	513	2	46		1												
AB05AC0140	1998	Summer	62	513	2	78		1												
AB05AC0140	1999	Fall	48	1258	7	74	2077	2	106	0.342	0.150	0.492	0.033	0.012	51781	1272	49417	20242	19756	PFG
AB05AC0140	1999	Spring	48	1258	7	28	845	2	48	0.634	0.096	0.730	0.073	0.018	51781	1272	49417	20242	19756	PFG
AB05AC0140	1999	Summer	48	1258	7	44	1195	3	72	0.656	0.032	0.688	0.100	0.016	51781	1272	49417	20242	19756	PFG
AB05AC0140	2000	Fall	29	247	7	47	29	2												
AB05AC0140	2000	Spring	29	247	7	12	176	2	21	0.564	0.031	0.596	0.112	0.024	51781	1315	49475	20057	20398	PFG
AB05AC0140	2000	Summer	29	247	7	28	30	3	34	0.288	0.008	0.296	0.079	0.008	51781	1315	49475	20057	20398	PFG
AB05AC0150	1999	Fall	176	10416	6	231	1585	2												
AB05AC0150	1999	Spring	176	10416	6	20		1												
AB05AC0150	1999	Summer	176	10416	6	191	9729	3												
AB05AC0150	2000	Fall	150	4418	7	172	15356	2												
AB05AC0150	2000	Spring	150	4418	7	110	3000	2												
AB05AC0150	2000	Summer	150	4418	7	163	1695	3												
AB05AC0160	1990	Fall	171	7876	7	175	10662	3	240	0.300	0.002	0.302	0.032	0.016	94701	3339	88732	37955	21379	PFG

STATION_NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ	
AB05AC0160	1990	Summer	171	7876	7	167	8606	4	295	0.455	0.002	0.457	0.140	0.123	94701	3339	88732	37955	21379	PFG
AB05AC0160	1998	Fall	37	88	2	44		1												
AB05AC0160	1998	Summer	37	88	2	30		1												
AB05AC0160	1999	Fall	77	2462	7	87	5007	2	137	0.477	0.059	0.535	0.045	0.011	94701	3940	91277	38194	36181	PFG
AB05AC0160	1999	Spring	77	2462	7	36	1457	2	63	0.709	0.029	0.738	0.091	0.017	94701	3940	91277	38194	36181	PFG
AB05AC0160	1999	Summer	77	2462	7	98	1703	3	129	0.898	0.103	1.001	0.256	0.025	94701	3940	91277	38194	36181	PFG
AB05AC0160	2000	Fall	103	1730	7	103	895	2												
AB05AC0160	2000	Spring	103	1730	7	53	378	2	66	0.766	0.005	0.771	0.182	0.057	94701	3970	91271	37920	36965	PFG
AB05AC0160	2000	Summer	103	1730	7	137	317	3	150	0.311	0.003	0.313	0.110	0.024	94701	3970	91271	37920	36965	PFG
AB05AC0175	1999	Fall	113	8154	7	108	3399	2												
AB05AC0175	1999	Spring	113	8154	7	61	1204	2												
AB05AC0175	1999	Summer	113	8154	7	151	17308	3												
AB05AC0175	2000	Fall	73	4171	6	37	32	2												
AB05AC0175	2000	Spring	73	4171	6	20		1												
AB05AC0175	2000	Summer	73	4171	6	115	5012	3												
AB05AC0190	1990	Fall	210	11161	9	249	19641	3	400	0.353	0.003	0.357	0.032	0.013	607233	16391	586125	273582	111320	PMG
AB05AC0190	1990	Summer	210	11161	9	200	13484	4	345	0.540	0.005	0.545	0.057	0.022	607233	16391	586125	273582	111320	PMG
AB05AC0190	1998	Fall	251	14967	3	316	4708	2	364	0.110	0.007	0.117	0.028	0.007	607233	19249	586423	288796	197205	PMG
AB05AC0190	1998	Summer	251	14967	3	121		1												
AB05AC0190	1999	Fall	257	16820	7	351	9689	2	421	0.280	0.009	0.289	0.014	0.005	607233	19599	586275	289402	203276	PMG
AB05AC0190	1999	Spring	257	16820	7	120	172	2	130	0.420	0.003	0.423	0.039	0.010	607233	19599	586275	289402	203276	PMG
AB05AC0190	1999	Summer	257	16820	7	286	16712	3	397	0.500	0.002	0.502	0.041	0.010	607233	19599	586275	289402	203276	PMG
AB05AC0190	2000	Fall	168	5404	7	182	0	2	182	0.205	0.002	0.207	0.008	0.005	607233	19949	586128	290008	209346	PMG
AB05AC0190	2000	Spring	168	5404	7	84	6258	2	140	0.600	0.002	0.602	0.050	0.007	607233	19949	586128	290008	209346	PMG
AB05AC0190	2000	Summer	168	5404	7	215	2460	3	253	0.253	0.002	0.255	0.021	0.012	607233	19949	586128	290008	209346	PMG
AB05AC0210	1999	Fall	50	397	7	55	71	2												
AB05AC0210	1999	Spring	50	397	7	42	489	2												
AB05AC0210	1999	Summer	50	397	7	53	809	3												
AB05AD0010	1991	Fall	22	751	5	14	49	2	19	0.260	0.041	0.301	0.018	0.007	1527305	78461	769453	327665	240094	PMG
AB05AD0010	1991	Spring	22	751	5	38	2156	2	70	0.340	0.003	0.343	0.045	0.009	1527305	78461	769453	327665	240094	PMG
AB05AD0010	1991	Summer	22	751	5	8		1												

STATION_NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB05AD0010	1992	Fall	58	2781	7	107	3208	2	147	0.160	0.003	0.163	0.018	0.002	1527305	78929	815779	332056	262880	PMG
AB05AD0010	1992	Spring	58	2781	7	5	5	2	7	0.410	0.035	0.445	0.032	0.008	1527305	78929	815779	332056	262880	PMG
AB05AD0010	1992	Summer	58	2781	7	60	1555	3	94	1.600	0.002	1.602	0.026	0.004	1527305	78929	815779	332056	262880	PMG
AB05AD0010	1993	Fall	20	17	2	23		1												
AB05AD0010	1993	Summer	20	17	2	17		1												
AB05AD0010	1999	Fall	48	153	3	60		1												
AB05AD0010	1999	Summer	48	153	3	42	98	2												
AB05AD0010	2000	Fall	84	1884	12	100	2018	5	166	0.190	0.027	0.217	0.008	0.004	1527305	82490	946574	338817	367688	PMG
AB05AD0010	2000	Summer	84	1884	12	73	1740	7	124	0.263	0.004	0.268	0.024	0.003	1527305	82490	946574	338817	367688	PMG
AB05AD0275	2000	Fall	15	29	9	20	8	4												
AB05AD0275	2000	Summer	15	29	9	11	11	5												
AB05AD0300	1999	Fall	8	18	3	4		1												
AB05AD0300	1999	Summer	8	18	3	10	8	2												
AB05AD0370	1980	Fall	45	2438	7	22	155	2	31		0.015		0.014	0.003	1527305	75535	780967	308701	213365	PMG
AB05AD0370	1980	Summer	45	2438	7	63	3861	4	141		0.019		0.046	0.004	1527305	75535	780967	308701	213365	PMG
AB05AD0370	1981	Fall	49	3615	8	125	6971	2	184		0.010		0.007	0.003	1527305	75535	780967	308701	213365	PMG
AB05AD0370	1981	Spring	49	3615	8	18		1												
AB05AD0370	1981	Summer	49	3615	8	16	25	2												
AB05AD0370	1984	Fall	92	5518	14	126	1335	2	152	0.540	0.043	0.583	0.040	0.016	1527305	76151	779637	326641	197556	PMG
AB05AD0370	1984	Spring	92	5518	14	81	2977	4	134	0.255	0.008	0.263	0.066	0.023	1527305	76151	779637	326641	197556	PMG
AB05AD0370	1984	Summer	92	5518	14	84	8358	6	249	0.360	0.024	0.384	0.036	0.015	1527305	76151	779637	326641	197556	PMG
AB05AD0500	1993	Fall	169	10077	2	240		1												
AB05AD0500	1993	Summer	169	10077	2	98		1												
AB05AD0610	2000	Fall	102	2427	10	119	2298	5	173	0.170	0.002	0.172	0.015	0.002	1527305	82490	946574	338817	367688	PMG
AB05AD0610	2000	Summer	102	2427	10	86	2505	5												
AB05AD0740	1980	Fall	108	7017	7	130	2319	2												
AB05AD0740	1980	Spring	108	7017	7	120		1												
AB05AD0740	1980	Summer	108	7017	7	123	14349	3												
AB05AD0740	1981	Fall	58	755	8	49		1												
AB05AD0740	1981	Spring	58	755	8	90	16	2												
AB05AD0740	1981	Summer	58	755	8	37		1												

STATION_NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB05AD0740	1984	Fall	188	14378	13	174		1												
AB05AD0740	1984	Spring	188	14378	13	287	24937	4												
AB05AD0740	1984	Summer	188	14378	13	156	3302	6												
AB05AD0740	1991	Fall	47	2350	4	111		1												
AB05AD0740	1991	Spring	47	2350	4	56		1												
AB05AD0740	1991	Summer	47	2350	4	10	207	2												
AB05AD0740	1992	Fall	238	40556	4	101		1												
AB05AD0740	1992	Spring	238	40556	4	531		1												
AB05AD0740	1992	Summer	238	40556	4	160	5053	2												
AB05AD0740	1993	Fall	29	1347	2	55		1												
AB05AD0740	1993	Summer	29	1347	2	3		1												
AB05AG0010	1999	Fall	22	396	3	40		1												
AB05AG0010	1999	Summer	22	396	3	13	317	2												
AB05AG0010	2000	Fall	39	320	12	56	150	5												
AB05AG0010	2000	Summer	39	320	12	28	96	7												
AB05AG0070	1984	Fall	158	8720	14	223	36545	2												
AB05AG0070	1984	Spring	158	8720	14	112	5414	4												
AB05AG0070	1984	Summer	158	8720	14	133	2089	6												
AB05AG0090	2000	Fall	20	102	10	25	109	5												
AB05AG0090	2000	Summer	20	102	10	16	78	5												
AB05AG0220	1993	Fall	39	664	4	52		1												
AB05AG0220	1993	Summer	39	664	4	34	881	3												
AB05AG0230	1980	Fall	23	295	10	29	347	3	41		0.006		0.031	0.015	2100018	116162	1266655	583839	371497	PMG
AB05AG0230	1980	Spring	23	295	10	31	1058	2	54		0.113		0.328	0.038	2100018	116162	1266655	583839	371497	PMG
AB05AG0230	1980	Summer	23	295	10	19	68	4	24		0.028		0.039	0.009	2100018	116162	1266655	583839	371497	PMG
AB05AG0230	1981	Fall	22	328	10	49	535	2	65		0.008		0.032	0.015	2100018	116162	1266655	583839	371497	PMG
AB05AG0230	1981	Spring	22	328	10	20	265	2	32		0.062		0.193	0.036	2100018	116162	1266655	583839	371497	PMG
AB05AG0230	1981	Summer	22	328	10	4	1	2												
AB05AG0230	1984	Fall	107	2078	14	66	1048	2	88	0.590	0.013	0.603	0.085	0.053	2100018	118527	1295461	617732	348820	PMG
AB05AG0230	1984	Spring	107	2078	14	91	2136	4	139	0.345	0.010	0.355	0.108	0.051	2100018	118527	1295461	617732	348820	PMG
AB05AG0230	1984	Summer	107	2078	14	113	1696	6	159	0.470	0.011	0.481	0.063	0.031	2100018	118527	1295461	617732	348820	PMG

STATION_NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB05AG0230	1986	Fall	50	407	7	54	329	3	70	0.473	0.002	0.476	0.056	0.022	2100018	120104	1314666	640327	333702	PMG
AB05AG0230	1986	Spring	50	407	7	27	10	2	30	0.440	0.003	0.443	0.057	0.017	2100018	120104	1314666	640327	333702	PMG
AB05AG0230	1986	Summer	50	407	7	66	194	2												
AB05AJ0040	1980	Fall	50	1130	6	43	998	2	65		0.239		0.055	0.022	5158189	786924	3011512	1352902	788048	PMG
AB05AJ0040	1980	Summer	50	1130	6	54	1497	4	102		0.150		0.082	0.018	5158189	786924	3011512	1352902	788048	PMG
AB05AJ0040	1981	Fall	26	580	8	41	1315	3	74		0.021		0.027	0.011	5158189	786924	3011512	1352902	788048	PMG
AB05AJ0040	1981	Spring	26	580	8	6		1												
AB05AJ0040	1981	Summer	26	580	8	14	11	2												
AB05AJ0040	1986	Fall	23	650	5	50	146	2	59	0.660	0.494	1.154	0.076	0.006	5158189	837896	3221916	1470399	626086	PMG
AB05AJ0040	1986	Spring	23	650	5	7		1												
AB05AJ0040	1986	Summer	23	650	5	4	0	2												
AB05AK0020	1980	Fall	54	654	7	65	643	2	83		0.112		0.033	0.014	5530833	804576	3322146	1472042	845502	PMG
AB05AK0020	1980	Summer	54	654	7	51	950	4	85		0.087		0.062	0.010	5530833	804576	3322146	1472042	845502	PMG
AB05AK0020	1981	Fall	24	226	8	31		1												
AB05AK0020	1981	Spring	24	226	8	48		1												
AB05AK0020	1981	Summer	24	226	8	11	175	2												
AB05AK0020	1986	Fall	14	745	6	27	1366	3	69	0.893	0.264	1.157	0.171	0.105	5530833	857165	3565355	1606125	677041	PMG
AB05AK0020	1986	Spring	14	745	6	1		1												
AB05AK0020	1986	Summer	14	745	6	1	2	2												
AB05AK0020	1998	Fall	27	85	5	27	0	2												
AB05AK0020	1998	Spring	27	85	5	29		1												
AB05AK0020	1998	Summer	27	85	5	27	337	2												
AB05AK0020	1999	Fall	8	41	7	11	112	2	19	0.195	0.250	0.445	0.017	0.007	5530833	1118910	3790154	1660278	1523270	PMG
AB05AK0020	1999	Spring	8	41	7	9	0	2	9	0.500	0.075	0.575	0.018	0.128	5530833	1118910	3790154	1660278	1523270	PMG
AB05AK0020	1999	Summer	8	41	7	6	51	3	14	0.427	0.045	0.472	0.046	0.008	5530833	1118910	3790154	1660278	1523270	PMG
AB05AK0020	2000	Fall	34	559	7	30	50	2	35	0.285	0.069	0.354	0.017	0.004	5530833	1148161	3777018	1659891	1582603	PMG
AB05AK0020	2000	Spring	34	559	7	5	29	2	9	0.450	0.125	0.575	0.039	0.008	5530833	1148161	3777018	1659891	1582603	PMG
AB05AK0020	2000	Summer	34	559	7	56	58	3	64	0.400	0.002	0.402	0.020	0.003	5530833	1148161	3777018	1659891	1582603	PMG
AB05AK0370	1980	Fall	38	384	4	24		1												
AB05AK0370	1980	Summer	38	384	4	54	126	2												
AB05AK0370	1981	Fall	41	750	7	83		1												

STATION_NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB05AK0370	1981	Spring	41	750	7	29		1												
AB05AK0370	1981	Summer	41	750	7	34	1037	2												
AB05AK0370	1986	Fall	68	6122	7	67	5761	3	152	0.673	0.209	0.882	0.091	0.014	5530833	857165	3565355	1606125	677041	PMG
AB05AK0370	1986	Spring	68	6122	7	134	8197	2	198	0.530	0.009	0.539	0.082	0.010	5530833	857165	3565355	1606125	677041	PMG
AB05AK0370	1986	Summer	68	6122	7	3	5	2												
AB05AK0490	1980	Fall	94	3075	3	90		1												
AB05AK0490	1980	Summer	94	3075	3	152		1												
AB05AK0490	1981	Fall	60	1311	7	41		1												
AB05AK0490	1981	Spring	60	1311	7	117		1												
AB05AK0490	1981	Summer	60	1311	7	73	213	3	82		0.007		0.060	0.004	6008284	824348	3609365	1517778	879752	PMG
AB05AK0490	1986	Fall	40	2346	7	34	750	3	66	1.013	0.268	1.281	0.315	0.119	6008284	874086	3911815	1658580	709666	PMG
AB05AK0490	1986	Spring	40	2346	7	14	51	2	19	0.540	0.005	0.545	0.061	0.007	6008284	874086	3911815	1658580	709666	PMG
AB05AK0490	1986	Summer	40	2346	7	75	8626	2												
AB05BB0010	1991	Fall	15	17	3	13	13	2												
AB05BB0010	1991	Spring	15	17	3	19		1												
AB05BB0020	1991	Fall	45	759	3	32	499	2												
AB05BB0020	1991	Spring	45	759	3	71		1												
AB05BB0030	1991	Fall	3	8	3	1	0	2												
AB05BB0030	1991	Spring	3	8	3	6		1												
AB05BB0040	1991	Fall	24	300	3	31	286	2												
AB05BB0040	1991	Spring	24	300	3	9		1												
AB05BB0050	1991	Fall	13	14	3	12	24	2												
AB05BB0050	1991	Spring	13	14	3	15		1												
AB05BB0060	1991	Fall	44	860	3	29	229	2												
AB05BB0060	1991	Spring	44	860	3	76		1												
AB05BE0010	1995	Fall	47	843	5	57	967	2												
AB05BE0010	1995	Spring	47	843	5	78		1												
AB05BE0010	1995	Summer	47	843	5	22	22	2												
AB05BE0010	1996	Fall	17	82	4	25	6	2												
AB05BE0010	1996	Summer	17	82	4	10	14	2												
AB05BE0030	1991	Fall	16	441	2	30		1												

STATION NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB05BE0030	1991	Summer	16	441	2	1		1												
AB05BE0050	1991	Fall	10	158	2	19		1												
AB05BE0050	1991	Summer	10	158	2	1		1												
AB05BE0065	2000	Fall	48	3469	7	95	13142	2	176	0.053	0.146	0.199	0.002	0.002	398135	9282	5022	226	354	MC
AB05BE0065	2000	Spring	48	3469	7	22	81	2	29	0.025	0.131	0.156	0.002	0.002	398135	9282	5022	226	354	MC
AB05BE0065	2000	Summer	48	3469	7	35	687	3	65	0.138	0.150	0.288	0.003	0.002	398135	9282	5022	226	354	MC
AB05BE0075	2000	Fall	13	214	7	16	71	2	22	0.083	0.159	0.241	0.002	0.002	398135	9282	5022	226	354	MC
AB05BE0075	2000	Spring	13	214	7	4	29	2	8	0.043	0.112	0.172	0.002	0.002	398135	9282	5022	226	354	MC
AB05BE0075	2000	Summer	13	214	7	16	493	3	42	0.190	0.141	0.331	0.007	0.002	398135	9282	5022	226	354	MC
AB05BE0090	1991	Fall	7	19	2	10		1												
AB05BE0090	1991	Summer	7	19	2	4		1												
AB05BE0100	1991	Fall	2	0	2	2		1												
AB05BE0100	1991	Summer	2	0	2	2		1												
AB05BE0105	2000	Fall	18	75	7	17	46	2	22	0.073	0.213	0.285	0.002	0.002	398135	9282	5022	226	354	MC
AB05BE0105	2000	Spring	18	75	7	20	37	2	24	0.025	0.177	0.202	0.002	0.002	398135	9282	5022	226	354	MC
AB05BE0105	2000	Summer	18	75	7	18	180	3	31	0.200	0.179	0.379	0.002	0.002	398135	9282	5022	226	354	MC
AB05BE0190	1991	Fall	29	514	2	45		1												
AB05BE0190	1991	Summer	29	514	2	13		1												
AB05BE0190	1993	Fall	45	5174	3	128		1												
AB05BE0190	1993	Summer	45	5174	3	4	2	2												
AB05BE0190	1994	Fall	32	1158	6	87		1												
AB05BE0190	1994	Spring	32	1158	6	1		1												
AB05BE0190	1994	Summer	32	1158	6	17	296	3	35	0.147	0.068	0.215	0.005	0.002	429958	14031	11544	339	1125	MC
AB05BE0190	1995	Fall	33	882	6	61	586	2	78	0.105	0.091	0.196	0.013	0.005	429958	14696	9140	280	1002	MC
AB05BE0190	1995	Spring	33	882	6	8		1												
AB05BE0190	1995	Summer	33	882	6	8	1	2												
AB05BE0190	1996	Fall	82	1842	4	93	163	2	102	0.085	0.050	0.135	0.004	0.004	429958	15360	6736	222	878	MC
AB05BE0190	1996	Spring	82	1842	4	121		1												
AB05BE0190	1996	Summer	82	1842	4	22		1												
AB05BE0190	1997	Fall	62	3765	5	60	155	2	69	0.048	0.106	0.153	0.009	0.002	429958	16072	7222	264	812	MC
AB05BE0190	1997	Spring	62	3765	5	164		1												

STATION NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB05BE0190	1997	Summer	62	3765	5	14	0	2												
AB05BE0190	1998	Fall	89	9843	6	211	1996	2	243	0.100	0.062	0.162	0.005	0.002	429958	16783	7709	307	745	MC
AB05BE0190	1998	Spring	89	9843	6	4		1												
AB05BE0190	1998	Summer	89	9843	6	36	805	3	68	0.137	0.084	0.221	0.007	0.002	429958	16783	7709	307	745	MC
AB05BE0190	1999	Fall	74	8570	7	158	27353	2	275	0.070	0.077	0.147	0.009	0.005	429958	17495	8195	349	679	MC
AB05BE0190	1999	Spring	74	8570	7	25	452	2	40	0.415	0.075	0.490	0.005	0.002	429958	17495	8195	349	679	MC
AB05BE0190	1999	Summer	74	8570	7	51	1615	3	76	0.108	0.091	0.200	0.007	0.002	429958	17495	8195	349	679	MC
AB05BE0190	2000	Fall	72	2077	7	103	1579	2	131	0.043	0.114	0.157	0.004	0.004	429958	18206	8681	391	613	MC
AB05BE0190	2000	Spring	72	2077	7	49	1	2	50	0.113	0.090	0.202	0.005	0.002	429958	18206	8681	391	613	MC
AB05BE0190	2000	Summer	72	2077	7	66	3941	3	128	0.107	0.093	0.200	0.016	0.006	429958	18206	8681	391	613	MC
AB05BE0240	1991	Fall	101	11766	2	177		1												
AB05BE0240	1991	Summer	101	11766	2	24		1												
AB05BH0010	1993	Fall	109	6731	4	154	8310	2	218	0.320	0.062	0.382	0.003	0.002	690566	20855	91907	25565	18002	PAP
AB05BH0010	1993	Spring	109	6731	4	110		1												
AB05BH0010	1993	Summer	109	6731	4	20		1												
AB05BH0010	1994	Fall	122	739	3	152		1												
AB05BH0010	1994	Summer	122	739	3	99		1												
AB05BH0010	1995	Fall	47	1692	5	30	865	2	51	0.095	0.070	0.165	0.008	0.003	690566	22845	77380	25086	18160	PAP
AB05BH0010	1995	Summer	47	1692	5	31	62	2												
AB05BH0010	1996	Fall	24	286	5	30	75	2	36	0.075	0.024	0.099	0.002	0.002	690566	23840	70117	24847	18240	PAP
AB05BH0010	1996	Spring	24	286	5	4		1												
AB05BH0010	1996	Summer	24	286	5	29	551	2												
AB05BH0010	1997	Fall	16	295	5	14	19	2	17	0.053	0.043	0.096	0.005	0.005	690566	25129	71455	25412	18165	PAP
AB05BH0010	1997	Spring	16	295	5	44		1												
AB05BH0010	1997	Summer	16	295	5	3	0	2												
AB05BH0010	1998	Fall	32	596	5	58	35	2	62	0.080	0.037	0.117	0.002	0.002	690566	26417	72793	25978	18091	PAP
AB05BH0010	1998	Spring	32	596	5	4		1												
AB05BH0010	1998	Summer	32	596	5	21	14	2												
AB05BH0010	1999	Fall	14	321	7	18	203	2	28	0.080	0.055	0.135	0.010	0.005	690566	27706	74131	26543	18016	PAP
AB05BH0010	1999	Spring	14	321	7	1	1	2	2	0.495	0.042	0.537	0.002	0.002	690566	27706	74131	26543	18016	PAP
AB05BH0010	1999	Summer	14	321	7	20	630	3	48	2.053	0.066	2.119	0.007	0.002	690566	27706	74131	26543	18016	PAP

STATION_NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECO2
AB05BH0010	2000	Fall	11	698	7	37	2267	2	71	0.038	0.072	0.109	0.004	0.002	690566	28995	75469	27109	17942	PAP
AB05BH0010	2000	Spring	11	698	7	0	0	2	1	0.125	0.068	0.193	0.003	0.002	690566	28995	75469	27109	17942	PAP
AB05BH0010	2000	Summer	11	698	7	0	0	3	0	0.098	0.097	0.195	0.011	0.005	690566	28995	75469	27109	17942	PAP
AB05BH0110	1980	Fall	43	508	8	56	332	3	72		0.015		0.005	0.002	744630	30745	109087	45240	28798	PAP
AB05BH0110	1980	Spring	43	508	8	11		1												
AB05BH0110	1980	Summer	43	508	8	43	608	3	60		0.033		0.008	0.003	744630	30745	109087	45240	28798	PAP
AB05BH0110	1981	Fall	22	195	10	26		1												
AB05BH0110	1981	Spring	22	195	10	21		1												
AB05BH0110	1981	Summer	22	195	10	13	26	5	20		0.054		0.011	0.002	744630	30745	109087	45240	28798	PAP
AB05BH0110	1993	Fall	7	26	4	14		1												
AB05BH0110	1993	Summer	7	26	4	5	5	3	7	0.440	0.057	0.497	0.009	0.002	744630	50152	141857	51384	32899	PAP
AB05BH0140	1983	Fall	70	2556	14	97	5385	4	169		0.010		0.020	0.007	744630	31893	111682	46680	27466	PAP
AB05BH0140	1983	Spring	70	2556	14	63	846	3	96		0.017		0.013	0.004	744630	31893	111682	46680	27466	PAP
AB05BH0140	1983	Summer	70	2556	14	58	1907	7	144		0.044		0.015	0.012	744630	31893	111682	46680	27466	PAP
AB05BH0140	1984	Fall	57	927	18	39	517	4	59		0.010		0.003	0.002	744630	32466	112979	47400	26800	PAP
AB05BH0140	1984	Spring	57	927	18	76	1088	5	123		0.009		0.017	0.018	744630	32466	112979	47400	26800	PAP
AB05BH0140	1984	Summer	57	927	18	53	704	6	85		0.022		0.013	0.008	744630	32466	112979	47400	26800	PAP
AB05BH0140	1985	Fall	40	668	10	55	40	3	62	0.233	0.037	0.270	0.006	0.004	744630	33040	114276	48120	26134	PAP
AB05BH0140	1985	Spring	40	668	10	49	2411	2	84	0.650	0.004	0.654	0.012	0.005	744630	33040	114276	48120	26134	PAP
AB05BH0140	1985	Summer	40	668	10	27	448	5	55	0.284	0.023	0.307	0.009	0.003	744630	33040	114276	48120	26134	PAP
AB05BH0140	1986	Fall	22	1272	9	8	129	2	16	0.290	0.026	0.316	0.006	0.003	744630	33613	115573	48839	25468	PAP
AB05BH0140	1986	Spring	22	1272	9	26	405	2	40	0.260	0.008	0.268	0.018	0.007	744630	33613	115573	48839	25468	PAP
AB05BH0140	1986	Summer	22	1272	9	2	7	2												
AB05BH0140	1987	Fall	41	2202	5	42		1												
AB05BH0140	1987	Summer	41	2202	5	2	1	2												
AB05BH0140	1988	Fall	19	64	6	17	223	2	28	0.130	0.033	0.163	0.007	0.002	744630	38949	131147	50055	27919	PAP
AB05BH0140	1988	Spring	19	64	6	20		1												
AB05BH0140	1988	Summer	19	64	6	20	43	3	28	0.193	0.035	0.228	0.013	0.003	744630	38949	131147	50055	27919	PAP
AB05BH0140	1989	Fall	13	73	6	16	152	2	24	0.085	0.026	0.111	0.006	0.004	744630	41617	138933	50663	29144	PAP
AB05BH0140	1989	Spring	13	73	6	20		1												
AB05BH0140	1989	Summer	13	73	6	9	55	3	15	0.123	0.021	0.144	0.011	0.003	744630	41617	138933	50663	29144	PAP

STATION_NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB05BH0140	1990	Fall	57	9776	5	128	22345	2	233	0.110	0.022	0.132	0.009	0.002	744630	44285	148720	51270	30369	PAP
AB05BH0140	1990	Spring	57	9776	5	21		1												
AB05BH0140	1990	Summer	57	9776	5	4	1	2												
AB05BH0140	1991	Fall	11	155	6	18	186	2	27	0.110	0.047	0.157	0.005	0.002	744630	46953	154506	51878	31594	PAP
AB05BH0140	1991	Spring	11	155	6	26		1												
AB05BH0140	1991	Summer	11	155	6	2	1	3	2	0.253	0.066	0.320	0.071	0.020	744630	46953	154506	51878	31594	PAP
AB05BH0140	1992	Fall	58	2485	7	31	99	2	38	0.380	0.030	0.410	0.008	0.004	744630	48553	148182	51631	32246	PAP
AB05BH0140	1992	Spring	58	2485	7	74		1												
AB05BH0140	1992	Summer	58	2485	7	64	6273	3	153	0.723	0.040	1.025	0.006	0.005	744630	48553	148182	51631	32246	PAP
AB05BH0140	1993	Fall	21	252	7	30	585	2	48	0.400	0.035	0.435	0.003	0.002	744630	50152	141857	51384	32899	PAP
AB05BH0140	1993	Spring	21	252	7	30		1												
AB05BH0140	1993	Summer	21	252	7	14	164	4	32	0.320	0.063	0.383	0.009	0.003	744630	50152	141857	51384	32899	PAP
AB05BH0140	1994	Fall	27	411	6	59		1												
AB05BH0140	1994	Spring	27	411	6	27		1												
AB05BH0140	1994	Summer	27	411	6	13	154	3	27	0.103	0.047	0.151	0.004	0.002	744630	51752	135533	51137	33552	PAP
AB05BH0140	1995	Fall	19	133	7	21	25	2	25	0.085	0.058	0.143	0.037	0.002	744630	53351	129208	50891	34204	PAP
AB05BH0140	1995	Spring	19	133	7	14		1												
AB05BH0140	1995	Summer	19	133	7	12	132	3	24	0.131	0.067	0.198	0.012	0.008	744630	53351	129208	50891	34204	PAP
AB05BH0140	1996	Fall	68	1241	4	47	21	2	51	0.095	0.032	0.127	0.002	0.002	744630	54950	122884	50644	34857	PAP
AB05BH0140	1996	Spring	68	1241	4	58		1												
AB05BH0140	1996	Summer	68	1241	4	120		1												
AB05BH0300	2000	Spring	3	0	2	2		1												
AB05BH0300	2000	Summer	3	0	2	3		1												
AB05BH0310	1999	Fall	40	1795	4	95		1												
AB05BH0310	1999	Spring	40	1795	4	5		1												
AB05BH0310	1999	Summer	40	1795	4	29	940	2												
AB05BH0310	2000	Fall	96	10151	6	217	3264	2												
AB05BH0310	2000	Spring	96	10151	6	8		1												
AB05BH0310	2000	Summer	96	10151	6	45	1389	3												
AB05BH0450	1981	Fall	77	2501	12	85	3269	4	167		0.050			0.002	995776	370018	224528	97554	59625	PFG
AB05BH0450	1981	Spring	77	2501	12	111	5347	2	162		0.055			0.002	995776	370018	224528	97554	59625	PFG

STATION_NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB05BH0450	1981	Summer	77	2501	12	49	1136	5	108		0.063			0.002	995776	370018	224528	97554	59625	PFG
AB05BH0450	1982	Fall	153	7113	7	225	32	3	228		0.063		0.007	0.003	995776	373161	224781	97885	57798	PFG
AB05BH0450	1982	Spring	153	7113	7	111		1												
AB05BH0450	1982	Summer	153	7113	7	94	7541	3	193		0.050		0.012	0.002	995776	373161	224781	97885	57798	PFG
AB05BH0450	1984	Fall	203	47960	5	69		1												
AB05BH0450	1984	Spring	203	47960	5	591		1												
AB05BH0450	1984	Summer	203	47960	5	119	1174	3	156		0.023			0.002	995776	379448	225286	98547	54143	PFG
AB05BH0520	1981	Fall	232	8794	12	232	13218	4	403		0.110			0.436	995776	370018	224528	97554	59625	PFG
AB05BH0520	1981	Spring	232	8794	12	236	37418	2	373		0.087			0.371	995776	370018	224528	97554	59625	PFG
AB05BH0520	1981	Summer	232	8794	12	219	3801	5	281		0.103			0.233	995776	370018	224528	97554	59625	PFG
AB05BH0520	1982	Fall	232	13486	7	189	1630	3	235		1.633		1.217	0.939	995776	373161	224781	97885	57798	PFG
AB05BH0520	1982	Spring	232	13486	7	228		1												
AB05BH0520	1982	Summer	232	13486	7	277	32996	3	428		0.600		0.883	0.827	995776	373161	224781	97885	57798	PFG
AB05BH0520	1984	Fall	268	3060	5	254		1												
AB05BH0520	1984	Spring	268	3060	5	346		1												
AB05BH0520	1984	Summer	268	3060	5	246	2277	3	297		1.260			0.010	995776	379448	225286	98547	54143	PFG
AB05BH0530	1981	Fall	144	7892	12	88	1310	4	141		0.789			0.133	995776	370018	224528	97554	59625	PFG
AB05BH0530	1981	Spring	144	7892	12	245	26079	2	359		0.507			0.116	995776	370018	224528	97554	59625	PFG
AB05BH0530	1981	Summer	144	7892	12	150	5863	5	268		0.241			0.050	995776	370018	224528	97554	59625	PFG
AB05BH0530	1982	Fall	188	7750	7	232	3935	3	270		1.275		0.204	0.168	995776	373161	224781	97885	57798	PFG
AB05BH0530	1982	Spring	188	7750	7	275		1												
AB05BH0530	1982	Summer	188	7750	7	116	4853	3	185		0.577		0.140	0.122	995776	373161	224781	97885	57798	PFG
AB05BH0530	1984	Fall	159	33416	5	67		1												
AB05BH0530	1984	Spring	159	33416	5	476		1												
AB05BH0530	1984	Summer	159	33416	5	84	3937	3	153		0.860			0.074	995776	379448	225286	98547	54143	PFG
AB05BH0610	1981	Fall	223	14770	12	189	1659	4	237		0.749			0.115	995776	370018	224528	97554	59625	PFG
AB05BH0610	1981	Spring	223	14770	12	271	81424	2	472		0.353			0.115	995776	370018	224528	97554	59625	PFG
AB05BH0610	1981	Summer	223	14770	12	214	14699	5	421		0.358			0.042	995776	370018	224528	97554	59625	PFG
AB05BH0610	1982	Fall	188	2589	7	177	2744	3	238		0.910		0.187	0.141	995776	373161	224781	97885	57798	PFG
AB05BH0610	1982	Spring	188	2589	7	247		1												
AB05BH0610	1982	Summer	188	2589	7	178	2970	3	226		0.425		0.107	0.082	995776	373161	224781	97885	57798	PFG

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AB05BH0610	1984	Fall	188	31956	5	226		1												
AB05BH0610	1984	Spring	188	31956	5	486		1												
AB05BH0610	1984	Summer	188	31956	5	76	33	3	82		0.645			0.061	995776	379448	225286	98547	54143	PFG
AB05BH2390	1998	Fall	20	55	6	21	19	2												
AB05BH2390	1998	Spring	20	55	6	8		1												
AB05BH2390	1998	Summer	20	55	6	22	46	3												
AB05BH2400	1998	Fall	209	6300	6	249	2280	2												
AB05BH2400	1998	Spring	209	6300	6	151		1												
AB05BH2400	1998	Summer	209	6300	6	201	11245	3												
AB05BJ0120	1988	Fall	18	399	7	37	1203	2	61	0.130	0.062	0.192	0.003	0.002	78033	207	16971	2416	2207	BP
AB05BJ0120	1988	Spring	18	399	7	6		1												
AB05BJ0120	1988	Summer	18	399	7	13	86	3	19	0.320	0.074	0.394	0.053	0.003	78033	207	16971	2416	2207	BP
AB05BJ0170	1988	Fall	43	731	9	36	643	2	54	0.120	0.045	0.165	0.002	0.002	121825	43691	41124	14819	8416	PAP
AB05BJ0170	1988	Spring	43	731	9	67		1												
AB05BJ0170	1988	Summer	43	731	9	51	1102	4	88	0.540	0.065	0.605	0.094	0.003	121825	43691	41124	14819	8416	PAP
AB05BJ0220	1990	Fall	39	1507	2	12		1												
AB05BJ0220	1990	Summer	39	1507	2	66		1												
AB05BJ0230	1991	Fall	12	53	4	11		1												
AB05BJ0230	1991	Spring	12	53	4	22		1												
AB05BJ0230	1991	Summer	12	53	4	7	14	2												
AB05BJ0230	1992	Fall	12	204	3	4		1												
AB05BJ0230	1992	Spring	12	204	3	28		1												
AB05BJ0230	1992	Summer	12	204	3	3		1												
AB05BJ0240	1990	Fall	11	57	2	17		1												
AB05BJ0240	1990	Summer	11	57	2	6		1												
AB05BJ0250	1991	Fall	10	34	4	15		1												
AB05BJ0250	1991	Spring	10	34	4	8		1												
AB05BJ0250	1991	Summer	10	34	4	9	76	2												
AB05BJ0250	1992	Fall	18	107	3	27		1												
AB05BJ0250	1992	Spring	18	107	3	19		1												
AB05BJ0250	1992	Summer	18	107	3	7		1												

