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The diversity and community composition of aquatic macrophytes in relation to physical and chemical environmental variables in the Rideau River, Ontario

by

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Table of Contents

Chapter 1:

Chapter 2:

List of Tables

List of Figures

List of Appendices

Abstract

Like many rivers around the world, the Rideau River is under pressure from a number of human induced activities resulting in a loss of species and habitat. In order to prioritise conservation efforts, it is necessary to understand what type of habitats will support the widest range of species. This study examines which physical and chemical factors exert the strongest influence on the diversity and community composition of aquatic macrophytes in the Rideau River. Macrophyte species were surveyed at 33 sites on the Rideau River, Ontario, in six 1 m^2 quadrats aligned in a belt transect perpendicular to shore along a depth gradient of 0.5 m to 2.0 m. Regression analysis showed species richness and Shannon diversity were significantly related to water velocity, transect length, slope, and organic content. Multiple regression provided a model whereby 70% of species richness was explained by organic content, transect length, water velocity and chlorophyll a, and 77% of Shannon diversity was explained by organic content and water velocity. Mantel tests showed only chlorophyll a was weakly correlated with species composition. Canonical correlation analysis showed floating and floating-leaved species to favour habitats with low water velocity. No other significant patterns were found. It appears that while species diversity can be predicted from physical environmental variables, species composition cannot.

Résumé

Comme de nombreux cours d'eau à travers le monde, la Rivière Rideau subit les effets d'activités humaines, qui peuvent resulter en une perte d'espèces et d'habitats. Afin de donner un ordre de priorité aux efforts de conservation, il est nécéssaire de comprendre quels types d'habitats supportent la plus grande variété d'espèces. Cette étude examine quels facteurs physiques et chimiques exercent les plus fortes influences sur la diversité et la composition des communautés de macrophytes aquatiques de la Rivière Rideau. Les espèces de macrophytes furent étudiées à 33 sites le long de la Rivière Rideau, Ontario, dans six quadrats de 1 m^2 alignés selon une transecte perpendiculaire à la berge et selon un gradient de profondeur de 0.5 m à 2.0 m. L'analyse de régression a démontré que la richesse des espèces et la diversité Shannon étaient significativement reliées à la vitesse du courant, la longueur de la transecte, la pente et le contenu organique des sédiments. La régression multiple a produit un modèle selon lequel 70% de la richesse des espèces s'explique par le contenu organique, la longeur de la transecte, la vitesse du courant et la chlorophylle a, et 77% de la diversité Shannon s'explique par le contenu organique et la vitesse du courant. Les tests Mantel ont démontré que seule la cholorphylle a était faiblement correlée avec la composition des espèces. Une analyse de correlation canonique a démontré que les espèces flottantes et à feuilles flottantes préfèrent les habitats avec une faible vitesse de courant. Aucune autre tendance significative n'a été trouvée. Il semblerait que, si la diversité d'espèces peut être prédite à l'aide des variables environnementales, la composition des espèces ne peut pas l'être.

General Introduction

Like their terrestrial counterparts, aquatic plants (macrophytes) have a number of important functions in aquatic ecosystems, the most basic being primary production. Aquatic macrophytes are distinguished from microscopic algae, the other main primary producer in aquatic systems. The relative contribution of macrophytes compared to algae depends on the nature of the water body. Macrophytes will only grow to a depth where there is a sufficient quantity of light to maintain photosynthesis, therefore large deep lakes and rivers will have only a narrow band of macrophytes around their edges, with the rest of the open water being occupied by planktonic algae. Shallow lakes and rivers can be either algae or macrophyte dominated depending on water clarity. There is evidence to suggest that competition for light and nutrients between macrophytes and phytoplankton ensures that one is usually dominant, and that a change in dominance is not easily reversed (Scheffer et al., 1993).

Aquatic plants vary in their tolerance to inundation. Emergent wetland species will grow in waterlogged soils to water depths of 0.5 metres or more. While rooted below the water, these species grow above the surface. Floating-leaved species are rooted in the sediment, with leaves floating on the water's surface, and occupy depths of 1 to 2 metres. Water-lilies (*Nymphaea, Nuphar*) are the best-known examples. Submerged species grow mostly under water in depths of 0.5 metres or more. Many of these species will have flowers growing just above the surface to facilitate pollination. Free-floating species such as *Lemna spp.* or *Spirodella spp.* are not rooted and common in quiet backwaters. Emergent, floating, and submerged plants form the three main functional groups of aquatic macrophytes. Some researchers also distinguish between erect, canopy-forming (elodeids), and bottom dwelling (isoetid) species of submerged plants and between free-floating (spirodelid) and floating-rooted (nymphaeid) plants. (Kalff, 2002; Scheffer, 1998; Eiseltova, 1994)

As food, macrophytes contribute more to the detrital food chains than the grazing food chains. (Carpenter and Lodge, 1986). While some macrophytes are consumed fresh by waterfowl and mammals, most aquatic consumers tend to feed on plankton, which has a higher nutrient content (Kalff, 2002). Macrophyte detritus, however, provides a good food source for invertebrates. Macrophytes also provide a substrate for periphyton which is also a food source for invertebrates (Carpenter and Lodge, 1986).

The presence of macrophytes allows for a higher diversity of fish, zooplankton and invertebrates. Macrophytes provide a daytime refuge for zooplankton and small fish to escape predation from predators (Chambers et al., 1999). Lakes without macrophytes were found to have a different species composition of zooplankton and fish (Scheffer, 1998). Macrophytes also slow water velocity and trap nutrient rich particles and organic matter (Chambers and Prepas, 1994), which provides a good substrate for fish eggs (Scheffer, 1998).

The relationship between macrophytes and their environment is a complex one. Macrophyte productivity, usually measured in terms of changes in biomass, has been found to be affected by a variety of factors. Macrophyte biomass has been found to be positively correlated with sediment organic content, phosphorus, nitrogen, and fine particulate matter (Carr and Chambers, 1998; French and Chambers, 1996). Nutrient concentrations in water do not appear to have as strong an influence on macrophyte standing crop as sediment nutrients (Canfield and Hoyer,1988), except under eutrophic conditions (Carnigan and Kalff, 1990). Experiments also show that nutrient uptake in rooted macrophytes comes mostly, if not entirely from sediment rather than from the water column (Carnigan and Kalff, 1990, Chambers et al, 1989).

Macrophyte abundance is also negatively correlated with current velocity (Chambers *et al.*, 1998; French and Chambers, 1997, 1996). There is some speculation that the impact of water velocity is mainly due to the washing away of organic material and fine particles (Nilsson, 1987), but an experiment with potted macrophytes by Chambers et al (1991) showed that biomass was negatively correlated with an increase in velocity regardless of sediment texture.

There has been less of a focus on morphological features such as littoral slope, depth and distance from shore, but these factors also have been shown to be related to macrophyte biomass (Chambers and Prepas, 1990). Duarte and Kalff (1986, 1990) found littoral slope to be a strong predictor of macrophyte biomass in lakes. Light availability has been found to limit macrophyte growth in small narrow streams where canopy cover can be signficant (Canfield and Hoyer, 1988; Haury, 1996), in deep lakes or rivers (Hudon et al, 2000; French and Chambers, 1996; Duarte and Kalff, 1990), and in brown-water systems (Toivonen and Huttunen, 1995; Stewart and Freedman, 1989) and under eutrophic conditions (Bini *et al.*, 1999).

Macrophytes, in turn, have an effect on temperature (Carter et al., 1991), water velocity (Butcher, 1933), substrate (Sand-Jenson, 1998), and concentrations of oxygen, nitrogen, phosphorus (Stephen *et al.*, 1997; Carter *et al.*, 1991; Landers, 1982), and dissolved organic carbon (Wetzel, 1999; Carpenter and Lodge, 1986). The presence of macrophyte beds also facilitates further establishment of macrophytes by slowing down water velocity, contributing organic material and nutrients to sediments, and trapping fine particles (French and Chambers, 1996; Carpenter and Lodge, 1986). Indeed, as Westlake (1973) states, "Much has been written about factors controlling the distribution of aquatic plants, but the complexity of the field situation is often not recognised, and oversimplified explanations are common".

Most macrophyte studies have focussed on overall macrophyte biomass and extent of colonisation. Few studies examine species diversity and composition beyond course functional groups. As well, most limnological studies have been on lakes or small rivers and streams in relatively pristine forest catchments. There is a need for studies in larger rivers, rivers in populated areas, and rivers that are modified or dammed (Kalff, 2002). These rivers, while not in a "natural state" nonetheless make up a significant part of the landscape, and therefore need to be better understood if management decisions are to be made on scientific principles.

The purpose of this study is to examine the relative importance of physical and chemical habitat characteristics on aquatic plant (macrophyte) diversity and community composition within one medium sized regulated river. Aquatic macrophytes were chosen as the organism of focus since they are easily identified *in situ*, they are sessile and thus better reflect local conditions than motile species and are an important component of aquatic systems that have an effect on other organisms. For these reasons they have been been recommended for use as indicators of water quality and aquatic ecosystem health (Holmes, 1996, in Demars and Harper, 1998; Haury, 1996).

This study focussed on one river for a variety of reasons. Aside from logistical considerations, most limnological studies compare different water bodies (and usually lakes). Management, however, typically occurs on the scale of one lake or river: rarely does one find more than two or three watersheds within a jurisdictional boundary. Rivers, being long and narrow, will even tend to cross jurisdictional boundaries. Most rivers and lakes tend to be managed through a series of small scale local decisions, such as whether to approve a boathouse, re-inforce a bank, or let water out of a reservoir to prevent flood damage. By understanding patterns and processes within a river, one could better predict the effects of a decision at a particular site.

The river that is the focus of this study is the Rideau River, a lake fed medium size river located in eastern Ontario, Canada. Like most rivers in populated areas, the Rideau River is under pressure from land development, nutrient contamination, boat traffic, and exotic species introduction (Poulin, 1999). Key management concerns are nutrient enrichment resulting in blooms of filamentous algae, invasion by zebra mussels (*Dreissena polymorpha*), and clogging of navigational channels by aquatic weeds (Poulin, 1999). About 2 to 5 tonnes per hectare of plant material, mostly Eurasian milfoil (*Myriophyllum spicatum*) and curly pondweed (*Potamogeton crispus*) is harvested from navigational channels each year, costing over $65,000 (Rideau River Roundtable, 2001).

A recent initiative by the Canadian Museum of Nature and the Rideau Valley Conservation Authority called the Rideau River Biodiversity Project involved an extensive survey of the biodiversity of the Rideau River. This project has also brought together stakeholders in the

Rideau River watershed and begun a community consultation process to discuss key issues and develop long term planning and conservation objectives.

The macrophyte component of the Rideau River Biodiversity Project identified the presence of 59 aquatic plants. The most frequently encountered species were *Vallisneria americana, Elodea canadensis, Ceratophyllum demersum, Myriophyllum sibiricum*, and *Lemna trisulca*. *Vallisneria americana* is an isoetid species with long flexible leaves. It is very common in the St. Lawrence seaway (Hudon, 1997). *Elodea canadensis* is common throughout North America and has been known to reach nuisance proportions in Europe. *Ceratophyllum demersum* and *Lemna trisulca* are both non-rooted submerged species. *Myriophyllum sibiricum* is a water-milfoil native to North America. Six long term monitoring sites were established on the river to show long term trends in macrophyte community composition. Preliminary analysis showed that the relative abundance aquatic macrophyte species is very dynamic at the quadrat level with shifts in dominance within and between seasons. No decline in diversity occurred over the four seasons that observations were made.