STATION_NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB05BJ0280	1988	Fall	6	15	6	5	0	2	6	0.150	0.029	0.179	0.005	0.002	117271	10808	40787	14653	8342	PAP
AB05BJ0280	1988	Summer	6	15	6	7	31	3	11	0.244	0.043	0.287	0.016	0.002	117271	10808	40787	14653	8342	PAP
AB05BJ0280	1990	Fall	5	0	2	5		1												
AB05BJ0280	1990	Summer	5	0	2	5		1												
AB05BJ0280	1991	Fall	27	1781	4	11		1												
AB05BJ0280	1991	Spring	27	1781	4	90		1												
AB05BJ0280	1991	Summer	27	1781	4	3	2	2												
AB05BJ0280	1992	Fall	5	21	3	2		1												
AB05BJ0280	1992	Spring	5	21	3	11		1												
AB05BJ0280	1992	Summer	5	21	3	3		1												
AB05BJ0290	1988	Fall	5	3	7	5	0	2	6	0.110	0.030	0.140	0.003	0.002	117271	10808	40787	14653	8342	PAP
AB05BJ0290	1988	Spring	5	3	7	5		1												
AB05BJ0290	1988	Summer	5	3	7	4	8	3	7	0.168	0.039	0.207	0.010	0.002	117271	10808	40787	14653	8342	PAP
AB05BJ0300	1988	Fall	108	1902	8	107	8954	2	174	0.140	0.023	0.163	0.004	0.002	117271	10808	40787	14653	8342	PAP
AB05BJ0300	1988	Spring	108	1902	8	103		1												
AB05BJ0300	1988	Summer	108	1902	8	119	865	4	148	0.180	0.029	0.209	0.012	0.003	117271	10808	40787	14653	8342	PAP
AB05BJ0340	1990	Fall	104	8372	2	169		1												
AB05BJ0340	1990	Summer	104	8372	2	40		1												
AB05BJ0340	1991	Fall	126	1099	4	85		1												
AB05BJ0340	1991	Spring	126	1099	4	120		1												
AB05BJ0340	1991	Summer	126	1099	4	150	415	2												
AB05BJ0340	1992	Fall	163	1918	3	213		1												
AB05BJ0340	1992	Spring	163	1918	3	133		1												
AB05BJ0340	1992	Summer	163	1918	3	142		1												
AB05BJ0350	1988	Fall	147	4971	8	203	1	2	204	0.260	0.002	0.262	0.020	0.006	165538	30854	59182	21534	12199	PAP
AB05BJ0350	1988	Spring	147	4971	8	262		1												
AB05BJ0350	1988	Summer	147	4971	8	91	902	4	122	0.196	0.005	0.201	0.008	0.003	165538	30854	59182	21534	12199	PAP
AB05BJ0350	1990	Fall	172	3065	2	212		1												
AB05BJ0350	1990	Summer	172	3065	2	133		1												
AB05BJ0350	1991	Fall	83	3503	4	50		1												
AB05BJ0350	1991	Spring	83	3503	4	43		1												

STATION_NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB05BJ0350	1991	Summer	83	3503	4	119	5171	2												
AB05BJ0350	1992	Fall	82	1094	3	120		1												
AB05BJ0350	1992	Spring	82	1094	3	58		1												
AB05BJ0350	1992	Summer	82	1094	3	68		1												
AB05BJ0370	1990	Fall	131	192	2	121		1												
AB05BJ0370	1990	Summer	131	192	2	140		1												
AB05BJ0370	1991	Fall	83	1124	4	41		1												
AB05BJ0370	1991	Spring	83	1124	4	80		1												
AB05BJ0370	1991	Summer	83	1124	4	105	692	2												
AB05BJ0370	1992	Fall	65	559	3	91		1												
AB05BJ0370	1992	Spring	65	559	3	44		1												
AB05BJ0370	1992	Summer	65	559	3	61		1												
AB05BJ0450	1988	Fall	400	68841	7	488	15	2	491	0.240	0.182	0.422	0.008	0.004	124839	77125	41404	14957	8476	PFG
AB05BJ0450	1988	Spring	400	68841	7	217		1												
AB05BJ0450	1988	Summer	400	68841	7	243	29386	3	440	0.304	0.121	0.425	0.011	0.003	124839	77125	41404	14957	8476	PFG
AB05BJ0450	1994	Fall	167	5415	6	262	25	2	265	0.105	0.030	0.135	0.004	0.001	124839	82260	37809	15019	9599	PFG
AB05BJ0450	1994	Spring	167	5415	6	130		1												
AB05BJ0450	1994	Summer	167	5415	6	116	50	3	124	0.148	0.037	0.184	0.006	0.002	124839	82260	37809	15019	9599	PFG
AB05BJ0450	1995	Fall	100	3963	5	160	3019	2	199	0.085	0.147	0.232	0.004	0.002	124839	85703	33789	14844	9561	PFG
AB05BJ0450	1995	Summer	100	3963	5	59	290	3	76	0.143	0.070	0.214	0.019	0.002	124839	85703	33789	14844	9561	PFG
AB05BJ0450	1996	Fall	139	4808	5	194	6083	2	249	0.180	0.033	0.213	0.004	0.002	124839	89146	29769	14670	9522	PFG
AB05BJ0450	1996	Spring	139	4808	5	69		1												
AB05BJ0450	1996	Summer	139	4808	5	118	1385	2												
AB05BJ0450	1997	Fall	300	25436	5	458	6059	2	513	0.153	0.133	0.285	0.005	0.002	124839	91135	29987	15036	9592	PFG
AB05BJ0450	1997	Spring	300	25436	5	218		1												
AB05BJ0450	1997	Summer	300	25436	5	185	12479	2												
AB05BJ0450	1998	Fall	134	1133	3	154	19	2	157	0.205	0.192	0.397	0.004	0.002	124839	93124	30205	15403	9662	PFG
AB05BJ0450	1998	Spring	134	1133	3	96		1												
AB05BJ0450	1999	Fall	59	2889	7	100	9492	2	169	0.110	0.165	0.275	0.005	0.002	124839	95112	30423	15769	9732	PFG
AB05BJ0450	1999	Spring	59	2889	7	50	44	2	55	0.505	0.188	0.693	0.008	0.002	124839	95112	30423	15769	9732	PFG
AB05BJ0450	1999	Summer	59	2889	7	38	1473	3	82	0.203	0.190	0.393	0.008	0.004	124839	95112	30423	15769	9732	PFG

STATION_NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB05BJ0450	2000	Fall	120	2974	7	187	3162	2	227	0.025	0.214	0.239	0.005	0.002	124839	97101	30641	16136	9803	PFG
AB05BJ0450	2000	Spring	120	2974	7	85	527	2	101	0.112	0.235	0.346	0.002	0.002	124839	97101	30641	16136	9803	PFG
AB05BJ0450	2000	Summer	120	2974	7	99	664	3	129	0.200	0.147	0.347	0.007	0.003	124839	97101	30641	16136	9803	PFG
AB05BK0009	2000	Fall	36	312	7	55	257	2	66	0.118	0.004	0.122	0.004	0.004	41945	32310	24114	10245	11313	PAP
AB05BK0009	2000	Spring	36	312	7	19	27	2	23	0.575	0.002	0.577	0.006	0.002	41945	32310	24114	10245	11313	PAP
AB05BK0009	2000	Summer	36	312	7	36	153	3	44	0.197	0.003	0.199	0.007	0.004	41945	32310	24114	10245	11313	PAP
AB05BK0035	2000	Fall	16	14	7	18	1	2	19	0.195	0.002	0.197	0.007	0.003	41945	32310	24114	10245	11313	PAP
AB05BK0035	2000	Spring	16	14	7	17	11	2												
AB05BK0035	2000	Summer	16	14	7	13	16	3	17	0.197	0.002	0.198	0.004	0.003	41945	32310	24114	10245	11313	PAP
AB05BK0045	2000	Fall	155	14058	7	258	9328	2	327	0.180	0.276	0.456	0.010	0.005	41945	32310	24114	10245	11313	PAP
AB05BK0045	2000	Spring	155	14058	7	30	1008	2												
AB05BK0045	2000	Summer	155	14058	7	170	10327	3	286	0.283	0.497	0.781	0.015	0.003	41945	32310	24114	10245	11313	PAP
AB05BK0053	2000	Fall	207	11519	7	327	91	2	333	0.170	0.499	0.669	0.009	0.006	43351	49445	24701	10552	11448	PFG
AB05BK0053	2000	Spring	207	11519	7	178	5322	2												
AB05BK0053	2000	Summer	207	11519	7	147	11337	3	263	0.137	0.558	0.695	0.011	0.005	43351	49445	24701	10552	11448	PFG
AB05BK0057	2000	Fall	190	3546	7	189	501	2	205	0.265	0.481	0.746	0.014	0.003	43351	49445	24701	10552	11448	PFG
AB05BK0057	2000	Spring	190	3546	7	199	743	2												
AB05BK0057	2000	Summer	190	3546	7	184	9881	3	298	0.177	0.424	0.601	0.017	0.002	43351	49445	24701	10552	11448	PFG
AB05BK0070	2000	Fall	93	1305	7	101	202	2	111	0.278	0.442	0.720	0.019	0.004	43351	49445	24701	10552	11448	PFG
AB05BK0070	2000	Spring	93	1305	7	90	4725	2	138	0.230	0.021	0.251	0.005	0.002	43351	49445	24701	10552	11448	PFG
AB05BK0070	2000	Summer	93	1305	7	89	1358	3	129	0.237	0.406	0.642	0.020	0.004	43351	49445	24701	10552	11448	PFG
AB05BL0160	1984	Summer	110	5894	5	110	5894	5												
AB05BL0160	1985	Fall	48	1103	11	55	214	3												
AB05BL0160	1985	Spring	48	1103	11	5		1												
AB05BL0160	1985	Summer	48	1103	11	41	830	6												
AB05BL0160	1986	Fall	30	858	6	13		1												
AB05BL0160	1986	Summer	30	858	6	22	425	4												
AB05BL0180	1984	Summer	65	1611	6	65	1611	6	126	0.332	0.007	0.339	0.135	0.004	724388	19190	578683	272019	97941	PFG
AB05BL0180	1985	Fall	33	356	11	40	418	3												
AB05BL0180	1985	Spring	33	356	11	8		1												
AB05BL0180	1985	Summer	33	356	11	32	382	6												

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AB05BL0180	1986	Fall	23	1031	7	10		1												
AB05BL0180	1986	Summer	23	1031	7	3	2	4												
AB05BL0180	1998	Fall	8	40	4	12	48	2	17	0.075	0.067	0.142	0.002	0.001	724386	25276	595023	204852	219820	PFG
AB05BL0180	1998	Summer	8	40	4	4	1	2												
AB05BL0230	1985	Fall	189	4334	8	247	3243	2												
AB05BL0230	1985	Spring	189	4334	8	182		1												
AB05BL0230	1985	Summer	189	4334	8	168	4523	5												
AB05BL0230	1986	Fall	140	1669	5	189		1												
AB05BL0230	1986	Summer	140	1669	5	119	1373	3												
AB05BL0390	1984	Summer	183	5959	6	183	5959	6	265	0.424	0.004	0.428	0.048	0.009	759556	20231	611967	287596	103671	PFG
AB05BL0390	1985	Fall	157	11054	11	116	3751	2												
AB05BL0390	1985	Spring	157	11054	11	92	5995	2												
AB05BL0390	1985	Summer	157	11054	11	183	16202	6												
AB05BL0390	1986	Fall	147	7431	6	254		1												
AB05BL0390	1986	Summer	147	7431	6	100	3209	4												
AB05BL0470	1985	Fall	166	15966	8	20		1												
AB05BL0470	1985	Spring	166	15966	8	7		1												
AB05BL0470	1985	Summer	166	15966	8	238	8955	5												
AB05BL0470	1986	Fall	91	8062	6	267		1												
AB05BL0470	1986	Summer	91	8062	6	53	895	4												
AB05BL0490	1984	Summer	185	17993	6	185	17993	6	389	0.476	0.007	0.482	0.088	0.008	998608	30886	769673	360007	124118	PFG
AB05BL0490	1985	Fall	151	8504	9	117	475	2												
AB05BL0490	1985	Summer	151	8504	9	176	10862	6												
AB05BL0490	1986	Fall	100	3919	6	166		1												
AB05BL0490	1986	Summer	100	3919	6	103	3045	4												
AB05BM0010	1987	Fall	295	36280	6	466	93031	2	682	0.360	1.010	1.370	0.048	0.022	2077669	719335	1086788	494408	183106	PFG
AB05BM0010	1987	Spring	295	36280	6	201		1												
AB05BM0010	1987	Summer	295	36280	6	212	158	3	222	0.793	0.717	1.510	0.040	0.019	2077669	719335	1086788	494408	183106	PFG
AB05BM0010	1988	Fall	276	18614	6	411	15129	2	498	0.270	0.645	0.915	0.025	0.014	2077669	736254	1103686	491257	201504	PFG
AB05BM0010	1988	Spring	276	18614	6	141		1												
AB05BM0010	1988	Summer	276	18614	6	232	8608	3	332	0.400	0.700	1.100	0.042	0.022	2077669	736254	1103686	491257	201504	PFG

STATION_NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB05BM0010	1989	Fall	266	24609	5	398	11057	2	472	0.280	0.835	1.115	0.025	0.014	2077669	753174	1120584	488107	219903	PFG
AB05BM0010	1989	Spring	266	24609	5	178	29075	2	299	1.310	1.200	2.510	0.253	0.041	2077669	753174	1120584	488107	219903	PFG
AB05BM0010	1989	Summer	266	24609	5	176		1												
AB05BM0010	1990	Fall	169	5276	5	240	1729	2	270	0.190	1.050	1.240	0.019	0.008	2077669	770094	1137482	484956	236302	PFG
AB05BM0010	1990	Spring	169	5276	5	85		1												
AB05BM0010	1990	Summer	169	5276	5	138	293	2												
AB05BM0010	1991	Fall	209	21822	5	344	25230	2	456	0.260	1.035	1.295	0.032	0.019	2077669	787013	1154380	481805	256700	PFG
AB05BM0010	1991	Spring	209	21822	5	153		1												
AB05BM0010	1991	Summer	209	21822	5	103	29	2												
AB05BM0010	1992	Fall	261	15080	6	359	11486	2	435	0.610	1.052	1.662	0.028	0.015	2077669	802197	1137082	485794	276615	PFG
AB05BM0010	1992	Spring	261	15080	6	361		1												
AB05BM0010	1992	Summer	261	15080	6	162	2678	3	221	0.973	0.549	1.522	0.030	0.011	2077669	802197	1137082	485794	276615	PFG
AB05BM0010	1993	Fall	174	2180	6	187	9	2	190	0.520	0.421	0.941	0.011	0.005	2077669	817381	1119784	489784	296530	PFG
AB05BM0010	1993	Spring	174	2180	6	210		1												
AB05BM0010	1993	Summer	174	2180	6	153	3946	3	207	0.613	0.374	0.987	0.105	0.011	2077669	817381	1119784	489784	296530	PFG
AB05BM0010	1994	Fall	251	57598	6	521		1												
AB05BM0010	1994	Spring	251	57598	6	6		1												
AB05BM0010	1994	Summer	251	57598	6	187	57579	3	460	0.290	0.423	0.713	0.026	0.011	2077669	832565	1102486	493773	316445	PFG
AB05BM0010	1995	Fall	165	19943	6	187	1842	2	217	0.190	0.619	0.809	0.030	0.020	2077669	847749	1085188	497762	336360	PFG
AB05BM0010	1995	Spring	165	19943	6	35		1												
AB05BM0010	1995	Summer	165	19943	6	82	3098	2												
AB05BM0010	1996	Fall	361	46544	5	508	10824	2	582	0.295	0.817	1.112	0.044	0.008	2077669	862933	1067891	501751	356275	PFG
AB05BM0010	1996	Spring	361	46544	5	507		1												
AB05BM0010	1996	Summer	361	46544	5	140	12832	2												
AB05BM0010	1997	Fall	260	7169	5	296	630	2	314	0.355	0.745	1.100	0.022	0.012	2077669	890295	1071756	503592	371014	PFG
AB05BM0010	1997	Spring	260	7169	5	337		1												
AB05BM0010	1997	Summer	260	7169	5	186	8440	2												
AB05BM0010	1998	Fall	355	31258	5	431	1964	2	463	0.240	0.684	0.924	0.032	0.023	2077669	917656	1075621	505434	385753	PFG
AB05BM0010	1998	Spring	355	31258	5	146		1												
AB05BM0010	1998	Summer	355	31258	5	382	66179	2												
AB05BM0010	1999	Fall	163	24034	7	324	23551	2	432	0.160	0.717	0.877	0.028	0.020	2077669	945018	1079486	507275	400491	PFG

STATION_NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB05BM0010	1999	Spring	163	24034	7	187	18826	2	284	0.815	0.630	1.445	0.095	0.043	2077669	945018	1079486	507275	400491	PFG
AB05BM0010	1999	Summer	163	24034	7	40	1969	3	90	0.270	0.379	0.649	0.033	0.011	2077669	945018	1079486	507275	400491	PFG
AB05BM0010	2000	Fall	145	2629	7	114	198	2	124	0.280	0.648	0.928	0.039	0.026	2077669	972380	1083351	509117	415230	PFG
AB05BM0010	2000	Spring	145	2629	7	200	477	2	215	0.450	0.667	1.117	0.044	0.014	2077669	972380	1083351	509117	415230	PFG
AB05BM0010	2000	Summer	145	2629	7	128	3200	3	183	0.262	0.315	0.576	0.030	0.018	2077669	972380	1083351	509117	415230	PFG
AB05BM0030	1981	Fall	212	7112	12	189	357	4	217		0.770			0.134	995776	370018	224528	97554	59625	PFG
AB05BM0030	1981	Spring	212	7112	12	123	5717	2	177		0.358			0.100	995776	370018	224528	97554	59625	PFG
AB05BM0030	1981	Summer	212	7112	12	262	10166	5	432		0.341			0.050	995776	370018	224528	97554	59625	PFG
AB05BM0030	1984	Fall	184	19446	5	140		1												
AB05BM0030	1984	Spring	184	19446	5	432		1												
AB05BM0030	1984	Summer	184	19446	5	115	23	3	121		0.525			0.005	995776	379448	225286	98547	54143	PFG
AB05BM0120	1981	Fall	226	11871	12	202	11872	4	331		0.894			0.196	1039127	410057	247727	108185	66330	PFG
AB05BM0120	1981	Spring	226	11871	12	145	423	2	160		0.350			0.125	1039127	410057	247727	108185	66330	PFG
AB05BM0120	1981	Summer	226	11871	12	278	16361	5	490		0.299			0.074	1039127	410057	247727	108185	66330	PFG
AB05BM0120	1982	Fall	153	5195	8	148	8886	3	231		1.167		0.232	0.196	1039127	413147	248090	108585	63629	PFG
AB05BM0120	1982	Spring	153	5195	8	152	113	2	160		0.510		0.305	0.260	1039127	413147	248090	108585	63629	PFG
AB05BM0120	1982	Summer	153	5195	8	159	9144	3	239		0.535		0.212	0.177	1039127	413147	248090	108585	63629	PFG
AB05BM0120	1984	Fall	162	10808	5	154		1												
AB05BM0120	1984	Spring	162	10808	5	337		1												
AB05BM0120	1984	Summer	162	10808	5	107	1654	3	148		0.980			0.041	1039127	419326	248816	109386	58228	PFG
AB05BM0140	1981	Fall	208	7711	12	220	1107	4	249		1.104			0.168	1039127	410057	247727	108185	66330	PFG
AB05BM0140	1981	Spring	208	7711	12	118	3401	2	159		0.380			0.119	1039127	410057	247727	108185	66330	PFG
AB05BM0140	1981	Summer	208	7711	12	221	14071	5	427		0.312			0.063	1039127	410057	247727	108185	66330	PFG
AB05BM0140	1982	Fall	150	9340	7	102	895	3	130		1.367		0.207	0.173	1039127	413147	248090	108585	63629	PFG
AB05BM0140	1982	Spring	150	9340	7	361		1												
AB05BM0140	1982	Summer	150	9340	7	127	673	3	157		0.672		0.166	0.145	1039127	413147	248090	108585	63629	PFG
AB05BM0140	1984	Fall	292	21508	5	409		1												
AB05BM0140	1984	Spring	292	21508	5	407		1												
AB05BM0140	1984	Summer	292	21508	5	215	20580	3	378		0.930			0.012	1039127	419326	248816	109386	58228	PFG
AB05BM0150	1980	Fall	224	15962	5	439		1												
AB05BM0150	1980	Spring	224	15962	5	232		1												

STATION_NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB05BM0150	1980	Summer	224	15962	5	164	218	2												
AB05BM0150	1981	Fall	267	19881	18	267	14451	4	419		1.285		0.230	0.168	1039127	410057	247727	108185	66330	PFG
AB05BM0150	1981	Spring	267	19881	18	194	25040	3	349		0.497		0.268	0.147	1039127	410057	247727	108185	66330	PFG
AB05BM0150	1981	Summer	267	19881	18	226	13648	7	408		0.445		0.106	0.052	1039127	410057	247727	108185	66330	PFG
AB05BM0150	1983	Fall	140	8597	14	229	12365	4	319		1.155		0.022	0.015	1039127	416236	248453	108986	60929	PFG
AB05BM0150	1983	Spring	140	8597	14	95	8049	3	192		0.587		0.072	0.030	1039127	416236	248453	108986	60929	PFG
AB05BM0150	1983	Summer	140	8597	14	109	2307	7	181		0.519		0.103	0.029	1039127	416236	248453	108986	60929	PFG
AB05BM0150	1984	Fall	277	44833	22	320	6267	5	455		1.105		0.080	0.020	1039127	419326	248816	109386	58228	PFG
AB05BM0150	1984	Spring	277	44833	22	483	64060	5	775		1.040		0.101	0.044	1039127	419326	248816	109386	58228	PFG
AB05BM0150	1984	Summer	277	44833	22	122	3294	9	197		0.744		0.024	0.009	1039127	419326	248816	109386	58228	PFG
AB05BM0150	1985	Fall	183	17089	10	236	40449	3	441	0.760	1.630	2.390	0.053	0.016	1039127	422415	249179	109786	55528	PFG
AB05BM0150	1985	Spring	183	17089	10	292	698	2	311	1.610	0.855	2.465	0.071	0.024	1039127	422415	249179	109786	55528	PFG
AB05BM0150	1985	Summer	183	17089	10	108	2895	5	181	0.738	1.022	1.760	0.044	0.024	1039127	422415	249179	109786	55528	PFG
AB05BM0150	1986	Fall	438	55376	10	225	8624	2	290	0.960	1.020	1.980	0.077	0.032	1039127	425505	249542	110187	52828	PFG
AB05BM0150	1986	Spring	438	55376	10	449	368	2	463	0.940	0.855	1.795	0.075	0.038	1039127	425505	249542	110187	52828	PFG
AB05BM0150	1986	Summer	438	55376	10	280	85289	2												
AB05BM0150	1987	Fall	142	5471	6	68	127	2	76	0.510	1.125	1.635	0.068	0.029	1039127	434301	260283	110747	55604	PFG
AB05BM0150	1987	Summer	142	5471	6	161	3526	2												
AB05BM0150	1988	Fall	112	5467	6	195	335	2	208	0.370	0.785	1.155	0.035	0.021	1039127	443098	271024	111307	58380	PFG
AB05BM0150	1988	Spring	112	5467	6	89		1												
AB05BM0150	1988	Summer	112	5467	6	65	3136	3	128	0.693	0.637	1.330	0.045	0.024	1039127	443098	271024	111307	58380	PFG
AB05BM0150	1989	Fall	94	11780	5	58		1												
AB05BM0150	1989	Spring	94	11780	5	79		1												
AB05BM0150	1989	Summer	94	11780	5	111	22352	3	284	0.477	0.717	1.193	0.051	0.031	1039127	451895	281764	111868	61157	PFG
AB05BM0150	1990	Fall	165	34029	5	91	6938	2	150	0.350	1.195	1.545	0.032	0.018	1039127	460692	292505	112428	63933	PFG
AB05BM0150	1990	Spring	165	34029	5	486		1												
AB05BM0150	1990	Summer	165	34029	5	78	32	2												
AB05BM0150	1991	Fall	248	38118	5	350	57981	2	520	0.460	0.990	1.450	0.049	0.033	1039127	469489	303246	112988	66709	PFG
AB05BM0150	1991	Spring	248	38118	5	370		1												
AB05BM0150	1991	Summer	248	38118	5	86	6381	2												
AB05BM0150	1992	Fall	395	105441	7	283	44065	2	431	0.780	1.135	1.915	0.051	0.029	1039127	480255	293145	113037	68830	PFG

STATION_NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB05BM0150	1992	Spring	395	105441	7	906		1												
AB05BM0150	1992	Summer	395	105441	7	176	11311	3	255	2.027	0.471	3.311	0.037	0.015	1039127	480255	293145	113037	68830	PFG
AB05BM0150	1993	Fall	230	26083	7	323	42205	3	560	0.840	0.408	1.248	0.021	0.008	1039127	491022	283044	113087	70952	PFG
AB05BM0150	1993	Spring	230	26083	7	296		1												
AB05BM0150	1993	Summer	230	26083	7	114	703	3	134	0.960	0.507	1.467	0.042	0.013	1039127	491022	283044	113087	70952	PFG
AB05BM0150	1994	Fall	136	20852	6	262		1												
AB05BM0150	1994	Spring	136	20852	6	34		1												
AB05BM0150	1994	Summer	136	20852	6	56	5518	3	141	0.470	0.514	0.984	0.058	0.030	1039127	501789	272943	113136	73073	PFG
AB05BM0150	1995	Fall	208	30223	7	220	47761	2	375	0.395	0.667	1.062	0.067	0.033	1039127	512555	262843	113185	75194	PFG
AB05BM0150	1995	Spring	208	30223	7	129		1												
AB05BM0150	1995	Summer	208	30223	7	177	51319	3	437	0.279	0.378	0.661	0.030	0.019	1039127	512555	262843	113185	75194	PFG
AB05BM0150	1996	Fall	248	41952	4	404	28904	2	524	0.710	0.819	1.529	0.041	0.024	1039127	523322	252742	113234	77316	PFG
AB05BM0150	1996	Spring	248	41952	4	82		1												
AB05BM0150	1996	Summer	248	41952	4	103		1												
AB05BM0150	1999	Fall	123	7329	7	191	19	2	194	0.275	0.686	0.961	0.062	0.037	1039127	575542	261468	120795	80258	PFG
AB05BM0150	1999	Spring	123	7329	7	138	29	2	141	0.485	0.458	0.943	0.082	0.019	1039127	575542	261468	120795	80258	PFG
AB05BM0150	1999	Summer	123	7329	7	69	12823	3	200	0.323	0.309	0.632	0.044	0.026	1039127	575542	261468	120795	80258	PFG
AB05BM0150	2000	Fall	163	10781	7	330		1												
AB05BM0150	2000	Spring	163	10781	7	206		1												
AB05BM0150	2000	Summer	163	10781	7	87	1026	4	107	0.308	0.629	0.937	0.049	0.037	1039127	592949	264377	123315	81239	PFG
AB05BM0170	1981	Fall	240	13308	11	214	850	3												
AB05BM0170	1981	Spring	240	13308	11	115	5117	2												
AB05BM0170	1981	Summer	240	13308	11	268	13321	5												
AB05BM0170	1982	Fall	217	22507	7	331	31673	3												
AB05BM0170	1982	Spring	217	22507	7	149		1												
AB05BM0170	1982	Summer	217	22507	7	126	1712	3												
AB05BM0170	1984	Fall	400	19036	5	613		1												
AB05BM0170	1984	Spring	400	19036	5	435		1												
AB05BM0170	1984	Summer	400	19036	5	317	4582	3												
AB05BM0180	1981	Fall	120	6247	11	129	178	3												
AB05BM0180	1981	Spring	120	6247	11	75	7878	2												

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AB05BM0180	1981	Summer	120	6247	11	92	1597	5											
AB05BM0180	1984	Fall	269	20867	5	123		1											
AB05BM0180	1984	Spring	269	20867	5	504		1											
AB05BM0180	1984	Summer	269	20867	5	239	2111	3											
AB05BM0190	1984	Fall	375	20877	5	528		1											
AB05BM0190	1984	Spring	375	20877	5	420		1											
AB05BM0190	1984	Summer	375	20877	5	309	22463	3											
AB05BM0200	1981	Fall	212	11221	11	268	4764	3											
AB05BM0200	1981	Spring	212	11221	11	115	5550	2											
AB05BM0200	1981	Summer	212	11221	11	177	5140	5											
AB05BM0200	1982	Fall	254	10020	7	343	7058	3											
AB05BM0200	1982	Spring	254	10020	7	214		1											
AB05BM0200	1982	Summer	254	10020	7	179	2092	3											
AB05BM0420	1981	Fall	211	7427	10	218	1151	3	254	0.912			0.139	2077669	655997	1008233	459929	246440	PFG
AB05BM0420	1981	Spring	211	7427	10	145		1											
AB05BM0420	1981	Summer	211	7427	10	186	7307	5	339	0.361			0.043	2077669	655997	1008233	459929	246440	PFG
AB05BM0420	1984	Fall	484	116377	5	193		1											
AB05BM0420	1984	Spring	484	116377	5	684		1											
AB05BM0420	1984	Summer	484	116377	5	514	169010	3	988	0.888			0.011	2077669	683848	1045227	482507	197400	PFG
AB05BM0470	1980	Fall	330	34570	7	312	1119	2	335	0.948		0.154	0.141	2077669	655997	1008233	459929	246440	PFG
AB05BM0470	1980	Spring	330	34570	7	271		1											
AB05BM0470	1980	Summer	330	34570	7	409	81793	3	739	0.647		0.134	0.091	2077669	655997	1008233	459929	246440	PFG
AB05BM0470	1981	Fall	270	32165	9	288	16236	2	378	1.350		0.185	0.175	2077669	655997	1008233	459929	246440	PFG
AB05BM0470	1981	Spring	270	32165	9	63		1											
AB05BM0470	1981	Summer	270	32165	9	108	41	2											
AB05BM0470	1983	Fall	287	26866	13	449	43000	4	743	1.060		0.013	0.008	2077669	674564	1032896	474981	213747	PFG
AB05BM0470	1983	Spring	287	26866	13	207	3346	3	263	0.740		0.072	0.031	2077669	674564	1032896	474981	213747	PFG
AB05BM0470	1983	Summer	287	26866	13	219	7094	6	301	0.564		0.040	0.017	2077669	674564	1032896	474981	213747	PFG
AB05BM0470	1984	Fall	325	36610	16	417	30805	4	584	1.008		0.016	0.010	2077669	683848	1045227	482507	197400	PFG
AB05BM0470	1984	Spring	325	36610	16	273	15075	5	404	1.110		0.085	0.050	2077669	683848	1045227	482507	197400	PFG
AB05BM0470	1984	Summer	325	36610	16	346	59896	5	753	0.775		0.037	0.022	2077669	683848	1045227	482507	197400	PFG

STATION_NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB05BM0470	1985	Fall	259	7453	9	244	8359	2	309	0.573	1.307	1.880	0.044	0.015	2077669	693132	1057559	490033	181053	PFG
AB05BM0470	1985	Spring	259	7453	9	322	7388	2	382	1.120	1.125	2.245	0.045	0.021	2077669	693132	1057559	490033	181053	PFG
AB05BM0470	1985	Summer	259	7453	9	239	8417	5	382	0.484	0.866	1.350	0.040	0.023	2077669	693132	1057559	490033	181053	PFG
AB05BM0470	1986	Fall	303	32025	7	256	43	2	261	0.390	1.170	1.560	0.036	0.034	2077669	702415	1069891	497559	164707	PFG
AB05BM0470	1986	Spring	303	32025	7	186	4529	2	234	0.710	0.855	1.565	0.115	0.041	2077669	702415	1069891	497559	164707	PFG
AB05BM0470	1986	Summer	303	32025	7	356	102066	2												
AB05BM0500	1981	Fall	158	9566	11	181	1584	3	222		0.900			0.109	2077669	655997	1008233	459929	246440	PMG
AB05BM0500	1981	Spring	158	9566	11	137	28994	2	257		0.563			0.099	2077669	655997	1008233	459929	246440	PMG
AB05BM0500	1981	Summer	158	9566	11	111	1511	5	151		0.405			0.035	2077669	655997	1008233	459929	246440	PMG
AB05BM0590	1985	Fall	197	11505	10	239	25796	3												
AB05BM0590	1985	Spring	197	11505	10	125	3812	2												
AB05BM0590	1985	Summer	197	11505	10	200	8149	5												
AB05BM0590	1986	Fall	238	41605	6	407	110850	2												
AB05BM0590	1986	Spring	238	41605	6	164	5114	2												
AB05BM0590	1986	Summer	238	41605	6	143	5754	2												
AB05BM0590	1987	Fall	238	18167	8	324	57406	2												
AB05BM0590	1987	Spring	238	18167	8	82		1												
AB05BM0590	1987	Summer	238	18167	8	207	2317	3												
AB05BM0590	1988	Fall	292	78409	4	123		1												
AB05BM0590	1988	Spring	292	78409	4	693		1												
AB05BM0590	1988	Summer	292	78409	4	176	18988	2												
AB05BM0590	1989	Fall	74	4511	5	103		1												
AB05BM0590	1989	Spring	74	4511	5	34		1												
AB05BM0590	1989	Summer	74	4511	5	77	7797	3												
AB05BM0590	1990	Fall	115	7882	5	129	51	2												
AB05BM0590	1990	Spring	115	7882	5	249		1												
AB05BM0590	1990	Summer	115	7882	5	35	123	2												
AB05BM0590	1991	Fall	98	4607	5	127	8069	2												
AB05BM0590	1991	Spring	98	4607	5	133		1												
AB05BM0590	1991	Summer	98	4607	5	52	3245	2												
AB05BM0590	1992	Fall	143	13668	5	278		1												

STATION NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB05BM0590	1992	Spring	143	13668	5	263		1												
AB05BM0590	1992	Summer	143	13668	5	59	339	3												
AB05BM0590	1993	Fall	101	5163	6	62	2236	2												
AB05BM0590	1993	Spring	101	5163	6	231		1												
AB05BM0590	1993	Summer	101	5163	6	84	1419	3												
AB05BM0590	1994	Fall	49	2783	5	137		1												
AB05BM0590	1994	Spring	49	2783	5	12		1												
AB05BM0590	1994	Summer	49	2783	5	32	609	3												
AB05BM0590	1995	Fall	65	818	5	72	261	2												
AB05BM0590	1995	Spring	65	818	5	21		1												
AB05BM0590	1995	Summer	65	818	5	81	492	2												
AB05BM0590	1996	Fall	291	15315	5	317	1529	2												
AB05BM0590	1996	Spring	291	15315	5	283		1												
AB05BM0590	1996	Summer	291	15315	5	267	57178	2												
AB05BM0590	1997	Fall	214	5294	5	224	31	2												
AB05BM0590	1997	Spring	214	5294	5	325		1												
AB05BM0590	1997	Summer	214	5294	5	149	133	2												
AB05BM0590	1998	Fall	176	2082	5	189	1324	2												
AB05BM0590	1998	Spring	176	2082	5	222		1												
AB05BM0590	1998	Summer	176	2082	5	139	1853	2												
AB05BM0590	1999	Fall	142	13806	7	271	30861	2												
AB05BM0590	1999	Spring	142	13806	7	79	2772	2												
AB05BM0590	1999	Summer	142	13806	7	98	1149	3												
AB05BM0590	2000	Fall	179	6581	7	256	1373	2												
AB05BM0590	2000	Spring	179	6581	7	116	1022	2												
AB05BM0590	2000	Summer	179	6581	7	170	8631	3												
AB05BM0670	1980	Fall	127	20778	10	185	37035	3	389	0.562			0.118	0.088	2527719	665711	1355734	641897	328258	PMG
AB05BM0670	1980	Spring	127	20778	10	63	436	2	78	0.415			0.184	0.106	2527719	665711	1355734	641897	328258	PMG
AB05BM0670	1980	Summer	127	20778	10	195	24635	3	366	0.466			0.095	0.048	2527719	665711	1355734	641897	328258	PMG
AB05BM0670	1981	Fall	126	27605	4	362		1												
AB05BM0670	1981	Summer	126	27605	4	71	6009	2												

STATION_NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB05BM0670	1983	Fall	257	29678	14	261	21881	5	424		0.664		0.022	0.008	2527719	684537	1388247	661606	282889	PMG
AB05BM0670	1983	Spring	257	29678	14	233	56939	3	509		0.740		0.060	0.034	2527719	684537	1388247	661606	282889	PMG
AB05BM0670	1983	Summer	257	29678	14	265	36446	6	456		0.267		0.038	0.022	2527719	684537	1388247	661606	282889	PMG
AB05BM0670	1984	Fall	190	27278	17	81	500	3	106		0.383		0.065	0.006	2527719	693950	1404504	671460	260205	PMG
AB05BM0670	1984	Spring	190	27278	17	358	45876	5	655		0.756		0.089	0.038	2527719	693950	1404504	671460	260205	PMG
AB05BM0670	1984	Summer	190	27278	17	154	3464	6	224		0.410		0.029	0.016	2527719	693950	1404504	671460	260205	PMG
AB05BN0010	1987	Fall	225	20625	6	324	57406	2	493	0.360	0.025	0.385	0.033	0.010	3025091	734456	1896870	813091	313172	PMG
AB05BN0010	1987	Spring	225	20625	6	82		1												
AB05BN0010	1987	Summer	225	20625	6	207	2317	3	245	0.487	0.002	0.488	0.041	0.008	3025091	734456	1896870	813091	313172	PMG
AB05BN0010	1988	Fall	76	1613	5	57	85	2	64	0.460	0.003	0.463	0.032	0.018	3025091	751455	1913626	807582	338405	PMG
AB05BN0010	1988	Spring	76	1613	5	64		1												
AB05BN0010	1988	Summer	76	1613	5	101	4278	2												
AB05BN0010	1989	Spring	72	1563	4	93	378	2	107	0.890	0.756	1.646	0.097	0.016	3025091	768453	1930381	802072	363637	PMG
AB05BN0010	1989	Summer	72	1563	4	50	2464	2												
AB05BN0010	1990	Fall	68	2451	5	40	95	2	47	0.290	0.052	0.342	0.024	0.007	3025091	785452	1947137	796563	388869	PMG
AB05BN0010	1990	Spring	68	2451	5	89		1												
AB05BN0010	1990	Summer	68	2451	5	86	7009	2												
AB05BN0010	1991	Fall	39	158	5	47	70	2	53	0.280	0.200	0.480	0.019	0.006	3025091	802450	1963892	791053	414101	PMG
AB05BN0010	1991	Spring	39	158	5	46		1												
AB05BN0010	1991	Summer	39	158	5	28	150	2												
AB05BN0010	1992	Fall	44	605	5	36	78	2	42	0.320	0.435	0.755	0.028	0.002	3025091	818126	1946026	799635	442033	PMG
AB05BN0010	1992	Spring	44	605	5	42		1												
AB05BN0010	1992	Summer	44	605	5	54	1980	2												
AB05BN0010	1993	Fall	94	262	4	104	268	2	116	0.380	0.290	0.670	0.016	0.003	3025091	833802	1928160	808216	469964	PMG
AB05BN0010	1993	Spring	94	262	4	77		1												
AB05BN0010	1993	Summer	94	262	4	91		1												
AB05BN0010	1994	Fall	42	1366	5	79		1												
AB05BN0010	1994	Spring	42	1366	5	21		1												
AB05BN0010	1994	Summer	42	1366	5	36	1795	3	85	0.358	0.116	0.475	0.046	0.006	3025091	849478	1910294	816798	497896	PMG
AB05BN0010	1995	Fall	40	936	5	22	82	2	28	0.270	0.259	0.529	0.015	0.002	3025091	865154	1892428	825380	525827	PMG
AB05BN0010	1995	Spring	40	936	5	37		1												

STATION_NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB05BN0010	1995	Summer	40	936	5	59	2253	2												
AB05BN0010	1996	Fall	55	1103	5	82	27	2	86	0.435	0.324	0.759	0.012	0.002	3025091	880830	1874562	833961	553758	PMG
AB05BN0010	1996	Spring	55	1103	5	4		1												
AB05BN0010	1996	Summer	55	1103	5	54	323	2												
AB05BN0010	1997	Fall	52	548	5	48	81	2	54	0.285	0.103	0.388	0.022	0.002	3025091	908839	1881138	838308	581331	PMG
AB05BN0010	1997	Spring	52	548	5	55		1												
AB05BN0010	1997	Summer	52	548	5	56	2036	2												
AB05BN0010	1998	Fall	52	1583	5	68	1441	2	94	1.520	0.271	1.791	0.013	0.002	3025091	936848	1887713	842656	608904	PMG
AB05BN0010	1998	Spring	52	1583	5	93		1												
AB05BN0010	1998	Summer	52	1583	5	16	153	2												
AB05BN0010	1999	Fall	39	946	7	45	111	2	52	0.295	0.417	0.712	0.026	0.007	3025091	964857	1894288	847003	636477	PMG
AB05BN0010	1999	Spring	39	946	7	69	1171	2	94	0.685	0.139	0.824	0.025	0.011	3025091	964857	1894288	847003	636477	PMG
AB05BN0010	1999	Summer	39	946	7	16	432	3	40	0.437	0.179	0.615	0.056	0.004	3025091	964857	1894288	847003	636477	PMG
AB05BN0010	2000	Fall	59	794	7	63	0	2	63	0.298	0.342	0.640	0.012	0.004	3025091	992866	1900864	851350	664050	PMG
AB05BN0010	2000	Spring	59	794	7	38	2620	2	75	0.295	0.257	0.552	0.018	0.003	3025091	992866	1900864	851350	664050	PMG
AB05BN0010	2000	Summer	59	794	7	70	466	3	87	0.293	0.008	0.302	0.015	0.007	3025091	992866	1900864	851350	664050	PMG
AB05BN0080	1980	Fall	63	2530	12	93	3765	3												
AB05BN0080	1980	Spring	63	2530	12	22	801	3												
AB05BN0080	1980	Summer	63	2530	12	95	757	4												
AB05BN0080	1981	Fall	78	4442	9	230		1												
AB05BN0080	1981	Spring	78	4442	9	104		1												
AB05BN0080	1981	Summer	78	4442	9	58	1592	5												
AB05BN0080	1983	Fall	60	936	14	50	454	5												
AB05BN0080	1983	Spring	60	936	14	78	2688	3												
AB05BN0080	1983	Summer	60	936	14	59	716	6												
AB05BN0080	1984	Fall	132	14619	15	36	217	3												
AB05BN0080	1984	Spring	132	14619	15	227	13767	5												
AB05BN0080	1984	Summer	132	14619	15	68	2725	6												
AB05BN0080	1985	Fall	43	1092	8	70	2488	2												
AB05BN0080	1985	Spring	43	1092	8	68		1												
AB05BN0080	1985	Summer	43	1092	8	27	466	5												

STATION NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB05BN0080	1986	Fall	45	150	6	38	39	2												
AB05BN0080	1986	Spring	45	150	6	51	468	2												
AB05BN0080	1986	Summer	45	150	6	47	57	2												
AB05BN0080	1987	Fall	117	6158	5	123	3895	2												
AB05BN0080	1987	Summer	117	6158	5	113	10308	3												
AB05BN0080	1988	Fall	109	335	5	111	90	2												
AB05BN0080	1988	Spring	109	335	5	80		1												
AB05BN0080	1988	Summer	109	335	5	121	111	2												
AB05BN0080	1989	Spring	92	747	4	122		1												
AB05BN0080	1989	Summer	92	747	4	82	515	3												
AB05BN0080	1990	Fall	35	222	5	47	409	2												
AB05BN0080	1990	Spring	35	222	5	31		1												
AB05BN0080	1990	Summer	35	222	5	26	10	2												
AB05BN0080	1991	Fall	52	644	5	49	9	2												
AB05BN0080	1991	Spring	52	644	5	92		1												
AB05BN0080	1991	Summer	52	644	5	34	352	2												
AB05BN0080	1992	Fall	54	1104	5	93		1												
AB05BN0080	1992	Spring	54	1104	5	22		1												
AB05BN0080	1992	Summer	54	1104	5	52	957	3												
AB05BN0080	1993	Fall	46	1868	4	20	52	2												
AB05BN0080	1993	Spring	46	1868	4	33		1												
AB05BN0080	1993	Summer	46	1868	4	110		1												
AB05BN0080	1994	Fall	47	779	5	78		1												
AB05BN0080	1994	Spring	47	779	5	27		1												
AB05BN0080	1994	Summer	47	779	5	44	864	3												
AB05BN0080	1995	Fall	58	2066	5	32	849	2												
AB05BN0080	1995	Spring	58	2066	5	122		1												
AB05BN0080	1995	Summer	58	2066	5	52	1928	2												
AB05BN0080	1996	Fall	49	709	5	53	198	2												
AB05BN0080	1996	Spring	49	709	5	10		1												
AB05BN0080	1996	Summer	49	709	5	65	547	2												

STATION_NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB05BN0080	1997	Fall	58	319	5	53	54	2												
AB05BN0080	1997	Spring	58	319	5	82		1												
AB05BN0080	1997	Summer	58	319	5	52	526	2												
AB05BN0080	1998	Fall	54	37	5	59	2	2												
AB05BN0080	1998	Spring	54	37	5	48		1												
AB05BN0080	1998	Summer	54	37	5	50	35	2												
AB05BN0080	1999	Fall	60	2419	7	84	3117	2												
AB05BN0080	1999	Spring	60	2419	7	104	145	2												
AB05BN0080	1999	Summer	60	2419	7	14	39	3												
AB05BN0080	2000	Fall	88	1303	7	71	229	2												
AB05BN0080	2000	Spring	88	1303	7	121	2226	2												
AB05BN0080	2000	Summer	88	1303	7	76	1076	3												
AB05BN0210	1980	Fall	94	777	8	113	360	2	126		0.219		0.051	0.020	3025091	670412	1721539	758433	411164	PMG
AB05BN0210	1980	Spring	94	777	8	76		1												
AB05BN0210	1980	Summer	94	777	8	109	716	3	136		0.108		0.060	0.019	3025091	670412	1721539	758433	411164	PMG
AB05BN0210	1981	Fall	60	2140	10	48		1												
AB05BN0210	1981	Spring	60	2140	10	97	409	2	112		0.410		0.130	0.084	3025091	670412	1721539	758433	411164	PMG
AB05BN0210	1981	Summer	60	2140	10	82	5015	3	160		0.146		0.060	0.017	3025091	670412	1721539	758433	411164	PMG
AB05BN0210	1983	Fall	114	3200	14	81	1863	5	139		0.030		0.026	0.017	3025091	689230	1784970	782500	361874	PMG
AB05BN0210	1983	Spring	114	3200	14	109	7523	3	209		0.337		0.038	0.014	3025091	689230	1784970	782500	361874	PMG
AB05BN0210	1983	Summer	114	3200	14	143	1677	6	197		0.075		0.050	0.015	3025091	689230	1784970	782500	361874	PMG
AB05BN0210	1984	Fall	124	12002	15	49	277	3	61		0.013		0.046	0.008	3025091	698639	1816685	794534	337230	PMG
AB05BN0210	1984	Spring	124	12002	15	210	25593	5	485		0.550		0.026	0.017	3025091	698639	1816685	794534	337230	PMG
AB05BN0210	1984	Summer	124	12002	15	93	1013	6	151		0.012		0.036	0.013	3025091	698639	1816685	794534	337230	PMG
AB05BN0210	1985	Fall	99	1128	9	128	2662	2	164	0.767	0.430	1.196	0.076	0.011	3025091	708048	1848400	806567	312585	PMG
AB05BN0210	1985	Spring	99	1128	9	121	1094	2	144	0.590	0.671	1.261	0.038	0.011	3025091	708048	1848400	806567	312585	PMG
AB05BN0210	1985	Summer	99	1128	9	79	196	5	94	0.642	0.007	0.649	0.026	0.011	3025091	708048	1848400	806567	312585	PMG
AB05BN0210	1986	Fall	118	11469	7	54	0	2	54	0.430	0.435	0.865	0.027	0.005	3025091	717457	1880115	818601	287940	PMG
AB05BN0210	1986	Spring	118	11469	7	147	7976	2	210	0.420	0.640	1.060	0.029	0.016	3025091	717457	1880115	818601	287940	PMG
AB05BN0210	1986	Summer	118	11469	7	52	1618	2												
AB05BN0260	1986	Fall	46	4063	7	36	1644	3	81	0.653	0.481	1.135	0.056	0.008	3058171	717792	1907251	830072	292383	PMG

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AB05BN0260	1986	Spring	46	4063	7	100	11716	2	177	0.280	0.038	0.318	0.018	0.008	3058171	1907251	830072	292383	PMG
AB05BN0260	1986	Summer	46	4063	7	7	52	2											
AB05CB0010	1983	Fall	15	79	10	22	3	2	24	0.060	0.051	0.111	0.006	0.006	486870	5403	98424	46039	31982 BP
AB05CB0010	1983	Spring	15	79	10	9	52	2	14	1.360	0.110	1.470	0.366	0.023	486870	5403	98424	46039	31982 BP
AB05CB0010	1983	Summer	15	79	10	12	47	5	19	0.372	0.039	0.410	0.084	0.013	486870	5403	98424	46039	31982 BP
AB05CB0010	1984	Fall	42	573	10	66	1050	3	103	0.873	0.043	0.916	0.007	0.002	486870	5510	101288	46455	31423 BP
AB05CB0010	1984	Spring	42	573	10	34	141	3	42	0.097	0.055	0.152	0.008	0.002	486870	5510	101288	46455	31423 BP
AB05CB0010	1984	Summer	42	573	10	31	132	4	43	0.225	0.033	0.258	0.009	0.002	486870	5510	101288	46455	31423 BP
AB05CB0010	1985	Fall	23	586	11	31	2311	3	87	0.267	0.039	0.305	0.008	0.003	486870	5617	104152	46871	30864 BP
AB05CB0010	1985	Spring	23	586	11	21	169	3	32	1.203	0.032	1.235	0.041	0.016	486870	5617	104152	46871	30864 BP
AB05CB0010	1985	Summer	23	586	11	23	140	4	34	0.398	0.082	0.479	0.012	0.003	486870	5617	104152	46871	30864 BP
AB05CB0010	1986	Fall	14	181	4	12	74	2	18	0.333	0.037	0.371	0.035	0.007	486870	5724	107017	47287	30306 BP
AB05CB0010	1986	Spring	14	181	4	30		1											
AB05CB0010	1986	Summer	14	181	4	0		1											
AB05CB0010	1987	Fall	9	62	7	5	21	2	8	0.460	0.040	0.500	0.009	0.004	486870	5645	109794	47276	31681 BP
AB05CB0010	1987	Spring	9	62	7	7		1											
AB05CB0010	1987	Summer	9	62	7	5	12	2											
AB05CC0009	1997	Fall	129	9794	4	192		1											
AB05CC0009	1997	Spring	129	9794	4	16		1											
AB05CC0009	1997	Summer	129	9794	4	154	11462	2											
AB05CC0010	1987	Fall	28	289	6	36	650	2	54	0.200	0.002	0.202	0.014	0.006	1184504	69760	605135	328977	201852 PAP
AB05CC0010	1987	Spring	28	289	6	14		1											
AB05CC0010	1987	Summer	28	289	6	27	226	3	39	0.347	0.026	0.372	0.017	0.004	1184504	69760	605135	328977	201852 PAP
AB05CC0010	1999	Fall	146	4623	4	168	11355	2	244	0.243	0.012	0.255	0.011	0.007	1184504	88560	640348	320356	287790 PAP
AB05CC0010	1999	Spring	146	4623	4	107		1											
AB05CC0010	1999	Summer	146	4623	4	140		1											
AB05CC0010	2000	Fall	151	11437	6	126	65	2	132	0.103	0.002	0.104	0.016	0.005	1184504	91130	644449	320833	289621 PAP
AB05CC0010	2000	Spring	151	11437	6	27		1											
AB05CC0010	2000	Summer	151	11437	6	210	15143	3	346	0.590	0.041	0.631	0.042	0.013	1184504	91130	644449	320833	289621 PAP
AB05CC0020	1983	Fall	43	1210	13	72	1436	2	99	0.200	0.020	0.220	0.015	0.007	592014	7221	139514	68605	46531 PAP
AB05CC0020	1983	Spring	43	1210	13	30	34	4	38	0.240	0.050	0.290	0.053	0.012	592014	7221	139514	68605	46531 PAP

STATION_NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB05CC0020	1983	Summer	43	1210	13	28	408	6	65	0.180	0.050	0.230	0.021	0.012	592014	7221	139514	68605	46531	PAP
AB05CC0020	1985	Fall	214	44451	12	91	6137	3	149	0.327	0.021	0.348	0.009	0.004	592014	7428	147305	69949	45126	PAP
AB05CC0020	1985	Spring	214	44451	12	110	9815	3	224	0.770	0.073	0.843	0.021	0.011	592014	7428	147305	69949	45126	PAP
AB05CC0020	1985	Summer	214	44451	12	365	90923	4	760	0.363	0.059	0.422	0.017	0.009	592014	7428	147305	69949	45126	PAP
AB05CC0020	1986	Fall	167	34029	10	80	8957	2	147	0.420	0.048	0.468	0.023	0.006	592014	7532	151200	70621	44423	PAP
AB05CC0020	1986	Spring	167	34029	10	29		1												
AB05CC0020	1986	Summer	167	34029	10	7	74	2												
AB05CC0020	1987	Fall	140	18730	11	97	275	2	109	0.160	0.022	0.182	0.009	0.003	592014	7481	153817	70449	46336	PAP
AB05CC0020	1987	Spring	140	18730	11	36		1												
AB05CC0020	1987	Summer	140	18730	11	10	58	3	18	0.347	0.057	0.404	0.009	0.003	592014	7481	153817	70449	46336	PAP
AB05CC0170	1983	Fall	39	598	13	58	227	2												
AB05CC0170	1983	Spring	39	598	13	27	764	4												
AB05CC0170	1983	Summer	39	598	13	34	324	6												
AB05CC0170	1984	Fall	179	13158	9	204	2068	3												
AB05CC0170	1984	Spring	179	13158	9	151	4	2												
AB05CC0170	1984	Summer	179	13158	9	175	32536	4												
AB05CC0170	1985	Fall	70	1417	11	61	2764	3												
AB05CC0170	1985	Spring	70	1417	11	71	1032	3												
AB05CC0170	1985	Summer	70	1417	11	63	1419	4												
AB05CC0170	1986	Fall	84	5128	9	128	7473	2												
AB05CC0170	1986	Spring	84	5128	9	101		1												
AB05CC0170	1986	Summer	84	5128	9	38	2789	2												
AB05CC0170	1987	Fall	39	1009	10	45	5	2												
AB05CC0170	1987	Spring	39	1009	10	55		1												
AB05CC0170	1987	Summer	39	1009	10	6	12	3												
AB05CC0200	1983	Fall	64	8180	13	49	16	2	51	0.180	0.001	0.181	0.007	0.025	1184504	65527	577776	322259	202831	PAP
AB05CC0200	1983	Spring	64	8180	13	111	26747	4	356	0.505	0.103	0.608	0.112	0.014	1184504	65527	577776	322259	202831	PAP
AB05CC0200	1983	Summer	64	8180	13	36	756	6	86	0.257	0.044	0.300	0.019	0.012	1184504	65527	577776	322259	202831	PAP
AB05CC0200	1984	Spring	241	24310	2	351		1												
AB05CC0200	1984	Summer	241	24310	2	130		1												
AB05CC0200	1985	Fall	140	7363	11	226	519	3	252	0.393	0.003	0.396	0.012	0.005	1184504	67817	594687	327601	197201	PAP

STATION_NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB05CC0200	1985	Spring	140	7363	11	64	1408	3	99	0.860	0.023	0.883	0.044	0.024	1184504	67817	594687	327601	197201	PAP
AB05CC0200	1985	Summer	140	7363	11	162	4543	4	240	0.343	0.002	0.345	0.015	0.008	1184504	67817	594687	327601	197201	PAP
AB05CC0200	1986	Fall	86	6316	5	133	16637	2	224	0.447	0.105	0.552	0.030	0.013	1184504	68961	603143	330272	194386	PAP
AB05CC0200	1986	Spring	86	6316	5	85		1												
AB05CC0200	1986	Summer	86	6316	5	40	85	2												
AB05CC0390	1984	Spring	209	751	4	222	89	3												
AB05CC0390	1984	Summer	209	751	4	170		1												
AB05CD0100	1983	Fall	104	16724	13	348	17823	2												
AB05CD0100	1983	Spring	104	16724	13	12	41	4												
AB05CD0100	1983	Summer	104	16724	13	72	3476	6												
AB05CD0100	1984	Fall	435	91673	10	835	8732	3												
AB05CD0100	1984	Spring	435	91673	10	222	89	3												
AB05CD0100	1984	Summer	435	91673	10	295	37299	4												
AB05CD0100	1985	Fall	261	13272	10	374	327	3												
AB05CD0100	1985	Spring	261	13272	10	125	2698	3												
AB05CD0100	1985	Summer	261	13272	10	279	6211	4												
AB05CD0100	1986	Fall	105	5623	5	82	8539	2												
AB05CD0100	1986	Spring	105	5623	5	167		1												
AB05CD0100	1986	Summer	105	5623	5	97	8945	2												
AB05CD0100	1987	Fall	225	10014	8	277	36	2												
AB05CD0100	1987	Spring	225	10014	8	77		1												
AB05CD0100	1987	Summer	225	10014	8	206	887	3												
AB05CD0160	1997	Fall	201	24799	5	438		1												
AB05CD0160	1997	Spring	201	24799	5	64		1												
AB05CD0160	1997	Summer	201	24799	5	168	10481	3												
AB05CD0250	1999	Fall	90	469	3	91	936	2	112	0.300	0.005	0.305	0.007	0.004	1562701	136177	1001682	521482	506159	PAP
AB05CD0250	1999	Summer	90	469	3	89		1												
AB05CD0250	2000	Fall	117	5282	6	135	383	2	148	0.123	0.002	0.124	0.007	0.003	1562701	139370	1006791	523263	515045	PAP
AB05CD0250	2000	Spring	117	5282	6	48		1												
AB05CD0250	2000	Summer	117	5282	6	127	10164	3	243	0.867	0.093	0.960	0.090	0.031	1562701	139370	1006791	523263	515045	PAP
AB05CD0320	1983	Fall	69	2506	13	144	325	2	157	0.210	0.001	0.211	0.011	0.009	1562701	105679	925174	529272	344230	PAP

STATION_NO	YEAR	SEASON	ACMe	ACV/a	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB05CD0320	1983	Spring	69	2506	13	34	1469	4	91	0.558	0.139	0.696	0.077	0.035	1562701	105679	925174	529272	344230	PAP
AB05CD0320	1983	Summer	69	2506	13	62	1558	6	117	0.367	0.003	0.369	0.034	0.014	1562701	105679	925174	529272	344230	PAP
AB05CD0370	1983	Fall	58	4155	11	42	24	2												
AB05CD0370	1983	Spring	58	4155	11	11	25	2												
AB05CD0370	1983	Summer	58	4155	11	78	6796	6												
AB05CE0010	1999	Fall	87	1139	4	68	61	2												
AB05CE0010	1999	Spring	87	1139	4	74		1												
AB05CE0010	1999	Summer	87	1139	4	137		1												
AB05CE0010	2000	Fall	111	5625	6	161	370	2												
AB05CE0010	2000	Spring	111	5625	6	19		1												
AB05CE0010	2000	Summer	111	5625	6	108	7105	3												
AB05CE0012	1997	Fall	112	4997	4	141		1												
AB05CE0012	1997	Summer	112	4997	4	103	6951	3												
AB05CE0030	1983	Fall	64	2214	12	63	338	2	76	0.220	0.002	0.222	0.006	0.005	2010479	120742	1354075	767365	438002	PMG
AB05CE0030	1983	Spring	64	2214	12	55	3311	3	121	0.656	0.203	0.859	0.107	0.022	2010479	120742	1354075	767365	438002	PMG
AB05CE0030	1983	Summer	64	2214	12	75	3110	6	156	0.493	0.010	0.503	0.085	0.031	2010479	120742	1354075	767365	438002	PMG
AB05CE0120	1983	Fall	21	172	11	31	90	2												
AB05CE0120	1983	Spring	21	172	11	20	421	3												
AB05CE0120	1983	Summer	21	172	11	16	106	5												
AB05CG0010	1983	Fall	56	1986	11	101	308	2												
AB05CG0010	1983	Spring	56	1986	11	67	4643	3												
AB05CG0010	1983	Summer	56	1986	11	36	869	5												
AB05CJ0070	1983	Fall	17	181	12	24	1	2	24	0.340	0.017	0.357	0.041	0.010	4262956	174515	3403254	1523120	823617	PMG
AB05CJ0070	1983	Spring	17	181	12	14	108	3	26	0.968	0.192	1.159	0.160	0.020	4262956	174515	3403254	1523120	823617	PMG
AB05CJ0070	1983	Summer	17	181	12	10	21	6	17	0.977	0.083	1.060	0.371	0.017	4262956	174515	3403254	1523120	823617	PMG
AB05CK0060	1983	Fall	34	647	10	17	78	2	23	0.360	0.001	0.361	0.051	0.009	4833553	177456	3893301	1630624	861372	PMG
AB05CK0060	1983	Spring	34	647	10	59	1210	3	92	1.208	0.241	1.448	0.331	0.016	4833553	177456	3893301	1630624	861372	PMG
AB05CK0060	1983	Summer	34	647	10	22	60	4	31	0.843	0.117	0.960	0.213	0.015	4833553	177456	3893301	1630624	861372	PMG
AB05DA0010	1985	Fall	4	14	5	8	0	2	8	0.025	0.073	0.098	0.005	0.001	188353	1528	3423	1055	982	MC
AB05DA0010	1985	Spring	4	14	5	3		1												
AB05DA0010	1985	Summer	4	14	5	0	0	2												

STATION NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB05DA0010	1986	Fall	5	44	2	10		1												
AB05DA0010	1986	Spring	5	44	2	1		1												
AB05DC0010	1985	Fall	4	41	5	9	78	2	15	0.025	0.064	0.089	0.003	0.001	414566	2777	34805	10726	9987	BP
AB05DC0010	1985	Spring	4	41	5	0		1												
AB05DC0010	1985	Summer	4	41	5	0	0	2												
AB05DC0010	1986	Fall	3	14	2	5		1												
AB05DC0010	1986	Spring	3	14	2	0		1												
AB05DC0030	1985	Fall	15	253	5	31	191	2												
AB05DC0030	1985	Spring	15	253	5	3		1												
AB05DC0030	1985	Summer	15	253	5	6	0	2												
AB05DC0030	1986	Fall	27	1378	2	53		1												
AB05DC0030	1986	Spring	27	1378	2	1		1												
AB05DC0050	1985	Fall	3	9	5	5	15	2	7	0.095	0.008	0.103	0.006	0.001	892022	7531	104571	32225	30007	BP
AB05DC0050	1985	Spring	3	9	5	0		1												
AB05DC0050	1985	Summer	3	9	5	3	9	2												
AB05DC0050	1986	Fall	9	159	2	18		1												
AB05DC0050	1986	Spring	9	159	2	0		1												
AB05DC0060	1985	Fall	11	57	5	10	2	2												
AB05DC0060	1985	Spring	11	57	5	1		1												
AB05DC0060	1985	Summer	11	57	5	17	51	2												
AB05DC0060	1986	Fall	35	0	2	34		1												
AB05DC0060	1986	Spring	35	0	2	35		1												
AB05DC0080	1985	Fall	12	13	5	13	0	2												
AB05DC0080	1985	Spring	12	13	5	12		1												
AB05DC0080	1985	Summer	12	13	5	10	45	2												
AB05DC0080	1986	Fall	10	18	2	14		1												
AB05DC0080	1986	Spring	10	18	2	7		1												
AB05DE0020	1985	Fall	0	1	5	0	0	2	0	0.090	0.005	0.095	0.003	0.001	2123484	22349	281981	94173	80628	BP
AB05DE0020	1985	Spring	0	1	5	2		1												
AB05DE0020	1985	Summer	0	1	5	0	0	2												
AB05DE0030	1988	Fall	4	3	2	6		1												

STATION_NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB05DE0030	1988	Summer	4	3	2	3		1												
AB05DE0060	1985	Fall	17	288	5	24	733	2												
AB05DE0060	1985	Spring	17	288	5	2		1												
AB05DE0060	1985	Summer	17	288	5	18	84	2												
AB05DE0080	1988	Fall	7	50	2	12		1												
AB05DE0080	1988	Summer	7	50	2	2		1												
AB05DF0120	1988	Fall	11	29	2	15		1												
AB05DF0120	1988	Summer	11	29	2	7		1												
AB05DF0140	1983	Fall	9	15	9	10	21	2												
AB05DF0140	1983	Spring	9	15	9	6	7	2												
AB05DF0140	1983	Summer	9	15	9	8	10	4												
AB05DF0140	1985	Fall	9	31	5	14	1	2												
AB05DF0140	1985	Spring	9	31	5	1		1												
AB05DF0140	1985	Summer	9	31	5	7	14	2												
AB05EB0020	1988	Fall	117	3263	2	158		1												
AB05EB0020	1988	Summer	117	3263	2	77		1												
AB05EB0190	1983	Fall	23	563	9	22	4	2												
AB05EB0190	1983	Spring	23	563	9	73		1												
AB05EB0190	1983	Summer	23	563	9	9	102	5												
AB05EB0210	1983	Fall	25	1168	9	50	3487	2												
AB05EB0210	1983	Spring	25	1168	9	5		1												
AB05EB0210	1983	Summer	25	1168	9	9	50	5												
AB05EB0300	1988	Fall	66	2398	2	100		1												
AB05EB0300	1988	Summer	66	2398	2	31		1												
AB05EB0360	1983	Fall	23	259	10	45	661	2												
AB05EB0360	1983	Spring	23	259	10	19		1												
AB05EB0360	1983	Summer	23	259	10	16	84	6												
AB05EB0380	1983	Fall	95	12008	9	53	1471	2												
AB05EB0380	1983	Spring	95	12008	9	113		1												
AB05EB0380	1983	Summer	95	12008	9	106	18025	6												
AB05EB0550	1983	Fall	96	10083	9	270		1												

STATION_NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB05EB0550	1983	Spring	96	10083	9	19		1												
AB05EB0550	1983	Summer	96	10083	9	61	4774	6												
AB05EB0550	1985	Fall	53	606	5	53	0	2												
AB05EB0550	1985	Spring	53	606	5	15		1												
AB05EB0550	1985	Summer	53	606	5	71	267	2												
AB05EB0550	1986	Fall	86	14326	2	171		1												
AB05EB0550	1986	Spring	86	14326	2	2		1												
AB05EB0570	1983	Fall	87	5507	9	157		1												
AB05EB0570	1983	Spring	87	5507	9	53		1												
AB05EB0570	1983	Summer	87	5507	9	65	5142	6												
AB05EB0570	1985	Fall	32	368	5	27	1261	2												
AB05EB0570	1985	Spring	32	368	5	41		1												
AB05EB0570	1985	Summer	32	368	5	33	63	2												
AB05EB0570	1986	Fall	102	927	2	123		1												
AB05EB0570	1986	Spring	102	927	2	80		1												
AB05EB0600	1988	Fall	172	19865	2	271		1												
AB05EB0600	1988	Summer	172	19865	2	72		1												
AB05EB0830	1988	Fall	285	119772	2	530		1												
AB05EB0830	1988	Summer	285	119772	2	40		1												
AB05EB0850	1985	Fall	33	794	5	31	1515	2												
AB05EB0850	1985	Spring	33	794	5	9		1												
AB05EB0850	1985	Summer	33	794	5	47	704	2												
AB05EB0850	1986	Fall	103	11968	2	181		1												
AB05EB0850	1986	Spring	103	11968	2	26		1												
AB05EB0860	1985	Fall	64	486	5	62	686	2												
AB05EB0860	1985	Spring	64	486	5	35		1												
AB05EB0860	1985	Summer	64	486	5	79	5	2												
AB05EB0860	1986	Fall	178	53101	2	341		1												
AB05EB0860	1986	Spring	178	53101	2	15		1												
AB05EB0910	1983	Fall	74	3470	9	112		1												
AB05EB0910	1983	Spring	74	3470	9	75		1												

STATION NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB05EB0910	1983	Summer	74	3470	9	45	539	6												
AB05EB0930	1983	Fall	107	6436	9	239		1												
AB05EB0930	1983	Spring	107	6436	9	107		1												
AB05EB0930	1983	Summer	107	6436	9	87	6333	6												
AB05EC0090	1985	Fall	185	11328	4	233		1												
AB05EC0090	1985	Spring	185	11328	4	28		1												
AB05EC0090	1985	Summer	185	11328	4	239	1170	2												
AB05EC0090	1986	Fall	62	22	2	66		1												
AB05EC0090	1986	Spring	62	22	2	59		1												
AB05EC0160	1983	Fall	123	11156	9	203		1												
AB05EC0160	1983	Spring	123	11156	9	33		1												
AB05EC0160	1983	Summer	123	11156	9	101	10091	6												
AB05EC0180	1983	Fall	96	7279	9	105		1												
AB05EC0180	1983	Spring	96	7279	9	29		1												
AB05EC0180	1983	Summer	96	7279	9	75	3446	6												
AB05EC0180	1988	Fall	234	85160	2	441		1												
AB05EC0180	1988	Summer	234	85160	2	28		1												
AB05EC0210	1985	Fall	179	5466	2	179	5466	2												
AB05EC0210	1986	Fall	133	23157	2	240		1												
AB05EC0210	1986	Spring	133	23157	2	25		1												
AB05ED0020	1985	Fall	136	11232	5	218	11703	2												
AB05ED0020	1985	Spring	136	11232	5	3		1												
AB05ED0020	1985	Summer	136	11232	5	120	1559	2												
AB05ED0110	1985	Fall	191	11905	5	236	39637	2												
AB05ED0110	1985	Spring	191	11905	5	152		1												
AB05ED0110	1985	Summer	191	11905	5	167	1316	2												
AB05ED0110	1986	Fall	87	6958	2	146		1												
AB05ED0110	1986	Spring	87	6958	2	28		1												
AB05ED0120	1988	Fall	294	56630	2	462		1												
AB05ED0120	1988	Summer	294	56630	2	125		1												
AB05EF0010	1985	Fall	64	3446	5	67	3424	2	108	0.410	0.219	0.629	0.099	0.035	5413195	856288	2902351	1518575	606854	PAP

STATION NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB05EF0010	1985	Spring	64	3446	5	8		1												
AB05EF0010	1985	Summer	64	3446	5	90	5889	2												
AB05EF0060	1988	Fall	94	4056	2	139		1												
AB05EF0060	1988	Summer	94	4056	2	49		1												
AB05EF0080	1985	Fall	105	16454	5	168	44531	2												
AB05EF0080	1985	Spring	105	16454	5	4		1												
AB05EF0080	1985	Summer	105	16454	5	93	3075	2												
AB05EF0080	1986	Fall	25	1559	3	71		1												
AB05EF0080	1986	Spring	25	1559	3	2		1												
AB07AC0010	1984	Fall	4	15	5	7	24	2												
AB07AC0010	1984	Spring	4	15	5	3		1												
AB07AC0010	1984	Summer	4	15	5	1	4	2												
AB07AD0050	1984	Fall	6	29	5	11	2	2	12	0.043	0.059	0.102	0.015	0.001	929019	3148	2716	806	643	BP
AB07AD0050	1984	Spring	6	29	5	5		1												
AB07AD0050	1984	Summer	6	29	5	1	0	2												
AB07AD0060	1987	Fall	18	501	3	44		1												
AB07AD0060	1987	Spring	18	501	3	3		1												
AB07AD0060	1987	Summer	18	501	3	8		1												
AB07AD0220	1984	Fall	13	399	4	42		1												
AB07AD0220	1984	Spring	13	399	4	4		1												
AB07AD0220	1984	Summer	13	399	4	2	0	2												
AB07AD0260	1984	Fall	14	549	5	35	738	2	55	0.150	0.057	0.207	0.015	0.001	953308	7182	4326	1284	1024	BP
AB07AD0260	1984	Spring	14	549	5	1		1												
AB07AD0260	1984	Summer	14	549	5	0	0	2												
AB07AD0350	1984	Fall	11	217	5	25	207	2												
AB07AD0350	1984	Spring	11	217	5	5		1												
AB07AD0350	1984	Summer	11	217	5	0	0	2												
AB07AD0380	1984	Fall	27	1379	5	60	1660	2												
AB07AD0380	1984	Spring	27	1379	5	11		1												
AB07AD0380	1984	Summer	27	1379	5	1	1	2												
AB07AD0460	1984	Fall	16	513	5	36	622	2												