The following study examines the relationship between key environmental variables and macrophyte diversity. This study can be seen as an extension of the Rideau River Biodiversity Project, furthering an understanding of the mechanisms influencing macrophyte diversity in the Rideau River and providing the tools necessary to determine key areas for priority in habitat conservation. The first chapter examines the extent to which the variation in physical and chemical properties of the Rideau River affect macrophyte biodiversity, and the second chapter examines their influence on community composition.

Chapter 1:

Biodiversity of aquatic macrophytes in the Rideau River.

Introduction

There have been a number of theories put forward with regards to what controls the diversity of species both at a global and local scale. On a global scale species richness has been found to relate to latitude, productivity, climate and available energy, and evapotranspiration, while on a local scale key features are habitat size and heterogeneity, productivity, and levels of disturbance (Rosenzweig, 1995). Species richness has been found to be highest at an intermediate point on the productivity-stress gradient (Grime, 1973; Tilman, 1982) and at intermediate levels of disturbance (Connell, 1978; Huston, 1979). The effects of productivity, stress and disturbance have been combined by Huston (1979) into a dynamic equilibrium model that accounts for the effects of disturbance offsetting the effects of productivity. However, a recent challenge to this theory has been posed in a meta-analysis by Mackey and Currie (in press), which shows that the unimodal relationship between diversity and disturbance is not as common as previously thought.

Species richness has also been found to increase with the size of the habitat (Gleason, 1922; MacArthur and Wilson, 1967). Habitat size is believed to be correlated with habitat heterogeneity (Rorslett, 1991; Rosenzweig, 1995), which has been found to contribute to species richness (Whittaker, 1956; Tilman and Pacala, 1993), possibly by allowing for a greater level of niche differentiation (Connell, 1978) and reducing the intensity of interactions between species (McLaughlin and Roughgarden, 1993).

While many of the theories surrounding biodiversity have been developed by examining terrestrial systems, they appear to apply to aquatic habitats as well. The dynamic-equilibrium model has been corroborated for algal species (Proulx *et al.*, 1996), riparian wetland plants (Pollack et al, 1998) and invertebrates (Townsend *et al.*, 1997). Macrophyte species richness has been found to be related to factors correlated with productivity such as water depth, light attenuation (Willby *et al.*, 2001), standing crop (Dobson et al, 2000; Day et al, 1988; Auclair 1976), nutrient concentrations and trophic status (Jeppesen *et al.*, 2000; Thiebaut and Muller, 1998); factors that affect biomass removal such as water velocity (Nilsson, 1987), boat traffic (Willby et al, 2001; Asplund and Cook, 1997) water level fluctuations (Wilcox and Meeker, 1991; Baattrup-Pederson and Riis, 1999; Rorslett, 1991), exposure (Bailey, 1988), and flood frequency (Pollack *et al.*, 1998; Nielsen and Chick, 1997; Barrat-Segretain and Amoros, 1996); and factors related to habitat heterogeneity (Pollack *et al.*, 1998; Jacques, 1996) and habitat size (Rorslett, 1991).

Many of the theories of biodiversity have been developed from observation of herbaceous plant species (e.g. Gleason, 1922; Grime, 1973; Tilman and Pacala, 1993) and then extended to other organisms. Plants have the advantage of being sessile (except for some free-floating species) and therefore highly responsive to local scale environmental variation as well as being easy to survey. These advantages are also true for aquatic plant species (macrophytes).

The objective of this study is to examine the relative importance of physical and chemical habitat characteristics on aquatic macrophyte species richness and diversity within one medium sized regulated river. The characteristics most likely to affect species diversity within a single river would be those that are related to productivity, disturbance, and habitat size and heterogeneity. Those associated with larger scale patterns in diversity such as latitude, climatic predictability, ecological and evolutionary age would not apply in this case. The specific physical and chemical characteristics associated with productivity, disturbance and habitat size which were examined were: water velocity, width of littoral zone, cross-sectional slope, substrate organic content, sediment and water nutrients, riparian features, and adjacent land use.

Hypotheses

It was expected that species richness and diversity could be predicted from physical and features and water chemistry at the scale of an individual river.

Diversity was expected to increase with a decrease in water velocity, then level out or decrease at very low water velocity, thus reflecting the peaked relationship due to stress described by Grime (1973).

Diversity was expected to be highest at intermediate levels of sediment organic content, since productivity would be expected to increase with sediment organic content, whereas a lack of organic matter would constitute a stress.

Diversity was expected to increase with littoral width, since a greater littoral width would mean a larger habitat, and possibly a more heterogeneous habitat, thus reflecting the relationship between species and area as described by MacArthur and Wilson (1967).

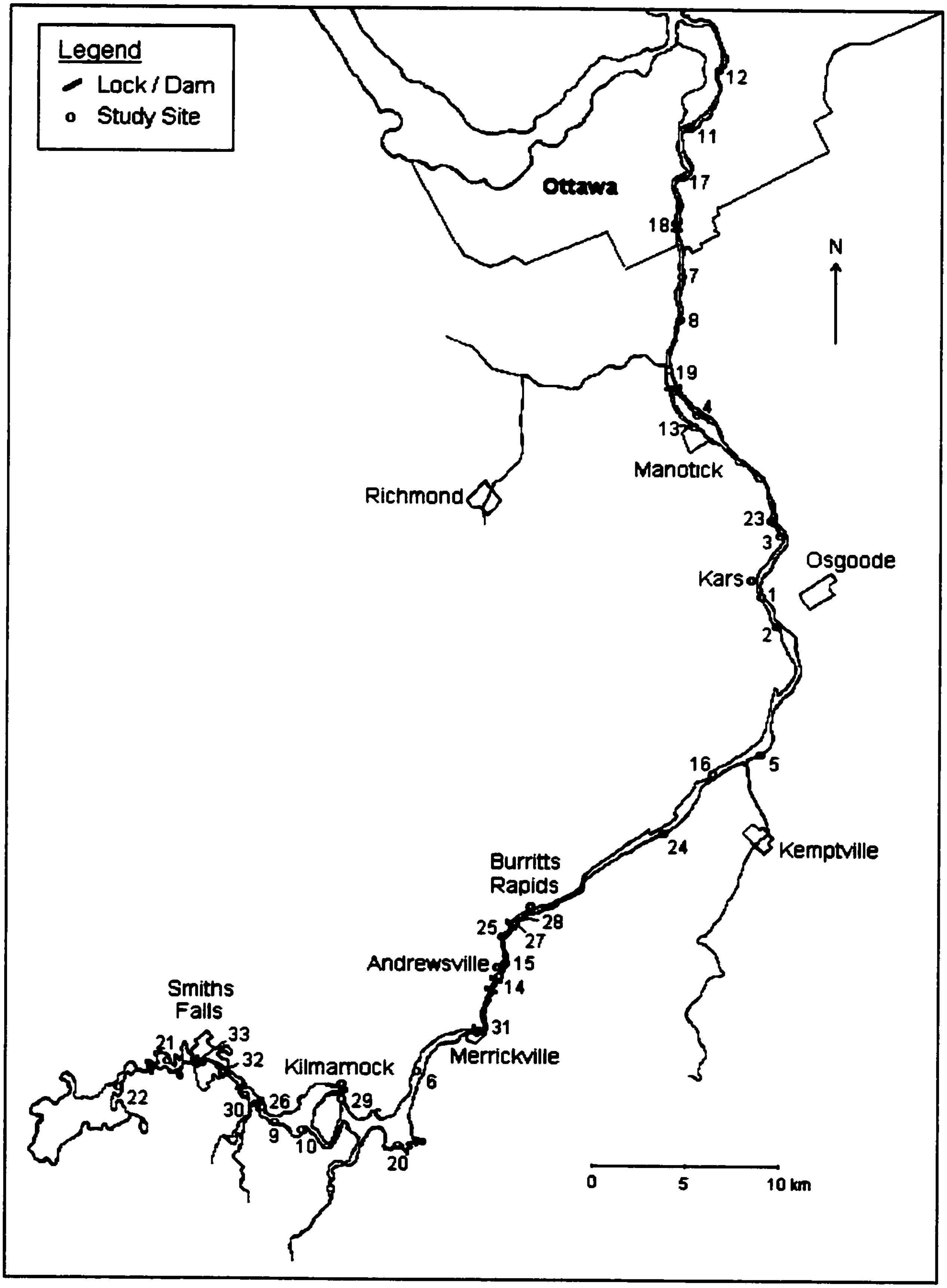
Diversity was expected to decrease with an increase in water nutrient content, since the Rideau River is already known to be enriched (Basu and Pick, 1997). Higher levels of nutrients would therefore increase productivity and eliminate species due to competitive exclusion.

Study Site

The Rideau River, a lake fed medium size river (about equivalent to fifth order) located in eastern Ontario, Canada (see Figure 1-1) is 110 km in length, has an average width of 250 metres, and drains an area of 3830 km^2. Depth ranges between 1 and 10 m, with the deeper portions being limited to the navigational channel, while 70% of the river is less than 2 metres in depth (Preece, 2001). It is also a major navigational river, being part of the Rideau Canal which is used by over 500,000 mostly recreational boaters a year (Spicer and Catling, 1990) and is considered a Heritage waterway. Since discharge and water levels are regulated by Parks Canada to prevent flooding and to maintain the navigational channel depth (Water Survey of Canada, 1990), water level fluctuations rarely exceed 10 cm during the navigation season (Parks Canada, unpublished data). A winter draw-down of about 2 metres occurs in the lower more-urbanised section from Manotick to Ottawa in navigable portions of the river, but appears to have little effect on water levels in the non-navigable portions of the Rideau River between Mooney's Bay and the Ottawa River (personal observation). The river is mesotrophic to eutrophic, with phosphorus levels ranging between 7-39 μg/L (Basu and Pick, 1997). High concentrations are observed downstream of Kemptville, where levels exceed Canadian Water Quality Guidelines (Basu and Pick, 1997). Nitrogen to phosphorus ratios are between 19-28 μg/L, suggesting that the system is phosphorus limited.

The most undisturbed portions of the river are from Merrickville to Edmonds Lock, and from Smiths Falls to Lower Rideau Lake. Shorelines are characterised by cattail marshes or forested swamps, with adjacent upland forests. The Smiths Falls portion of the river is channelized as it passes through several locks. Much of the adjacent shoreline is public park land, with some private residential land. From Merrickville to Manotick the land use is mostly agricultural. A strip of riparian vegetation is usually present between fields and the river. From Manotick to Mooney's Bay much of the shoreline on both sides of the river is privately owned residential land. Shoreline modifications vary in severity, but overall are characterised by reinforced banks and boat docks. The urban portion of the river within Ottawa is mostly surrounded by public park on both sides of the river. This is a popular recreational area, and is also used as a bicycle corridor. There are no major industries in the watershed.

Figure 1-1: Map of the Rideau River, Ontario, Canada, showing sample sites. Sites are numbered in the order that they were sampled.