STATION_NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB07AD0460	1984	Spring	16	513	5	5		1												
AB07AD0460	1984	Summer	16	513	5	0	0	2												
AB07AE0080	1984	Fall	21	1006	4	37	1954	2	68	0.113	0.029	0.141	0.012	0.001	1901818	14424	72477	22756	14712	BP
AB07AE0080	1984	Summer	21	1006	4	5	5	2												
AB07AE0360	1987	Fall	14	8	3	11		1												
AB07AE0360	1987	Spring	14	8	3	17		1												
AB07AE0360	1987	Summer	14	8	3	13		1												
AB07AF0050	1985	Fall	44	1178	6	17	217	2												
AB07AF0050	1985	Spring	44	1178	6	86		1												
AB07AF0050	1985	Summer	44	1178	6	48	1223	3												
AB07AF0060	1985	Fall	28	499	3	8		1												
AB07AF0060	1985	Spring	28	499	3	52		1												
AB07AF0060	1985	Summer	28	499	3	24		1												
AB07AF0100	1985	Fall	27	1645	3	3		1												
AB07AF0100	1985	Spring	27	1645	3	74		1												
AB07AF0100	1985	Summer	27	1645	3	4		1												
AB07AF0120	1985	Fall	20	475	3	13		1												
AB07AF0120	1985	Spring	20	475	3	45		1												
AB07AF0120	1985	Summer	20	475	3	3		1												
AB07AF0150	1985	Fall	21	274	3	4		1												
AB07AF0150	1985	Spring	21	274	3	22		1												
AB07AF0150	1985	Summer	21	274	3	37		1												
AB07AF0170	1985	Fall	30	895	6	60	1156	2												
AB07AF0170	1985	Spring	30	895	6	3		1												
AB07AF0170	1985	Summer	30	895	6	18	203	3												
AB07AF0180	1985	Fall	58	5556	6	124	14725	2												
AB07AF0180	1985	Spring	58	5556	6	15		1												
AB07AF0180	1985	Summer	58	5556	6	29	39	3												
AB07AF0190	1985	Fall	80	6001	7	162	32	3												
AB07AF0190	1985	Spring	80	6001	7	7		1												
AB07AF0190	1985	Summer	80	6001	7	22	288	3												

STATION_NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB07AF0200	1984	Fall	29	800	6	60	665	2												
AB07AF0200	1984	Spring	29	800	6	1		1												
AB07AF0200	1984	Summer	29	800	6	18	120	3												
AB07AF0210	1985	Fall	6	7	3	4		1												
AB07AF0210	1985	Spring	6	7	3	9		1												
AB07AF0210	1985	Summer	6	7	3	4		1												
AB07AF0240	1985	Fall	80	4641	3	2		1												
AB07AF0240	1985	Spring	80	4641	3	128		1												
AB07AF0240	1985	Summer	80	4641	3	110		1												
AB07AF0260	1985	Fall	12	142	2	3		1												
AB07AF0260	1985	Summer	12	142	2	20		1												
AB07AF0310	1985	Fall	13	2	2	12		1												
AB07AF0310	1985	Summer	13	2	2	14		1												
AB07AF0330	1984	Fall	8	20	6	9	6	2												
AB07AF0330	1984	Spring	8	20	6	3		1												
AB07AF0330	1984	Summer	8	20	6	9	32	3												
AB07AF0330	1985	Fall	17	20	3	15		1												
AB07AF0330	1985	Spring	17	20	3	13		1												
AB07AF0330	1985	Summer	17	20	3	22		1												
AB07AF0340	1985	Fall	52	1644	6	43	1	2												
AB07AF0340	1985	Spring	52	1644	6	16		1												
AB07AF0340	1985	Summer	52	1644	6	70	2897	3												
AB07AF0350	1984	Fall	25	42	5	24	9	2	26	0.223	0.070	0.292	0.011	0.004	266013	824	18388	5459	4351	BP
AB07AF0350	1984	Summer	25	42	5	25	77	3	35	0.128	0.025	0.153	0.010	0.003	266013	824	18388	5459	4351	BP
AB07AF0350	1985	Fall	40	322	5	39	200	2												
AB07AF0350	1985	Spring	40	322	5	26		1												
AB07AF0350	1985	Summer	40	322	5	49	735	2												
AB07AF0380	1984	Fall	24	466	5	7		1												
AB07AF0380	1984	Spring	24	466	5	4		1												
AB07AF0380	1984	Summer	24	466	5	37	318	3	57	0.243	0.003	0.246	0.009	0.005	180558	559	12499	3711	2958	BP
AB07AF0390	1984	Fall	10	85	7	16	104	2												

STATION_NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB07AF0390	1984	Spring	10	85	7	1		1												
AB07AF0390	1984	Summer	10	85	7	9	84	4												
AB07AF0390	1985	Fall	25	195	2	16		1												
AB07AF0390	1985	Summer	25	195	2	35		1												
AB07AG0010	1985	Fall	15	30	5	14	0	2												
AB07AG0010	1985	Spring	15	30	5	8		1												
AB07AG0010	1985	Summer	15	30	5	20	33	2												
AB07AG0020	1986	Fall	12	5	2	13		1												
AB07AG0020	1986	Summer	12	5	2	10		1												
AB07AG0070	1986	Fall	21	701	2	2		1												
AB07AG0070	1986	Summer	21	701	2	40		1												
AB07AG0130	1985	Fall	108	12	2	111		1												
AB07AG0130	1985	Summer	108	12	2	106		1												
AB07AG0150	1986	Fall	202	65103	2	21		1												
AB07AG0150	1986	Summer	202	65103	2	382		1												
AB07AG0170	1986	Fall	180	54605	2	15		1												
AB07AG0170	1986	Summer	180	54605	2	346		1												
AB07AG0200	1986	Fall	168	51075	2	8		1												
AB07AG0200	1986	Summer	168	51075	2	328		1												
AB07AG0210	1986	Fall	137	33367	2	8		1												
AB07AG0210	1986	Summer	137	33367	2	267		1												
AB07AG0240	1985	Fall	67	2230	5	81	4037	2												
AB07AG0240	1985	Spring	67	2230	5	18		1												
AB07AG0240	1985	Summer	67	2230	5	77	1926	2												
AB07AG0250	1986	Fall	82	10818	2	8		1												
AB07AG0250	1986	Summer	82	10818	2	155		1												
AB07AG0270	1986	Fall	76	9699	2	6		1												
AB07AG0270	1986	Summer	76	9699	2	146		1												
AB07AG0290	1986	Fall	76	8117	2	13		1												
AB07AG0290	1986	Summer	76	8117	2	140		1												
AB07AG0310	1985	Fall	96	13097	5	31	768	2												

STATION_NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB07AG0310	1985	Spring	96	13097	5	31		1												
AB07AG0310	1985	Summer	96	13097	5	193	19848	2												
AB07AG0370	1987	Fall	9	16	3	4		1												
AB07AG0370	1987	Spring	9	16	3	12		1												
AB07AG0370	1987	Summer	9	16	3	9		1												
AB07AG0420	1984	Fall	8	115	4	12	281	2	24	0.330	0.004	0.334	0.023	0.006	896693	10039	62769	18667	14767	BP
AB07AG0420	1984	Spring	8	115	4	2		1												
AB07AG0420	1984	Summer	8	115	4	8		1												
AB07AG0420	1985	Fall	78	17684	5	5	7	2												
AB07AG0420	1985	Spring	78	17684	5	6		1												
AB07AG0420	1985	Summer	78	17684	5	188	30966	2												
AB07AH0330	1984	Fall	12	229	4	21	382	2												
AB07AH0330	1984	Spring	12	229	4	1		1												
AB07AH0330	1984	Summer	12	229	4	7		1												
AB07AH0350	1987	Fall	5	5	3	3		1												
AB07AH0350	1987	Spring	5	5	3	8		1												
AB07AH0350	1987	Summer	5	5	3	5		1												
AB07BA0010	1985	Fall	22	207	3	24		1												
AB07BA0010	1985	Summer	22	207	3	22	412	2												
AB07BA0020	1984	Fall	59	2276	6	94	6311	2												
AB07BA0020	1984	Summer	59	2276	6	41	445	4												
AB07BA0030	1984	Fall	58	1517	7	85	1175	2												
AB07BA0030	1984	Spring	58	1517	7	3		1												
AB07BA0030	1984	Summer	58	1517	7	59	1159	4												
AB07BA0030	1985	Fall	48	2198	2	81		1												
AB07BA0030	1985	Summer	48	2198	2	15		1												
AB07BA0050	1985	Fall	70	412	3	90		1												
AB07BA0050	1985	Summer	70	412	3	60	231	2												
AB07BA0060	1985	Fall	39	1125	2	62		1												
AB07BA0060	1985	Summer	39	1125	2	15		1												
AB07BA0070	1985	Fall	54	1432	3	96		1												

STATION_NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB07BA0070	1985	Summer	54	1432	3	33	256	2												
AB07BC0080	1984	Fall	11	172	3	26		1												
AB07BC0080	1984	Spring	11	172	3	2		1												
AB07BC0080	1984	Summer	11	172	3	5		1												
AB07BD0090	1987	Fall	11	96	3	21		1												
AB07BD0090	1987	Spring	11	96	3	10		1												
AB07BD0090	1987	Summer	11	96	3	1		1												
AB07BD0100	1984	Fall	5	65	4	9	128	2												
AB07BD0100	1984	Spring	5	65	4	1		1												
AB07BD0100	1984	Summer	5	65	4	0		1												
AB07BE0310	1984	Fall	5	71	4	9	151	2	17	0.360	0.021	0.381	0.040	0.003	7174976	86862	1060514	477745	271396	BP
AB07BE0310	1984	Spring	5	71	4	1		1												
AB07BE0310	1984	Summer	5	71	4	0		1												
AB07BE0330	1987	Fall	4	2	3	4		1												
AB07BE0330	1987	Spring	4	2	3	2		1												
AB07BE0330	1987	Summer	4	2	3	5		1												
AB07CA0040	1984	Fall	6	2	4	7	2	2												
AB07CA0040	1984	Spring	6	2	4	6		1												
AB07CA0040	1984	Summer	6	2	4	5		1												
AB07CB0360	1984	Fall	2	2	5	1	1	2	2	0.507	0.034	0.541	0.097	0.013	7174976	86862	1060514	477745	271396	BP
AB07CB0360	1984	Spring	2	2	5	1		1												
AB07CB0360	1984	Summer	2	2	5	2	6	2												
AB07CB0640	1984	Fall	19	546	3	27	755	2												
AB07CB0640	1984	Spring	19	546	3	4		1												
AB07CB0730	1984	Fall	7	126	5	16	223	2												
AB07CB0730	1984	Spring	7	126	5	2		1												
AB07CB0730	1984	Summer	7	126	5	0	0	2												
AB07CB0770	1984	Fall	16	636	5	36	1173	2												
AB07CB0770	1984	Spring	16	636	5	4		1												
AB07CB0770	1984	Summer	16	636	5	1	3	2												
AB07CC0010	1984	Fall	4	27	5	9	31	2	13	0.350	0.004	0.354	0.043	0.007	19380868	201779	2567568	1142709	618508	BP

STATION_NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB07CC0010	1984	Spring	4	27	5	4		1												
AB07CC0010	1984	Summer	4	27	5	0	0	2												
AB07CD0100	1984	Fall	12	407	5	27	837	2	48	0.515	0.014	0.529	0.061	0.023	3825764	2191	30803	7669	4398	BP
AB07CD0100	1984	Spring	12	407	5	5		1												
AB07CD0100	1984	Summer	12	407	5	0	0	2												
AB07DA0090	1984	Fall	4	48	5	8	127	2	16	0.450	0.021	0.471	0.056	0.013	14169854	132487	1344428	583961	316483	BP
AB07DA0090	1984	Spring	4	48	5	3		1												
AB07DA0090	1984	Summer	4	48	5	0	0	2												
AB07DA0110	1984	Fall	19	471	5	31	762	2	50	1.060	0.080	1.140	0.045	0.030	57678	64	1768	440	252	BP
AB07DA0110	1984	Spring	19	471	5	32		1												
AB07DA0110	1984	Summer	19	471	5	0	0	2												
AB07DA0860	1984	Fall	2	4	4	3	3	2												
AB07DA0860	1984	Summer	2	4	4	0	0	2												
AB07DD0040	1984	Fall	3	11	3	1	1	2	1	0.430	0.008	0.438	0.048	0.008	28315549	261552	2734311	1165495	630805	BP
AB07DD0040	1984	Spring	3	11	3	6		1												
AB07FD0050	1988	Fall	53	2348	4	66		1												
AB07FD0050	1988	Spring	53	2348	4	32		1												
AB07FD0050	1988	Summer	53	2348	4	58	6390	2												
AB07FD0070	1988	Fall	27	1473	4	5		1												
AB07FD0070	1988	Spring	27	1473	4	16		1												
AB07FD0070	1988	Summer	27	1473	4	43	3268	2												
AB07FD0100	1988	Fall	41	1246	3	49		1												
AB07FD0100	1988	Spring	41	1246	3	3		1												
AB07FD0100	1988	Summer	41	1246	3	72		1												
AB07FD0110	1988	Fall	36	666	3	16		1												
AB07FD0110	1988	Spring	36	666	3	26		1												
AB07FD0110	1988	Summer	36	666	3	65		1												
AB07HA0210	1988	Fall	8	153	4	3		1												
AB07HA0210	1988	Spring	8	153	4	2		1												
AB07HA0210	1988	Summer	8	153	4	14	333	2												
AB07HA0250	1988	Fall	22	1195	4	12		1												

STATION_NO	YEAR	SEASON	ACMe	ACVa	ACN	SCMe	SCVa	SCN	SCMa	TKN	NOX	TN	TP	TDP	BAS	POP	FARM	CROP	LU	ECOZ
AB07HA0250	1988	Spring	22	1195	4	1		1												
AB07HA0250	1988	Summer	22	1195	4	37	2593	2												
AB07HC0070	1988	Fall	7	56	3	6		1												
AB07HC0070	1988	Spring	7	56	3	1		1												
AB07HC0070	1988	Summer	7	56	3	16		1												
AB07HD0010	1988	Fall	21	730	3	52		1												
AB07HD0010	1988	Spring	21	730	3	1		1												
AB07HD0010	1988	Summer	21	730	3	11		1												
AB07HF0060	1988	Spring	4	1	2	4		1												
AB07HF0060	1988	Summer	4	1	2	3		1												
AB11AA0010	1986	Fall	23	112	6	16	6	2	18	0.530	0.002	0.532	0.006	0.002	35231	178	16206	8080	3447	PMG
AB11AA0010	1986	Spring	23	112	6	20		1												
AB11AA0010	1986	Summer	23	112	6	29	171	3	43	0.433	0.002	0.435	0.014	0.006	35231	178	16206	8080	3447	PMG
AB11AA0020	1986	Fall	17	26	3	14	0	2	14	0.500	0.030	0.530	0.008	0.004	95424	992	93226	46033	18623	PMG
AB11AA0020	1986	Summer	17	26	3	23		1												
AB11AA0030	1986	Fall	6	6	8	9	7	2	11	0.533	0.013	0.546	0.010	0.003	172795	2090	150194	72985	26819	PMG
AB11AA0030	1986	Spring	6	6	8	6	0	2	7	0.330	0.005	0.335	0.036	0.013	172795	2090	150194	72985	26819	PMG
AB11AA0030	1986	Summer	6	6	8	5	5	4	8	0.330	0.006	0.336	0.050	0.008	172795	2090	150194	72985	26819	PMG
AB11AA0050	1986	Fall	74	8351	3	44		1												
AB11AA0050	1986	Spring	74	8351	3	1		1												

Table A.2. Alberta Environment stations with unique identifier (Station_No), name, description, latitude, longitude, and ecozone or ecoregion in which the station falls. MC: montane cordillera ecozone; BP: boreal plains ecozone; PMG: mixed and moist mixed grassland ecoregions; PFG: fescue grassland ecoregion; PAP: aspen parkland ecoregion. Note that ecozone/ecoregion was only determined for stations included in regression models of Chapter 1.

STATION_NO	STATION_NAME	STATION_DESCRIPTION	ECOZONE	LATITUDE	LONGITUDE
AB05AA0050	OLDMAN RIVER	OLDMAN RIVER NEAR WALDONS CORNER	MC	49.81417	114.18333
AB05AA0070	OLDMAN RIVER	OLDMAN RIVER NEAR OLIN CREEK 11 MILES NORTH OF COWLEY		49.72583	114.08667
AB05AA0220	CROWSNEST RIVER	CROWSNEST RIVER UPSTREAM OF CONNELLY CREEK		49.59583	114.10694
AB05AA0270	CROWSNEST RIVER	CROWSNEST RIVER NEAR THE MOUTH	PFG	49.59778	114.09028
AB05AA0400	CASTLE RIVER	CASTLE RIVER AT CASTLE RIVER RECREATION AREA		49.55	114.025
AB05AA0410	CASTLE RIVER	CASTLE RIVER AT HIGHWAY #3 BRIDGE NEAR COWLEY	PFG	49.54333	114.03167
AB05AB0040	OLDMAN RIVER	OLDMAN RIVER NEAR BROCKET - RIGHT BANK SAMPLE	PFG	49.5575	113.82222
AB05AB0070	OLDMAN RIVER	OLDMAN RIVER NEAR BROCKET - LEFT BANK SAMPLE	PFG	49.55861	113.82222
AB05AB0130	OLDMAN RIVER	OLDMAN RIVER AT FORT MACLEOD - RIGHT BANK SAMPLE	PMG	49.72083	113.45
AB05AB0170	WILLOW CREEK DOWNSTREAM OF CHAIN LAKES	WILLOW CREEK DOWNSTREAM OF CHAIN LAKES		50.1625	114.06389
AB05AB0200	WILLOW CREEK ABOVE HIGHWAY 527	WILLOW CREEK ABOVE HIGHWAY 527		50.12917	113.79583
AB05AB0220	WILLOW CREEK ABOVE CLARESHOLM WATER INTAKE	WILLOW CREEK ABOVE CLARESHOLM WATER INTAKE AT HWY 520	PMG	50.00139	113.71389
AB05AB0250	WILLOW CREEK AT SEC HWY 519	WILLOW CREEK AT SEC.HWY. #519	PMG	49.875	113.54583
AB05AB0260	WILLOW CREEK AT SEC HWY 811	WILLOW CREEK AT SEC.HWY. #811	PMG	49.75722	113.40694
AB05AB0770	WILLOW CREEK UPSTREAM OF PINE COULEE DIVERSION	WILLOW CREEK UPSTREAM OF PINE COULEE DIVERSION AT OXLEY CREEK RANCH		50.12922	113.84639
AB05AB0780	WILLOW CREEK DOWNSTREAM OF PINE COULEE RESERVOIR	WILLOW CREEK DOWNSTREAM OF PINE COULEE RESERVOIR OUTLET AT BOLDUC RANCH		50.09822	113.73275
AB05AB0790	WILLOW CREEK AT WILLOW CREEK PROVINCIAL PARK	WILLOW CREEK AT WILLOW CREEK PROVINCIAL PARK, BESIDE CAMPGROUND SITE # 13		50.11939	113.76611
AB05AB0970	OLDMAN RIVER AT ROCKY COULEE	OLDMAN RIVER AT ROCKY COULEE WATER QUALITY SITE		49.85083	113.25694
AB05AC0010	OLDMAN RIVER	OLDMAN RIVER NEAR MONARCH - RIGHT BANK SAMPLE	PMG	49.79028	113.12361
AB05AC0066	LITTLE BOW RIVER AT HIGHWOOD RIVER	LITTLE BOW RIVER AT HIGHWOOD RIVER CONTROL STRUCTURE AND WSC GAUGE		50.54186	113.87167
AB05AC0080	LITTLE BOW RIVER	LITTLE BOW RIVER AT HIGHWAY #2 SOUTHEAST OF HIGH RIVER		50.53833	113.825

STATION_NO	STATION_NAME	STATION_DESCRIPTION	ECOZONE	LATITUDE	LONGITUDE
AB05AC0089	LITTLE BOW RIVER UPSTREAM OF FRANK LAKE CONFLUENCE	LITTLE BOW RIVER UPSTREAM OF FRANK LAKE CONFLUENCE		50.47811	113.86667
AB05AC0093	LITTLE BOW RIVER AT 658 AVE	LITTLE BOW RIVER AT 658 AVE		50.4555	113.80833
AB05AC0100	LITTLE BOW RIVER	LITTLE BOW RIVER AT HIGHWAY #533 EAST OF NANTON		50.35378	113.52583
AB05AC0110	MOSQUITO CREEK	MOSQUITO CREEK AT HIGHWAY #534-WEST OF CONNEMARA		50.39667	113.98333
AB05AC0120	WOMEN'S COULEE AT 690 AVE	WOMEN'S COULEE AT 690 AVE		50.42639	113.87167
AB05AC0130	NANTON CREEK	NANTON CREEK AT HIGHWAY #2	PFG	50.36008	113.83333
AB05AC0140	MOSQUITO CREEK UPSTREAM NANTON	MOSQUITO CREEK UPSTREAM OF NANTON AT HWY 2	PFG	50.37272	113.78667
AB05AC0150	MOSQUITO CREEK DOWNSTREAM NANTON	MOSQUITO CREEK DOWNSTREAM NANTON AT RG RD 281		50.33967	113.72
AB05AC0160	MOSQUITO CREEK	MOSQUITO CREEK AT HWY. #529 EAST OF PARKLAND	PFG	50.252	113.55167
AB05AC0175	LITTLE BOW RIVER D/S OF NEW RESERVOIR	LITTLE BOW RIVER DOWNSTREAM OF NEW RESERVOIR		50.22533	113.4
AB05AC0190	LITTLE BOW RIVER	LITTLE BOW RIVER AT CARMANGAY	PMG	50.13436	113.13583
AB05AC0210	LITTLE BOW RIVER	LITTLE BOW RIVER AT INLET TO TRAVERS RESERVOIR		50.20306	112.97972
AB05AD0010	OLDMAN RIVER	OLDMAN RIVER ABOVE LETHBRIDGE LONG TERM ORGANIC SITE	PMG	49.70833	112.875
AB05AD0275	OLDMAN RIVER DOWNSTREAM OF BELLY RIVER	OLDMAN RIVER DOWNSTREAM OF BELLY RIVER		49.70806	112.97472
AB05AD0300	OLDMAN RIVER	OLDMAN RIVER U/S OF LETHBRIDGE AT POPSON PARK, LEFT BANK GRAB		49.64158	112.86278
AB05AD0370	OLDMAN RIVER	OLDMAN RIVER ABOVE LETHBRIDGE STP OUTFALL -HWY#3 RIGHT BANK SAMPLE	PMG	49.71028	112.86167
AB05AD0500	OLDMAN RIVER	OLDMAN RIVER AT PAVAN PARK D/S OF LETH. STP RIGHT BANK PLUS 10 METERS		49.75583	112.85222
AB05AD0610	OLDMAN RIVER	OLDMAN RIVER SOUTH WEST OF DIAMOND CITY FROM RIGHT BANK - 10 METERS	PMG	49.77583	112.84556
AB05AD0740	OLDMAN RIVER	OLDMAN RIVER BELOW PICTURE BUTTE AT HWY. #845 RIGHT BANK SAMPLE ORGANIC SITE		49.85833	112.62333
AB05AG0010	OLDMAN RIVER	OLDMAN RIVER ABOVE TABER (HWY#864) RIGHT BANK SAMPLE		49.96111	112.08472
AB05AG0070	OLDMAN RIVER	OLDMAN RIVER ABOVE TABER (HWY#864) LEFT BANK SAMPLE		49.81528	112.17222
AB05AG0090	OLDMAN RIVER	OLDMAN RIVER NEAR FINCASTLE ADJACENT TO DATASONDE MONITORING SITE		49.81639	112.17222
AB05AG0220	OLDMAN RIVER	OLDMAN RIVER AT THE MOUTH		49.91667	111.75722
AB05AG0230	OLDMAN RIVER	OLDMAN RIVER AT THE MOUTH	PMG	49.93389	111.69667
AB05AJ0040	SOUTH SASKATCHEWAN RIVER	SOUTH SASKATCHEWAN RIVER AT HIGHWAY #879	PMG	49.90528	111.47222
AB05AK0020	SOUTH SASKATCHEWAN RIVER	SOUTH SASKATCHEWAN RIVER ABOVE MEDICINE HAT	PMG	50.04333	110.72222
AB05AK0370	SOUTH SASKATCHEWAN RIVER	SOUTH SASKATCHEWAN RIVER BELOW MEDICINE HAT	PMG	50.14167	110.65778
AB05AK0490	SOUTH SASKATCHEWAN RIVER	SOUTH SASKATCHEWAN RIVER AT HIGHWAY #41 BRIDGE	PMG	50.73194	110.07111

STATION_NO	STATION_NAME	STATION_DESCRIPTION	ECOZONE	LATITUDE	LONGITUDE
AB05BB0010	BOW RIVER	BOW RIVER BELOW BOW FALLS AND UPSTREAM OF SPRAY RIVER GOLF COURSE STUDY SITE #1		51.16528	115.55722
AB05BB0020	BOW RIVER	BOW RIVER AT BANFF SPRINGS MAINTENANCE AREA GOLF COURSE STUDY SITE #2		51.16889	115.55
AB05BB0030	BOW RIVER	BOW RIVER AT BANFF SPRINGS CLUB HOUSE GOLF COURSE STUDY SITE #3		51.17556	115.53694
AB05BB0040	BOW RIVER	BOW RIVER AT EASTERN EDGE OF BANFF SPRINGS GOLF COURSE GOLF COURSE STUDY SITE #4		51.18028	115.5275
AB05BB0050	BOW RIVER	BOW RIVER UPSTREAM OF BANFF SEWAGE DISCHARGE GOLF COURSE STUDY SITE #5		51.17833	115.50722
AB05BB0060	BOW RIVER	BOW RIVER DOWNSREAM OF BANFF SEWAGE DISCHARGE GOLF COURSE STUDY SITE #6		51.17306	115.50722
AB05BE0010	BOW RIVER	BOW RIVER U/S OF CANMORE		51.12278	115.38667
AB05BE0030	BOW RIVER	BOW RIVER AT CANMORE BRIDGE - LEFT BANK SAMPLE		51.08556	115.36306
AB05BE0050	BOW RIVER	BOW RIVER AT CANMORE BRIDGE - RIGHT BANK SAMPLE		51.08556	115.36444
AB05BE0065	SPRING CREEK NEAR CONFLUENCE WITH POLICEMAN CREEK	SPRING CREEK AT RESTWELL TRAILER PARK	MC	51.08519	115.349
AB05BE0075	POLICEMAN CREEK NEAR BOW RIVER CONFLUENCE	POLICEMAN CREEK UPSTREAM OF BOW VALLEY TRAIL	MC	51.07778	115.343
AB05BE0090	BOW RIVER	BOW RIVER BELOW CANMORE AT HIGHWAY # 1 BRIDGE RIGHT BANK SAMPLE		51.06417	115.32389
AB05BE0100	BOW RIVER	BOW RIVER BELOW CANMORE AT HIGHWAY # 1 BRIDGE LEFT BANK SAMPLE		51.065	115.32389
AB05BE0105	BILL GRIFFITHS CREEK NEAR BOW RIVER CONFLUENCE	BILL GRIFFITHS CREEK AT OLD CAMP DAY USE AREA	MC	51.06386	115.29075
AB05BE0190	BOW RIVER	BOW RIVER UPSTREAM OF EXSHAW CREEK LEFT BANK SAMPLE	MC	51.05667	115.16083
AB05BE0240	BOW RIVER	BOW RIVER AT BOW VALLEY PROVINCIAL PARK RIGHT BANK SAMPLE		51.08694	115.09056
AB05BH0010	BOW RIVER	BOW RIVER AT COCHRANE LONG TERM ORGANIC SITE	PAP	51.17361	114.46667
AB05BH0110	BOW RIVER	BOW RIVER BELOW BEARSPAW DAM	PAP	51.08611	114.28889
AB05BH0140	BOW RIVER	BOW RIVER UPSTREAM OF 85 STREET BRIDGE	PAP	51.1	114.21
AB05BH0300	NOSE CREEK	NOSE CREEK ABOVE AIRDRIE		51.30167	114.67
AB05BH0310	NOSE CREEK	NOSE CREEK BELOW AIRDRIE		51.26472	114.00222
AB05BH0450	BOW RIVER	BOW RIVER NEAR INGLEWOOD GOLF COURSE BONNYBROOK STUDY M1 KILOMETRE 0	PFG	50.99472	114.02528
AB05BH0520	BOW RIVER	BOW RIVER BELOW BONNYBROOK SEWAGE PLANT OUTFALL BONNYBROOK STUDY M2 KILOMETRE 2	PFG	50.98028	114.02972
AB05BH0530	BOW RIVER	BOW RIVER NEAR ACADIA TRAILER PARK	PFG	50.97222	114.02861
AB05BH0610	BOW RIVER	BOW RIVER NEAR QUEENSLAND DOWNS BONNYBROOK STUDY M4 KILOMETRE 8	PFG	50.94111	114.00528
AB05BH2390	PILE OF BONES CREEK UPSTREAM OF GAS PLANT	PILE OF BONES CREEK UPSTREAM OF GAS PLANT DISCHARGE		51.14075	114.58281

STATION NO	STATION NAME	STATION DESCRIPTION	ECOZONE	LATITUDE	LONGITUDE
AB05BH2400	PILE OF BONES CREEK DOWNSTREAM OF GAS PLANT	PILE OF BONES CREEK DOWNSTREAM OF GAS PLANT DISCHARGE		51.14306	114.58186
AB05BJ0120	ELBOW RIVER	ELBOW RIVER D/S OF BRAGG CREEK TOWN JUNE 1988	BP	50.95833	114.55833
AB05BJ0170	ELBOW RIVER	ELBOW RIVER AT HIGHWAY #22	PAP	51.03194	114.46806
AB05BJ0220	ELBOW RIVER	ELBOW RIVER UPSTREAM OF GLENCOE GOLF COURSE GOLF COURSE STUDY OCTOBER 1990		51.03056	114.32083
AB05BJ0230	ELBOW RIVER	ELBOW RIVER UPSTREAM OF GLENCOE GOLF AND COUNTRY CLUB - MAIN CHANNEL		51.03222	114.32083
AB05BJ0240	ELBOW RIVER	ELBOW RIVER MID-COURSE OF GLENCOE GOLF COURSE GOLF COURSE STUDY OCTOBER 1990		51.0325	114.31111
AB05BJ0250	ELBOW RIVER	ELBOW RIVER MIDCOURSE OF GLENCOE GOLF AND COUNTRY CLUB, DOWNSTREAM OF PIPELINE CROSSING		51.03361	114.3025
AB05BJ0280	ELBOW RIVER	ELBOW RIVER AT GLENCOE GOLF CLUB JUNE 1988	PAP	51.03194	114.30417
AB05BJ0290	ELBOW RIVER	ELBOW RIVER UPSTREAM OF TWIN BRIDGES AT HIGHWAY # 8	PAP	51.01667	114.24028
AB05BJ0300	ELBOW RIVER	ELBOW RIVER AT SARCEE BRIDGE JUNE 1988	PAP	50.995	114.16528
AB05BJ0340	ELBOW RIVER	ELBOW RIVER UPSTREAM OF CALGARY GOLF&COUNTRY CLUB GOLF COURSE STUDY OCTOBER 1990		51.00083	114.09194
AB05BJ0350	ELBOW RIVER	ELBOW RIVER AT CALGARY GOLF AND COUNTRY CLUB	PAP	51	114.09583
AB05BJ0370	ELBOW RIVER	ELBOW RIVER D/S OF CALGARY GOLF&COUNTRY CLUB GOLF COURSE STUDY OCTOBER 1990		51.00944	114.08556
AB05BJ0450	ELBOW RIVER	ELBOW RIVER AT 9TH. AVE. BRIDGE	PFG	51.04306	114.04167
AB05BK0009	FISH CREEK	FISH CREEK UPSTREAM OF 37TH STREET	PAP	50.93044	114.14044
AB05BK0035	FISH CREEK	FISH CREEK UPSTREAM OF STORM OUTFALL F6S	PAP	50.9335	114.09508
AB05BK0045	FISH CREEK	FISH CREEK UPSTREAM OF STORM OUTFALL F3A	PAP	50.92931	114.07817
AB05BK0053	FISH CREEK	FISH CREEK UPSTREAM OF STORM OUTFALL F1S	PFG	50.92869	114.04808
AB05BK0057	FISH CREEK	FISH CREEK UPSTREAM OF STORM OUTFALL F1A	PFG	50.91328	114.03767
AB05BK0070	FISH CREEK	FISH CREEK NEAR THE MOUTH NO. 8 FISH CREEK SURVEY NE 1/4-25-22-1-W5	PFG	50.85	113.91667
AB05BL0160	HIGHWOOD RIVER	HIGHWOOD RIVER BELOW PEKISKO CREEK - REACH #1		50.5125	114.08111
AB05BL0180	HIGHWOOD RIVER	HIGHWOOD RIVER ABOVE HIGH RIVER - REACH #2	PFG	50.57611	113.89778
AB05BL0230	HIGHWOOD RIVER - REACH #3	HIGHWOOD RIVER - REACH #3 BELOW HIGH RIVER AT SOD FARM		50.62917	113.84583
AB05BL0390	HIGHWOOD RIVER	HIGHWOOD RIVER DOWNSTREAM OF HWY.547 BRIDGE NEAR ALDERSYDE - REACH #4 FEBRUARY 1988	PFG	50.70167	113.85667
AB05BL0470	SHEEP RIVER	SHEEP RIVER 1.6 KM. DOWNSTREAM OF HWY. #2		50.71444	113.86056
AB05BL0490	HIGHWOOD RIVER	HIGHWOOD RIVER AT HIGHWAY #552 - REACH #5	PFG	50.77778	113.82583
AB05BM0010	BOW RIVER	BOW RIVER BELOW CARSELAND DAM LONG TERM ORGANIC SITE	PFG	50.83056	113.41667
AB05BM0030	BOW RIVER	BOW RIVER NEAR DEER RUN BONNYBROOK STUDY M5 KILOMETRE 12	PFG	50.91139	113.99833
AB05BM0120	BOW RIVER	BOW RIVER APPROXIMATELY 200 YARDS DOWNSTREAM FROM CONFLUENCE OF FISH CREEK FISH CREEK SURVEY LOCATION NO. 11	PFG	50.905	114.00639

STATION NO	STATION NAME	STATION DESCRIPTION	ECOZONE	LATITUDE	LONGITUDE
AB05BM0140	BOW RIVER	BOW RIVER NEAR ACADEMY BONNYBROOK STUDY M7 KILOMETER 17.5	PFG	50.87278	113.99139
AB05BM0150	BOW RIVER	BOW RIVER AT STIERS RANCH	PFG	50.855	113.93333
AB05BM0170	BOW RIVER	BOW RIVER NEAR TREE NURSERY BONNYBROOK STUDY M9 KILOMETER 30.0		50.85028	113.84889
AB05BM0180	BOW RIVER	BOW RIVER BELOW CONFLUENCE OF HIGHWOOD RIVER BONNYBROOK STUDY M10 KILOMETER 37.0			
AB05BM0190	BOW RIVER	BOW RIVER BELOW CONFLUENCE OF HIGHWOOD RIVER		50.81861	113.77639
AB05BM0200	BOW RIVER	BOW RIVER NEAR DALEMEAD BONNYBROOK STUDY M11 KILOMETER 45.0		50.81194	113.73722
AB05BM0420	BOW RIVER	BOW RIVER ABOVE CARSELAND WEIR BONNYBROOK STUDY M12 KILOMETER 52.0	PFG	50.80889	113.68056
AB05BM0470	BOW RIVER	BOW RIVER BELOW CARSELAND WEIR UPSTREAM OF HIGHWAY #24	PFG	50.79694	113.58333
AB05BM0500	BOW RIVER	BOW RIVER NEAR STRANGMUIR BONNYBROOK STUDY M13 - KILOMETER 74	PMG	50.83222	113.41278
AB05BM0590	BOW RIVER	BOW RIVER AT CLUNY		50.84694	113.34722
AB05BM0670	BOW RIVER	BOW RIVER BELOW BASSANO DAM	PMG	50.68333	112.83611
AB05BN0010	BOW RIVER	BOW RIVER RONALANE BRIDGE LONG TERM ORGANIC SITE	PMG	50.74778	112.52417
AB05BN0080	BOW RIVER	BOW RIVER AT BOW CITY BRIDGE		50.04639	111.59111
AB05BN0210	BOW RIVER	BOW RIVER AT RONALANE BRIDGE	PMG	50.43194	112.22194
AB05BN0260	BOW RIVER	BOW RIVER BEFORE CONFLUENCE WITH OLDMAN RIVER	PMG	50.04417	111.58111
AB05CB0010	RED DEER RIVER WEST OF BOWDEN	RED DEER RIVER WEST OF BOWDEN UPSTREAM DICKSON DAM IMPACT STUDY - SITE 1	BP	49.94083	111.69028
AB05CC0009	RED DEER RIVER	RED DEER RIVER NEAR HWY 2 - TRANSECT		51.94306	114.49861
AB05CC0010	RED DEER RIVER	RED DEER RIVER AT HIGHWAY # 2 BRIDGE - ABOVE RED DEER LONG TERM ORGANIC SITE	PAP	52.27	113.8625
AB05CC0020	RED DEER RIVER	RED DEER RIVER 4KM BELOW DICKSON DAM DAM IMPACT STUDY - SITE 3	PAP	52.26722	113.86361
AB05CC0170	RED DEER RIVER	RED DEER RIVER AT INNISFAIL HWY. 54 BRIDGE DAM IMPACT STUDY SITE - 4		52.06667	114.21667
AB05CC0200	RED DEER RIVER	RED DEER RIVER ABOVE RED DEER FT. NORMANDEAU DAM IMPACT STUDY - SITE 5	PAP	52.07056	113.98611
AB05CC0390	RED DEER RIVER - 10 KM ABOVE	RED DEER RIVER - 10 KM ABOVE CONFLUENCE OF BLINDMAN RIVER		52.26083	113.87806
AB05CD0100	RED DEER RIVER	RED DEER RIVER BELOW RED DEER JOFFRE BRIDGE DAM IMPACT STUDY - SITE 6		52.33333	113.78333
AB05CD0160	RED DEER RIVER	RED DEER RIVER AT JOFFRE BRIDGE TRANSECT CODE		52.26667	113.58472
AB05CD0250	RED DEER RIVER	RED DEER RIVER AT NEVIS BRIDGE - RIGHT BANK	PAP	52.26833	113.58667
AB05CD0320	RED DEER RIVER	RED DEER RIVER AT NEVIS BRIDGE - LEFT BANK	PAP	52.30639	113.07917
AB05CD0370	RED DEER RIVER	RED DEER RIVER - AT HWY. #585 BRIDGE NEAR TROCHU		52.30639	113.07528
AB05CE0010	RED DEER RIVER	RED DEER RIVER AT MORRIN BRIDGE - CENTER LONG TERM ORGANIC SITE		51.83333	113
AB05CE0012	RED DEER RIVER	RED DEER RIVER AT MORRIN BRIDGE - TRANSECT CODE		51.65278	112.90417
AB05CE0030	RED DEER RIVER	RED DEER RIVER ABOVE DRUMHELLER AT HWY 9 - LEFT BANK	PMG	51.65111	112.9025
				51.46806	112.70833