Legend
Lock / Dam
Study Site
Ottawa
N
Richmond
Manotick
Kars
Osgoode
Kemptville
Burritts Rapids
Andrewsville
Merrickville
Kilmarnock
Smiths Falls
12
11
17
18
7
8
19
4
13
23
3
1
2
16
5
24
28
25
27
15
14
31
6
33
32
21
22
26
30
29
9
10
20
0
5
10 km

Methods:

Field Sampling

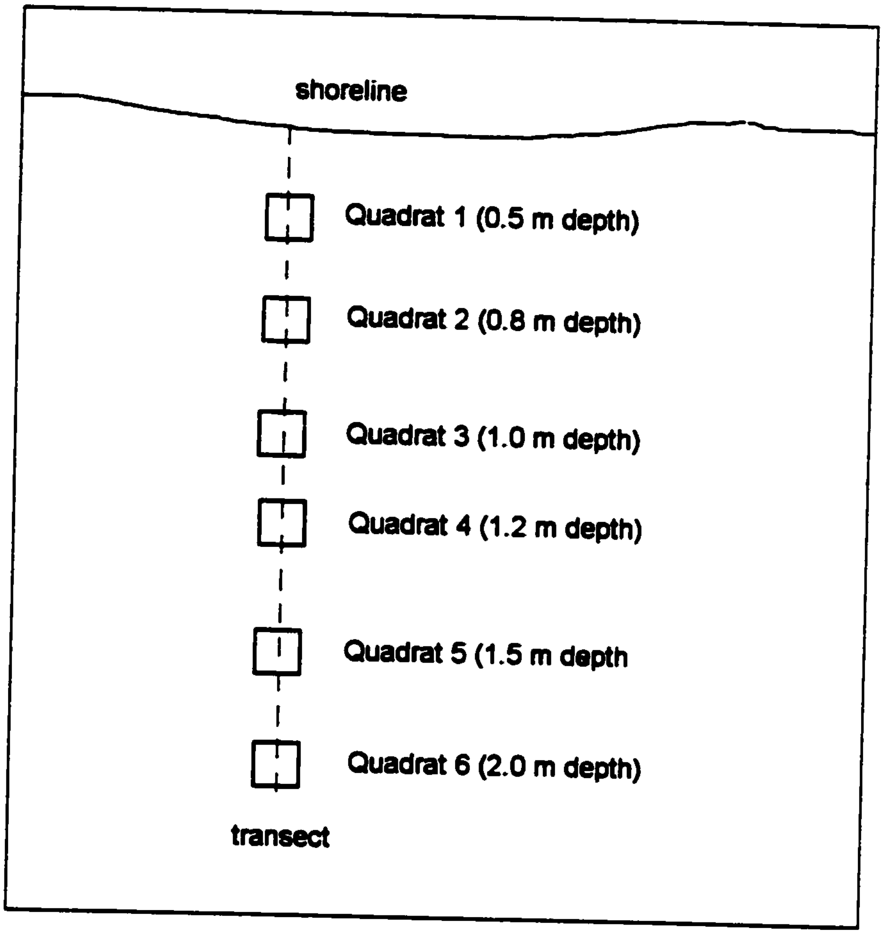
Thirty-three sites were sampled along the Rideau River from Lower Rideau Lake to Ottawa during July and August, 2000 and 2001. Sites were chosen to represent the range of conditions on the Rideau River in terms of channel morphology, distance along the river, water velocity, river width, and adjacent land use. Sites were first selected from navigational maps, and adjusted depended on field conditions. Care was taken to not look in the water at the macrophytes before selecting the location for sites and quadrats to prevent bias towards interesting species.

For the purposes of this study, aquatic macrophytes include vascular plants, and plant-like colonial algae (Characeae). Filamentous metaphytic algae (e.g. Cladaphora, Spirogyra), which are often associated with macrophyte beds, were not included.

Sampling and measurements were made in six $1 m^2$ quadrats aligned in a belt transect perpendicular to the shore, at depths of 0.5 m, 0.8 m, 1.0 m, 1.2 m, 1.5 m, and 2.0 m (see Figure 1-2). If the depth did not reach 2.0 metres, quadrat 6 was established at the deepest point in the channel, and the other quadrats were set as close to the predetermined depths as possible. The distance to shore from quadrat 6 was determined to be the littoral width. Preliminary data from the Rideau River showed six quadrats were adequate in order to sample most of the species at a site (Appendix 1-1), as well as being the number of quadrats that could be sampled in one day under the most difficult field conditions.

Figure 1-2: Diagram of Transect. Data were collected in belt transects composed of six quadrats spanning a depth gradient of approx. 0.5 to 2.0 m.

Figure 1-2


shoreline
Quadrat 1 (0.5 m depth)
Quadrat 2 (0.8 m depth)
Quadrat 3 (1.0 m depth)
Quadrat 4 (1.2 m depth)
Quadrat 5 (1.5 m depth
Quadrat 6 (2.0 m depth)
transect

At each quadrat, species were listed and cover estimates made for each species using a Braun-Blanquet scale from 1 to 5 (Braun-Blanquet, 1932) with cover values as follows: 1: up to 5%, 2: 5-25%, 3: 25-50%, 4: 50-75%, 5: 75-100%. Species were observed either from a boat using a viewing tube, or from the water using a mask and snorkel. Samples were taken of unidentified macrophyte species for later identification. Water velocity was calculated at each quadrat using the time it took an orange to travel 1 metre. If after 2.0 minutes the orange had not yet moved 1.0 m, the velocity was considered below detection and was entered as 0.005 m/s. The distance from each quadrat to shore was measured directly. Bank height and the depth at shore were also measured.

A sediment sample was collected from the top 5 cm of the surface by hand at each quadrat. Sediments were analysed for total organic content by measuring the loss on ignition at 500°C for 2 hours.

Underwater slope was calculated from depth and distance measurements using the following formula solving for θ:

$$\text{tangent } \theta = (\text{depth}_2 - \text{depth}_1) / (\text{distance}_2 - \text{distance}_1)$$

where depth_2 and distance_2 were depth and distance at the deeper adjacent quadrat and depth_1 and distance_1 were the depth and distance at the shallower adjacent quadrat (Appendix 1-2 for a sample calculation).

At quadrats 3 and 6 (1.0 m and 2.0 m) dissolved oxygen and pH were measured, and water samples were taken and analysed by the City of Ottawa surface water quality laboratories using standard methods for total and reactive phosphorous, total Kjedahl nitrogen and NH_3. Chlorophyll-*a* was extracted using DMSO and 90% acetone (Burnison 1980) and calculated from photospectrometer readings (Jeffery and Humphrey, 1975). Chlorophyll-*a* concentration is a reflection of phytoplankton biomass, as well as an indicator of light attenuation.

Shoreline features were approximately 300 m upstream and downstream from the site and adjacent land use within 1-2 km from the site were noted and then assigned to one of four categories. For adjacent land use the categories were: agricultural, forested, residential and urban. For shoreline features the categories were lawn (mowed to the water's edge), forest, wetland, and undisturbed riparian strip (usually a strip of 2-5 metres back from the river's edge that is let to grow undisturbed).

For analyses comparing sites, data were summarised for each site as follows: each species was tallied according to the number of quadrats they were found in, giving a frequency measure between 1 and 6; species richness was the total number of species found at the site; velocity and sediment organic content were averaged over the six quadrats; width of littoral zone was simply the distance to shore at quadrat 6 (usually at 2 metres depth); water quality measurements were averaged over the two samples. Shannon diversity (H) was calculated for the site using the following formula:

$$H = -\sum_{i=1}^{n} (p_i \ln p_i)$$

where p_i is the the number of quadrats in which the ith species is found (out of 6 quadrats per site), n is the number of species and ln is the natural log.

Vascular plant species were identified using Crow and Hellequist (2000), and Charaphytes using Wood (1967). Vouchers were taken of all species and deposited in the herbarium at the Canadian Museum of Nature in Aylmer, Québec.

Statistical analysis

Model I regression analysis was used to analyse the relationship between species richness and each of the environmental variables (water velocity, organic content, slope, littoral width, chlorophyll-*a*, pH, ammonia, total Kjeldahl nitrogen, reactive phosphorus, and total phosphorus), and between Shannon diversity and the aforementioned variables. Log transformation was done on all independent variables except total Kjeldahl nitrogen (TKN) and pH in order to obtain a normal distribution of the data and a linear relationship between the dependent and independent variables. Normality was determined using Lilliefor's probability test (Appendix 1-3) and linearity by visual inspection of the plotted data. Variation in species richness according to land use and adjacent shoreline features was analysed using analysis of variance (ANOVA).

All continuous independent variables were combined in a multiple regression in order to build predictive models for species richness and Shannon diversity. The two categorical variables, adjacent land use and riparian features, were excluded from the model building exercise since the sample size was not large enough to yield meaningful results. Backwards and forwards stepwise selection using alpha to enter/leave at 0.15 were compared to determine the optimal model for species richness and Shannon diversity.

A principal components analysis was done to determine if some of the environmental variables could be combined. Littoral width and sediment organic content had very similar loadings as did the four nutrient variables (Appendix1-4). Given the loadings for sediment organic content and littoral width, there might have been some justification for eliminating one of these from the analysis, but it was decided to keep them both since littoral width and sediment organic content represent quite different features, and the reduction of one variable from a set of eight was not likely to provide much model simplification. The nutrient data, whilst having similar loadings, were not so similar as to be considered essentially the same variable. Some attempt was made to combine the variables into one using their first principal component, but this had little effect on the loadings of the other variables and would only complicate the final interpretation. It was decided to use all nutrient variables in the model.

In light of their exclusion from the multiple regression, the relationship between the two categorical variables, adjacent land use and riparian features, and the independent continuous variables were examined using ANOVA.

Results

A total of 38 species of aquatic plants were observed in the quadrats out of 59 species recorded during by the Rideau River Biodiversity Study (Gillespie *et al.*, in prep). The most ubiquitous species found were tape-grass (*Vallisneria americana*, 29 of 33 sites), Canada water-weed (*Elodea canadensis*, 25 sites), star duckweed (*Lemna trisulca*, 24 sites), and coontail (*Ceratophyllum demersum*, 23 sites)(Table 1-1). An additional 13 species were observed in the river, but did not land in the quadrats. Nine of these species were emergents that typically grow in water less than 0.5 metres in depth, and while common in the shallow water close to the shoreline, they did not appear in the quadrats. The eight species that were not found at all were rarely found in the Rideau River Biodiversity Study.

Species richness per site ranged from 0 to 14, and Shannon diversity from 0 to 2.98. Up to 11 species were found in a 1 m^2 quadrat, with the maximum richness found at depths from 0.8 to 1.5 metres (Figure 1-3). Species richness was low from Manotick downstream to Ottawa, never exceeding 9 species per site (Figure 1-4). Species richness was also low at sites which were just below dams, where water velocity was fast and the substrate rocky. There are no dams between Burritts Rapids and Manotick.

Table 1-1: List of species, and the number of sites and quadrats in which each species were found. A total of 198 quadrats in 33 sites were surveyed.

Species	Family	sites found	quadrats found
Vallisneria americana L.	Hydrocharitaceae	29	91
Elodea canadensis Michx.	Hydrocharitaceae	25	74
Lemna trisulca L.	Lemnaceae	24	91
Ceratophyllum demersum L.	Ceratophyllaceae	23	85
Myriophyllum sibiricum Komarov.	Haloragaceae	17	47
Myriophyllum spicatum L.	Haloragaceae	17	47
Potamogeton zosteriformis Fern.	Potamogetonaceae	17	42
Zosterella dubia (Jacq.) Small.	Pontederiaceae	17	39
Nymphaea odorata Aiton	Nymphaeaceae	13	17
Najas flexilis (Willd.) Rostkov and Schmidt	Najadaceae	11	27
Ranunculis aquatilis L.	Ranunculaceae	11	27
Potamogeton pusillus L.	Potamogetonaceae	10	23
Butomus umbellatus L.	Butomaceae	9	14
Potamogeton crispus L.	Potamogetonaceae	9	11
Potamogeton richarsonii (Ar. Bennett) Rydb.	Potamogetonaceae	8	17
Spirodella polyrhiza (L.) Schleiden	Lemnaceae	8	12
Potamogeton pectinatus L.	Potamogetonaceae	7	12
Wolffia borealis (Engelm.) Landolt	Lemnaceae	7	12
Potamogeton friesii Rupr.	Potamogetonaceae	7	9
Hydrocharis morsus-ranae L.	Hydrocharitaceae	5	8
Nuphar variegata Durand.	Nymphaeaceae	5	8
Potamogeton robbinsii Oakes	Potamogetonaceae	5	8
Bidens beckii Torr.	Asteraceae	4	7
Alisma gramineum Gmel.	Alismataceae	3	5
Chara globularis Thuill	Characeae	3	3
Nitella flexilis (L.) Ag.	Characeae	2	6
Lemna minor L.	Lemnaceae	2	3
Chara vulgaris L.	Characeae	2	2
Sagittaria latifolia Pursh.	Alismataceae	2	2
Sparganium eurycarpum Engelm.	Sparganiaceae	2	2
Typha angustifolia L		2	2
Chara braunii Gm.	Characeae	1	2
Potamogeton foliosus Raf.	Potamogetonaceae	1	2
Scirpus pungens Vahl	Cyperaceae	1	2
Docodon verticillatus (L.) Elliott	Lythracaea	1	1
Phalaris arundinacea L.	Poaceae	1	1
Potamogeton amplifolius Tuckerman	Potamogetonaceae	1	1
Utricularia vulgaris L.	Lentibulariaceae	1	1

Figure 1-3: Macrophyte species richness in each quadrat against water depth. Species richness peaks at a depth of 1 metre, and declines as water deepens.

Figure 1-3

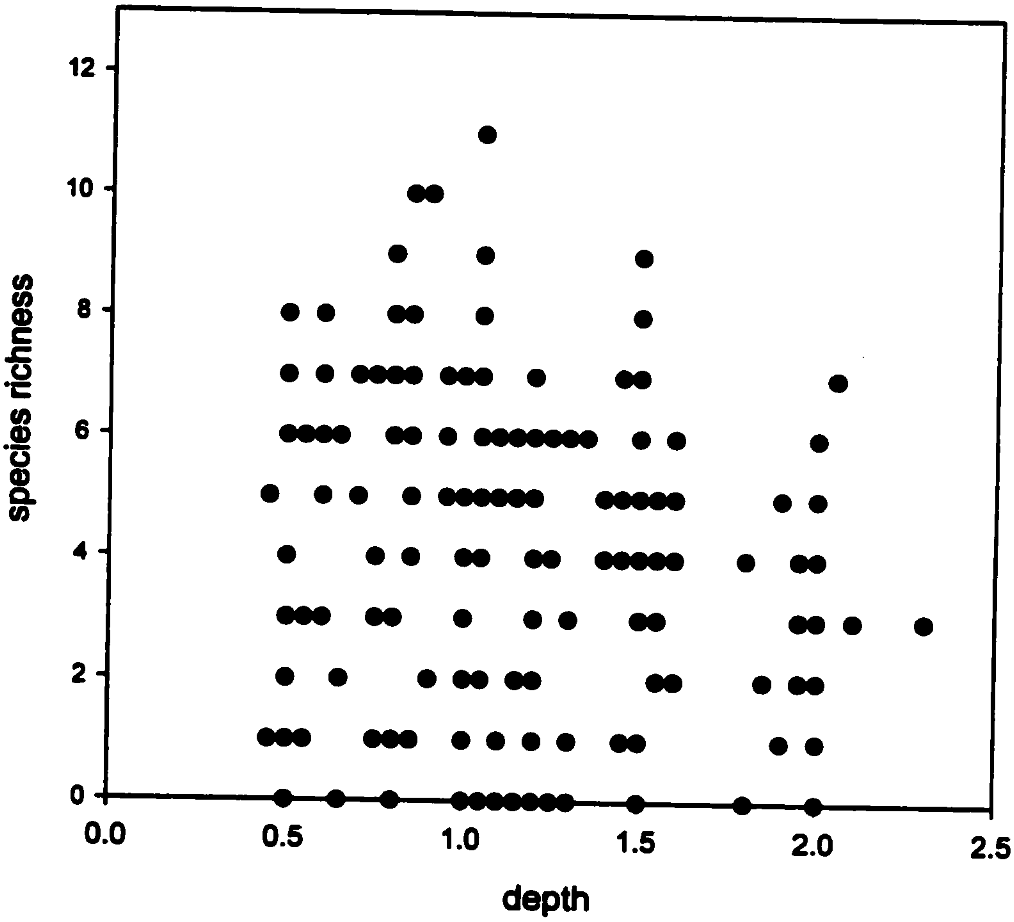
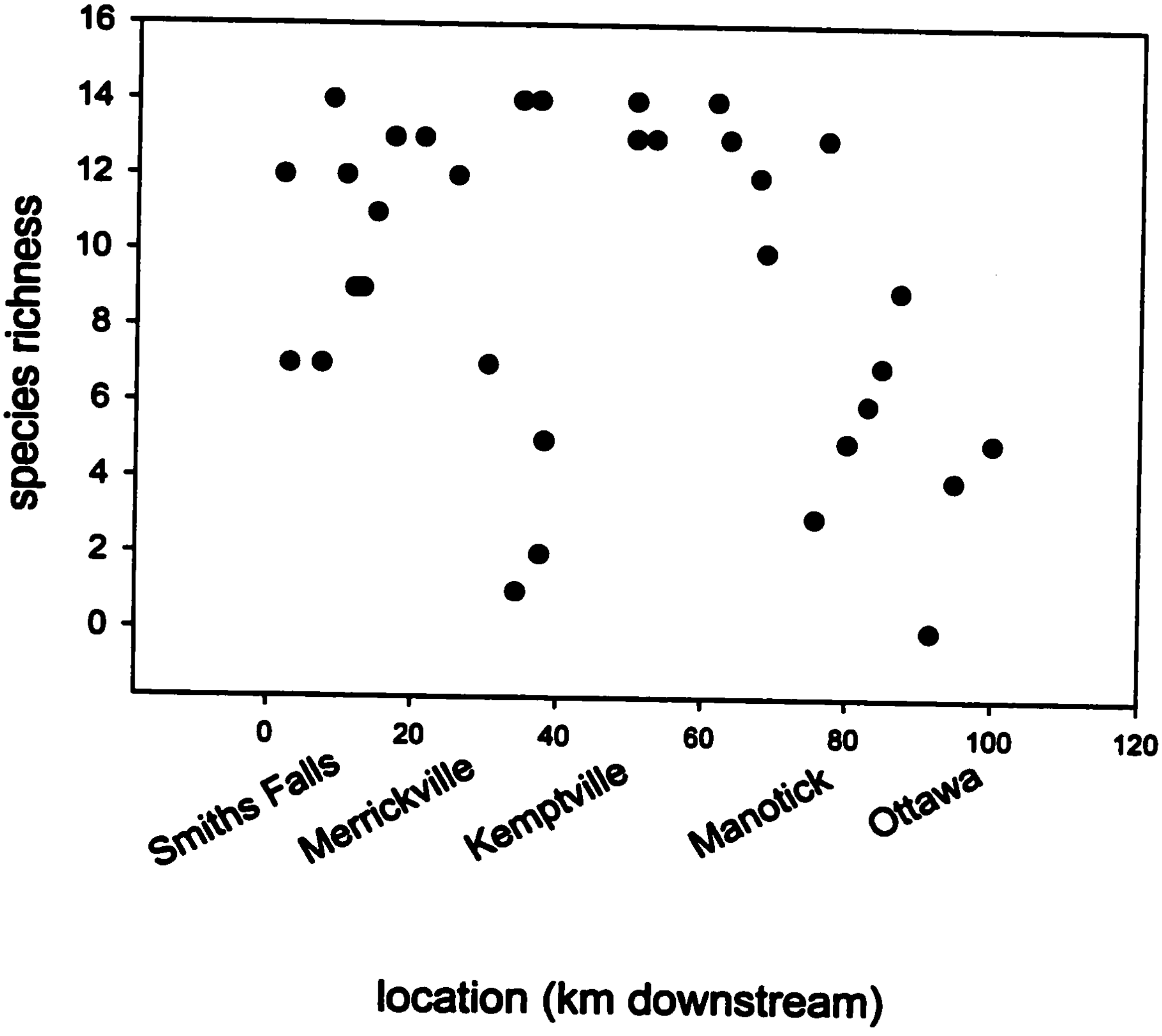


Figure 1-4: Scatterplot of aquatic macrophyte species richness against location in the Rideau River (measured in kilometers downstream). Communities along the river are shown for reference.

Figure 1-4



16
14
12
10
8
6
4
2
0
species richness
0
20
40
60
80
100
120
Smiths Falls
Merrickville
Kemptville
Manotick
Ottawa
location (km downstream)

There was a high correlation between species richness and Shannon diveristy ($r=0.928$, $p<0.001$). Shannon diversity is an index that takes into consideration the evenness of the species distribution as well as the number of species. The high correlation indicates an even species distribution within a site without any one species being dominant. There was also a high correlation between the number of sites where a species was found and the number of quadrats in which it was found ($r=0.964$, $p<0.001$) (Table 1-1) indicating that species were generally found throughout a site, rather than having a patchy distribution.

Linear regression showed that species richness increased significantly with littoral width and organic content, and decreased with an increase in water velocity and cross-sectional slope (Figure 1-5). Similar trends were noted for Shannon diversity (Figure 1-6).

The model best describing species richness (S) using backwards and forwards selection included per cent sediment organic content (OC), littoral width (LW), and chlorophyll-*a* (CA), ($r^2=0.703$, $p<0.001$)(Table 1-2a) and was as follows:

$S = 1.03 + 1.16\,OC - 1.05\,WV + 1.35\,LW + 1.34\,CA$

Manual selection showed that velocity and organic content accounted for much of the variation ($r^2=0.652$, $p<0.001$). For Shannon diversity (H), the best fitting model using backwards and forwards selection included only organic content and water velocity ($r^2=0.770$, $p<0.001$) (Table 1-2b) and was as follows:

$H = 1.65 + 0.283\,OC - 0.286\,WV$

The distribution of residuals from the regression on Shannon diversity was not normal (Lilliefors, $p=0.004$). When the model was re-run after removing an outlier (site 17, which had no macrophytes) the distribution of the residuals was normal. All other assumptions were met. There was no violation of assumptions from the regression on species richness.

No significant relationships were found between either species richness or Shannon diversity and pH, ammonia, total Kjeldahl nitrogen (TKN), reactive phosphorus, and total phosphorus (Table 1-3). Dissolved nutrient levels increased with distance downstream with the highest levels being in the urban and suburban areas of Ottawa and Manotick (Figure 1-7), but this does not appear to have an impact on species diversity.

The relationships between (log transformed) continuous independent variables were examined using a correlation matrix (Table 1-4). There was a significant correlation between littoral width and organic content which might explain the exclusion of littoral width from the Shannon model. There was, as expected, a significant correlation between TKN, ammonia, total phosphorus, and reactive phosphorus. There was also a relatively strong correlation between littoral width, organic content and total and reactive phosphorus, although not statistically significant. Regardless, there was no significant correlation between species richness and phosphorus, even when all other variables were held constant.

Table 1-2: Multiple regression models for a) species richness and b) Shannon diversity, using backwards stepwise selection with p to enter/ leave = 0.10. Full output is in Appendix 1-5. Similar results were found using forward selection.

Table 1-2 a)

Effect	co-efficient	standard error	standard co-efficient	tolerance	t	p (2 tail)
constant	1.037	4.221	0.000	.	0.246	0.808
velocity	-1.149	0.591	-0.255	0.465	-1.776	0.087
littoral width	1.354	0.622	0.283	0.566	2.176	0.038
organic content	1.156	0.441	0.421	0.372	2.623	0.014
chlorophyll-*a*	1.339	0.775	0.179	0.893	1.728	0.095

Table 1-2 b)

Effect	co-efficient	standard error	standard co-efficient	tolerance	t	p (2 tail)
constant	1.652	0.514	0.000	.	3.213	0.003
velocity	-0.286	0.088	-0.386	0.513	-3.262	0.003
organic	0.283	0.059	0.572	0.513	4.829	0.001

Table 1-3: Results of regression of species richness and Shannon diversity on independent variables. All independent variables except pH and TKN were log transformed.