STATION_NO	STATION_NAME	STATION_DESCRIPTION	ECOZONE	LATITUDE	LONGITUDE
AB05CE0120	RED DEER RIVER	RED DEER RIVER BELOW DRUMHELLER NEAR EAST COULEE AT HWY 10 - LEFT BANK		51.33222	112.48694
AB05CG0010	RED DEER RIVER	RED DEER RIVER AT FINNEGAN ABOVE HWY. 36 - RIGHT BANK		51.12472	112.08611
AB05CJ0070	RED DEER RIVER AT HWY. 884 NR JENNER - RIGHT BANK	RED DEER RIVER D/S DINOSAUR PROV. PK. AT HWY. 884 NEAR JENNER - RIGHT BANK	PMG	50.83861	111.15222
AB05CK0060	RED DEER RIVER NEAR BORDER	RED DEER RIVER NEAR BORDER	PMG	50.96389	110.02889
AB05DA0010	NORTH SASKATCHEWAN RIVER	NORTH SASKATCHEWAN RIVER AT WHIRLPOOL POINT	MC	52.00278	116.47222
AB05DC0010	NORTH SASKATCHEWAN RIVER	NORTH SASKATCHEWAN RIVER BELOW BIGHORN RESERVOIR(LAKE ABRAHAM)	BP	52.34583	116.26667
AB05DC0030	NORTH SASKATCHEWAN RIVER	NORTH SASKATCHEWAN RIVER AT ANCONA		52.44167	115.9
AB05DC0050	NORTH SASKATCHEWAN RIVER -	NORTH SASKATCHEWAN RIVER - 3KM. ABOVE ROCKY MOUNTAIN HOUSE	BP	52.35833	114.96111
AB05DC0060	NORTH SASKATCHEWAN RIVER	NORTH SASKATCHEWAN RIVER 1KM. ABOVE BAPTISTE RIVER		52.65833	115.05278
AB05DC0080	NORTH SASKATCHEWAN RIVER	NORTH SASKATCHEWAN RIVER 1KM. ABOVE BRAZEAU RIVER		52.90833	115.21111
AB05DE0020	NORTH SASKATCHEWAN RIVER	NORTH SASKATCHEWAN RIVER AT DRAYTON VALLEY BRIDGE	BP	53.21111	114.925
AB05DE0030	NORTH SASKATCHEWAN RIVER	NORTH SASKATCHEWAN RIVER AT DRAYTON VALLEY BRIDGE LEFT BANK SAMPLE - OCTOBER 15, 1988		53.21111	114.925
AB05DE0060	NORTH SASKATCHEWAN RIVER	NORTH SASKATCHEWAN RIVER AT GENESEE BRIDGE		53.38056	114.27778
AB05DE0080	NORTH SASKATCHEWAN RIVER	NORTH SASKATCHEWAN RIVER AT GENESEE BRIDGE RIGHT BANK SAMPLE - OCTOBER 15, 1988		52.38056	114.27778
AB05DF0120	NORTH SASKATCHEWAN RIVER	NORTH SASKATCHEWAN RIVER DEVON LEFT BANK 84		53.37167	113.74722
AB05DF0140	NORTH SASKATCHEWAN RIVER	NORTH SASKATCHEWAN RIVER UPSTREAM OF DEVON BRIDGE COMPOSITE SAMPLE - LEFT CENTRE, RIGHT		53.37194	113.74722
AB05EB0020	NORTH SASKATCHEWAN RIVER	NORTH SASKATCHEWAN RIVER AT 109 STREET BRIDGE LEFT BANK SAMPLE - OCTOBER 15, 1988		53.52889	113.50944
AB05EB0190	NORTH SASKATCHEWAN RIVER LEFT BANK	NORTH SASKATCHEWAN RIVER LEFT BANK 50TH STREET FOOT BRIDGE 90M UPSTREAM		53.56444	113.4175
AB05EB0210	NORTH SASKATCHEWAN RIVER RIGHT BANK	NORTH SASKATCHEWAN RIVER RIGHT BANK 50TH STREET FOOT BRIDGE 90M UPSTREAM		53.56306	113.4175
AB05EB0300	NORTH SASKATCHEWAN RIVER LEFT BANK	NORTH SASKATCHEWAN RIVER LEFT BANK RUNDLE FOOT BRIDGE - 90M UPSTREAM		53.55333	113.39278
AB05EB0360	NORTH SASKATCHEWAN RIVER LEFT BANK	NORTH SASKATCHEWAN RIVER LEFT BANK BEVERLY RAILWAY TRESTLE 180M DOWNSTREAM		53.57444	113.38833
AB05EB0380	NORTH SASKATCHEWAN RIVER RIGHT BANK	NORTH SASKATCHEWAN RIVER RIGHT BANK BEVERLY RAILWAY TRESTLE 180M DOWNSTREAM		53.57361	113.38639
AB05EB0550	NORTH SASKATCHEWAN RIVER LEFT BANK	NORTH SASKATCHEWAN RIVER LEFT BANK ABOVE FORT SASK. RAILWAY TRESTLE 90M UPSTREAM		53.71472	113.24083
AB05EB0570	NORTH SASKATCHEWAN RIVER RIGHT BANK	NORTH SASKATCHEWAN RIVER RIGHT BANK ABOVE FORT SASK. RAILWAY TRESTLE 90M UPSTREAM		53.71306	113.23889

STATION_NO	STATION_NAME	STATION_DESCRIPTION	ECOZONE	LATITUDE	LONGITUDE
AB05EB0600	NORTH SASKATCHEWAN RIVER	NORTH SASKATCHEWAN RIVER BELOW FORT SASKATCHEWAN APPROX. 1 KM. ABOVE MOUTH OF STURGEON RIVER LEFT BANK SAMPLE		53.75833	113.17111
AB05EB0830	NORTH SASKATCHEWAN RIVER	NORTH SASKATCHEWAN RIVER VINCA BRIDGE - LEFT BANK AUGUST 1988		53.85	113.06667
AB05EB0850	NORTH SASKATCHEWAN RIVER	NORTH SASKATCHEWAN RIVER AT VINCA TRAILER SITE - RIGHT BANK		53.87861	113.01389
AB05EB0860	NORTH SASKATCHEWAN RIVER	NORTH SASKATCHEWAN RIVER AT VINCA TRAILER SITE - LEFT BANK		53.87917	113.01389
AB05EB0910	NORTH SASKATCHEWAN RIVER LEFT BANK	NORTH SASKATCHEWAN RIVER LEFT BANK DOWNSTREAM OF CONFLUENCE WITH BEAVERHILLS CREEK		53.93389	113.90472
AB05EB0930	NORTH SASKATCHEWAN RIVER RIGHT BANK	NORTH SASKATCHEWAN RIVER RIGHT BANK DOWNSTREAM OF CONFLUENCE WITH BEAVERHILLS CREEK		53.93222	113.90306
AB05EC0090	NORTH SASKATCHEWAN RIVER	NORTH SASKATCHEWAN RIVER AT WASKATENAU BRIDGE		54.01389	112.83333
AB05EC0160	NORTH SASKATCHEWAN RIVER LEFT BANK	NORTH SASKATCHEWAN RIVER LEFT BANK ABOVE PAKAN BRIDGE 90M UPSTREAM		53.99167	112.47972
AB05EC0180	NORTH SASKATCHEWAN RIVER RIGHT BANK	NORTH SASKATCHEWAN RIVER RIGHT BANK ABOVE PAKAN BRIDGE 90M UPSTREAM		53.98944	112.47972
AB05EC0210	NORTH SASKATCHEWAN RIVER - PAKAN BRIDGE	NORTH SASKATCHEWAN RIVER -PAKAN BRIDGE		54	112.41278
AB05ED0020	NORTH SASKATCHEWAN RIVER	NORTH SASKATCHEWAN RIVER AT DUVERNAY MARCH,87		53.78889	111.69167
AB05ED0110	NORTH SASKATCHEWAN RIVER -	NORTH SASKATCHEWAN RIVER - AT ELK POINT		53.8625	110.89167
AB05ED0120	NORTH SASKATCHEWAN RIVER	NORTH SASKATCHEWAN RIVER AT ELK POINT BRIDGE RIGHT BANK SAMPLE - OCT.15,1988		53.8625	110.89167
AB05EF0010	NORTH SASKATCHEWAN RIVER -	NORTH SASKATCHEWAN RIVER - AT LEA PARK	PAP	53.65833	110.33889
AB05EF0060	NORTH SASKATCHEWAN RIVER	NORTH SASKATCHEWAN RIVER AT LEA PARK RIGHT BANK SAMPLE - OCT.15,1988		53.65833	110.33889
AB05EF0080	NORTH SASKATCHEWAN RIVER	NORTH SASKATCHEWAN RIVER AT LLOYDMINSTER FERRY MARCH,87		53.59722	109.99028
AB07AC0010	BERLAND RIVER-BEFORE CONFLUENCE	BERLAND RIVER-BEFORE CONFLUENCE WITH ATHABASCA RIVER MOUTH: ARC KM 1139.2		53.00417	116.84722
AB07AD0050	ATHABASCA RIVER	ATHABASCA RIVER AT OLD ENTRANCE TOWN SITE (COMPOSITE OF LEFT AND RIGHT BANK)	BP	53.3675	117.72333
AB07AD0060	ATHABASCA RIVER	ATHABASCA RIVER AT OLD ENTRANCE TOWN SITE RIGHT BANK SAMPLE		53.3675	117.72417
AB07AD0220	ATHABASCA RIVER	ATHABASCA RIVER BELOW HINTON AT BRIDGE ON CHAMPION HAUL ROAD LEFT BANK SAMPLE		53.43056	117.55694
AB07AD0260	ATHABASCA RIVER	ATHABASCA RIVER BELOW HINTON AT BRIDGE ON CHAMPION HAUL ROAD RIGHT BANK SAMPLE	BP	53.42917	117.55639
AB07AD0350	ATHABASCA RIVER AT OBED MOUNTAIN	ATHABASCA RIVER AT OBED MOUNTAIN COALS BRIDGE APPROX. 20KM BELOW HINTON LEFT BANK SAMPLE ARC KM 1220.5		53.52472	117.36417
AB07AD0380	ATHABASCA RIVER AT OBED MOUNTAIN	ATHABASCA RIVER AT OBED MOUNTAIN COALS BRIDGE APPROX. 20KM BELOW HINTON RIGHT BANK SAMPLE ARC KM 1220.5		53.52389	117.36222

STATION_NO	STATION_NAME	STATION_DESCRIPTION	ECOZONE	LATITUDE	LONGITUDE
AB07AD0460	ATHABASCA RIVER	ATHABASCA RIVER APPROXIMATELY 50 KM. BELOW HINTON ON CHAMPION HAUL ROAD BRIDGE COMPOSITE SAMPLE LEFT AND RIGHT BANK		53.7025	117.1625
AB07AE0080	ATHABASCA RIVER - NEAR WINDFALL	ATHABASCA RIVER - NEAR WINDFALL 1.5 KM. UPSTREAM OF PASS CREEK SAMPLED AT CENTRE OF RIVER	BP	54.23611	116.29167
AB07AE0360	ATHABASCA RIVER	ATHABASCA RIVER AT WHITECOURT AT HIGHWAY #43 BRIDGE RIGHT BANK SAMPLE RIGHT BANK SAMPLE		54.14889	115.72083
AB07AF0050	MCLEOD RIVER	MCLEOD RIVER U/S OF CADOMIN		53.01028	117.33194
AB07AF0060	MCLEOD RIVER	MCLEOD RIVER ABOVE CONFLUENCE WITH LUSCAR CREEK		53.05139	117.31889
AB07AF0100	MCLEOD RIVER	MCLEOD RIVER 3.5KM DOWNSTREAM OF LUSCAR CREEK		53.07056	117.27806
AB07AF0120	MCLEOD RIVER NEAR	MCLEOD RIVER NEAR CADOMIN AT WSC GAUG NEAR FIDLER		53.07889	117.19722
AB07AF0150	MCLEOD RIVER	MCLEOD RIVER 2KM. DOWNSTREAM OF CONFLUENCE WITH MACKENZIE CREEK		53.10778	117.12917
AB07AF0170	MCLEOD RIVER AT STEEPER	MCLEOD RIVER AT STEEPER		53.13889	117.10389
AB07AF0180	MCLEOD RIVER	MCLEOD RIVER DOWNSTREAM OF TRI-CREEKS STUDY AREA		53.1625	117.26667
AB07AF0190	MCLEOD RIVER	MCLEOD RIVER DOWNSTREAM OF MARY GREGG CREEK		53.17917	116.3
AB07AF0200	MCLEOD RIVER	MCLEOD RIVER U/S CONFLUENCE WITH THE GREGG RIVER		53.29333	117.27917
AB07AF0210	GREGG RIVER	GREGG RIVER ABOVE LUSCAR VALLEY (CRC) MINE		53.05944	117.45
AB07AF0240	GREGG RIVER	GREGG RIVER - 0.5 KM BELOW GREGG RIVER RESOURCE MINE		53.09278	117.43944
AB07AF0260	GREGG RIVER	GREGG RIVER NEAR HIGHWAY 40 AND D/S FALLS CREEK		53.09889	117.49722
AB07AF0310	GREGG RIVER	GREGG RIVER DOWNSTREAM OF WARDEN CREEK		53.20278	117.49472
AB07AF0330	GREGG RIVER	GREGG RIVER 8 KM U/S CONFLUENCE WITH MCLEOD RIVER		53.25167	117.35917
AB07AF0340	MCLEOD RIVER	MCLEOD RIVER BELOW CONFLUENCE WITH GREGG RIVER		53.32889	117.25306
AB07AF0350	MCLEOD RIVER	MCLEOD RIVER U/S CONFLUENCE WITH EMBARRAS RIVER	BP	53.45833	116.62083
AB07AF0380	EMBARRAS RIVER	EMBARRAS RIVER NEAR CONFLUENCE WITH MCLEOD RIVER	BP	53.45861	116.61667
AB07AF0390	LOVETT RIVER	LOVETT RIVER ABOVE CONFLUENCE OF COAL CREEK		53.06389	116.81389
AB07AG0010	MCLEOD RIVER DOWNSTREAM	MCLEOD RIVER DOWNSTREAM OF CONFLUENCE WITH THE EMBARRAS RIVER		53.5	116.58
AB07AG0020	MCLEOD RIVER DOWNSTREAM OF CONFLUENCE	MCLEOD RIVER DOWNSTREAM OF CONFLUENCE OF EMBARRAS RIVER - LEFT BANK		53.5	116.58
AB07AG0070	MCLEOD RIVER	MCLEOD RIVER 100 METERS UPSTREAM OF EDSON SEWAGE OUTFLOW - LEFT BANK SAMPLE		53.60694	116.31472
AB07AG0130	MCLEOD RIVER	MCLEOD RIVER 100 METERS BELOW EDSON SEWAGE OUTFLOW		53.60833	115.31472
AB07AG0150	MCLEOD RIVER	MCLEOD RIVER AT ART'S PLACE LEFT BANK SAMPLE		53.59278	116.28472
AB07AG0170	MCLEOD RIVER	MCLEOD RIVER AT ART'S PLACE RIGHT BANK SAMPLE		53.59417	116.3
AB07AG0200	MCLEOD RIVER	MCLEOD RIVER BELOW CONFLUENCE OF WOLF CREEK LEFT BANK SAMPLE		53.65417	116.28111
AB07AG0210	MCLEOD RIVER	MCLEOD RIVER BELOW CONFLUENCE OF WOLF CREEK RIGHT BANK SAMPLE		53.65417	116.28056
AB07AG0240	MCLEOD RIVER	MCLEOD RIVER DOWNSTREAM OF ROSEVEAR FERRY		53.7	116.15556
AB07AG0250	MCLEOD RIVER	MCLEOD RIVER DOWNSTREAM OF ROSEVEAR FERRY LEFT BANK SAMPLE		53.7	116.15556
AB07AG0270	MCLEOD RIVER	MCLEOD RIVER DOWNSTREAM OF ROSEVEAR FERRY RIGHT BANK SAMPLE		53.7	116.15556

STATION_NO	STATION_NAME	STATION_DESCRIPTION	ECOZONE	LATITUDE	LONGITUDE
AB07AG0290	MCLEOD RIVER	MCLEOD RIVER AT PEERS LEFT BANK SAMPLE		53.71667	116.01667
AB07AG0310	MCLEOD RIVER	MCLEOD RIVER AT MAHASKA		53.89028	115.87083
AB07AG0370	MCLEOD RIVER	MCLEOD RIVER AT WHITECOURT - HIGHWAY # 43 BRIDGE LEFT BANK SAMPLE		54.13611	115.7
AB07AG0420	MCLEOD RIVER	MCLEOD RIVER AT WHITECOURT	BP	54.13861	115.6975
AB07AH0330	ATHABASCA RIVER	14 KM U/S OF FREEMAN RIVER - CENTRE OF RIVER		54.32222	114.93611
AB07AH0350	ATHABASCA RIVER	14 KM U/S OF FREEMAN RIVER - LEFT BANK SAMPLE		54.32194	114.93611
AB07BA0010	PEMBINA RIVER	PEMBINA RIVER ABOVE CENTRE CREEK		52.97639	116.69722
AB07BA0020	LOVETT RIVER	LOVETT RIVER AT TOWN OF LOVETTVILLE		53.03278	116.69028
AB07BA0030	LOVETT RIVER	LOVETT RIVER DOWNSTREAM OF LOVETTVILLE AT FEDERAL GAUGING STATION		53.01528	116.67083
AB07BA0050	PEMBINA RIVER	PEMBINA RIVER ADJACENT TO HIGHWAY #40		52.965	116.6
AB07BA0060	PEMBINA RIVER	PEMBINA RIVER AT HIGHWAY #40 BRIDGE		52.93333	116.56806
AB07BA0070	PEMBINA RIVER	PEMBINA RIVER 10.0 KM DOWNSTREAM OF HWY. #40 BRIDGE		53.00944	116.50417
AB07BC0080	PEMBINA RIVER BEFORE CONFLUENCE WITH	PEMBINA RIVER BEFORE CONFLUENCE WITH ATHABASCA RIVER RIGHT BANK SAMPLE		54.75778	114.26556
AB07BD0090	ATHABASCA RIVER	ATHABASCA RIVER ABOVE TOWN OF SMITH AT HIGHWAY #2 BRIDGE		55.07083	114.0925
AB07BD0100	ATHABASCA RIVER - ABOVE SMITH	ATHABASCA RIVER - ABOVE SMITH DOWNSTREAM OF RAILWAY BRIDGE		55.16111	114.05556
AB07BE0310	ATHABASCA RIVER 45 KM ABOVE TOWN OF	ATHABASCA RIVER 45 KM ABOVE TOWN OF ATHABASCA AND 10.2 KM NORTH OF HOWIE LAKE CENTER OF RIVER SAMPLE ARC KM 732.3	BP	55.0325	113.47778
AB07BE0330	ATHABASCA RIVER	ATHABASCA RIVER AT ATHABASCA TOWN 1 KM UPSTREAM OF HIGHWAY 813 BRIDGE LEFT BANK SAMPLE		54.72444	113.2825
AB07CA0040	LA BICHE RIVER BEFORE CONFLUENCE	LA BICHE RIVER BEFORE CONFLUENCE WITH ATHABASCA RIVER MOUTH: ARC KM 625.6		55.01611	112.72611
AB07CB0360	ATHABASCA RIVER	ATHABASCA RIVER BELOW ATHABASCA TOWN 5.0 KM DOWNSTREAM OF HWY. #813 BRIDGE CENTRE OF RIVER SAMPLE	BP	54.76278	113.24083
AB07CB0640	CALLING RIVER	CALLING RIVER NEAR CONFLUENCE WITH ATHABASCA RIVER MOUTH ARC KM.610.1		55.08972	112.88306
AB07CB0730	ATHABASCA RIVER	ATHABASCA RIVER 13.3 KM DOWNSTREAM OF PELICAN RIVER CENTRE OF RIVER SAMPLE		55.92222	112.64111
AB07CB0770	HOUSE RIVER - BEFORE CONFLUENCE	HOUSE RIVER - BEFORE CONFLUENCE WITH ATHABASCA RIVER LEFT BANK SAMPLE MOUTH: ARC KM 443.0		56.2	112.49583
AB07CC0010	ATHABASCA RIVER	ATHABASCA RIVER 100 METERS ABOVE THE CONFLUENCE WITH THE HORSE RIVER - AOSERP	BP	56.71833	111.40306
AB07CD0100	CLEARWATER RIVER	CLEARWATER RIVER NEAR WATERWAYS MOUTH: ARC KM 292.8	BP	56.70139	111.32944
AB07DA0090	ATHABASCA RIVER - BELOW FT. MCMURRAY	ATHABASCA RIVER - BELOW FT. MCMURRAY 3.3 KM UPSTREAM OF POPLAR CREEK CENTRE OF RIVER SAMPLE	BP	56.91139	111.41778
AB07DA0110	POPLAR CREEK	POPLAR CREEK 21.6 KM NORTH OF FT. MCMURRAY VIA HIGHWAY #63	BP	56.91389	111.45806

STATION_NO	STATION_NAME	STATION_DESCRIPTION	ECOZONE	LATITUDE	LONGITUDE
		AOSERP			
AB07DA0860	ATHABASCA RIVER	ATHABASCA RIVER 5.0 KM DOWNSTREAM OF BITUMOUNT CENTRE OF RIVER SAMPLE ARC KM 214.4		57.43139	111.64222
AB07DD0040	ATHABASCA RIVER	ATHABASCA RIVER AT EMBARRAS AIRPORT - AT WSC GAUGE ARC KM. 111.3 - AOSERP	BP	58.205	111.39
AB07FD0050	PEACE RIVER	PEACE RIVER AT DUNVEGAN 1.5 KM UPSTREAM OF BRIDGE-LEFT BANK JULY 1988		55.92806	118.62778
AB07FD0070	PEACE RIVER	PEACE RIVER AT DUNVEGAN 1.5 KM UPSTREAM OF BRIDGE-RIGHT BANK JULY 1988		55.92167	118.62222
AB07FD0100	PEACE RIVER ABOVE SMOKY RIVER	PEACE RIVER ABOVE SMOKY RIVER 0.75 KM BELOW SHAFTESBURY FERRY ON SEC. HWY. #740 LEFT BANK JULY 1988		56.09861	117.56111
AB07FD0110	PEACE RIVER ABOVE SMOKY RIVER	PEACE RIVER ABOVE SMOKY RIVER 0.75 KM BELOW SHAFTESBURY FERRY ON SEC. HWY. #740 RIGHT BANK JULY 1988		56.09583	117.54889
AB07HA0210	PEACE RIVER 1.5 KM ABOVE THE	PEACE RIVER 1.5 KM ABOVE THE CONFLUENCE OF THE WHITEMUD RIVER LEFT BANK JULY 1988		56.655	117.14833
AB07HA0250	PEACE RIVER 1.5 KM ABOVE THE	PEACE RIVER 1.5 KM ABOVE THE CONFLUENCE OF THE WHITEMUD RIVER RIGHT BANK JULY 1988		56.65806	117.145
AB07HC0070	PEACE RIVER 15.5 KM ABOVE THE	PEACE RIVER 15.5 KM ABOVE THE CONFLUENCE OF THE NOTIKEWIN RIVER CENTER SAMPLE JULY 1988		57.17694	117.0975
AB07HD0010	PEACE RIVER NEAR CARCAJOU	PEACE RIVER NEAR CARCAJOU 0.5 KM ABOVE SCULLY CREEK CENTER SAMPLE JULY 1988		57.71472	117.115
AB07HF0060	PEACE RIVER	PEACE RIVER AT FORT VERMILION CENTER SAMPLE JULY 1988		58.40444	116.12806
AB11AA0010	MILK RIVER	MILK RIVER UPSTREAM OF CONFLUENCE TO NORTH MILK RIVER	PMG	49.13528	112.37778
AB11AA0020	NORTH MILK RIVER	NORTH MILK RIVER UPSTREAM OF CONFLUENCE TO MILK RIVER	PMG	49.13611	112.38028
AB11AA0030	MILK RIVER DOWNSTREAM OF	MILK RIVER DOWNSTREAM OF TOWN OF MILK RIVER	PMG	49.12278	112.05389
AB11AA0050	MILK RIVER AT HWY 878	MILK RIVER AT HWY 878		49.10361	111.63944

**Appendix B. Bacteria means and variances from
published sources used in mean-variance study of
Chapter 2**

Table B.1. Bacteria means, variances (VAR), and number of replicates (N) used in mean-variance study of Chapter 2. ENVT: benthic or planktonic bacteria; MEAS: bacterial abundance (abund) or production (prod); UNITS: measurement units; METHOD: enumeration (bacterial abundance) or isotope (bacterial production) methods used; MANIP: determines if samples underwent any form of manipulation (planktonic bacteria) or if they were sampled from natural or artificial substrata (benthic bacteria); HAB: habitat from which the samples were taken (river, lake, marine). Refer to reference list of Chapter 2 for complete references to original data.

REF	ENVT	MEAS	UNITS	MEAN	VAR	N	METHOD	MANIP	HAB
Hudson et al. 1992	benthic	abund	cells cm2	110000000	6.62424E+14	4	DAPI	natural	river
Hudson et al. 1992	benthic	abund	cells cm2	140000000	7.72368E+15	4	DAPI	natural	river
Hudson et al. 1992	benthic	abund	cells cm2	140000000	1.13885E+16	4	DAPI	natural	river
Hudson et al. 1992	benthic	abund	cells cm2	210000000	3.63171E+15	4	DAPI	natural	river
Hudson et al. 1992	benthic	abund	cells cm2	230000000	8.86647E+15	4	DAPI	natural	river
Hudson et al. 1992	benthic	abund	cells cm2	250000000	1.71655E+15	4	DAPI	natural	river
Hudson et al. 1992	benthic	abund	cells cm2	350000000	3.78461E+15	4	DAPI	natural	river
Hudson et al. 1992	benthic	abund	cells cm2	370000000	4.03523E+14	4	DAPI	natural	river
Hudson et al. 1992	benthic	abund	cells cm2	420000000	8.33843E+16	4	DAPI	natural	river
Hudson et al. 1992	benthic	abund	cells cm2	430000000	7.72368E+15	4	DAPI	natural	river
Hudson et al. 1992	benthic	abund	cells cm2	1400000000	5.10709E+16	4	DAPI	natural	river
Hudson et al. 1992	benthic	abund	cells cm2	1900000000	1.13885E+18	4	DAPI	natural	river
Hudson et al. 1992	benthic	abund	cells cm2	2900000000	9.07927E+16	4	DAPI	natural	river
Hudson et al. 1992	benthic	abund	cells cm2	3000000000	1.00881E+18	4	DAPI	natural	river
Hudson et al. 1992	benthic	abund	cells cm2	3700000000	1.68761E+17	5	DAPI	natural	river
Hudson et al. 1992	benthic	abund	cells cm2	3700000000	1.00881E+18	4	DAPI	natural	river
Hudson et al. 1992	benthic	abund	cells cm2	3800000000	1.57626E+18	4	DAPI	natural	river
Hudson et al. 1992	benthic	abund	cells cm2	3900000000	3.26326E+17	4	DAPI	natural	river
Hudson et al. 1992	benthic	abund	cells cm2	5400000000	1.27677E+18	4	DAPI	natural	river
Hudson et al. 1992	benthic	abund	cells cm2	5700000000	1.57626E+18	4	DAPI	natural	river
Mohamed et al. 1998	benthic	abund	cells cm2	1894310.395	4.39919E+11	3	Confocal	artificial	river
Mohamed et al. 1998	benthic	abund	cells cm2	3617519.626	9.89817E+11	3	Confocal	artificial	river
Mohamed et al. 1998	benthic	abund	cells cm2	4574858.085	4.39919E+11	3	Confocal	artificial	river
Mohamed et al. 1998	benthic	abund	cells cm2	8550873.321	1.741E+12	3	Confocal	artificial	river
Mohamed et al. 1998	benthic	abund	cells cm2	9084537.12	1.75967E+12	3	Confocal	artificial	river
Mohamed et al. 1998	benthic	abund	cells cm2	9850407.516	8.90834E+12	3	Confocal	artificial	river
Mohamed et al. 1998	benthic	abund	cells cm2	10080576.83	1.10214E+13	3	Confocal	artificial	river
Mohamed et al. 1998	benthic	abund	cells cm2	10272044.38	5.40539E+12	3	Confocal	artificial	river
Mohamed et al. 1998	benthic	abund	cells cm2	10502212.74	5.38899E+12	3	Confocal	artificial	river
Mohamed et al. 1998	benthic	abund	cells cm2	11268082.93	1.75967E+12	3	Confocal	artificial	river
Mohamed et al. 1998	benthic	abund	cells cm2	12150055.4	3.56333E+13	3	Confocal	artificial	river
Mohamed et al. 1998	benthic	abund	cells cm2	12465773.45	2.74949E+12	3	Confocal	artificial	river
Mohamed et al. 1998	benthic	abund	cells cm2	12799823.28	7.03869E+12	3	Confocal	artificial	river
Mohamed et al. 1998	benthic	abund	cells cm2	14380448.89	1.75967E+12	3	Confocal	artificial	river

REF	ENVT	MEAS	UNITS	MEAN	VAR	N	METHOD	MANIP	HAB
Mohamed et al. 1998	benthic	abund	cells cm2	14380448.89	2.47454E+13	3	Confocal	artificial	river
Romani and Sabater 1999a	benthic	abund	cells cm2	4941214582	1.49481E+18	3	DAPI	artificial	river
Romani and Sabater 1999a	benthic	abund	cells cm2	9176494366	5.97924E+18	3	DAPI	artificial	river
Romani and Sabater 1999a	benthic	abund	cells cm2	10588262452	5.97924E+18	3	DAPI	artificial	river
Romani and Sabater 1999a	benthic	abund	cells cm2	10588268452	1.49481E+18	3	DAPI	artificial	river
Romani and Sabater 1999a	benthic	abund	cells cm2	31764711716	1.2108E+20	3	DAPI	artificial	river
Romani and Sabater 1999a	benthic	abund	cells cm2	33176490194	1.49481E+18	3	DAPI	artificial	river
Romani and Sabater 1999a	benthic	abund	cells cm2	45176481250	5.38131E+19	3	DAPI	artificial	river
Romani and Sabater 1999a	benthic	abund	cells cm2	55058827527	3.73702E+19	3	DAPI	artificial	river
Romani and Sabater 1997	benthic	abund	cells cm2	1786000000	3.136E+17	3	DAPI	natural	river
Romani and Sabater 1997	benthic	abund	cells cm2	7300000000	4.225E+17	3	DAPI	natural	river
Sabater and Romani 1996	benthic	abund	cells cm2	3448284147	1.18906E+17	3	DAPI	artificial	river
Sabater and Romani 1996	benthic	abund	cells cm2	10344837465	7.60999E+18	3	DAPI	artificial	river
Sabater and Romani 1996	benthic	abund	cells cm2	12068975790	1.9025E+18	3	DAPI	artificial	river
Sabater and Romani 1996	benthic	abund	cells cm2	12068978421	4.75624E+17	3	DAPI	artificial	river
Sabater and Romani 1996	benthic	abund	cells cm2	14482769309	1.43876E+19	3	DAPI	artificial	river
Sabater and Romani 1996	benthic	abund	cells cm2	15862076422	2.97265E+18	3	DAPI	artificial	river
Sabater and Romani 1996	benthic	abund	cells cm2	16206907541	1.43876E+19	3	DAPI	artificial	river
Sabater and Romani 1996	benthic	abund	cells cm2	22758626814	2.00951E+19	3	DAPI	artificial	river
Freeman and Lock 1995	benthic	abund	cells cm2	2024548.212	8.12977E+11	6	AODC	artificial	river
Freeman and Lock 1995	benthic	abund	cells cm2	2576695.9	2.03244E+11	6	AODC	artificial	river
Freeman and Lock 1995	benthic	abund	cells cm2	4992864.564	5.64185E+11	6	AODC	artificial	river
Freeman and Lock 1995	benthic	abund	cells cm2	5798374.757	8.12733E+11	6	AODC	artificial	river
Freeman and Lock 1995	benthic	abund	cells cm2	6159644.142	1.82865E+12	6	AODC	artificial	river
Freeman and Lock 1995	benthic	abund	cells cm2	7290865.61	3.25093E+12	6	AODC	artificial	river
Freeman and Lock 1995	benthic	abund	cells cm2	7429090.695	5.64185E+11	6	AODC	artificial	river
Freeman and Lock 1995	benthic	abund	cells cm2	7849702.996	8.12733E+11	6	AODC	artificial	river
Freeman and Lock 1995	benthic	abund	cells cm2	15276077.74	2.03244E+13	6	AODC	artificial	river
Freeman and Lock 1995	benthic	abund	cells cm2	15644177.12	1.64628E+13	6	AODC	artificial	river
Freeman and Lock 1995	benthic	abund	cells cm2	17484666.08	1.64628E+13	6	AODC	artificial	river
Freeman and Lock 1995	benthic	abund	cells cm2	18552948.02	9.02697E+12	6	AODC	artificial	river
Freeman and Lock 1995	benthic	abund	cells cm2	18773011.55	9.95897E+12	6	AODC	artificial	river
Freeman and Lock 1995	benthic	abund	cells cm2	20676886.02	9.02697E+12	6	AODC	artificial	river
Freeman and Lock 1995	benthic	abund	cells cm2	20969406.26	3.4338E+13	6	AODC	artificial	river
Freeman and Lock 1995	benthic	abund	cells cm2	24110431.1	6.58512E+13	6	AODC	artificial	river
Freeman and Lock 1995	benthic	abund	cells cm2	24272759.96	1.37352E+14	6	AODC	artificial	river
Freeman and Lock 1995	benthic	abund	cells cm2	25582823.15	8.96307E+13	6	AODC	artificial	river
Freeman and Lock 1995	benthic	abund	cells cm2	25717836.66	2.464E+13	6	AODC	artificial	river
Freeman and Lock 1995	benthic	abund	cells cm2	25726868.15	2.92584E+13	6	AODC	artificial	river
Freeman and Lock 1995	benthic	abund	cells cm2	35179477.2	1.42087E+13	6	AODC	artificial	river
Freeman and Lock 1995	benthic	abund	cells cm2	35469191.14	1.1058E+14	6	AODC	artificial	river
Freeman and Lock 1995	benthic	abund	cells cm2	40761158.11	4.60736E+13	6	AODC	artificial	river
Freeman and Lock 1995	benthic	abund	cells cm2	44423962.38	6.82664E+13	6	AODC	artificial	river
Lock et al. 1984	benthic	abund	cells cm2	9543430.663	6.48592E+13	5	SEM	artificial	river
Lock et al. 1984	benthic	abund	cells cm2	14552796.17	1.16888E+13	5	SEM	artificial	river
Lock et al. 1984	benthic	abund	cells cm2	127934431.8	2.5153E+14	5	SEM	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	843408.1116	1.19957E+11	3	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	1418415.908	83303691477	3	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	1497514.322	2.69904E+11	3	AODC	artificial	river

REF	ENVT	MEAS	UNITS	MEAN	VAR	N	METHOD	MANIP	HAB
Findlay et al. 1993	benthic	abund	cells cm2	2139177.489	3.36675E+11	3	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	2234271.25	4.78763E+11	3	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	4208141.247	2.25253E+12	3	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	5000000	4E+12	4	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	6000000	2.5E+13	4	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	6000000	2.5E+13	4	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	7000000	6.4E+13	4	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	8000000	6.4E+13	4	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	8500000	1.6E+13	4	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	11000000	2.304E+13	4	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	11000000	9.216E+13	4	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	12300815.23	1.77456E+14	3	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	25553999.5	9.70208E+13	3	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	30280665.65	3.34623E+14	3	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	35819852.96	9.95573E+13	3	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	36877645.27	2.77987E+14	3	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	38404798.21	1.35508E+14	3	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	40920368.06	3.98424E+14	3	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	42473372.15	9.98192E+13	3	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	47797941.67	6.93188E+13	3	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	50443170.54	6.22233E+14	3	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	52703431.44	6.2387E+14	3	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	52949954.24	4.00926E+15	3	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	55661534.67	2.24593E+14	3	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	60813523.83	3.35503E+14	3	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	61257259.22	9.98191E+13	3	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	62924684.3	2.76548E+14	3	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	65275332.97	5.45452E+14	3	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	65916247.89	4.67672E+14	3	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	72547285.07	1.87438E+15	3	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	74446102.49	7.07963E+14	3	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	79030458.03	9.98191E+13	3	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	79893237.56	5.41471E+14	3	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	83048531.75	1.00096E+15	3	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	83664795.17	2.77275E+14	3	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	89876795.55	1.87438E+15	3	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	101123857.5	5.11299E+15	2	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	101124344.2	5.11299E+15	2	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	110608083.2	4.00386E+15	3	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	112777352.7	3.99276E+14	3	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	118545630.6	8.98372E+14	3	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	118685390.4	2.83185E+15	3	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	126405301	3.55069E+15	2	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	134832456.6	5.68109E+14	2	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	143259393.1	6.95934E+15	2	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	150369276	2.16813E+15	3	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	151686332	2.27244E+15	2	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	168540278	2.27244E+15	2	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	168540318.9	2.27244E+15	2	AODC	artificial	river