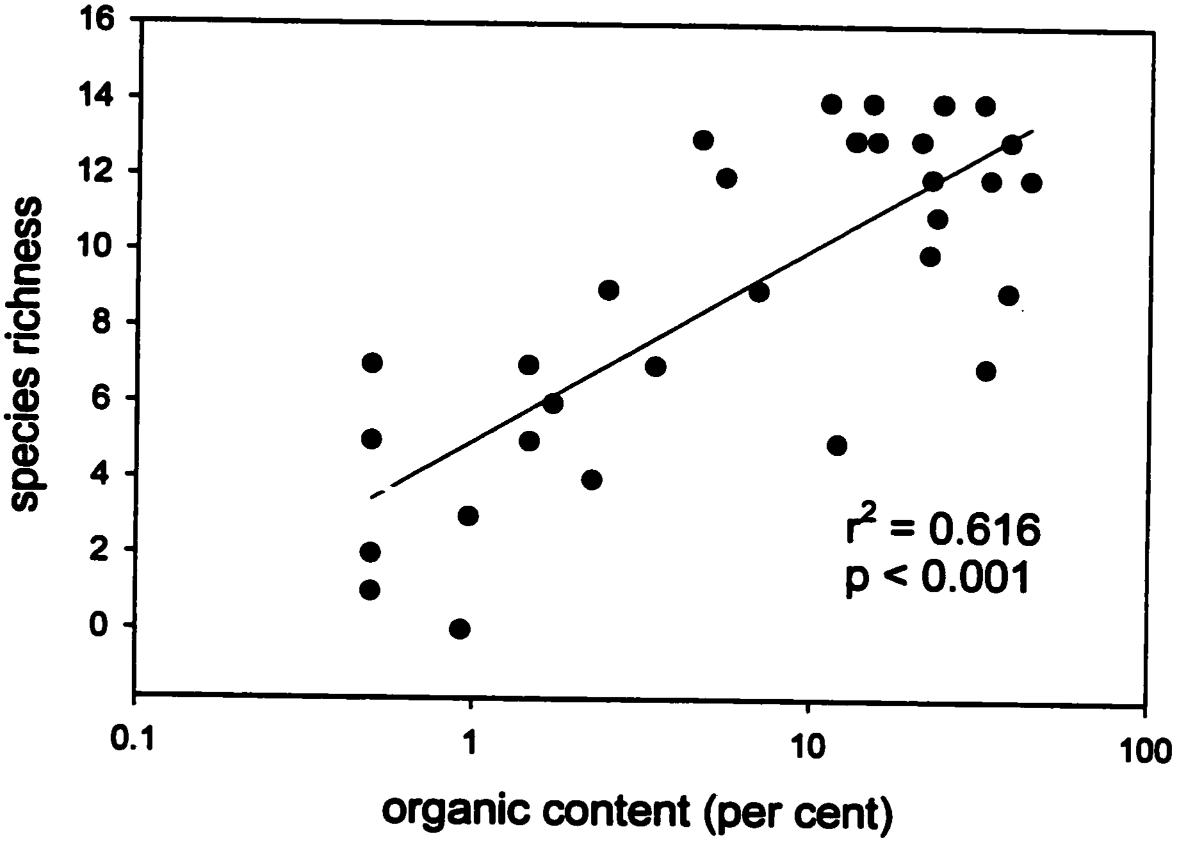
	species richness		Shannon diversity	
Variable	r^2	p	r^2	p
water velocity	.518	.000	.617	.000
littoral width	.436	.000	.338	.000
organic content	.616	.000	.708	.000
littoral slope	.256	.003	.137	.037
pH		.278		.439
chlorophyll a		.228		.473
reactive phosphorus		.125		.210
total phosphorus		.309		.502
total nitrogen (TKN)		.644		.584
ammonia (NH3)		.864		.997

Table 1-4: Pearson correlation matrix of independent variables. Significant correlations ($p<0.05$, Bonferonni adjusted) are marked with *.

	velocity	littoral with	organic content	TKN	NH_3	RP	TP
velocity	1						
littoral width	-0.538	1					
organic content	-0.552	0.742*	1				
TKN	-0.234	-0.087	-0.185	1			
NH_3	-0.169	-0.251	-0.098	0.400	1		
reactive phosphorus	-0.013	-0.510	-0.584	0.530	0.623*	1	
total phosphorus	-0.059	-0.482	-0.458	0.769*	0.602	0.871*	1
chlorophyll a	-0.081	-0.108	-0.007	0.365	0.207	0.121	0.365

Figure 1-5: Macrophyte species richness in relation to a) percent sediment organic content b) water velocity c) littoral width as measured by the distance to shore at a depth of 2 metres, and d) littoral slope in the Rideau River.

Figure 1-5 a)



16
14
12
10
8
6
4
2
0
species richness
r² = 0.616
p < 0.001
0.1
1
10
100
organic content (per cent)

Figure 1-5 b)

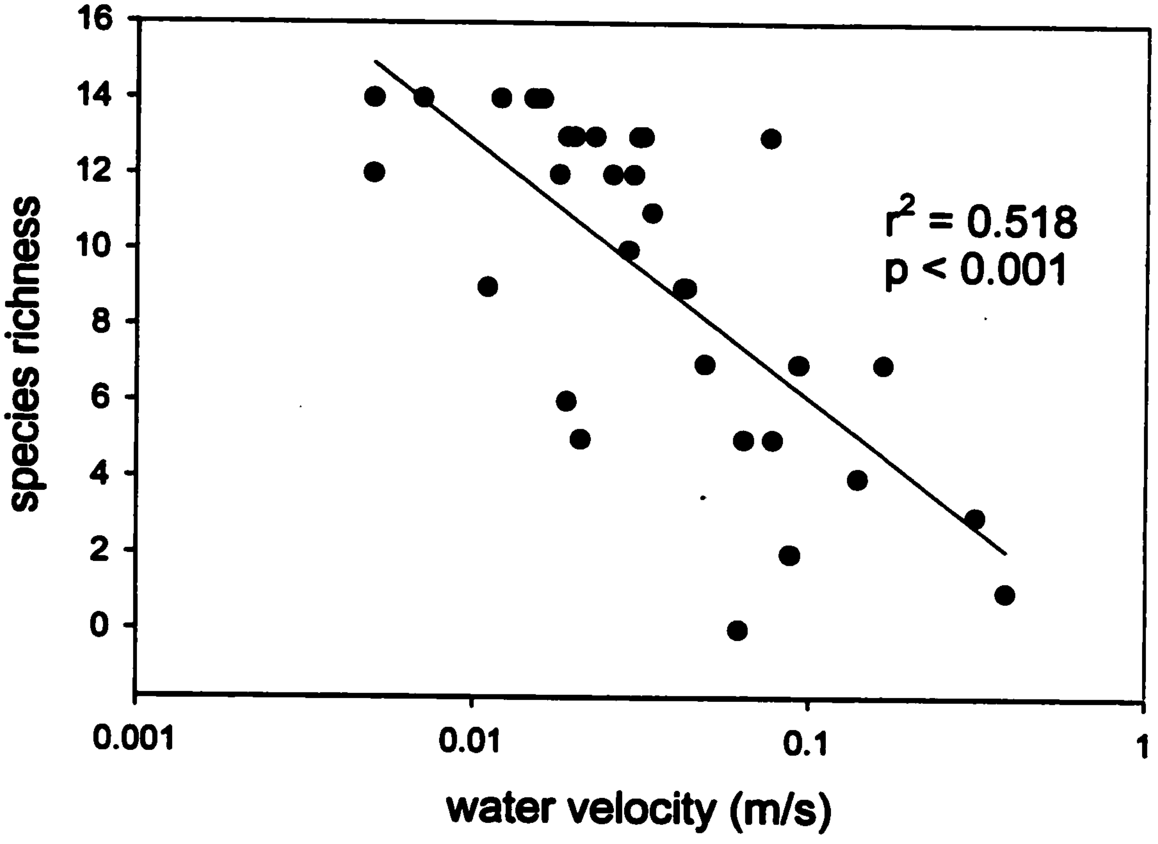

16
14
12
10
8
6
4
2
0
species richness
$r^2 = 0.518$
$p < 0.001$
0.001
0.01
0.1
1
water velocity (m/s)

Figure 1-5 c)

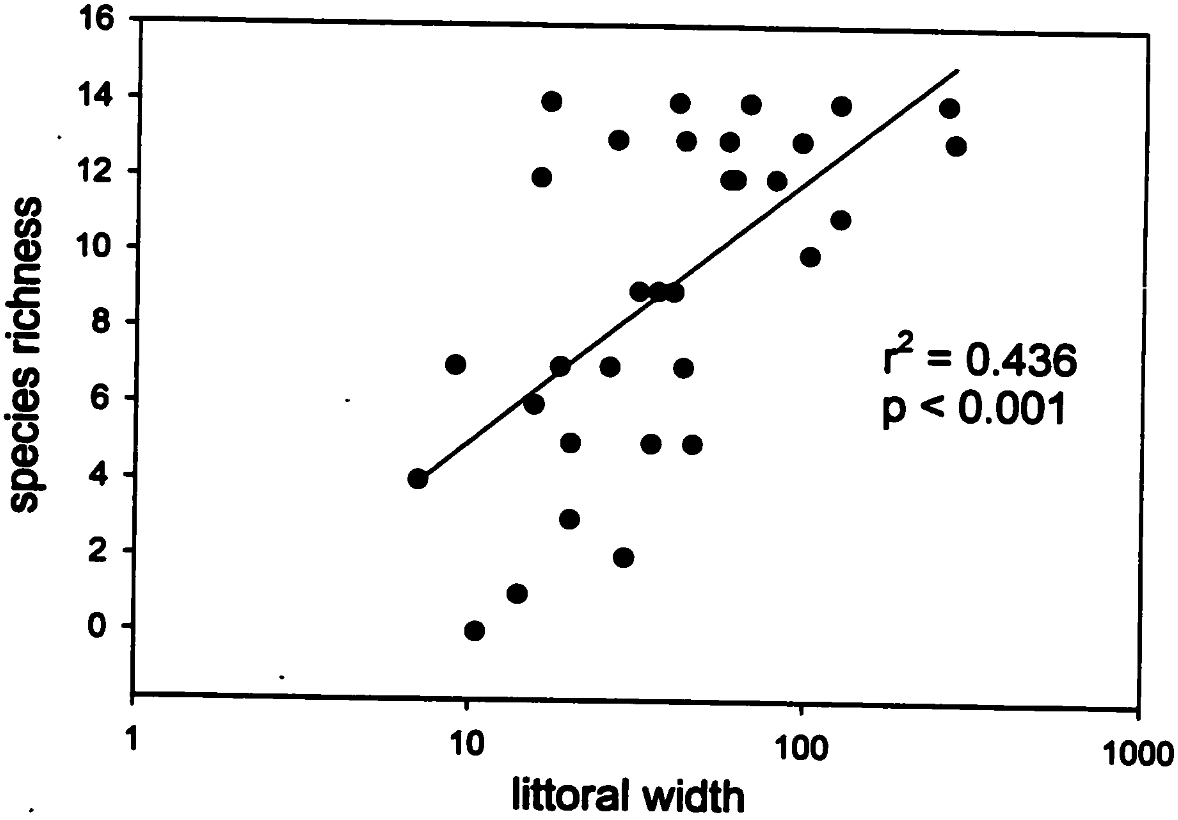
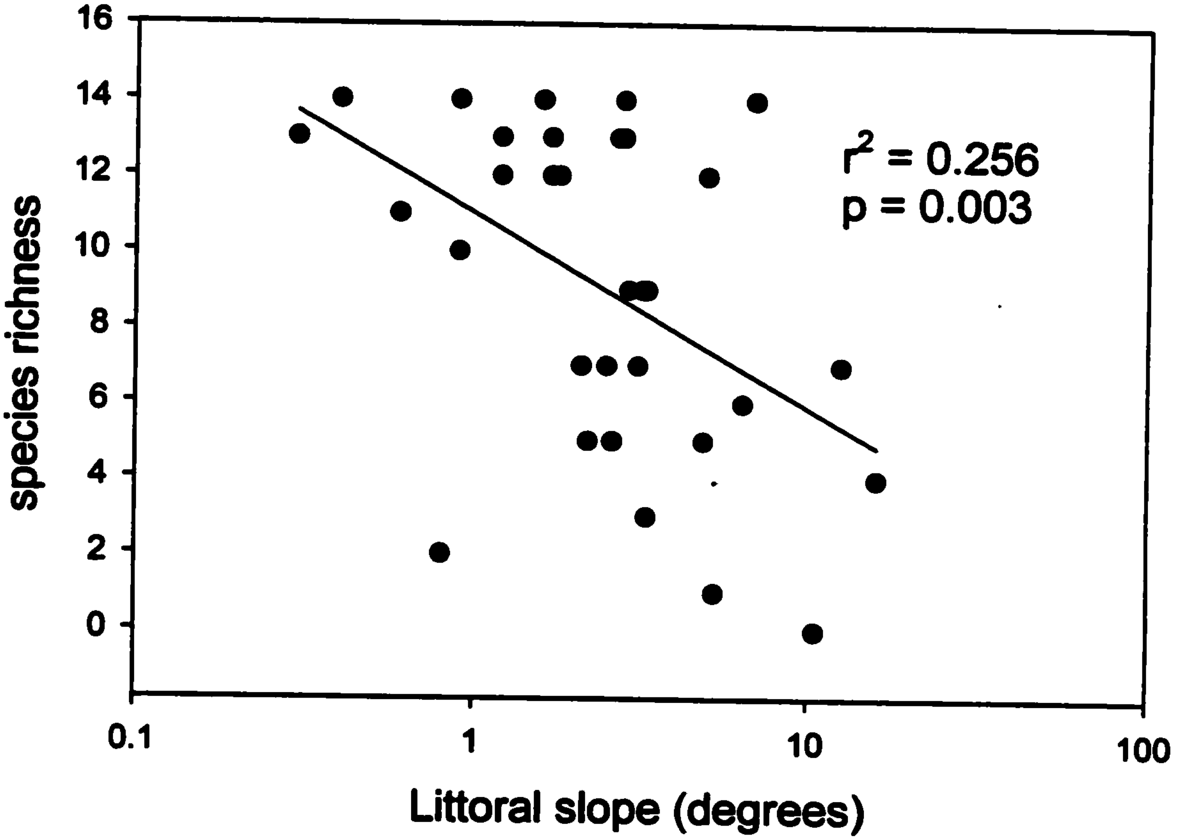

16
14
12
10
8
6
4
2
0
species richness
1
10
100
1000
littoral width
$r^2 = 0.436$
$p < 0.001$

Figure 1-5 d)



16
14
12
10
8
6
4
2
0
species richness
r^2 = 0.256
p = 0.003
0.1
1
10
100
Littoral slope (degrees)

Figure 1-6: Regression of macrophyte Shannon diversity against a) percent sediment organic content b) water velocity c) littoral width as measured by the distance to shore at a depth of 2 metres, and d) littoral slope in the Rideau River.

Figure 1-6 a)

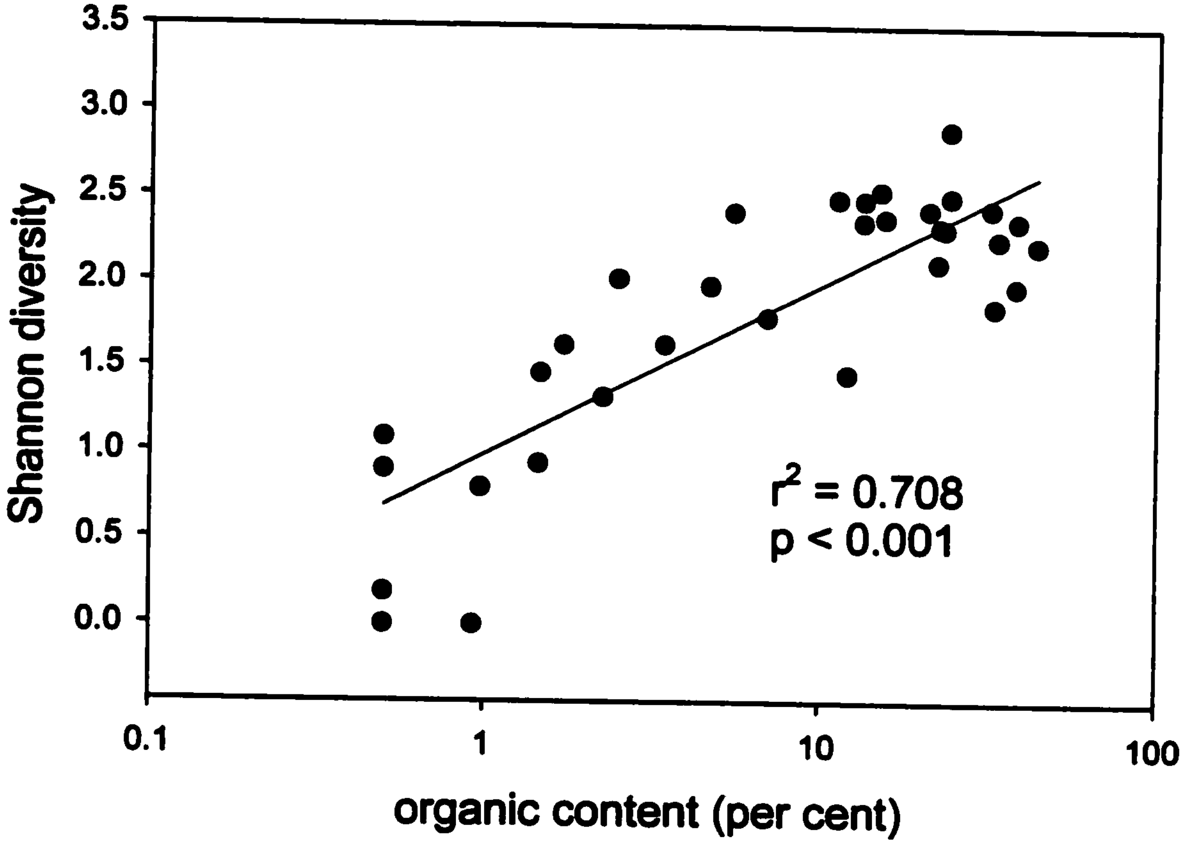

3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Shannon diversity
$r^2 = 0.708$
$p < 0.001$
0.1
1
10
100
organic content (per cent)

Figure 1-6 b)

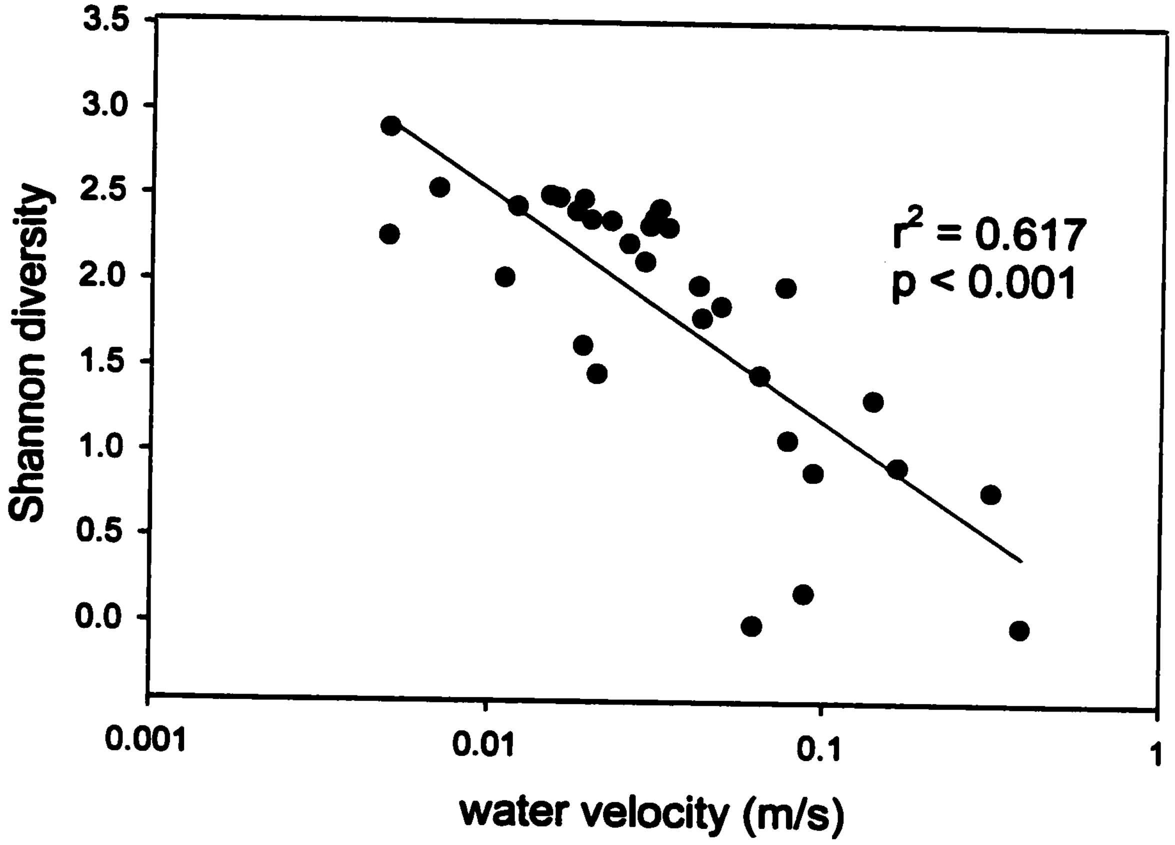
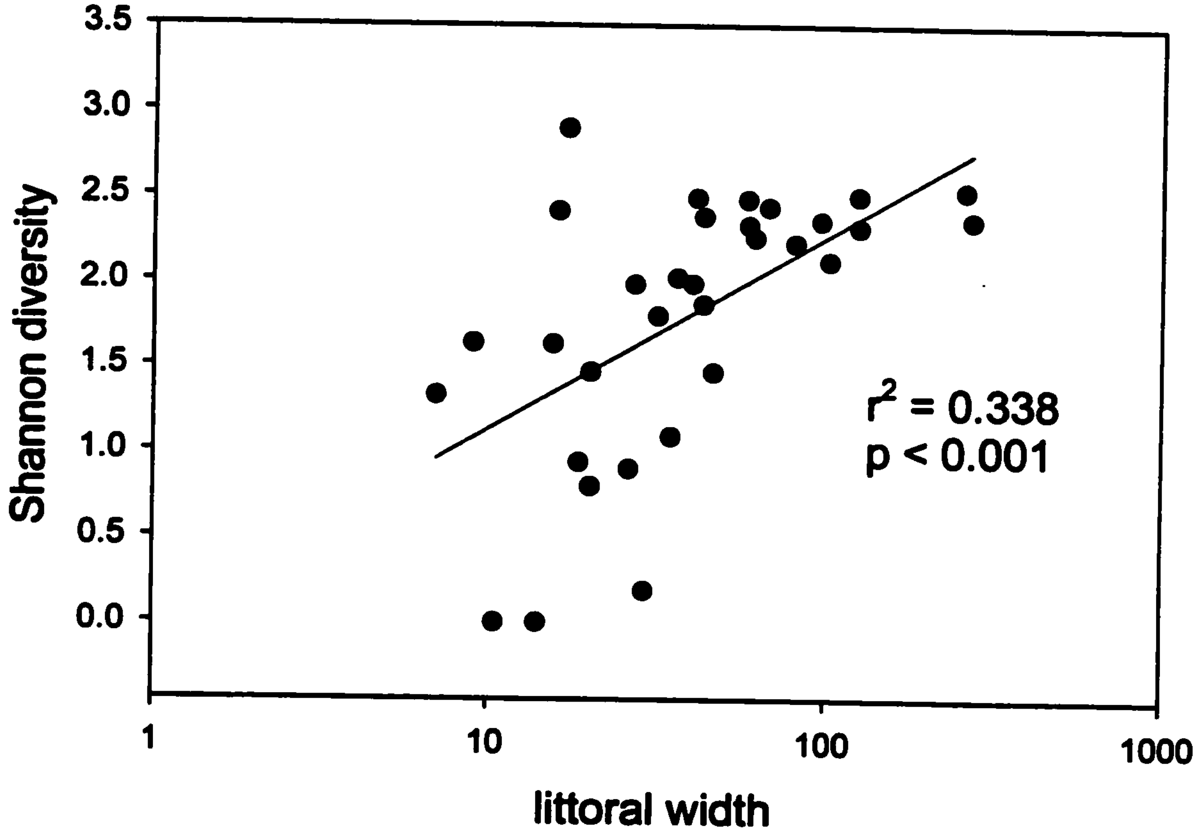