REF	ENVT	MEAS	UNITS	MEAN	VAR	N	METHOD	MANIP	HAB
Findlay et al. 1993	benthic	abund	cells cm2	168540334.8	5.11298E+15	2	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	176967095.1	1.27825E+15	2	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	185393518.6	5.6811E+14	2	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	193821142.9	3.55068E+15	2	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	219101838.3	9.08976E+15	2	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	227528952.8	1.71853E+16	2	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	235955480.2	5.6811E+14	2	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	235955913.3	5.68109E+14	2	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	252809804.7	2.04519E+16	2	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	269663840.8	2.27244E+15	2	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	286517393.3	3.6359E+16	2	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	294944354.7	1.15042E+16	2	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	379214086.9	3.19562E+16	2	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	387641057.3	9.08976E+15	2	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	421349151.2	9.08975E+15	2	AODC	artificial	river
Findlay et al. 1993	benthic	abund	cells cm2	674157676.7	9.60106E+16	2	AODC	artificial	river
Ledger and Hildrew 1998	benthic	abund	cells cm2	1004008.209	1.57957E+11	7	DAPI	natural	river
Ledger and Hildrew 1998	benthic	abund	cells cm2	2016064.243	1.53961E+12	7	DAPI	natural	river
Ledger and Hildrew 1998	benthic	abund	cells cm2	2317709.283	1.96027E+11	7	DAPI	natural	river
Ledger and Hildrew 1998	benthic	abund	cells cm2	3284295.489	1.69024E+12	7	DAPI	natural	river
Ledger and Hildrew 1998	benthic	abund	cells cm2	4048296.922	5.98058E+11	7	DAPI	natural	river
Ledger and Hildrew 1998	benthic	abund	cells cm2	4048297.755	2.56808E+12	7	DAPI	natural	river
Ledger and Hildrew 1998	benthic	abund	cells cm2	4340590.891	6.87538E+11	7	DAPI	natural	river
Ledger and Hildrew 1998	benthic	abund	cells cm2	4340592.821	1.36422E+13	7	DAPI	natural	river
Ledger and Hildrew 1998	benthic	abund	cells cm2	4653993.832	3.39402E+12	7	DAPI	natural	river
Ledger and Hildrew 1998	benthic	abund	cells cm2	4653994.13	7.90406E+11	7	DAPI	natural	river
Ledger and Hildrew 1998	benthic	abund	cells cm2	4653994.19	1.56833E+13	7	DAPI	natural	river
Ledger and Hildrew 1998	benthic	abund	cells cm2	4990015.835	3.90182E+12	7	DAPI	natural	river
Ledger and Hildrew 1998	benthic	abund	cells cm2	5350311.136	4.48561E+12	7	DAPI	natural	river
Ledger and Hildrew 1998	benthic	abund	cells cm2	6150813.72	5.92827E+12	7	DAPI	natural	river
Ledger and Hildrew 1998	benthic	abund	cells cm2	6594913.754	6.81525E+12	7	DAPI	natural	river
Ledger and Hildrew 1998	benthic	abund	cells cm2	7071081.799	1.82461E+12	7	DAPI	natural	river
Ledger and Hildrew 1998	benthic	abund	cells cm2	7071082.61	1.89397E+13	7	DAPI	natural	river
Ledger and Hildrew 1998	benthic	abund	cells cm2	7071083.307	3.62041E+13	7	DAPI	natural	river
Ledger and Hildrew 1998	benthic	abund	cells cm2	7581630.229	9.00717E+12	7	DAPI	natural	river
Ledger and Hildrew 1998	benthic	abund	cells cm2	7581630.632	2.17734E+13	7	DAPI	natural	river
Ledger and Hildrew 1998	benthic	abund	cells cm2	7581630.78	2.17734E+13	7	DAPI	natural	river
Ledger and Hildrew 1998	benthic	abund	cells cm2	8129041.068	2.50311E+13	7	DAPI	natural	river
Ledger and Hildrew 1998	benthic	abund	cells cm2	10020035.14	3.80312E+13	7	DAPI	natural	river
Ledger and Hildrew 1998	benthic	abund	cells cm2	10743497.81	8.35752E+13	7	DAPI	natural	river
Ledger and Hildrew 1998	benthic	abund	cells cm2	14198838.01	7.63672E+13	7	DAPI	natural	river
Ledger and Hildrew 1998	benthic	abund	cells cm2	15224020.24	8.7793E+13	7	DAPI	natural	river
Ledger and Hildrew 1998	benthic	abund	cells cm2	16323232.96	9.72324E+12	7	DAPI	natural	river
Geesey et al. 1978	benthic	abund	cells cm2	624755.0295	2.54162E+11	2	AODC	natural	river
Geesey et al. 1978	benthic	abund	cells cm2	2942189.945	1.34358E+13	2	AODC	natural	river
Geesey et al. 1978	benthic	abund	cells cm2	3577554.557	1.0825E+12	2	AODC	natural	river
Geesey et al. 1978	benthic	abund	cells cm2	6334578.625	1.07595E+13	2	AODC	natural	river
Geesey et al. 1978	benthic	abund	cells cm2	6754726.272	1.92206E+12	2	AODC	natural	river
Geesey et al. 1978	benthic	abund	cells cm2	8538488.558	2.33722E+12	2	AODC	natural	river

REF	ENV	MEAS	UNITS	MEAN	VAR	N	METHOD	MANIP	HAB
Geesey et al. 1978	benthic	abund	cells cm2	9368598.784	1.29918E+13	2	AODC	natural	river
Geesey et al. 1978	benthic	abund	cells cm2	9430990.801	2.9223E+12	2	AODC	natural	river
Geesey et al. 1978	benthic	abund	cells cm2	9531989.577	2.38529E+12	2	AODC	natural	river
Geesey et al. 1978	benthic	abund	cells cm2	12529074.95	1.30755E+13	2	AODC	natural	river
Geesey et al. 1978	benthic	abund	cells cm2	12651635.48	1.15295E+13	2	AODC	natural	river
Geesey et al. 1978	benthic	abund	cells cm2	13058117.55	1.198E+13	2	AODC	natural	river
Geesey et al. 1978	benthic	abund	cells cm2	13643553.12	5.38764E+13	2	AODC	natural	river
Geesey et al. 1978	benthic	abund	cells cm2	14528891.25	5.77729E+13	2	AODC	natural	river
Geesey et al. 1978	benthic	abund	cells cm2	15285233.47	4.344E+13	2	AODC	natural	river
Geesey et al. 1978	benthic	abund	cells cm2	15448920.26	2.21864E+12	2	AODC	natural	river
Geesey et al. 1978	benthic	abund	cells cm2	15662117.32	5.02714E+13	2	AODC	natural	river
Geesey et al. 1978	benthic	abund	cells cm2	17124450.41	2.72598E+12	2	AODC	natural	river
Geesey et al. 1978	benthic	abund	cells cm2	19160374.75	5.43412E+13	2	AODC	natural	river
Geesey et al. 1978	benthic	abund	cells cm2	19390425.47	3.88952E+13	2	AODC	natural	river
Geesey et al. 1978	benthic	abund	cells cm2	19598074.41	1.19334E+14	2	AODC	natural	river
Geesey et al. 1978	benthic	abund	cells cm2	20670152.52	7.3177E+13	2	AODC	natural	river
Geesey et al. 1978	benthic	abund	cells cm2	21646611.48	3.96311E+13	2	AODC	natural	river
Geesey et al. 1978	benthic	abund	cells cm2	22911958.73	1.73707E+13	2	AODC	natural	river
Geesey et al. 1978	benthic	abund	cells cm2	25977225.8	2.80918E+14	2	AODC	natural	river
Geesey et al. 1978	benthic	abund	cells cm2	26221584.99	9.18468E+13	2	AODC	natural	river
Geesey et al. 1978	benthic	abund	cells cm2	27024653.8	2.02872E+13	2	AODC	natural	river
Geesey et al. 1978	benthic	abund	cells cm2	29831737.44	8.89128E+14	2	AODC	natural	river
Geesey et al. 1978	benthic	abund	cells cm2	32930397.95	7.99853E+13	2	AODC	natural	river
Geesey et al. 1978	benthic	abund	cells cm2	36207510.46	4.60654E+14	2	AODC	natural	river
Geesey et al. 1978	benthic	abund	cells cm2	36494894.11	6.33348E+13	2	AODC	natural	river
Geesey et al. 1978	benthic	abund	cells cm2	48895698.74	6.27019E+14	2	AODC	natural	river
Geesey et al. 1978	benthic	abund	cells cm2	53338262.67	1.00976E+14	2	AODC	natural	river
Geesey et al. 1978	benthic	abund	cells cm2	58707988.36	1.53228E+15	2	AODC	natural	river
Geesey et al. 1978	benthic	abund	cells cm2	59972107.57	8.69669E+14	2	AODC	natural	river
Kaplan and Bott 1989	benthic	abund	cells cm2	24000000	1.6E+13	6	DAPI	artificial	river
Kaplan and Bott 1989	benthic	abund	cells cm2	26000000	3.6E+13	5	DAPI	artificial	river
Kaplan and Bott 1989	benthic	abund	cells cm2	43000000	1.44E+14	5	DAPI	artificial	river
Kaplan and Bott 1989	benthic	abund	cells cm2	47000000	6.4E+13	5	DAPI	artificial	river
Kaplan and Bott 1989	benthic	abund	cells cm2	565000000	1E+16	8	DAPI	natural	river
Kaplan and Bott 1989	benthic	abund	cells cm2	581000000	1.21E+16	8	DAPI	natural	river
Kaplan and Bott 1989	benthic	abund	cells cm2	628000000	3.4596E+16	8	DAPI	natural	river
Kaplan and Bott 1989	benthic	abund	cells cm2	682000000	1.8496E+16	8	DAPI	natural	river
Romani and Sabater 1999b	benthic	abund	cells cm2	1402618221	5.76364E+17	3	DAPI	artificial	river
Romani and Sabater 1999b	benthic	abund	cells cm2	2295190709	1.32845E+18	3	DAPI	artificial	river
Romani and Sabater 1999b	benthic	abund	cells cm2	2765386505	6.08232E+17	3	DAPI	artificial	river
Romani and Sabater 1999b	benthic	abund	cells cm2	2777341234	5.97514E+17	3	DAPI	artificial	river
Romani and Sabater 1999b	benthic	abund	cells cm2	3928920777	1.44091E+17	3	DAPI	artificial	river
Romani and Sabater 1999b	benthic	abund	cells cm2	7945496616	3.73446E+18	3	DAPI	artificial	river
Romani and Sabater 1999b	benthic	abund	cells cm2	10447888364	5.40968E+18	3	DAPI	artificial	river
Romani and Sabater 1999b	benthic	abund	cells cm2	11061533985	9.60295E+18	3	DAPI	artificial	river
Romani and Sabater 1999b	benthic	abund	cells cm2	11177089094	1.49378E+17	3	DAPI	artificial	river
Romani and Sabater 1999b	benthic	abund	cells cm2	14727454862	2.36876E+18	3	DAPI	artificial	river
Romani and Sabater 1999b	benthic	abund	cells cm2	14767295889	1.49379E+19	3	DAPI	artificial	river
Romani and Sabater 1999b	benthic	abund	cells cm2	14900000000	2.56E+18	3	DAPI	artificial	river

REF	ENV	MEAS	UNITS	MEAN	VAR	N	METHOD	MANIP	HAB
Romani and Sabater 1999b	benthic	abund	cells cm2	15807306299	5.40968E+18	3	DAPI	artificial	river
Romani and Sabater 1999b	benthic	abund	cells cm2	16978807516	5.37762E+18	3	DAPI	artificial	river
Romani and Sabater 1999b	benthic	abund	cells cm2	19987253135	7.31954E+18	3	DAPI	artificial	river
Romani and Sabater 1999b	benthic	abund	cells cm2	21800000000	1.849E+19	3	DAPI	artificial	river
Romani and Sabater 1999b	benthic	abund	cells cm2	21872014145	1.3444E+18	3	DAPI	artificial	river
Hudson et al. 1990	benthic	prod	mgCm2h1	1.3	1.209798359	4	thymidine	natural	river
Hudson et al. 1990	benthic	prod	mgCm2h1	2.5	2.427998095	4	thymidine	natural	river
Hudson et al. 1990	benthic	prod	mgCm2h1	2.6	2.150752637	4	thymidine	natural	river
Hudson et al. 1990	benthic	prod	mgCm2h1	3	39.99895823	4	thymidine	natural	river
Hudson et al. 1990	benthic	prod	mgCm2h1	3.2	14.12271556	4	thymidine	natural	river
Hudson et al. 1990	benthic	prod	mgCm2h1	4.6	12.77849516	4	thymidine	natural	river
Hudson et al. 1990	benthic	prod	mgCm2h1	8.2	33.34506726	4	thymidine	natural	river
Hudson et al. 1990	benthic	prod	mgCm2h1	15	483.9193434	4	thymidine	natural	river
Hudson et al. 1990	benthic	prod	mgCm2h1	37	4116.67497	4	thymidine	natural	river
Hudson et al. 1990	benthic	prod	mgCm2h1	51	2271.732473	4	thymidine	natural	river
Hudson et al. 1992	benthic	prod	mgCm2h1	93	3126.152564	4	thymidine	natural	river
Hudson et al. 1992	benthic	prod	mgCm2h1	120	1029.168743	4	thymidine	natural	river
Hudson et al. 1992	benthic	prod	mgCm2h1	40	406.6266705	4	thymidine	natural	river
Hudson et al. 1992	benthic	prod	mgCm2h1	70	1935.677374	4	thymidine	natural	river
Hudson et al. 1992	benthic	prod	mgCm2h1	64	3999.895823	4	thymidine	natural	river
Hudson et al. 1992	benthic	prod	mgCm2h1	18	2.427998095	4	thymidine	natural	river
Hudson et al. 1992	benthic	prod	mgCm2h1	78	1213.15891	4	thymidine	natural	river
Hudson et al. 1992	benthic	prod	mgCm2h1	73	1029.168743	4	thymidine	natural	river
Hudson et al. 1992	benthic	prod	mgCm2h1	140	6359.002622	4	thymidine	natural	river
Hudson et al. 1992	benthic	prod	mgCm2h1	98	164.6669988	4	thymidine	natural	river
Hudson et al. 1992	benthic	prod	mgCm2h1	2.5	2.427998095	4	thymidine	natural	river
Hudson et al. 1992	benthic	prod	mgCm2h1	4.6	12.77849516	4	thymidine	natural	river
Hudson et al. 1992	benthic	prod	mgCm2h1	3	39.99895823	4	thymidine	natural	river
Hudson et al. 1992	benthic	prod	mgCm2h1	37	4116.67497	4	thymidine	natural	river
Hudson et al. 1992	benthic	prod	mgCm2h1	8.2	33.34506726	4	thymidine	natural	river
Hudson et al. 1992	benthic	prod	mgCm2h1	2.6	2.150752637	4	thymidine	natural	river
Hudson et al. 1992	benthic	prod	mgCm2h1	1.3	1.209798359	4	thymidine	natural	river
Hudson et al. 1992	benthic	prod	mgCm2h1	3.2	14.12271556	4	thymidine	natural	river
Hudson et al. 1992	benthic	prod	mgCm2h1	15	483.9193434	4	thymidine	natural	river
Hudson et al. 1992	benthic	prod	mgCm2h1	51	2271.732473	4	thymidine	natural	river
Stock and Ward 1989	benthic	prod	mgCm2h1	0.685619082	0.043885261	4	thymidine	natural	river
Stock and Ward 1989	benthic	prod	mgCm2h1	0.785755975	0.257090032	4	thymidine	natural	river
Stock and Ward 1989	benthic	prod	mgCm2h1	1.185836735	0.01214981	4	thymidine	natural	river
Stock and Ward 1989	benthic	prod	mgCm2h1	1.751548615	0.578540479	4	thymidine	natural	river
Stock and Ward 1989	benthic	prod	mgCm2h1	1.927910391	0.204238058	4	thymidine	natural	river
Stock and Ward 1989	benthic	prod	mgCm2h1	2.006584938	0.857181673	4	thymidine	natural	river
Stock and Ward 1989	benthic	prod	mgCm2h1	2.185745198	0.140495544	4	thymidine	natural	river
Stock and Ward 1989	benthic	prod	mgCm2h1	2.900757757	0.064361171	4	thymidine	natural	river
Stock and Ward 1989	benthic	prod	mgCm2h1	3.026788658	0.817163571	4	thymidine	natural	river
Stock and Ward 1989	benthic	prod	mgCm2h1	3.318275633	5.007330553	4	thymidine	natural	river
Stock and Ward 1989	benthic	prod	mgCm2h1	3.51843203	0.082132698	4	thymidine	natural	river
Stock and Ward 1989	benthic	prod	mgCm2h1	4.102163991	0.423010148	4	thymidine	natural	river
Rosenfeld and Hudson 1997	benthic	prod	mgCm2h1	3.413970305	1.336527177	5	leucine	natural	river
Rosenfeld and Hudson 1997	benthic	prod	mgCm2h1	30.87443799	5.375128131	5	leucine	natural	river

REF	ENVT	MEAS	UNITS	MEAN	VAR	N	METHOD	MANIP	HAB
Rosenfeld and Hudson 1997	benthic	prod	mgCm2h1	71.21959623	589.7126789	5	leucine	natural	river
Rosenfeld and Hudson 1997	benthic	prod	mgCm2h1	95.21179496	281.4248664	5	leucine	natural	river
Neely and Wetzel 1995	benthic	prod	mgCm2h1	0.259075175	0.000492394	3	thymidine	artificial	river
Neely and Wetzel 1995	benthic	prod	mgCm2h1	0.318861575	0.005112391	3	thymidine	artificial	river
Neely and Wetzel 1995	benthic	prod	mgCm2h1	0.347331244	0.003215762	3	thymidine	artificial	river
Neely and Wetzel 1995	benthic	prod	mgCm2h1	0.427046352	0.011239979	3	thymidine	artificial	river
Neely and Wetzel 1995	benthic	prod	mgCm2h1	0.444128202	0.005841871	3	thymidine	artificial	river
Neely and Wetzel 1995	benthic	prod	mgCm2h1	0.492526911	0.035111981	3	thymidine	artificial	river
Neely and Wetzel 1995	benthic	prod	mgCm2h1	0.62064072	0.005471047	3	thymidine	artificial	river
Neely and Wetzel 1995	benthic	prod	mgCm2h1	0.700355959	0.008322069	3	thymidine	artificial	river
Benner et al. 1995	plankton	abund	cells L	460000000	5.29E+16	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	530000000	3.61E+16	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	580000000	2.89E+16	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	620000000	1.44E+16	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	710000000	4.9E+15	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	770000000	6.4E+15	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	830000000	2.5E+15	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	830000000	6.4E+15	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	900000000	2.56E+16	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	900000000	1.024E+17	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	910000000	6.25E+16	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	930000000	1.521E+17	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	940000000	1.225E+17	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	980000000	2.5E+15	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	990000000	1.96E+16	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	990000000	8.41E+16	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	990000000	5.29E+16	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	1030000000	2.5E+17	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	1030000000	2.5E+15	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	1060000000	1.444E+17	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	1130000000	1E+14	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	1130000000	1.21E+16	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	1140000000	1.96E+16	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	1170000000	1E+16	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	1190000000	3.249E+17	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	1260000000	4.41E+16	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	1280000000	6.4E+15	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	1290000000	3.364E+17	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	1300000000	1.69E+16	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	1350000000	2.025E+17	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	1350000000	2.401E+17	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	1390000000	9E+16	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	1390000000	4.489E+17	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	1430000000	3.969E+17	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	1460000000	3.6E+15	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	1530000000	2.304E+17	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	1620000000	1.024E+17	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	1790000000	4.096E+17	3	DAPI	no	river
Benner et al. 1995	plankton	abund	cells L	2590000000	6.25E+16	3	DAPI	no	river

REF	ENVY	MEAS	UNITS	MEAN	VAR	N	METHOD	MANIP	HAB
Eisenmann et al. 1999	plankton	abund	cells L	720000000	2.56E+14	3	DAPI	no	river
Eisenmann et al. 1999	plankton	abund	cells L	780000000	5.76E+14	3	DAPI	no	river
Eisenmann et al. 1999	plankton	abund	cells L	940000000	8.1E+13	3	DAPI	no	river
Eisenmann et al. 1999	plankton	abund	cells L	1620000000	1.2321E+16	3	DAPI	no	river
Eisenmann et al. 1999	plankton	abund	cells L	1700000000	1.764E+15	3	DAPI	no	river
Eisenmann et al. 1999	plankton	abund	cells L	2750000000	6.084E+15	3	DAPI	no	river
Eisenmann et al. 1999	plankton	abund	cells L	3050000000	5.4289E+16	2	DAPI	no	river
Eisenmann et al. 1999	plankton	abund	cells L	3500000000	5.1076E+16	3	DAPI	no	river
Bouvy et al. 1998	plankton	abund	cells L	21000000000	5.83223E+16	5	DAPI	no	lake
Bouvy et al. 1998	plankton	abund	cells L	22000000000	2.1083E+16	5	DAPI	no	lake
Bouvy et al. 1998	plankton	abund	cells L	24000000000	2.61325E+17	5	DAPI	no	lake
Bouvy et al. 1998	plankton	abund	cells L	25000000000	9.15063E+16	5	DAPI	no	lake
Bouvy et al. 1998	plankton	abund	cells L	25000000000	1.82756E+17	5	DAPI	no	lake
Bouvy et al. 1998	plankton	abund	cells L	27000000000	5.39168E+16	5	DAPI	no	lake
Bouvy et al. 1998	plankton	abund	cells L	27000000000	1.38831E+17	5	DAPI	no	lake
Bouvy et al. 1998	plankton	abund	cells L	31000000000	3.6542E+17	5	DAPI	no	lake
Bouvy et al. 1998	plankton	abund	cells L	32000000000	5.41696E+15	5	DAPI	no	lake
Bouvy et al. 1998	plankton	abund	cells L	34000000000	2.77556E+16	5	DAPI	no	lake
Bouvy et al. 1998	plankton	abund	cells L	34000000000	1.4761E+17	5	DAPI	no	lake
Bouvy et al. 1998	plankton	abund	cells L	35000000000	4.7089E+16	5	DAPI	no	lake
Bouvy et al. 1998	plankton	abund	cells L	37000000000	3.46097E+17	5	DAPI	no	lake
Bouvy et al. 1998	plankton	abund	cells L	40000000000	1.69744E+17	5	DAPI	no	lake
Bouvy et al. 1998	plankton	abund	cells L	42000000000	1.90794E+17	5	DAPI	no	lake
Bouvy et al. 1998	plankton	abund	cells L	43000000000	1.17745E+17	5	DAPI	no	lake
Bouvy et al. 1998	plankton	abund	cells L	44000000000	1.02414E+16	5	DAPI	no	lake
Bouvy et al. 1998	plankton	abund	cells L	46000000000	1.48596E+18	5	DAPI	no	lake
Bouvy et al. 1998	plankton	abund	cells L	52000000000	8.1796E+16	5	DAPI	no	lake
Bouvy et al. 1998	plankton	abund	cells L	95000000000	1.11197E+18	5	DAPI	no	lake
Bouvy et al. 1998	plankton	abund	cells L	100000000000	4.7524E+18	5	DAPI	no	lake
Bouvy et al. 1998	plankton	abund	cells L	110000000000	1.8605E+18	5	DAPI	no	lake
Boon 1994	plankton	abund	cells L	40000000000	1.47E+18	3	AODC	yes	river
Boon 1994	plankton	abund	cells L	40000000000	4.8E+17	3	AODC	yes	river
Boon 1994	plankton	abund	cells L	210000000000	2.7E+19	3	AODC	yes	river
Boon 1994	plankton	abund	cells L	240000000000	3E+18	3	AODC	yes	river
Boon 1994	plankton	abund	cells L	240000000000	3E+18	3	AODC	yes	river
Boon 1994	plankton	abund	cells L	270000000000	2.7E+19	3	AODC	yes	river
Boon 1994	plankton	abund	cells L	290000000000	4.8E+19	3	AODC	yes	river
Boon 1994	plankton	abund	cells L	340000000000	2.7E+19	3	AODC	yes	river
Boon 1994	plankton	abund	cells L	390000000000	4.8E+19	3	AODC	yes	river
Boon 1994	plankton	abund	cells L	410000000000	4.8E+19	3	AODC	yes	river
Boon 1994	plankton	abund	cells L	470000000000	4.32E+20	3	AODC	yes	river
Boon 1994	plankton	abund	cells L	480000000000	4.8E+19	3	AODC	yes	river
Boon 1994	plankton	abund	cells L	490000000000	7.5E+19	3	AODC	yes	river
Boon 1994	plankton	abund	cells L	550000000000	6.75E+20	3	AODC	yes	river
Boon 1994	plankton	abund	cells L	620000000000	1.2E+19	3	AODC	yes	river
Boon 1994	plankton	abund	cells L	620000000000	1.47E+20	3	AODC	yes	river
Boon 1994	plankton	abund	cells L	640000000000	1.08E+20	3	AODC	yes	river
Boon 1994	plankton	abund	cells L	720000000000	1.08E+20	3	AODC	yes	river
Boon 1994	plankton	abund	cells L	740000000000	4.8E+19	3	AODC	yes	river

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Boon 1994	plankton	abund	cells L	75000000000	1.2E+19	3	AODC	yes	river
Boon 1994	plankton	abund	cells L	75000000000	2.43E+20	3	AODC	yes	river
Boon 1994	plankton	abund	cells L	76000000000	1.92E+20	3	AODC	yes	river
Boon 1994	plankton	abund	cells L	77000000000	7.5E+19	3	AODC	yes	river
Boon 1994	plankton	abund	cells L	78000000000	3.63E+20	3	AODC	yes	river
Boon 1994	plankton	abund	cells L	86000000000	2.43E+20	3	AODC	yes	river
Boon 1994	plankton	abund	cells L	90000000000	5.07E+20	3	AODC	yes	river
Boon 1994	plankton	abund	cells L	1.11E+11	5.88E+20	3	AODC	yes	river
Boon 1994	plankton	abund	cells L	1.35E+11	5.07E+20	3	AODC	yes	river
Boon 1994	plankton	abund	cells L	1.36E+11	3.63E+20	3	AODC	yes	river
Boon 1994	plankton	abund	cells L	3.11E+11	2.352E+21	3	AODC	yes	river
Boon 1994	plankton	abund	cells L	7.36E+11	9.408E+21	3	AODC	yes	river
Boon 1994	plankton	abund	cells L	1.22E+12	4.6128E+22	3	AODC	yes	river
Boon 1994	plankton	abund	cells L	1.28E+12	4.9923E+22	3	AODC	yes	river
Boon 1994	plankton	abund	cells L	1.52E+12	8.2668E+22	3	AODC	yes	river
Boon 1994	plankton	abund	cells L	1.55E+12	1.587E+23	3	AODC	yes	river
Boon 1994	plankton	abund	cells L	1.65E+12	2.09088E+23	3	AODC	yes	river
Boon 1994	plankton	abund	cells L	3.29E+12	6.65523E+23	3	AODC	yes	river
Boon 1994	plankton	abund	cells L	6.24E+12	4.65708E+23	3	AODC	yes	river
Palumbo et al. 1987	plankton	abund	cells L	119000000	5.29E+14	3	AODC	no	river
Palumbo et al. 1987	plankton	abund	cells L	146000000	6.76E+14	2	AODC	no	river
Palumbo et al. 1987	plankton	abund	cells L	158000000	6.084E+15	3	AODC	no	river
Palumbo et al. 1987	plankton	abund	cells L	164000000	2.601E+15	3	AODC	no	river
Palumbo et al. 1987	plankton	abund	cells L	348000000	5.29E+14	3	AODC	no	river
Palumbo et al. 1987	plankton	abund	cells L	474000000	6.561E+15	3	AODC	no	river
Palumbo et al. 1987	plankton	abund	cells L	598000000	2.56E+16	3	AODC	no	river
Palumbo et al. 1987	plankton	abund	cells L	613000000	2.5E+15	3	AODC	no	river
Carlsson and Caron 2001	plankton	abund	cells L	196831872.3	8.21734E+14	3	FC	yes	lake
Carlsson and Caron 2001	plankton	abund	cells L	329502318.1	2.90696E+16	3	FC	no	lake
Carlsson and Caron 2001	plankton	abund	cells L	356322253.7	3.24276E+16	3	FC	no	lake
Carlsson and Caron 2001	plankton	abund	cells L	490421874.3	5.8719E+13	3	FC	no	lake
Carlsson and Caron 2001	plankton	abund	cells L	500961080.3	8.88313E+15	3	FC	yes	lake
Carlsson and Caron 2001	plankton	abund	cells L	501916126.8	2.97265E+14	3	FC	no	lake
Carlsson and Caron 2001	plankton	abund	cells L	567050170.9	1.15089E+16	3	FC	no	lake
Carlsson and Caron 2001	plankton	abund	cells L	609195729.2	2.87723E+15	3	FC	no	lake
Carlsson and Caron 2001	plankton	abund	cells L	616408540.3	3.71073E+16	3	FC	yes	lake
Carlsson and Caron 2001	plankton	abund	cells L	647509812.7	7.105E+15	3	FC	no	lake
Carlsson and Caron 2001	plankton	abund	cells L	674329769.9	3.08642E+15	3	FC	no	lake
Carlsson and Caron 2001	plankton	abund	cells L	681992497.8	6.16917E+15	3	FC	no	lake
Carlsson and Caron 2001	plankton	abund	cells L	689655425.5	9.17484E+13	3	FC	no	lake
Carlsson and Caron 2001	plankton	abund	cells L	701149676.5	8.10688E+15	3	FC	no	lake
Carlsson and Caron 2001	plankton	abund	cells L	743295235	1.9414E+15	3	FC	no	lake
Carlsson and Caron 2001	plankton	abund	cells L	811739707.5	1.50891E+14	3	FC	yes	lake
Carlsson and Caron 2001	plankton	abund	cells L	833014941	6.71852E+13	3	FC	yes	lake
Carlsson and Caron 2001	plankton	abund	cells L	835249184.8	9.9235E+15	3	FC	no	lake
Carlsson and Caron 2001	plankton	abund	cells L	844435236.9	6.72036E+15	3	FC	yes	lake
Carlsson and Caron 2001	plankton	abund	cells L	869731831.8	1.32118E+14	3	FC	no	lake
Carlsson and Caron 2001	plankton	abund	cells L	869731910.5	2.48088E+15	3	FC	no	lake
Carlsson and Caron 2001	plankton	abund	cells L	871714224.5	8.22376E+14	3	FC	yes	lake

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Carlsson and Caron 2001	plankton	abund	cells L	1000262781	8.22378E+14	3	FC	yes	lake
Carlsson and Caron 2001	plankton	abund	cells L	1144487903	1.94134E+16	3	FC	yes	lake
Carlsson and Caron 2001	plankton	abund	cells L	1292945982	1.07423E+15	3	FC	yes	lake
Carlsson and Caron 2001	plankton	abund	cells L	2001598355	2.68704E+16	3	FC	yes	lake
Carlsson and Caron 2001	plankton	abund	cells L	2342140185	2.96325E+16	3	FC	yes	lake
Carlsson and Caron 2001	plankton	abund	cells L	2349373838	9.67466E+15	3	FC	yes	lake
Ferguson and Rublee 1976	plankton	abund	cells L	640000000	3.6E+15	4	AODC	no	marine
Ferguson and Rublee 1976	plankton	abund	cells L	610000000	1.21E+16	8	AODC	no	marine
Ferguson and Rublee 1976	plankton	abund	cells L	600000000	3.6E+15	4	AODC	no	marine
Ferguson and Rublee 1976	plankton	abund	cells L	720000000	2.56E+16	4	AODC	no	marine
Ferguson and Rublee 1976	plankton	abund	cells L	740000000	1.44E+16	8	AODC	no	marine
Ferguson and Rublee 1976	plankton	abund	cells L	780000000	1.96E+16	4	AODC	no	marine
Edwards 1987	plankton	abund	cells L	2030000000	3E+16	3	AODC	yes	river
Edwards 1987	plankton	abund	cells L	3040000000	3E+14	3	AODC	yes	river
Edwards 1987	plankton	abund	cells L	3100000000	5.547E+17	3	AODC	yes	river
Edwards 1987	plankton	abund	cells L	3550000000	1.452E+17	3	AODC	yes	river
Edwards 1987	plankton	abund	cells L	3670000000	8.67E+16	3	AODC	yes	river
Edwards 1987	plankton	abund	cells L	3960000000	1.3068E+18	3	AODC	yes	river
Edwards 1987	plankton	abund	cells L	4280000000	1.08E+16	3	AODC	yes	river
Edwards 1987	plankton	abund	cells L	4600000000	4.107E+17	3	AODC	yes	river
Edwards 1987	plankton	abund	cells L	5340000000	3E+18	3	AODC	yes	river
Edwards 1987	plankton	abund	cells L	6510000000	3.675E+17	3	AODC	yes	river
Edwards 1987	plankton	abund	cells L	7140000000	9.747E+17	3	AODC	yes	river
Edwards 1987	plankton	abund	cells L	7770000000	6.75E+18	3	AODC	yes	river
Edwards 1987	plankton	abund	cells L	9080000000	2.5947E+18	3	AODC	yes	river
Edwards 1987	plankton	abund	cells L	9460000000	1.21203E+19	3	AODC	yes	river
Edwards 1987	plankton	abund	cells L	10100000000	3E+18	3	AODC	yes	river
Edwards 1987	plankton	abund	cells L	12100000000	2.8812E+18	3	AODC	yes	river
Edwards 1987	plankton	abund	cells L	13910000000	1.92E+18	3	AODC	yes	river
Edwards 1987	plankton	abund	cells L	13920000000	5.07E+18	3	AODC	yes	river
Edwards 1987	plankton	abund	cells L	14900000000	1.31043E+19	3	AODC	yes	river
Edwards 1987	plankton	abund	cells L	16400000000	7.5E+15	3	AODC	yes	river
Edwards 1987	plankton	abund	cells L	16810000000	4.5387E+18	3	AODC	yes	river
Edwards 1987	plankton	abund	cells L	17000000000	5.07E+16	3	AODC	yes	river
Edwards 1987	plankton	abund	cells L	22020000000	8.84547E+19	3	AODC	yes	river
Edwards 1987	plankton	abund	cells L	25400000000	2.22913E+20	3	AODC	yes	river
Edwards 1987	plankton	abund	cells L	28960000000	1.32269E+20	3	AODC	yes	river
Edwards 1987	plankton	abund	cells L	70900000000	2.57799E+20	3	AODC	yes	river
Edwards 1987	plankton	abund	cells L	1.159E+11	2.54043E+21	3	AODC	yes	river
Lind and Davalos-Lind 1991	plankton	abund	cells L	400000000	4E+16	6	AODC	no	lake
Lind and Davalos-Lind 1991	plankton	abund	cells L	400000000	4E+16	6	AODC	no	lake
Lind and Davalos-Lind 1991	plankton	abund	cells L	540000000	7.29E+16	6	AODC	no	lake
Lind and Davalos-Lind 1991	plankton	abund	cells L	580000000	1.296E+17	6	AODC	no	lake
Lind and Davalos-Lind 1991	plankton	abund	cells L	580000000	8.41E+16	6	AODC	no	lake
Lind and Davalos-Lind 1991	plankton	abund	cells L	610000000	9.61E+16	6	AODC	no	lake
Lind and Davalos-Lind 1991	plankton	abund	cells L	670000000	1.764E+17	6	AODC	no	lake
Lind and Davalos-Lind 1991	plankton	abund	cells L	690000000	1.6E+17	6	AODC	no	lake
Lind and Davalos-Lind 1991	plankton	abund	cells L	700000000	1.764E+17	6	AODC	no	lake
Lind and Davalos-Lind 1991	plankton	abund	cells L	720000000	1.296E+17	6	AODC	no	lake