3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Shannon diversity
$r^2 = 0.617$
$p < 0.001$
0.001
0.01
0.1
1
water velocity (m/s)

Figure 1-6 c)



3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Shannon diversity
1
10
100
1000
littoral width
$r^2 = 0.338$
$p < 0.001$

Figure 1-6 d)

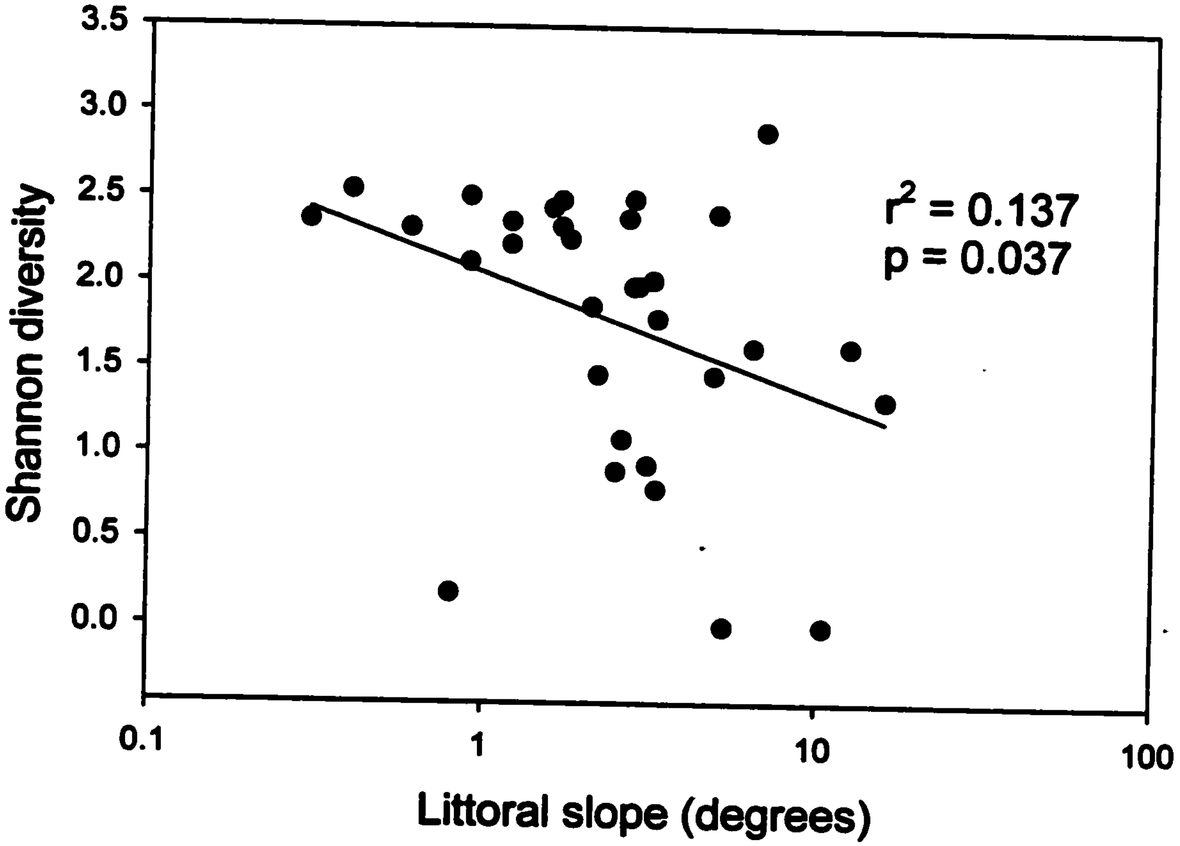
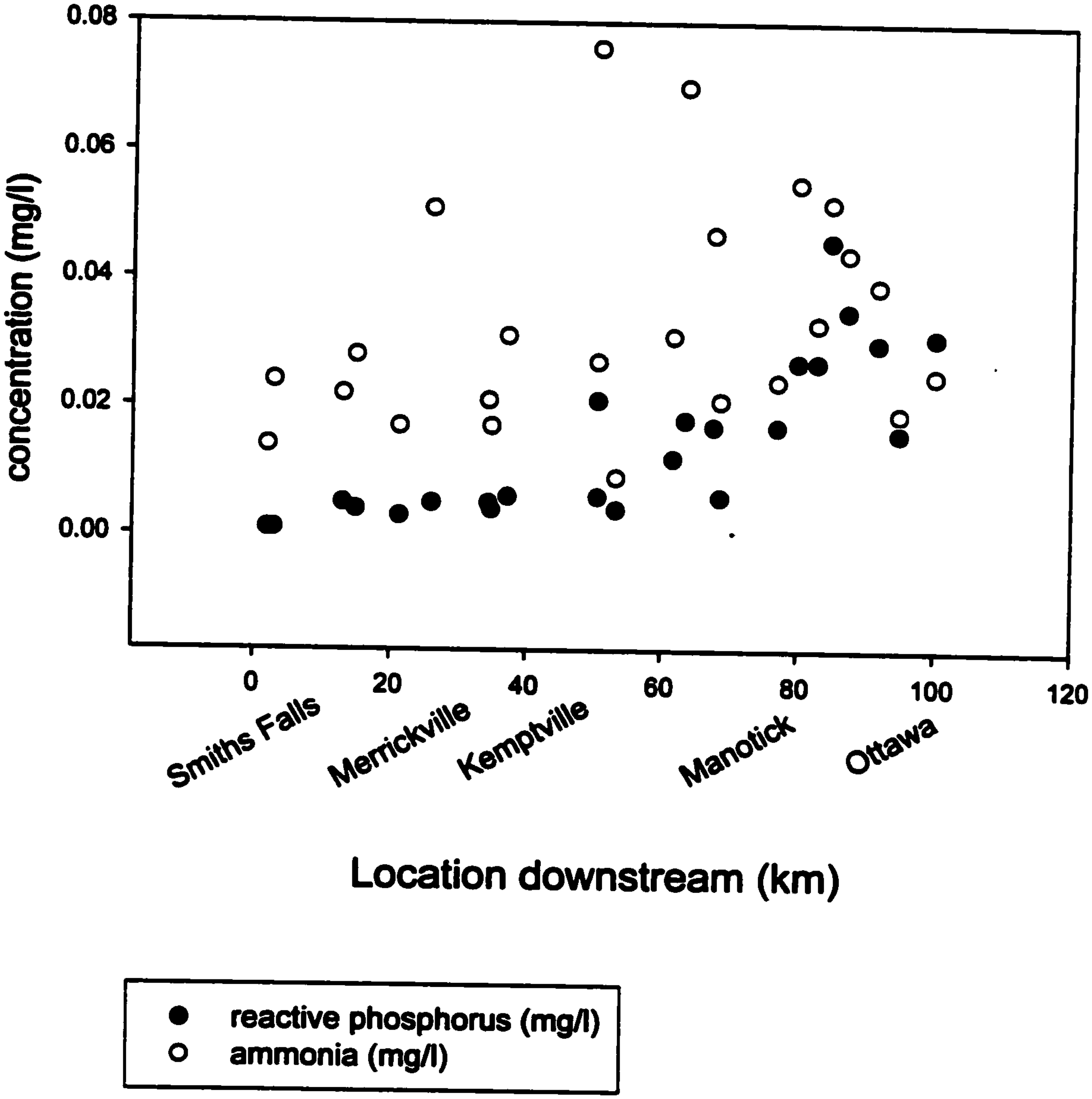

3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Shannon diversity
0.1
1
10
100
Littoral slope (degrees)
$r^2 = 0.137$
$p = 0.037$

Figure 1-7: Concentrations of reactive phosphorus and ammonia against location in the Rideau River (measured in kilometers downstream). Communities along the river are shown for reference. Note that ammonia and phosphorus concentrations increase at Manotick and downstream.

Figure 1-7

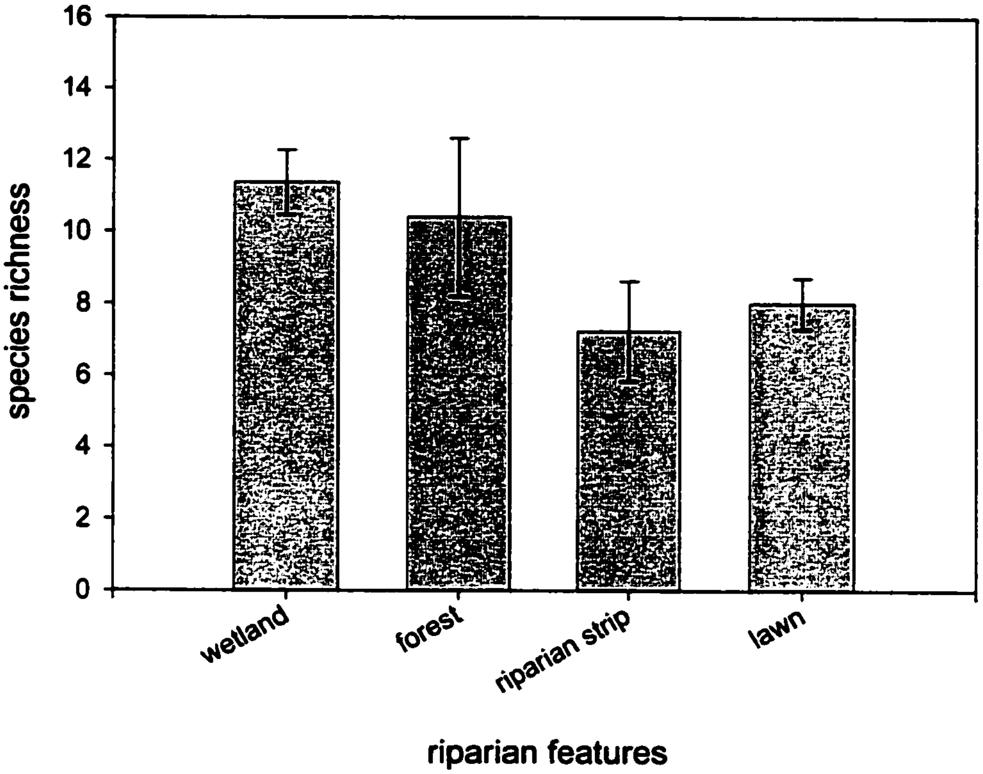

0.08
0.06
0.04
0.02
0.00
concentration (mg/l)
0
20
40
60
80
100
120
Smiths Falls
Merrickville
Kemptville
Manotick
Ottawa
Location downstream (km)
● reactive phosphorus (mg/l)
○ ammonia (mg/l)

Species richness was somewhat higher where adjacent land use was forested or agricultural, as opposed to urban or residential (p=0.053), and where the shoreline is forest or wetland, as opposed to lawn or a riparian strip (p=0.063) (Figure 1-8). There was less of a difference in Shannon diversity between different land uses (p= 0.126) and riparian features (p=0.188) (Figure 1-9).