REF	ENVY	MEAS	UNITS	MEAN	VAR	N	METHOD	MANIP	HAB
Lind and Davaalos-Lind 1991	plankton	abund	cells L	730000000	1.369E+17	6	AODC	no	lake
Lind and Davaalos-Lind 1991	plankton	abund	cells L	870000000	1.936E+17	6	AODC	no	lake
Lind and Davaalos-Lind 1991	plankton	abund	cells L	950000000	2.304E+17	6	AODC	no	lake
Lind and Davaalos-Lind 1991	plankton	abund	cells L	960000000	2.704E+17	6	AODC	no	lake
Lind and Davaalos-Lind 1991	plankton	abund	cells L	1100000000	4.489E+17	6	AODC	no	lake
Lind and Davaalos-Lind 1991	plankton	abund	cells L	1110000000	4.9E+17	6	AODC	no	lake
Lind and Davaalos-Lind 1991	plankton	abund	cells L	1340000000	6.241E+17	6	AODC	no	lake
Lind and Davaalos-Lind 1991	plankton	abund	cells L	1380000000	5.184E+17	6	AODC	no	lake
Lind and Davaalos-Lind 1991	plankton	abund	cells L	1590000000	6.4E+17	6	AODC	no	lake
Lind and Davaalos-Lind 1991	plankton	abund	cells L	2050000000	1.0609E+18	6	AODC	no	lake
Lind and Davaalos-Lind 1991	plankton	abund	cells L	2430000000	2.0449E+18	6	AODC	no	lake
Lind and Davaalos-Lind 1991	plankton	abund	cells L	2500000000	2.0736E+18	6	AODC	no	lake
Lind and Davaalos-Lind 1991	plankton	abund	cells L	2710000000	1.9321E+18	6	AODC	no	lake
Lind and Davaalos-Lind 1991	plankton	abund	cells L	2820000000	1.9881E+18	6	AODC	no	lake
Lind and Davaalos-Lind 1991	plankton	abund	cells L	3010000000	2.3104E+18	6	AODC	no	lake
Lind and Davaalos-Lind 1991	plankton	abund	cells L	3160000000	2.4964E+18	6	AODC	no	lake
Lind and Davaalos-Lind 1991	plankton	abund	cells L	3190000000	2.5281E+18	6	AODC	no	lake
Lind and Davaalos-Lind 1991	plankton	abund	cells L	3350000000	3.1329E+18	6	AODC	no	lake
Lind and Davaalos-Lind 1991	plankton	abund	cells L	4170000000	5.1076E+18	6	AODC	no	lake
Lind and Davaalos-Lind 1991	plankton	abund	cells L	5610000000	7.84E+18	6	AODC	no	lake
Lind and Davaalos-Lind 1991	plankton	abund	cells L	6840000000	1.17649E+19	6	AODC	no	lake
Lind and Davaalos-Lind 1991	plankton	abund	cells L	7630000000	1.94481E+19	6	AODC	no	lake
Lind and Davaalos-Lind 1991	plankton	abund	cells L	7890000000	1.66464E+19	6	AODC	no	lake
Lind and Davaalos-Lind 1991	plankton	abund	cells L	9040000000	2.73529E+19	6	AODC	no	lake
Kroer 1993	plankton	abund	cells L	365000000	1.6875E+16	3	AODC	yes	marine
Kroer 1993	plankton	abund	cells L	388000000	6.075E+15	3	AODC	yes	marine
Kroer 1993	plankton	abund	cells L	589000000	1.92E+14	3	AODC	yes	marine
Kroer 1993	plankton	abund	cells L	852000000	4.1067E+16	3	AODC	yes	marine
Kroer 1993	plankton	abund	cells L	904000000	2.1168E+16	3	AODC	yes	marine
Kroer 1993	plankton	abund	cells L	999000000	2.352E+15	3	AODC	yes	marine
Kroer 1993	plankton	abund	cells L	1140000000	1.5552E+16	3	AODC	yes	marine
Kroer 1993	plankton	abund	cells L	19300000000	3.4347E+18	3	AODC	yes	marine
Suzuki et al. 1993	plankton	abund	cells L	310000000	8.1E+15	10	DAPI	no	marine
Suzuki et al. 1993	plankton	abund	cells L	320000000	6.4E+15	10	DAPI	no	marine
Suzuki et al. 1993	plankton	abund	cells L	490000000	4E+14	10	DAPI	no	marine
Suzuki et al. 1993	plankton	abund	cells L	500000000	8.1E+15	10	AODC	no	marine
Suzuki et al. 1993	plankton	abund	cells L	600000000	9E+14	10	DAPI	no	marine
Suzuki et al. 1993	plankton	abund	cells L	670000000	1E+14	10	DAPI	no	marine
Suzuki et al. 1993	plankton	abund	cells L	780000000	1.6E+15	10	AODC	no	marine
Suzuki et al. 1993	plankton	abund	cells L	1130000000	4E+14	10	DAPI	no	marine
Suzuki et al. 1993	plankton	abund	cells L	1530000000	4E+14	10	AODC	no	marine
Suzuki et al. 1993	plankton	abund	cells L	2980000000	4E+16	10	DAPI	no	marine
Suzuki et al. 1993	plankton	abund	cells L	3210000000	7.84E+16	10	DAPI	no	marine
Suzuki et al. 1993	plankton	abund	cells L	3230000000	7.29E+16	10	DAPI	no	marine
Suzuki et al. 1993	plankton	abund	cells L	3260000000	4.9E+17	10	DAPI	no	marine
Suzuki et al. 1993	plankton	abund	cells L	3920000000	1.444E+17	10	AODC	no	marine
Suzuki et al. 1993	plankton	abund	cells L	4030000000	1E+16	10	AODC	no	marine
Suzuki et al. 1993	plankton	abund	cells L	4390000000	1.6E+15	10	AODC	no	marine
Suzuki et al. 1993	plankton	abund	cells L	5400000000	1.0609E+18	10	DAPI	no	marine

REF	ENV	MEAS	UNITS	MEAN	VAR	N	METHOD	MANIP	HAB
Suzuki et al. 1993	plankton	abund	cells L	5460000000	1.6E+15	10	AODC	no	marine
Suzuki et al. 1993	plankton	abund	cells L	5810000000	5.625E+17	10	DAPI	no	marine
Suzuki et al. 1993	plankton	abund	cells L	7250000000	9E+14	10	AODC	no	marine
Suzuki et al. 1993	plankton	abund	cells L	7250000000	1.296E+17	10	AODC	no	marine
Tapper and Hicks 1998	plankton	abund	cells L	1190000000	3.721E+17	3	DAPI	no	lake
Tapper and Hicks 1998	plankton	abund	cells L	1650000000	1.089E+17	3	DAPI	no	lake
Tapper and Hicks 1998	plankton	abund	cells L	1740000000	1.6E+15	3	DAPI	no	lake
Tapper and Hicks 1998	plankton	abund	cells L	2230000000	1.96E+16	3	DAPI	no	lake
Tapper and Hicks 1998	plankton	abund	cells L	4610000000	4.624E+17	3	DAPI	no	lake
Tapper and Hicks 1998	plankton	abund	cells L	5200000000	3.6E+15	3	DAPI	no	lake
Tapper and Hicks 1998	plankton	abund	cells L	9150000000	1.08241E+19	3	DAPI	no	lake
Tapper and Hicks 1998	plankton	abund	cells L	18270000000	1.3689E+18	3	DAPI	no	lake
Benner and Biddanda 1998	plankton	abund	cells L	16000000	3.92E+14	8	DAPI	yes	marine
Benner and Biddanda 1998	plankton	abund	cells L	25000000	5.76E+14	16	DAPI	yes	marine
Benner and Biddanda 1998	plankton	abund	cells L	178000000	5.184E+15	16	DAPI	yes	marine
Benner and Biddanda 1998	plankton	abund	cells L	510000000	1.6875E+16	3	DAPI	yes	marine
Scavia et al. 1986	plankton	abund	cells L	694368264.3	4.30652E+16	3	AODC	no	lake
Scavia et al. 1986	plankton	abund	cells L	699030926.1	3.02916E+16	3	AODC	no	lake
Scavia et al. 1986	plankton	abund	cells L	758449060.2	1.00793E+16	3	AODC	no	lake
Scavia et al. 1986	plankton	abund	cells L	763510132.6	3.14803E+16	3	AODC	no	lake
Scavia et al. 1986	plankton	abund	cells L	794115479.5	9.43176E+15	3	AODC	no	lake
Scavia et al. 1986	plankton	abund	cells L	809578131.7	1.37366E+16	3	AODC	no	lake
Scavia et al. 1986	plankton	abund	cells L	986796383.4	6.64638E+16	3	AODC	no	lake
Scavia et al. 1986	plankton	abund	cells L	1039718764	1.70458E+16	3	AODC	no	lake
Findlay et al. 1986	plankton	abund	cells L	6048131512	8.74475E+18	2	AODC	yes	river
Findlay et al. 1986	plankton	abund	cells L	22049193794	3.29133E+19	2	AODC	yes	river
Findlay et al. 1986	plankton	abund	cells L	25822461223	7.55885E+17	2	AODC	yes	river
Findlay et al. 1986	plankton	abund	cells L	28845762919	2.12328E+19	2	AODC	yes	river
Findlay et al. 1986	plankton	abund	cells L	48202756465	2.26161E+20	2	AODC	yes	river
Scavia and Laird 1987	plankton	abund	cells L	661701849.1	1.93703E+16	2	AODC	no	lake
Scavia and Laird 1987	plankton	abund	cells L	688603313.6	2.79054E+16	2	AODC	no	lake
Scavia and Laird 1987	plankton	abund	cells L	725192051.9	6.55995E+15	2	AODC	no	lake
Scavia and Laird 1987	plankton	abund	cells L	736622462.1	2.2309E+16	2	AODC	no	lake
Scavia and Laird 1987	plankton	abund	cells L	788050184.1	7.41597E+15	2	AODC	no	lake
Scavia and Laird 1987	plankton	abund	cells L	812363148.4	5.02246E+15	2	AODC	no	lake
Scavia and Laird 1987	plankton	abund	cells L	95668343.7	4.52278E+16	2	AODC	no	lake
Scavia and Laird 1987	plankton	abund	cells L	1014665541	1.1307E+16	2	AODC	no	lake
Kroer 1993	plankton	abund	cells L	117250673.9	2.07197E+15	3	AODC	yes	marine
Kroer 1993	plankton	abund	cells L	626685087.2	2.94366E+16	3	AODC	yes	marine
Kroer 1993	plankton	abund	cells L	1083558286	1.96162E+16	3	AODC	yes	marine
Kroer 1993	plankton	abund	cells L	1099730795	7.65155E+16	3	AODC	yes	marine
Kroer 1993	plankton	abund	cells L	1144205136	1.50187E+16	3	AODC	yes	marine
Kroer 1993	plankton	abund	cells L	1180593260	3.06503E+16	3	AODC	yes	marine
Tranvik 1994	plankton	abund	cells L	160782429.4	7.14847E+15	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	202897643.4	1.55315E+15	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	240131372.2	4.00712E+15	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	243028384.5	3.96022E+15	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	287446263.8	2.29971E+15	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	356556161	4.05429E+15	4	DAPI	yes	lake

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Tranvik 1994	plankton	abund	cells L	395322634.3	1.20568E+16	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	493041842.2	9.90055E+14	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	603144936.8	1.25918E+16	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	617815323.9	3.86576E+16	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	702197333.2	4.43773E+16	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	704047799.9	2.68027E+16	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	716378791.6	1.82795E+16	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	798578950.5	1.42441E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	901937476.9	6.05836E+15	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	944936303.2	3.99847E+16	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	978058603.5	2.36432E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	996234972.1	3.0802E+16	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	1010155597	9.70978E+16	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	1061107988	4.1444E+16	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	1158825469	4.63578E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	1233866346	2.96026E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	1237983972	7.61961E+16	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	1238038783	7.50624E+16	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	1247879687	4.74181E+16	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	1263786566	2.40071E+16	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	1269121903	7.39594E+16	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	1293616560	1.92086E+16	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	1336768652	9.38381E+16	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	1383386894	5.17603E+16	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	1411066707	6.26993E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	1466802173	1.72217E+16	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	1477351388	2.0237E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	1507059483	2.73316E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	1520669430	2.23923E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	1563741362	2.51667E+16	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	1580497258	4.43524E+16	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	1587333922	4.56986E+15	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	1625682908	8.29831E+16	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	1629909703	9.96116E+16	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	1663412006	1.64903E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	1680804413	1.21541E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	1791120037	3.55609E+16	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	1887231793	4.77268E+16	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	1908360806	5.68596E+16	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	1930482807	1.13863E+18	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	2008594272	5.5885E+16	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	2038661918	8.28528E+16	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	2080322381	1.0419E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	2102807027	1.43782E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	2113493762	3.32317E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	2147345369	4.15163E+16	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	2152976450	1.66408E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	2166010800	1.2836E+16	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	2223442947	2.84413E+16	4	DAPI	yes	lake

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Tranvik 1994	plankton	abund	cells L	2295298766	1.04079E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	2371239229	2.41014E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	2378302982	5.57406E+16	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	2383764468	1.26096E+16	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	2398062198	3.31126E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	2604528662	1.91041E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	2841786045	2.61641E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	2923515546	1.57292E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	3048503387	1.38165E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	3111244366	8.84571E+16	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	3338910184	2.0838E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	3523887780	5.69718E+16	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	3571779168	9.69931E+15	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	3674020101	1.58305E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	3693708358	2.3323E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	3784705718	5.42496E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	3956605757	2.69158E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	3957040575	1.52766E+18	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	3968358600	1.9862E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	3984858033	9.59391E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	4056660040	1.15561E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	4079323274	4.62245E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	4101986084	6.84251E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	4371311062	7.63628E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	5983004495	3.49573E+18	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	6148762513	3.90398E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	6390936117	5.25932E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	6730879264	7.41647E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	6855089911	3.90801E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	7070822313	4.31942E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	7164906726	6.37533E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	7388102516	3.88414E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	7618133054	2.70159E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	9026381787	2.35427E+18	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	9131299558	6.32706E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	9152605447	5.88568E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	9402467719	1.57792E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	9851502168	5.83301E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	13137171057	3.22809E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	13899715406	3.38176E+18	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	14516258460	3.22809E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	14593735116	4.26704E+17	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	15231304620	1.85982E+18	4	DAPI	yes	lake
Tranvik 1994	plankton	abund	cells L	15607712648	2.61145E+17	4	DAPI	yes	lake
Lindell et al. 1995	plankton	abund	cells L	5236046134	4.2812E+17	4	AODC	yes	lake
Lindell et al. 1995	plankton	abund	cells L	6912592794	2.21869E+17	4	AODC	yes	lake
Lindell et al. 1995	plankton	abund	cells L	7571219646	1.3567E+18	4	AODC	yes	lake
Lindell et al. 1995	plankton	abund	cells L	7723557092	1.44988E+18	4	AODC	yes	lake
Lindell et al. 1995	plankton	abund	cells L	7966559889	1.64638E+17	4	AODC	yes	lake

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Lindell et al. 1995	plankton	abund	cells L	8021245353	1.71284E+18	4	AODC	yes	lake
Lindell et al. 1995	plankton	abund	cells L	8058798952	8.15652E+17	4	AODC	yes	lake
Lindell et al. 1995	plankton	abund	cells L	8222718084	6.58831E+17	4	AODC	yes	lake
Seitzinger and Sanders 1999	plankton	abund	cells L	132069903.7	5.11469E+13	2	AODC	yes	marine
Seitzinger and Sanders 1999	plankton	abund	cells L	175996872.2	1.10846E+15	2	AODC	yes	marine
Seitzinger and Sanders 1999	plankton	abund	cells L	972062630.4	6.48411E+16	2	AODC	yes	marine
Seitzinger and Sanders 1999	plankton	abund	cells L	1231399001	3.63569E+15	2	AODC	yes	marine
Seitzinger and Sanders 1999	plankton	abund	cells L	1320055174	2.48386E+16	2	AODC	yes	marine
Seitzinger and Sanders 1999	plankton	abund	cells L	1712577666	4.18066E+16	2	AODC	yes	marine
Seitzinger and Sanders 1999	plankton	abund	cells L	2043938490	1.95756E+17	2	AODC	yes	marine
Seitzinger and Sanders 1999	plankton	abund	cells L	2498264776	4.48395E+15	2	AODC	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	544186426.2	1.8572E+16	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	589474609.9	8.55489E+15	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	601941810.4	1.25152E+16	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	666105164.6	3.41791E+16	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	673048589.1	4.79312E+16	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	676141294.2	1.04439E+16	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	703409327.2	1.72481E+16	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	738284222.9	9.45195E+15	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	738546734	5.22586E+16	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	746427107.9	1.60077E+16	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	763841296.2	6.43025E+16	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	789354745.2	3.49002E+16	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	794649651.2	2.96113E+16	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	838268070.4	1.14679E+16	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	845085503.9	1.60146E+16	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	854069635.8	7.03835E+16	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	874131505.6	5.45757E+16	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	912292023.3	3.7695E+16	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	954254018.4	4.79551E+16	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	958546210.9	3.78397E+16	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	986811213.6	2.13413E+16	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	989267196.2	6.43025E+16	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	1039919332	3.97917E+16	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	1044347884	4.8018E+16	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	1047076695	5.22586E+16	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	1053857578	7.97869E+16	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	1084819767	5.45013E+16	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	1223979261	9.55627E+16	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	1231827253	5.67751E+16	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	1254996564	7.41394E+16	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	1301648905	7.34901E+16	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	1313037533	9.14178E+16	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	1400256553	5.24749E+16	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	1463109926	8.90969E+16	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	1464364096	9.69402E+16	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	1523076888	9.09895E+16	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	1552718578	9.99778E+16	3	DAPI	yes	marine
Kirchman et al. 2000	plankton	abund	cells L	1759919565	7.08844E+16	3	DAPI	yes	marine

REF	ENV	MEAS	UNITS	MEAN	VAR	N	METHOD	MANIP	HAB
Kirchman et al. 2000	plankton	abund	cells L	1868447315	1.29691E+17	3	DAPI	yes	marine
Langenheder and Jurgens 2001	plankton	abund	cells L	1072632673	1.12356E+17	3	DAPI	yes	lake
Langenheder and Jurgens 2001	plankton	abund	cells L	1139672188	2.8089E+16	3	DAPI	yes	lake
Langenheder and Jurgens 2001	plankton	abund	cells L	1608944322	1.7977E+16	3	DAPI	yes	lake
Langenheder and Jurgens 2001	plankton	abund	cells L	1675982716	4.49424E+15	3	DAPI	yes	lake
Langenheder and Jurgens 2001	plankton	abund	cells L	1675984019	2.8089E+16	3	DAPI	yes	lake
Langenheder and Jurgens 2001	plankton	abund	cells L	2279332558	1.0112E+16	3	DAPI	yes	lake
Langenheder and Jurgens 2001	plankton	abund	cells L	2286006319	7.18029E+16	3	DAPI	yes	lake
Langenheder and Jurgens 2001	plankton	abund	cells L	2318212000	1.62084E+17	3	DAPI	yes	lake
Langenheder and Jurgens 2001	plankton	abund	cells L	2335441897	1.35666E+17	3	DAPI	yes	lake
Langenheder and Jurgens 2001	plankton	abund	cells L	2412215854	5.5051E+16	3	DAPI	yes	lake
Langenheder and Jurgens 2001	plankton	abund	cells L	2476625297	4.04457E+16	3	DAPI	yes	lake
Langenheder and Jurgens 2001	plankton	abund	cells L	2494981633	5.51389E+16	3	DAPI	yes	lake
Langenheder and Jurgens 2001	plankton	abund	cells L	2579619228	1.12349E+17	3	DAPI	yes	lake
Langenheder and Jurgens 2001	plankton	abund	cells L	2681565641	4.49424E+17	3	DAPI	yes	lake
Langenheder and Jurgens 2001	plankton	abund	cells L	2720434892	4.04456E+16	3	DAPI	yes	lake
Langenheder and Jurgens 2001	plankton	abund	cells L	2796460603	7.19033E+16	3	DAPI	yes	lake
Langenheder and Jurgens 2001	plankton	abund	cells L	2949724632	1.61793E+17	3	DAPI	yes	lake
Langenheder and Jurgens 2001	plankton	abund	cells L	3217882845	2.87631E+17	3	DAPI	yes	lake
Langenheder and Jurgens 2001	plankton	abund	cells L	3307664272	7.17026E+16	3	DAPI	yes	lake
Langenheder and Jurgens 2001	plankton	abund	cells L	3340621475	4.0521E+16	3	DAPI	yes	lake
Langenheder and Jurgens 2001	plankton	abund	cells L	3349235415	5.52269E+16	3	DAPI	yes	lake
Langenheder and Jurgens 2001	plankton	abund	cells L	3435369155	1.61632E+17	3	DAPI	yes	lake
Langenheder and Jurgens 2001	plankton	abund	cells L	3518137189	1.80261E+16	3	DAPI	yes	lake
Langenheder and Jurgens 2001	plankton	abund	cells L	3843958619	2.20204E+17	3	DAPI	yes	lake
Langenheder and Jurgens 2001	plankton	abund	cells L	4562267725	4.02951E+16	3	DAPI	yes	lake
Langenheder and Jurgens 2001	plankton	abund	cells L	4692738721	1.89882E+17	3	DAPI	yes	lake
Langenheder and Jurgens 2001	plankton	abund	cells L	4790716781	1.61782E+17	3	DAPI	yes	lake
Langenheder and Jurgens 2001	plankton	abund	cells L	4949131546	1.126E+17	3	DAPI	yes	lake
Langenheder and Jurgens 2001	plankton	abund	cells L	5134514903	1.01491E+16	3	DAPI	yes	lake
Langenheder and Jurgens 2001	plankton	abund	cells L	5510148103	2.20204E+17	3	DAPI	yes	lake
Langenheder and Jurgens 2001	plankton	abund	cells L	5646841248	7.19034E+16	3	DAPI	yes	lake
Langenheder and Jurgens 2001	plankton	abund	cells L	5678300431	2.80872E+16	3	DAPI	yes	lake
Langenheder and Jurgens 2001	plankton	abund	cells L	6240810227	5.43493E+17	3	DAPI	yes	lake
Langenheder and Jurgens 2001	plankton	abund	cells L	7910617663	1.62242E+18	3	DAPI	yes	lake
Langenheder and Jurgens 2001	plankton	abund	cells L	8916203056	7.19078E+16	3	DAPI	yes	lake
Langenheder and Jurgens 2001	plankton	abund	cells L	10324023731	2.92238E+18	3	DAPI	yes	lake
Langenheder and Jurgens 2001	plankton	abund	cells L	10592179917	4.05605E+17	3	DAPI	yes	lake
Bouvy et al. 1998	plankton	prod	ugCL-1h-1	1.55	0.07308405	5	thymidine	no	lake
Bouvy et al. 1998	plankton	prod	ugCL-1h-1	1.58	0.484413938	5	thymidine	no	lake
Bouvy et al. 1998	plankton	prod	ugCL-1h-1	1.78	0.239673618	5	thymidine	no	lake
Bouvy et al. 1998	plankton	prod	ugCL-1h-1	1.78	0.705301682	5	thymidine	no	lake
Bouvy et al. 1998	plankton	prod	ugCL-1h-1	1.94	0.71555445	5	thymidine	no	lake
Bouvy et al. 1998	plankton	prod	ugCL-1h-1	3.19	0.638244992	5	thymidine	no	lake
Bouvy et al. 1998	plankton	prod	ugCL-1h-1	4.58	0.907124418	5	thymidine	no	lake
Bouvy et al. 1998	plankton	prod	ugCL-1h-1	4.74	4.404098952	5	thymidine	no	lake
Bouvy et al. 1998	plankton	prod	ugCL-1h-1	4.77	2.840016978	5	thymidine	no	lake
Bouvy et al. 1998	plankton	prod	ugCL-1h-1	4.99	2.136553081	5	thymidine	no	lake
Bouvy et al. 1998	plankton	prod	ugCL-1h-1	5.07	6.858195845	5	thymidine	no	lake

REF	ENV	MEAS	UNITS	MEAN	VAR	N	METHOD	MANIP	HAB
Bouvy et al. 1998	plankton	prod	ugCL-1h-1	5.29	0.745636345	5	thymidine	no	lake
Bouvy et al. 1998	plankton	prod	ugCL-1h-1	5.41	1.969157768	5	thymidine	no	lake
Bouvy et al. 1998	plankton	prod	ugCL-1h-1	5.42	1.410654728	5	thymidine	no	lake
Bouvy et al. 1998	plankton	prod	ugCL-1h-1	6.37	3.019732898	5	thymidine	no	lake
Bouvy et al. 1998	plankton	prod	ugCL-1h-1	6.38	1.238227848	5	thymidine	no	lake
Bouvy et al. 1998	plankton	prod	ugCL-1h-1	8.02	14.45408029	5	thymidine	no	lake
Bouvy et al. 1998	plankton	prod	ugCL-1h-1	15.61	3.958453265	5	thymidine	no	lake
Bouvy et al. 1998	plankton	prod	ugCL-1h-1	17.04	11.49977117	5	thymidine	no	lake
Bouvy et al. 1998	plankton	prod	ugCL-1h-1	18.24	12.30315725	5	thymidine	no	lake
Theil-Nielsen and Sondergaard 1999	plankton	prod	ugCL-1h-1	0.819290358	0.097594664	3	thymidine	no	lake
Theil-Nielsen and Sondergaard 1999	plankton	prod	ugCL-1h-1	1.498105742	0.023978614	3	thymidine	no	lake
Theil-Nielsen and Sondergaard 1999	plankton	prod	ugCL-1h-1	1.712366787	0.095914479	3	thymidine	no	lake
Theil-Nielsen and Sondergaard 1999	plankton	prod	ugCL-1h-1	2.001532324	0.052346818	3	thymidine	no	lake
Theil-Nielsen and Sondergaard 1999	plankton	prod	ugCL-1h-1	2.515446507	0.023978593	3	thymidine	no	lake
Theil-Nielsen and Sondergaard 1999	plankton	prod	ugCL-1h-1	4.304535923	0.298619877	3	thymidine	no	lake
Theil-Nielsen and Sondergaard 1999	plankton	prod	ugCL-1h-1	4.643441147	0.982956564	3	thymidine	no	lake
Theil-Nielsen and Sondergaard 1999	plankton	prod	ugCL-1h-1	6.050436672	0.296309171	3	thymidine	no	lake
Theil-Nielsen and Sondergaard 1999	plankton	prod	ugCL-1h-1	6.310790827	0.209387078	3	thymidine	no	lake
Theil-Nielsen and Sondergaard 1999	plankton	prod	ugCL-1h-1	7.270438375	0.870786568	3	thymidine	no	lake
Theil-Nielsen and Sondergaard 1999	plankton	prod	ugCL-1h-1	24.84020566	1.884483407	3	thymidine	no	lake
Theil-Nielsen and Sondergaard 1999	plankton	prod	ugCL-1h-1	26.64146949	6.958280424	3	thymidine	no	lake
Theil-Nielsen and Sondergaard 1999	plankton	prod	ugCL-1h-1	38.40358398	5.462194405	3	thymidine	no	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	0.120500664	0.004427432	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	0.128433606	0.000457426	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	0.229001272	0.0004582	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	0.289342145	0.009037288	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	0.371892393	0.032611869	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	0.424480227	0.000456653	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	0.456448485	0.023131053	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	0.477375203	0.015863065	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	0.514186675	0.005428317	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	0.530414682	0.084053395	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	0.550763191	0.003818643	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	0.615766026	0.00949123	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	0.76769227	0.043728373	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	0.906245773	0.012474725	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	0.941454704	0.083335624	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	0.972748529	0.008157861	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	1.257978089	0.042265116	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	1.50477476	0.551515917	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	1.718502938	0.06090647	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	1.75201992	0.548828775	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	2.019186807	1.147889127	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	2.040464206	0.137375073	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	2.431714998	0.54882891	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	2.671717931	0.137542869	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	2.94386928	0.083204938	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	3.029445213	0.061018291	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	3.153071883	0.612645499	3	leucine	yes	lake

REF	ENVT	MEAS	UNITS	MEAN	VAR	N	METHOD	MANIP	HAB
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	4.45722566	1.738813657	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	4.760161955	0.169619573	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	4.851181777	2.452000548	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	5.087566121	1.330756489	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	5.175866038	0.083335635	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	6.551562477	0.083074393	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	6.735414138	4.591553513	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	7.416012355	1.528254973	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	7.730732735	0.083335627	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	8.029601644	2.583476816	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	10.0315629	0.083204922	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	11.87503278	7.6213403	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	14.79352075	1.630678898	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	15.59819909	5.714439481	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	17.41042447	6.117494732	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	18.38582076	4.245148597	3	leucine	yes	lake
Carlsson and Caron 2001	plankton	prod	ugCL-1h-1	24.84181571	3.438569756	3	leucine	yes	lake
Moeseneder and Herndl 1995	plankton	prod	ugCL-1h-1	0.1	0.0009	9	thymidine	yes	marine
Moeseneder and Herndl 1995	plankton	prod	ugCL-1h-1	0.1	0.0009	9	thymidine	yes	marine
Moeseneder and Herndl 1995	plankton	prod	ugCL-1h-1	0.39	0.0256	7	thymidine	yes	marine
Moeseneder and Herndl 1995	plankton	prod	ugCL-1h-1	0.41	0.0484	7	thymidine	yes	marine
Moeseneder and Herndl 1995	plankton	prod	ugCL-1h-1	0.43	0.0576	9	thymidine	yes	marine
Moeseneder and Herndl 1995	plankton	prod	ugCL-1h-1	0.5	0.0625	9	thymidine	yes	marine
Moeseneder and Herndl 1995	plankton	prod	ugCL-1h-1	0.56	0.1444	7	thymidine	yes	marine
Moeseneder and Herndl 1995	plankton	prod	ugCL-1h-1	0.62	0.2601	4	thymidine	yes	marine
Moeseneder and Herndl 1995	plankton	prod	ugCL-1h-1	0.69	0.1296	4	thymidine	yes	marine
Moeseneder and Herndl 1995	plankton	prod	ugCL-1h-1	0.71	0.2809	4	thymidine	yes	marine
Moeseneder and Herndl 1995	plankton	prod	ugCL-1h-1	0.78	0.25	7	thymidine	yes	marine
Moeseneder and Herndl 1995	plankton	prod	ugCL-1h-1	0.81	0.04	4	thymidine	yes	marine
Moeseneder and Herndl 1995	plankton	prod	ugCL-1h-1	0.9	0.5625	4	thymidine	yes	marine
Moeseneder and Herndl 1995	plankton	prod	ugCL-1h-1	0.99	0.64	4	thymidine	yes	marine
Moeseneder and Herndl 1995	plankton	prod	ugCL-1h-1	1.19	0.8836	4	thymidine	yes	marine
Moeseneder and Herndl 1995	plankton	prod	ugCL-1h-1	1.34	1.4161	6	thymidine	yes	marine
Moeseneder and Herndl 1995	plankton	prod	ugCL-1h-1	1.4	1.1881	4	thymidine	yes	marine
Moeseneder and Herndl 1995	plankton	prod	ugCL-1h-1	1.46	1.5376	6	thymidine	yes	marine
Moeseneder and Herndl 1995	plankton	prod	ugCL-1h-1	1.53	0.7225	4	thymidine	yes	marine
Moeseneder and Herndl 1995	plankton	prod	ugCL-1h-1	1.58	0.5041	4	thymidine	yes	marine
Moeseneder and Herndl 1995	plankton	prod	ugCL-1h-1	1.62	0.7396	4	thymidine	yes	marine
Moeseneder and Herndl 1995	plankton	prod	ugCL-1h-1	1.83	0.5929	4	thymidine	yes	marine
Moeseneder and Herndl 1995	plankton	prod	ugCL-1h-1	2.35	0.7569	4	thymidine	yes	marine
Moeseneder and Herndl 1995	plankton	prod	ugCL-1h-1	2.51	0.1089	4	thymidine	yes	marine
Moeseneder and Herndl 1995	plankton	prod	ugCL-1h-1	2.54	0.7744	4	thymidine	yes	marine
Moeseneder and Herndl 1995	plankton	prod	ugCL-1h-1	2.67	0.1296	4	thymidine	yes	marine
Moeseneder and Herndl 1995	plankton	prod	ugCL-1h-1	4.14	3.1684	7	thymidine	yes	marine
Moeseneder and Herndl 1995	plankton	prod	ugCL-1h-1	4.58	3.6864	7	thymidine	yes	marine
Moeseneder and Herndl 1995	plankton	prod	ugCL-1h-1	4.64	3.8809	7	thymidine	yes	marine
Moeseneder and Herndl 1995	plankton	prod	ugCL-1h-1	4.81	4.6656	7	thymidine	yes	marine
Rich et al. 1996	plankton	prod	ugCL-1h-1	0.0255	0.000324	6	thymidine	yes	marine
Rich et al. 1996	plankton	prod	ugCL-1h-1	0.032	0.00024025	3	thymidine	yes	marine

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Rich et al. 1996	plankton	prod	ugCL-1h-1	0.0325	0.00009025	3	thymidine	yes	marine
Rich et al. 1996	plankton	prod	ugCL-1h-1	0.033	0.000144	6	thymidine	yes	marine
Rich et al. 1996	plankton	prod	ugCL-1h-1	0.035	0.00070225	8	thymidine	yes	marine
Rich et al. 1996	plankton	prod	ugCL-1h-1	0.037	0.00050625	11	thymidine	yes	marine
Rich et al. 1996	plankton	prod	ugCL-1h-1	0.037	0.00030625	8	thymidine	yes	marine
Rich et al. 1996	plankton	prod	ugCL-1h-1	0.038	0.00060025	7	thymidine	yes	marine
Rich et al. 1996	plankton	prod	ugCL-1h-1	0.038	0.00060025	8	thymidine	yes	marine
Rich et al. 1996	plankton	prod	ugCL-1h-1	0.0385	0.0004	14	thymidine	yes	marine
Rich et al. 1996	plankton	prod	ugCL-1h-1	0.0395	0.00024025	11	thymidine	yes	marine
Rich et al. 1996	plankton	prod	ugCL-1h-1	0.0405	0.00065025	5	thymidine	yes	marine
Rich et al. 1996	plankton	prod	ugCL-1h-1	0.0445	0.00005625	6	thymidine	yes	marine
Rich et al. 1996	plankton	prod	ugCL-1h-1	0.0445	0.000256	6	thymidine	yes	marine
Rich et al. 1996	plankton	prod	ugCL-1h-1	0.0465	0.00015625	9	thymidine	yes	marine
Rich et al. 1996	plankton	prod	ugCL-1h-1	0.047	0.00034225	5	thymidine	yes	marine
Rich et al. 1996	plankton	prod	ugCL-1h-1	0.047	0.00011025	6	thymidine	yes	marine
Rich et al. 1996	plankton	prod	ugCL-1h-1	0.05	0.000289	14	thymidine	yes	marine
Rich et al. 1996	plankton	prod	ugCL-1h-1	0.055	0.000729	11	thymidine	yes	marine
Rich et al. 1996	plankton	prod	ugCL-1h-1	0.0555	0.00060025	5	thymidine	yes	marine
Rich et al. 1996	plankton	prod	ugCL-1h-1	0.059	0.000784	11	thymidine	yes	marine
Rich et al. 1996	plankton	prod	ugCL-1h-1	0.063	0.000961	8	thymidine	yes	marine
Rich et al. 1996	plankton	prod	ugCL-1h-1	0.0705	0.002601	11	thymidine	yes	marine
Rich et al. 1996	plankton	prod	ugCL-1h-1	0.075	0.00060025	6	thymidine	yes	marine
Rich et al. 1996	plankton	prod	ugCL-1h-1	0.0755	0.001024	11	thymidine	yes	marine
Rich et al. 1996	plankton	prod	ugCL-1h-1	0.079	0.00207025	8	thymidine	yes	marine
Rich et al. 1996	plankton	prod	ugCL-1h-1	0.0825	0.002025	11	thymidine	yes	marine
Bertilsson and Tranvik 1998	plankton	prod	ugCL-1h-1	0.0082	0.00000036	3	leucine	yes	lake
Bertilsson and Tranvik 1998	plankton	prod	ugCL-1h-1	0.0144	0.00000081	3	leucine	yes	lake
Bertilsson and Tranvik 1998	plankton	prod	ugCL-1h-1	0.0264	0.00000169	3	leucine	yes	lake
Bertilsson and Tranvik 1998	plankton	prod	ugCL-1h-1	0.0324	0.00000016	3	leucine	yes	lake
Bertilsson and Tranvik 1998	plankton	prod	ugCL-1h-1	0.0326	0.000000361	3	leucine	yes	lake
Bertilsson and Tranvik 1998	plankton	prod	ugCL-1h-1	0.0342	0.000000361	3	leucine	yes	lake
Bertilsson and Tranvik 1998	plankton	prod	ugCL-1h-1	0.035	0.00001296	3	leucine	yes	lake
Bertilsson and Tranvik 1998	plankton	prod	ugCL-1h-1	0.0369	0.00000225	3	leucine	yes	lake
Bertilsson and Tranvik 1998	plankton	prod	ugCL-1h-1	0.0382	0.00000196	3	leucine	yes	lake
Bertilsson and Tranvik 1998	plankton	prod	ugCL-1h-1	0.0413	0.00000576	3	leucine	yes	lake
Bertilsson and Tranvik 1998	plankton	prod	ugCL-1h-1	0.0454	0.000001	3	leucine	yes	lake
Bertilsson and Tranvik 1998	plankton	prod	ugCL-1h-1	0.0487	0.00000064	3	leucine	yes	lake
Benner and Biddanda 1998	plankton	prod	ugCL-1h-1	0.07	0.0012	3	leucine	yes	marine
Benner and Biddanda 1998	plankton	prod	ugCL-1h-1	0.16	0.03	3	leucine	yes	marine
Benner and Biddanda 1998	plankton	prod	ugCL-1h-1	0.21	0.0432	3	leucine	yes	marine
Benner and Biddanda 1998	plankton	prod	ugCL-1h-1	0.32	0.0363	3	leucine	yes	marine
Bunte and Simon 1999	plankton	prod	ugCL-1h-1	0.017	0.00012996	3	leucine	no	lake
Bunte and Simon 1999	plankton	prod	ugCL-1h-1	0.0194	0.00027556	3	leucine	no	lake
Bunte and Simon 1999	plankton	prod	ugCL-1h-1	0.0228	0.00006561	3	leucine	no	lake
Bunte and Simon 1999	plankton	prod	ugCL-1h-1	0.0241	0.00011236	3	leucine	no	lake
Bunte and Simon 1999	plankton	prod	ugCL-1h-1	0.0353	0.00097969	3	leucine	no	lake
Bunte and Simon 1999	plankton	prod	ugCL-1h-1	0.0402	0.00019881	3	leucine	no	lake
Bunte and Simon 1999	plankton	prod	ugCL-1h-1	0.0455	0.00063504	3	leucine	no	lake
Bunte and Simon 1999	plankton	prod	ugCL-1h-1	0.0505	0.00380689	3	leucine	no	lake

REF	ENV	MEAS	UNITS	MEAN	VAR	N	METHOD	MANIP	HAB
Bunte and Simon 1999	plankton	prod	ugCL-1h-1	0.1141	0.00108241	3	leucine	no	lake
Bunte and Simon 1999	plankton	prod	ugCL-1h-1	0.1246	0.00318096	3	leucine	no	lake
Bunte and Simon 1999	plankton	prod	ugCL-1h-1	0.1269	0.0004469	3	leucine	no	lake
Bunte and Simon 1999	plankton	prod	ugCL-1h-1	0.1575	0.02134521	3	leucine	no	lake
Bunte and Simon 1999	plankton	prod	ugCL-1h-1	0.2869	0.21874329	3	leucine	no	lake
Bunte and Simon 1999	plankton	prod	ugCL-1h-1	0.3724	0.00822649	3	leucine	no	lake
Bunte and Simon 1999	plankton	prod	ugCL-1h-1	0.4402	0.001652423	3	leucine	no	lake
Bunte and Simon 1999	plankton	prod	ugCL-1h-1	0.5794	0.002891213	3	leucine	no	lake
Bunte and Simon 1999	plankton	prod	ugCL-1h-1	0.6074	0.000831169	3	leucine	no	lake
Bunte and Simon 1999	plankton	prod	ugCL-1h-1	0.9218	0.002002563	3	leucine	no	lake
Cole and Pace 1995	plankton	prod	ugCL-1h-1	0.032362721	0.00363656	5	leucine	no	lake
Cole and Pace 1995	plankton	prod	ugCL-1h-1	0.074055837	0.001033036	5	leucine	no	lake
Cole and Pace 1995	plankton	prod	ugCL-1h-1	0.076471262	0.000581249	5	leucine	no	lake
Cole and Pace 1995	plankton	prod	ugCL-1h-1	0.107893635	0.00710746	5	leucine	no	lake
Cole and Pace 1995	plankton	prod	ugCL-1h-1	0.112328042	0.003160947	5	leucine	no	lake
Cole and Pace 1995	plankton	prod	ugCL-1h-1	0.132262092	0.013193399	5	leucine	no	lake
Cole and Pace 1995	plankton	prod	ugCL-1h-1	0.25029103	0.044077245	5	leucine	no	lake
Cole and Pace 1995	plankton	prod	ugCL-1h-1	0.399138511	0.024583128	5	leucine	no	lake
Cole and Pace 1995	plankton	prod	ugCL-1h-1	0.456401977	0.147661451	5	leucine	no	lake
Cole and Pace 1995	plankton	prod	ugCL-1h-1	0.524298073	0.396678363	5	leucine	no	lake
Cole and Pace 1995	plankton	prod	ugCL-1h-1	0.535743413	0.008260387	5	leucine	no	lake
Cole and Pace 1995	plankton	prod	ugCL-1h-1	0.676299706	0.026381649	5	leucine	no	lake
Cole and Pace 1995	plankton	prod	ugCL-1h-1	0.77300409	0.026053289	5	leucine	no	lake
Cole and Pace 1995	plankton	prod	ugCL-1h-1	1.070181991	0.04072667	5	leucine	no	lake
Cole and Pace 1995	plankton	prod	ugCL-1h-1	1.823085983	0.393329972	5	leucine	no	lake
Cole and Pace 1995	plankton	prod	ugCL-1h-1	2.019093281	0.147023195	5	leucine	no	lake
Cole and Pace 1995	plankton	prod	ugCL-1h-1	2.071198432	0.321325822	5	leucine	no	lake
Cole and Pace 1995	plankton	prod	ugCL-1h-1	2.355304386	0.39142887	5	leucine	no	lake
Cole and Pace 1995	plankton	prod	ugCL-1h-1	2.912621716	0.3933295	5	leucine	no	lake
Cochlan 2001	plankton	prod	ugCL-1h-1	0.065	8.50694E-06	2	leucine	yes	marine
Cochlan 2001	plankton	prod	ugCL-1h-1	0.095833333	1.11111E-05	2	leucine	yes	marine
Cochlan 2001	plankton	prod	ugCL-1h-1	0.101666667	1.5625E-06	2	leucine	yes	marine
Cochlan 2001	plankton	prod	ugCL-1h-1	0.110833333	6.26736E-05	2	leucine	yes	marine
Cochlan 2001	plankton	prod	ugCL-1h-1	0.1275	0.000025	2	leucine	yes	marine
Cochlan 2001	plankton	prod	ugCL-1h-1	0.275416667	0.00005625	2	leucine	yes	marine
Cochlan 2001	plankton	prod	ugCL-1h-1	0.31625	0.000711111	2	leucine	yes	marine
Cochlan 2001	plankton	prod	ugCL-1h-1	0.335833333	0.001314063	2	leucine	yes	marine
Alldredge et al. 1986	plankton	prod	ugCL-1h-1	0.089	0.000289	2	thymidine	no	marine
Alldredge et al. 1986	plankton	prod	ugCL-1h-1	0.019	0.000081	2	thymidine	no	marine
Alldredge et al. 1986	plankton	prod	ugCL-1h-1	0.223	0.0004	2	thymidine	no	marine
Alldredge et al. 1986	plankton	prod	ugCL-1h-1	0.201	0.003844	2	thymidine	no	marine

**Appendix C: Raw data used in algal and bacterial study
of Chapter 3**

Table C.1. Periphyton algal and bacterial abundance and production, and water quality data from Chapter 3. STATION: unique

station identifier; Region: sampling region; Year: sampling year; CHLA: periphyton chlorophyll *a* (mg chl *a* m⁻²); AFDM: ash free dry mass (mg m⁻²); BACT: Bacterial abundance (cells cm⁻²); AP: algal production (mg C m⁻² d⁻¹); BP: Bacterial production (mg C m⁻² d⁻¹); TP: total phosphorus (mg L⁻¹); RP: reactive phosphorus (mg L⁻¹); NOX: NO₂+NO₃ (mg L⁻¹); NH34: ammonia (mg L⁻¹); TKN: total Kjeldahl nitrogen (mg L⁻¹); TN: total nitrogen; PH: pH; ALK: alkalinity (mg L⁻¹); COND: conductivity (μS cm⁻¹); TSS: total suspended solids (mg L⁻¹); DOC: dissolved organic carbon (mg L⁻¹).

STATION	Region	Year	CHLA	AFDM	BACT	AP	BP	TP	RP	NOX	NH34	TKN	TN	PH	ALK	COND	TSS	DOC
C11	Waterloo	2001	92	34	377549915			0.186	0.134	1.093	0.524	1.222	2.315	8.08	230	1041	5.0	4.74
C12	Waterloo	2001	79	100	486365639			0.013	0.002	1.520	0.005	0.435	1.955	8.41	228	563	3.4	
C13	Waterloo	2001	61	17	268394627			0.055	0.028	5.680	0.011	0.575	6.255	8.35	235	1142	13.4	
C15	Waterloo	2001	65	19	126225941			0.106	0.038	1.945	0.132	0.860	2.805	8.12	179	1056	27.3	
C2	Waterloo	2001	111	53	192785597			0.070	0.035	3.785	0.057	0.645	4.430	8.24	264	1153	6.6	
C3	Waterloo	2001	166	80	454507648			0.040	0.004	1.270	0.023	0.570	1.840	8.41	218	670	16.9	
C5	Waterloo	2001	113	124	540497763			0.042	0.010	0.634	0.017	0.480	1.114	8.46	212	584	11.5	
C6	Waterloo	2001	89	150	794666461			0.043	0.003	0.546	0.015	0.520	1.066	8.47	209	575	14.5	
C8	Waterloo	2001	165	76	233347307			0.083	0.046	0.719	0.026	0.575	1.294	8.38	213	679	6.5	
CK13-01	Ottawa	2001	80	10	219143645			0.087	0.018	3.223	0.019	0.768	3.990	8.21	208	818	28.0	4.30
CK18-03-00	Ottawa	2001	77	33	162987774			0.013	0.003	0.048	0.013	0.403	0.450	8.21	247	1000	3.3	7.38
CK18-Q	Ottawa	2001	38	14	143883199			0.091	0.038	0.688	0.053	0.683	1.370	8.26	232	1483	36.8	5.28
CK19-01	Ottawa	2001	45	15	75964953			0.049	0.013	0.428	0.028	0.660	1.088	8.26	204	845	5.8	4.78
CK20-10	Ottawa	2001	55	15	171716588			0.084	0.044	0.025	0.044	0.793	0.818	8.19	210	645	13.0	9.98
CK21-003	Ottawa	2001	157	28	202654221			0.064	0.039	0.337	0.060	0.831	1.111	7.82	172	1413	14.5	8.65
CK24-002	Ottawa	2001	175	23	151766476			0.111	0.079	1.120	0.042	0.690	1.810	8.33	230	775	62.0	4.38
CK25-001	Ottawa	2001	94	24	502889079			0.086	0.046	1.318	0.034	0.718	2.035	8.41	223	613	17.3	6.65
CK3-04	Ottawa	2001	101	32	86090364			0.013	0.002	0.005	0.006	0.770	0.775	8.18	155	353	2.0	17.47

STATION	Region	Year	CHLA	AFDM	BACT	AP	BP	TP	RP	NOX	NH34	TKN	TN	PH	ALK	COND	TSS	DOC
CK31-01	Ottawa	2001	76	10	83659871			0.076	0.029	0.650	0.021	1.075	1.725	8.25	180	725	25.8	12.40
CK41-01	Ottawa	2001	90	30	316423261			0.043	0.011	0.470	0.051	0.613	1.083	8.24	230	780	10.8	4.80
CK42-05-03	Ottawa	2001	96	14	252182382			0.084	0.027	0.608	0.070	1.063	1.670	8.33	240	565	24.8	13.98
CK42-07	Ottawa	2001	17	23	161560421			0.012	0.002	0.008	0.012	0.627	0.634	8.25	165	330	2.3	14.50
CK44-02	Ottawa	2001	31	16	190720749			0.020	0.004	0.009	0.016	0.653	0.661	8.41	154	343	2.5	10.80
CK5-01	Ottawa	2001	80	15	104965364			0.050	0.023	0.618	0.052	0.628	1.245	8.32	179	700	11.0	5.33
CK63-001	Ottawa	2001	65	38	354243132			0.071	0.047	1.150	0.030	0.698	1.848	8.26	225	628	15.0	7.58
CK63-206	Ottawa	2001	163	39	196126326			0.036	0.012	0.393	0.036	0.688	1.080	8.31	225	1003	12.3	7.45
CK63-265	Ottawa	2001	64	23	257871832			0.033	0.012	0.215	0.026	0.768	0.983	8.23	206	723	6.5	11.10
CK63-266	Ottawa	2001	54	106	1219875933			0.046	0.020	0.393	0.024	0.750	1.143	8.30	223	873	7.3	9.73
CK65-04	Ottawa	2001	57	13	241502186			0.053	0.019	0.058	0.045	0.720	0.778	8.32	190	1083	8.8	5.75
CK7-01	Ottawa	2001	161	27	236069951			0.100	0.026	0.392	0.081	0.854	1.272	8.15	208	1350	27.3	6.60
CK8-01	Ottawa	2001	168	32	345758864			0.043	0.013	1.276	0.045	0.582	1.857	8.19	202	1189	16.0	3.68
G1	Waterloo	2001	186	106	1183106183			0.087	0.004	3.378	0.031	0.895	4.273	8.33	209	676	17.4	
G20	Waterloo	2001	83	57	252042641			0.069	0.008	0.907	0.144	0.665	1.572	8.19	182	391	7.3	
G21	Waterloo	2001	56	17	81661077			0.034	0.001	0.530	0.035	0.860	1.390	8.36	154	337	6.3	
G25	Waterloo	2001	76	54	467133800			0.045	0.001	2.686	0.018	0.655	3.341	8.46	207	502	3.8	
G28	Waterloo	2001	142	65	495431329			0.042	0.003	3.554	0.051	0.845	4.399	8.38	215	533	5.5	
G30	Waterloo	2001	53	13	137724619			0.093	0.007	2.919	0.044	0.930	3.849	8.37	202	571	30.5	
G35	Waterloo	2001	120	54	233117733			0.021	0.004	4.160	0.011	0.505	4.665	8.32	227	715	4.1	
G4	Waterloo	2001	83	38	185855371			0.176	0.013	4.973	0.213	1.430	6.403	8.34	183	489	48.8	
G5	Waterloo	2001	105	46	327594271			0.043	0.006	4.085	0.033	0.790	4.875	8.61	176	462	7.8	
G9	Waterloo	2001	97	186	304445471			0.038	0.001	1.255	0.032	0.425	1.680	8.29	232	561	8.3	
M1	Waterloo	2001	76	84	814656762			0.032	0.008	3.568	0.030	0.752	4.320	8.37	257	557	2.8	
M3	Waterloo	2001	103	72	48629826			0.030	0.004	3.108	0.040	0.744	3.852	8.38	219	525	4.3	
M5	Waterloo	2001	88	37	96820467			0.026	0.003	2.676	0.042	0.748	3.424	8.38	214	505	6.4	
M6	Waterloo	2001	151	48	592601148			0.070	0.023	1.329	0.031	0.996	2.325	8.51	227	915	7.0	

STATION	Region	Year	CHLA	AFDM	BACT	AP	BP	TP	RP	NOX	NH34	TKN	TN	PH	ALK	COND	TSS	DOC
M7	Waterloo	2001	43	25	161300902			0.148	0.074	1.435	0.041	1.180	2.615	8.44	269	1154	3.0	
R010-32	Ottawa	2001	67	25	204891501			0.020	0.007	1.195	0.067	0.620	1.815	8.17	280	990	3.8	6.73
T1	Waterloo	2001	153	46	338503896			0.132	0.047	9.575	0.120	1.055	10.630	8.22	179	1176	49.9	
T13	Waterloo	2001	69	25	330203164			0.113	0.041	2.838	0.047	0.885	3.723	8.31	248	570	21.3	
T15	Waterloo	2001	92	61	514366218			0.057	0.018	3.328	0.162	0.935	4.263	8.20	166	417	12.6	
T5	Waterloo	2001	214	34	241951353			0.015	0.004	8.910	0.010	0.400	9.310	8.30	280	754	7.5	
T6	Waterloo	2001	129	26	187426651			0.039	0.008	4.595	0.043	0.685	5.280	8.46	202	634	11.3	
T8	Waterloo	2001	104	26	257320680			0.283	0.217	10.058	0.059	0.915	10.973	8.30	177	774	9.4	
CK24-002	Ottawa	2002	124	30	188378201	5.84	99.9	0.091	0.056	1.925	0.064	0.755	2.680	8.26	221	685	27.5	5.83
CK25-001	Ottawa	2002	52	62	95155984	2.96	80.2	0.115	0.098	1.233	0.081	0.885	2.118	8.28	198	495	17.8	8.40
CK41-01	Ottawa	2002	90	39	305827247	25.98	198.3	0.028	0.012	1.575	0.029	0.675	2.250	8.16	260	810	3.8	6.53
CK42-05-03	Ottawa	2002	114	31	132955678	36.57	199.8	0.055	0.033	2.555	0.018	1.103	3.658	8.14	260	598	4.3	15.85
CK42-07	Ottawa	2002	13	20	25874790		47.6	0.011	0.003	0.012	0.006	0.688	0.700	8.07	186	365	2.0	17.18
CK44-02	Ottawa	2002	19	40	80178403	2.11	111.9	0.015	0.005	0.010	0.006	0.623	0.632	8.23	189	383	2.3	11.20
Blackburn	Ottawa	2002	4	1	4837461	0.35	28.6	0.011		0.021		0.330	0.351	7.57	26	68		9.64
Chelsea	Ottawa	2002	4	3	6476299	0.80	88.4	0.024		0.080		0.476	0.556	7.94	73	287		6.69
Corriveau	Ottawa	2002	24	13	14499612	4.10	113.0	0.011		0.082		0.236	0.318	7.40	27	74		5.77
La Peche	Ottawa	2002	14	3	10198759	2.03	144.5	0.031		0.022		0.470	0.492	7.51	31	76		9.97
CK21-003	Ottawa	2002	76	28	93368161	6.95	109.7	0.072	0.057	0.663	0.056	1.015	1.678	8.17	178	1410	17.8	10.83
CK63-001	Ottawa	2002	79	70	118543632	7.91	114.6	0.078	0.057	1.653	0.045	0.850	2.503	8.19	221	608	7.5	9.88
CK63-265	Ottawa	2002	36	44	150614994	3.12	124.2	0.036	0.023	0.305	0.023	0.753	1.058	8.22	202	653	5.8	13.30
CK63-266	Ottawa	2002	84	63	300573236	4.09	27.8	0.053	0.035	0.528	0.037	0.803	1.330	8.18	212	768	7.8	10.63
CK18-03-00	Ottawa	2002	106	24	66386623	5.16	114.9	0.022	0.007	0.180	0.010	0.532	0.712	8.11	229	845	4.3	7.38
CK18-Q	Ottawa	2002	146	14	90139133	9.07	62.4	0.088	0.031	0.893	0.042	0.710	1.603	8.13	227	1299	36.6	4.90
CK19-01	Ottawa	2002	34	23	115084742	8.05	86.3	0.045	0.020	0.788	0.030	0.608	1.395	8.10	220	935	11.3	5.15
CK20-10	Ottawa	2002	50	17	108911278	8.83	27.6	0.072	0.039	0.040	0.030	0.785	0.825	8.13	190	550	5.8	12.38
CK65-04	Ottawa	2002	61	31	78791928	6.46	86.8	0.073	0.036	0.113	0.022	0.688	0.800	8.07	169	648	7.8	8.98

STATION	Region	Year	CHLA	AFDM	BACT	AP	BP	TP	RP	NOX	NH34	TKN	TN	PH	ALK	COND	TSS	DOC
CK7-01	Ottawa	2002	120	27	165428387	14.28	286.5	0.081	0.048	1.210	0.025	0.715	1.925	8.12	195	950	29.0	10.13
CK8-01	Ottawa	2002	72	23	89993188	7.34	178.3	0.058	0.028	2.705	0.031	0.503	3.208	8.20	203	1055	21.5	6.70
CK9-01	Ottawa	2002	89	32	38584146	13.43	77.7	0.038	0.023	1.608	0.019	0.415	2.023	8.10	147	860	7.3	3.95

Table C.2. Sampling station names, locations, and identifiers for algae and bacteria study in Chapter 3. Station ID corresponds to Ontario Ministry of the Environment unique station identifiers for Waterloo stations and to City of Ottawa station identifiers for stations in the National Capital Region (NCR). Four stations in the NCR do not have unique identifiers (labelled 'n/a') because they are located in Québec and are not part of the City of Ottawa water quality monitoring network.

STATION	REGION	STATION ID	LATITUDE	LONGITUDE	STN_NAME
CK13-01	NCR	CK13-01	45.320008	-75.70001	Black Rapids Ck @ Prince of Wales Drive
CK18-03-00	NCR	CK18-03-00	45.337875	-75.63348	Sawmill Creek @ northeast tributary, at Lester and Albion Roads
CK18-Q	NCR	CK18-Q	45.38999	-75.67619	Sawmill Creek @ Riverside Drive westbound lane (downstream)
CK19-01	NCR	CK19-01	45.346534	-75.69626	Hunt Club Creek @ 200 meters d/s of Riverside Drive (southbound lane, b/w CNR tracks and Nelligan Drive)
CK20-10	NCR	CK20-10	45.282953	-75.66827	Mosquito Creek @ Limebank Road
CK21-003	NCR	CK21-003	45.420444	-75.59221	Green Creek @ Innes Rd Bridge, u/s of culvert
CK24-002	NCR	CK24-002	45.492664	-75.47075	Leonard/Cardinal @ Queen St
CK25-001	NCR	CK25-001	45.520245	-75.35815	Beckett's Creek @ Hwy 17 u/s of culvert
CK3-04	NCR	CK3-04	45.277111	-76.11426	Coady Ck @ March Road, near Peter Robinson Rd
CK31-01	NCR	CK31-01	45.399397	-75.28248	Bear Brook Creek @ Russell Rd, near Samure Rd
CK41-01	NCR	CK41-01	45.223708	-75.70187	Mud Creek @ Bankfield Rd, u/s of culverts
CK42-05-03	NCR	CK42-05-03	45.139852	-75.72669	Taylor Drain @ Fourth line rd, b/w Roger Stevens Rd and Phelan E.
CK42-07	NCR	CK42-07	45.089755	-75.79119	Steven Creek @ Roger Stevens Rd, as it exits Marlborough Forest (approx 2 km w of Malakoff Rd)
CK44-02	NCR	CK44-02	44.984983	-75.80118	Brassil's Creek @ Dwyer Hill Rd, near Donnelly Rd
CK5-01	NCR	CK5-01	45.373862	-75.93261	Shirley's Brook @ Fourth Line Rd, near 1375-Fourth Line Rd (1.5 km d/s of Klondike Rd)
CK63-001	NCR	CK63-001	45.252413	-75.39516	South Castor River @ Gregoire Rd, 250 m s of Victoria Rd
CK63-206	NCR	CK63-206	45.295569	-75.50547	North Castor River @ 8th line Rd, 1 km s of Mitch Owens drive
CK63-265	NCR	CK63-265	45.222163	-75.49306	Middle Castor River @ Hwy 31, 0.5 km s of Victoria Rd

STATION	REGION	STATION ID	LATITUDE	LONGITUDE	STN NAME
CK63-266	NCR	CK63-266	45.254733	-75.39676	Middle Castor/North Castor Rivers, @ intersection of Gregoire and Victoria Rds
CK65-04	NCR	CK65-04	45.383699	-75.97086	Harwood Creek @ Dunrobin Rd, near Thomas Dolan Parkway
CK7-01	NCR	CK7-01	45.349693	-75.82456	Stillwater Creek @ Carling Ave westbound lane, d/s of culvert
CK8-01	NCR	CK8-01	45.350396	-75.81594	Graham Creek @ Carling Ave westbound lane, d/s of culvert
CK9-1	NCR	CK9-1	45.373642	-75.78661	Pinecrest Creek @ Ottawa River Parkway, westbound lane, downstream of culverts, off the east shoreline, midstream
R010-32	NCR	R010-32	45.262433	-75.92558	Poole Ck @ Main Street, Stittsville, u/s of culvert
Blackburn	NCR	n/a	45.641313	-75.81519	Blackburn Creek, Québec
Chelsea	NCR	n/a	45.502086	-75.81147	Chelsea Creek, at Chelsea Picnic Area, Chelsea
Corriveau	NCR	n/a	45.684471	-75.73946	Corriveau Creek, Québec
LaPeche	NCR	n/a	45.621187	-76.09988	LaPeche, inside Gatineau Park, Québec
T1	Waterloo	4001302502	43.365	-81.018	Avon River @ Lorne Ave, Stratford
T6	Waterloo	4001304102	43.032	-81.000	Middle Thames River @ 2nd concession Rd south of Thamesford
T8	Waterloo	4001304402	43.447	-81.208	North Thames River @ Concession Rd 2 south of Mitchell
T13	Waterloo	4001305502	43.306	-80.849	Thames R @ Hwy 59 south of Tavistock
T15	Waterloo	4001306402	43.271	-81.096	Trout Ck @ Perth County Rd No 28, St. Mary's
T5	Waterloo	4001306902	43.044	-80.820	Folden's Ck @ Concession Rd No 3 West Oxford Township
C3	Waterloo	6007600302	43.648	-79.857	Credit R @ Hwy 7, Norval
C13	Waterloo	6007600402	43.647	-79.866	Credit R West Branch @ Hwy 7, Norval
C2	Waterloo	6007600802	43.629	-80.011	Black Ck @ First concession, u/s Limehouse
C5	Waterloo	6007601002	43.723	-79.931	Credit R @ County Rd 9, Terra Cotta
C6	Waterloo	6007601302	43.669	-79.927	Credit R @ 22nd Side Rd, Glen Williams
C12	Waterloo	6007601502	43.784	-80.036	Credit R Erin Branch @ Wellington and Peel County boundary
C15	Waterloo	6007601602	43.659	-79.742	Fletcher's Ck @ Steel's Avenue, Brampton
C8	Waterloo	6007601802	43.856	-80.049	Credit R @ 20 side road, Caledon Township
C11	Waterloo	6007602402	43.902	-80.053	Credit R @ Hwy 10, 2nd bridge below Orangeville
M1	Waterloo	8005600202	43.749	-81.446	Blyth Brook @ side road, W of Blyth
M5	Waterloo	8005600302	43.896	-81.354	Maitland River @ Hwy 86, 2 miles NW of Wingham
M6	Waterloo	8005600902	43.731	-81.028	Middle Maitland River @ Hamlet of Trowbridge

STATION	REGION	STATION ID	LATITUDE	LONGITUDE	STN NAME
M7	Waterloo	8005601302	43.727	-80.973	Middle Maitland River @ Hwy 23, d/s from Listowel
M3	Waterloo	8005603502	43.799	-81.170	Little Maitland River @ Grey Township Concession II, 2.5 Km east of James-
G5	Waterloo	16018402902	43.526	-80.515	Conestogo River @ Waterloo County Rd no 22
G30	Waterloo	16018403202	43.376	-80.678	Nith River @ 1st bridge d/s from New Hamburg
G20	Waterloo	16018403702	43.725	-80.344	Grand R @ 1st Concession d/s of Bellwood Lake
G1	Waterloo	16018403802	43.343	-80.532	Alder Ck @ first concession road S of New Dundee
G21	Waterloo	16018403902	43.894	-80.300	Grand R @ East Luther and Amaranth Township line
G4	Waterloo	16018405102	43.616	-80.560	Canagagigue Ck @ first concession N of Elmira
G28	Waterloo	16018409102	43.758	-80.748	Moorefield Ck @ County Rd 10, village of Morrefield
G9	Waterloo	16018410202	43.548	-80.184	Eramosa River @ County Rd No 41, Northwest of Arkell
G25	Waterloo	16018410402	43.695	-80.448	Irvine Ck @ William St, Salem
G35	Waterloo	16018410602	43.126	-80.384	Whiteman's Ck @ 1st concession rd west of Hwy 24A

**Appendix D: Data used in study of predictive power of
periphyton models (Chapter 4)**

Table D.1. Data used for meta-analysis of predictive power of periphyton regression models (Chapter 4). Reference: source of data;

Year: publication year; Dep: model of instantaneous (Inst) or temporal mean (Temp) chlorophyll; Indep: independent

variables in model; r2: reported r2 values; RMS: reported residual mean square; Area: geographic extent of study area;

Terms: number of independent terms in model; Model n: number of observations in model; Sample n: number of sampling replicates at one time; Temp n: number of dates sampled; MinChla: minimum reported periphyton chlorophyll *a* (mg chla m⁻²); MaxChla: maximum reported periphyton chlorophyll *a* (mg chla m⁻²). Refer to reference list of Chapter 4 for complete references to original data.

Reference	Year	Dep	Indep		r ²	rms	Area (km2)	Terms	Model n	Sample n	Temp n	No sites	MinChla	MaxChla
Kjeldsen 1994	1994	Inst	DIP (µg P/L)		0.61	0.075	33000	1	20	5	1	20	38	2235
Welch et al 1988	1988	Temp	Velocity		0.989	0.00061	1165	1	5	10	8	5	23	166
Biggs Close 1989	1989	Temp	Time in flood, TSS, flow		0.633	0.111	10000	3	9	5	29	9	5	136
Biggs Close 1989	1989	Temp	DRP, TIN		0.576	0.118	10000	2	9	5	29	9	5	136
Biggs Close 1989	1989	Temp	DRP, Time in flood, TIN, TSS, Flow, Rock size		0.939	0.102	10000	6	9	5	29	9	5	136
Alizaki Sakamoto 1988	1988	Inst	PO4		0.484	0.312	15400	1	26	1	1	26	3	1399
Alizaki Sakamoto 1988	1988	Inst	PO4		0.422	0.415	15400	1	13	1	1	13	3	1399
Alizaki Sakamoto 1988	1988	Inst	TIN		0.846	0.097	15400	1	11	1	1	11	3	1399
Chetelat et al 1999	1999	Inst	Conductivity µS/cm		0.71	0.058	35200	1	25	3	1	25	10	497
Chetelat et al 1999	1999	Inst	Log TP µg/L		0.56	0.071	35200	1	33	3	1	33	10	497
Chetelat et al 1999	1999	Inst	Log TN µg/L		0.5	0.079	35200	1	30	3	1	30	10	497
Bourassa Cattaneo 1998	1998	Inst	Log Velocity cm/s, depth cm		0.29	0.079	15000	2	46	6	1	23	3	62
Cattaneo 1996	1996	Inst	Distance from headwater m, DH ² , NH ₄ , Lake surface		0.68		70	4	42	8	1	14	16	126
Cattaneo 1996	1996	Inst	Distance from headwater m, DH ² , NH ₄		0.69		70	3	39	8	1	13	16	126
Cattaneo 1996	1996	Inst	Distance d/s from lake, dh, dh ² , surface area of lake		0.39		70	4	42	8	1	14	2	18
Cattaneo 1996	1996	Inst	Distance d/s from lake		0.27		70	1	39	8	1	13	2	18

Reference	Year	Dep	Indep	r ²	rms	Area (km ²)	Terms	Model n	Sample n	Temp n	No sites	MinChla	MaxChla
Uehlinger et al. 1996	1996	Inst	Average discharge, time since last spate of Qmax>14m ³ /s	0.56		10	2	43	17	1	1	1	240
Horner and Welch 1981	1981	Inst	Accrual time, Velocity cm/s, OrthoP µg/L	0.374		72.5	3	24	1	1	12	1	500
Horner and Welch 1981	1981	Inst	Accrual time, Velocity cm/s, OrthoP µg/L	0.459		72.5	3	13	1	1	12	1	500
Horner and Welch 1981	1981	Inst	Accrual time, Velocity cm/s, OrthoP µg/L	0.546		72.5	3	8	1	1	8	1	500
Horner and Welch 1981	1981	Inst	Accrual time, Velocity cm/s, OrthoP µg/L	0.779		72.5	3	7	1	1	7	1	500
Horner and Welch 1981	1981	Inst	Accrual time, Velocity cm/s, OrthoP µg/L	0.531		72.5	3	7	1	1	7	1	500
Horner and Welch 1981	1981	Inst	Accrual time, Velocity cm/s, OrthoP µg/L	0.699		72.5	3	15	1	1	15	1	500
Pan et al. 1999	1999	Inst	TP	0.0841		300000	1	89	11	1	89	3	50
Pan et al. 1999	1999	Inst	TN	0.241		50000	1	17	11	1	17	3	50
Pan et al. 1999	1999	Inst	TP	0.476		60000	1	12	11	1	12	3	50
Mosisch and Bunn 1997	1997	Inst	water depth in 2 weeks preceding sampling	0.516		1	1	12	10	1	1	10	11
Biggs 1995	1995	Temp	Flood frequency, high land use, alkaline rocks	0.89	0.0545	150000	3	15	10	13	15	2	281
Mulholland and Rosemond 1992	1992	Inst	SRP µg/L	0.125	0.015	1	1	28	4	7	4	21	67
Biggs and Hickey 1994	1995	Inst	Depth	0.237	0.184	1	1	54	3	1	1	0	54
Scrimgeour and Chambers 2000	2000	Temp	SRP and DIN µg/L	0.67	0.199	300000	2	33	10	2	33	9	677
Scrimgeour and Chambers 2000	2000	Temp	DIN µg/L	0.63	0.196	300000	1	33	10	2	33	9	677
Lohman et al. 1992	1992	Temp	LogTN	0.58	0.03382	2500	1	22	5	18	22	10	217
Lohman et al. 1992	1992	Temp	LogTN	0.6	0.02665	2500	1	22	5	18	22	10	217
Lohman et al. 1992	1992	Temp	LogTP	0.47	0.03799	2500	1	22	5	18	22	10	217
Lohman et al. 1992	1992	Temp	LogTP	0.6	0.02478	2500	1	22	5	18	22	10	217
Biggs et al. 1998	1998	Temp	Flood frequency, %cellular N	0.856	0.06154	150000	2	15	10	13	15	2	281
Martin et al. 2001	2001	Temp	TP (TN not significant in MR)	0.417	0.122	4715	1	9	6	1	9	4	57
Dodds et al. 2002	2002	Temp	logTN	0.3	0.215	15000000	1	198	5	2	198	0	500
Dodds et al. 2002	2002	Temp	logTP	0.13	0.26	15000000	1	254	5	2	254	0	500
Dodds et al. 2002	2002	Temp	logTN+logTP	0.38	0.184	15000000	2	193	5	2	193	0	500
Dodds et al. 2002	2002	Temp	Log TN	0.12		9372610	1	313	5	2	313	0	70
Dodds et al. 2002	2002	Temp	logDIN+logSRP	0.18		9372610	2	41	5	2	41	0	70
Dodds et al. 1997	1997	Temp	logIn, logIn2, logTP	0.474	0.171	95000000	3	141	5	2	141	0	428
Dodds et al. 1997	1997	Inst	logtp, logtp2, logIn	0.388	0.174	95000000	3	104	5	2	104	4	913
Uehlinger 1991	1991	Temp	Time since last flood, Qmax, temperature	0.689		10	3	29	1	29	10	5	525

Reference	Year	Dep	Indep	r^2	rms	Area (km ²)	Terms	Model n	Sample n	Temp n	No sites	MinChla	MaxChla
Rier and Stevenson 2001	2001	Inst	SRP	0.2		10000	1	40	5	1	40	0	70
Rier and Stevenson 2001	2001	Inst	NH4-N	0.441		10000	1	40	5	1	40	0	70
Marcus 1980	1980	Temp	TIN	0.929	0.0158	10	1	4	8	5	1	8	62
Rosemond 1994	1994	Inst	Irradiance (mmole quanta m ² day)	0.25	0.00562	1	1	11	20	1	1	11	23
Bernhardt and Likens 2004	2004	Inst	NOx	0.95	0.00229	1	1	5	10	6	1	3	8
Mosisch et al. 2001	2001	Inst	Riparian cover	0.48		225	1	15	2	1	15	10	40
Sand Jensen et al. 1988	1988	Inst	Cumulative irradiance (Einst m ⁻²)	0.79	0.08406	917	1	18	20	8	2	9	522
Stockner and Shortreed 1976	1976	Temp	Light - Percent penetration	0.651	0.07319	15	1	10	1	8	10	1	18
Carr et al 2004 (Chapter 1)	2004	Temp	LogNox, logTDP	0.227	0.234	460500	2	447	3	2	447	0	514
Carr et al 2004 (Chapter 1)	2004	Temp	PopDen	0.276	0.219	460500	1	447	3	2	447	0	514
Carr et al 2004 (Chapter 1)	2004	Temp	TDP PopDen	0.337	0.201	460500	2	447	3	2	447	0	514
Carr et al 2004 (Chapter 1)	2004	Temp	TDP PopDen	0.296	0.083	15000	2	171	3	2	171	4	211
Carr et al 2004 (Chapter 1)	2004	Temp	PopDen	0.125	0.17	79000	1	132	3	2	132	11	514
Carr et al 2004 (Chapter 1)	2004	Temp	Crop Density	0.197	0.197	59000	1	84	3	2	84	3	358
Carr et al 2004 (Chapter 1)	2004	Temp	TDP PopDen	0.398	0.095	47500	2	28	3	2	28	0	365
Carr et al 2004 (Chapter 1)	2004	Temp	NOx	0.156	0.262	260000	1	30	3	2	30	0	66
Carr et al. 2004 (Chapter 1)	2004	Inst	TDP NOx	0.239	0.224	460500	2	447	3	1	447	0	988
Carr et al. 2004 (Chapter 1)	2004	Inst	PopDen	0.249	0.221	460500	1	447	3	1	447	0	988
Carr et al. 2004 (Chapter 1)	2004	Inst	TDP PopDen	0.323	0.22	460500	2	447	3	1	447	0	988
Carr et al 2004 (Chapter 3)	2004	Inst	LogNOx, logBacteria, LogBacteria2	0.694	0.038	17500	3	75	6	1	75	4	214
Carr et al 2004 (Chapter 3)	2004	Inst	LogNOx	0.378	0.068	17500	1	75	6	1	75	4	214