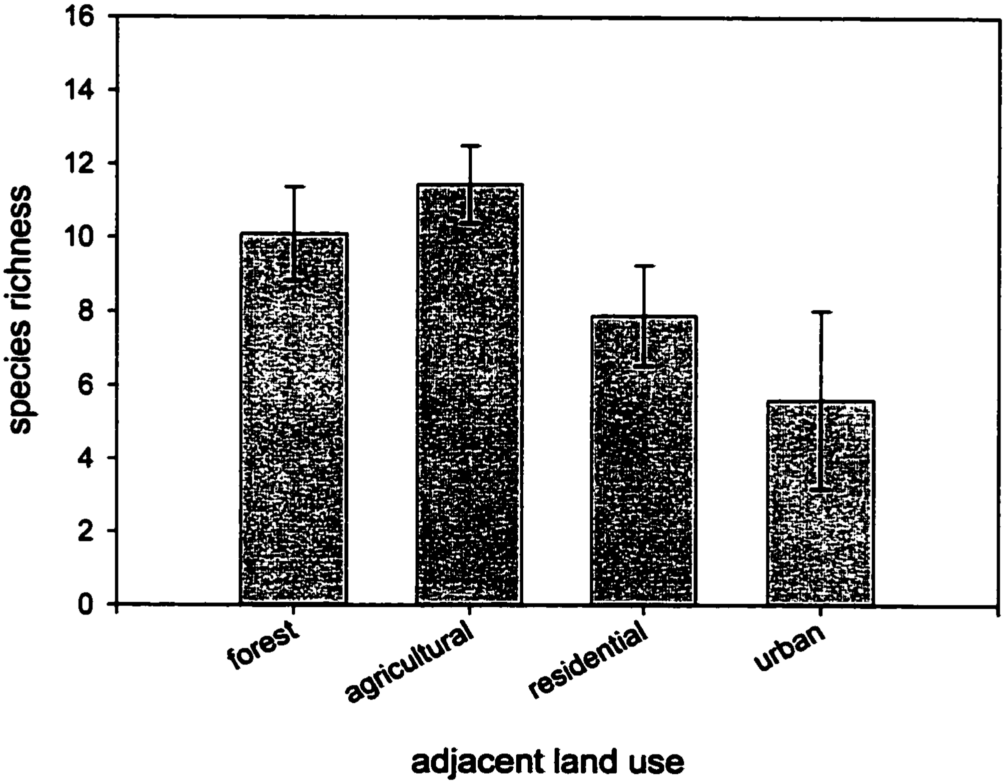
It was also found that littoral width and sediment organic content were lower in residential and urban areas than in agricultural and forested areas (ANOVA, p=0.001 for littoral width and p=0.02 for organic content. This alone might explain the relationship between diversity and adjacent land use. Both total and reactive phosphorus were lower in forested areas than the other areas (ANOVA, p= 0.010 and 0.001 respectively). Littoral widths were wider where the shoreline was forested or wetland, as opposed to lawn or riparian strips (ANOVA, p=0.018). No other statistically significant relationships were found.

Figure 1-8: Mean macrophyte species richness (± standard error) corresponding to different a) land use and b) riparian features.

Figure 1-8



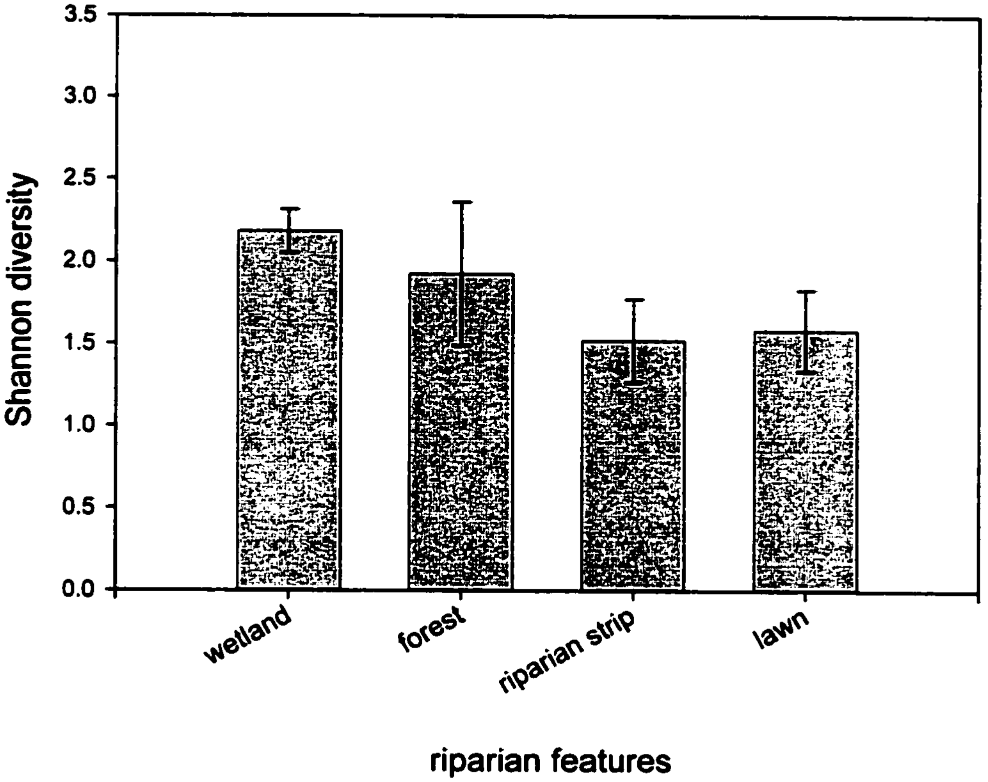
16
14
12
10
8
6
4
2
0
species richness
wetland
forest
riparian strip
lawn
riparian features



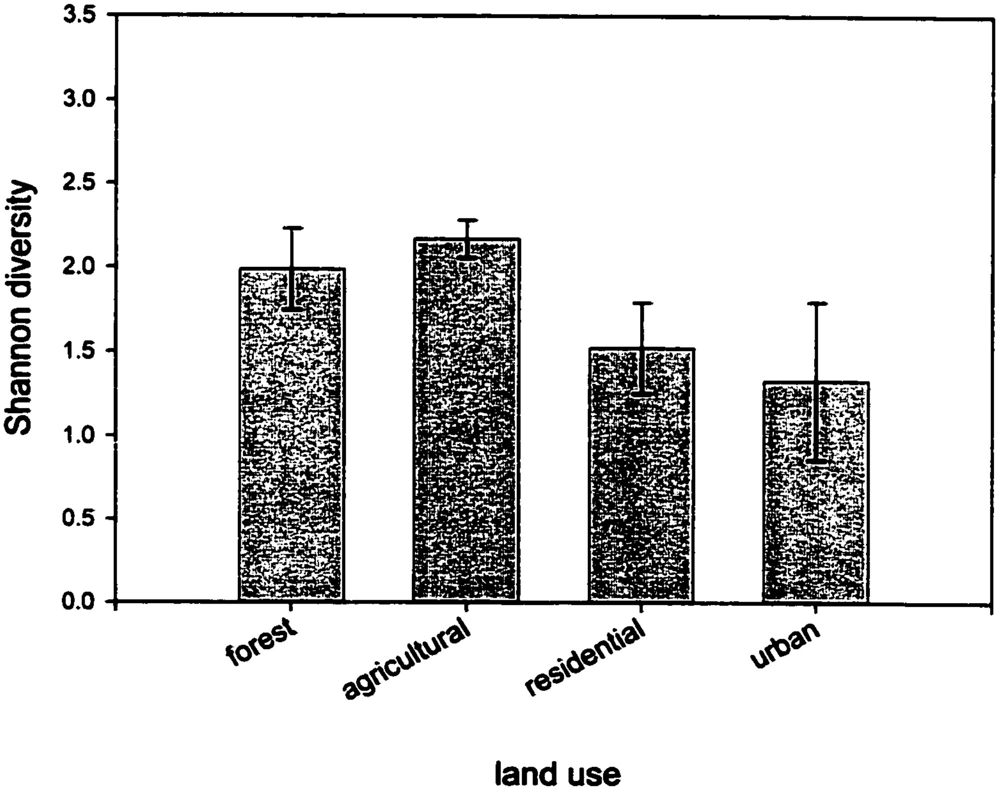
16
14
12
10
8
6
4
2
0
species richness
forest
agricultural
residential
urban
adjacent land use

Figure 1-9: Mean macrophyte Shannon diversity (± standard error) corresponding to different a) land use and b) riparian features.

Figure 1-9



Shannon diversity
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
wetland
forest
riparian strip
lawn
riparian features



Shannon diversity
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
forest
agricultural
residential
urban
land use

Discussion

The increase in diversity with organic content is likely to be a reflection of the relationship between productivity and diversity. Previous studies in aquatic and wetland systems have shown that species diversity is highest at intermediate levels of productivity (Dobson *et al.*, 2000; Day *et al.*, 1988; Auclair 1976). The productivity-diversity relationship has also been shown in the Rideau River (Bergeron *et al.*, unpublished data).

Much of the organic matter in sediment is composed of decomposing plant material. Like fine particulate matter, it tends to accumulate in areas of low current and slope (Sand-Jensen, 1998, Duarte and Kalff, 1986, Westlake, 1973), and be high in nutrients which are adsorbed to organic and fine particulate matter. As nutrient uptake in rooted macrophytes comes mostly, if not entirely from sediment rather than in the water (Carnigan and Kalff, 1990, Chambers et al, 1989) productivity would be expected to increase with sediment organic content. The relationship in the Rideau River showed a logarithmic increase in species richness, rather than a peaked one, without a downward trend at the uppermost levels of sediment organic content. This indicates that levels of productivity did not reach the point where competitive exclusion takes place. Field observations also did not reveal any areas of dense monoculture that is typical where there is competitive exclusion. This might be because macrophyte productivity levels in the Rideau river do not reach the point where species richness begins to decline. Maximum average organic content was about 45%.

Water velocity also has a strong negative influence on species diversity. The relationship was log-linear, rather than unimodal as hypothesized. While there is no doubt that sites of high water velocity present a stress that makes it unlikely for a wide variety of species to become established, extremely low levels of water velocity simply create lake-like conditions, in which case other factors would be more responsible for determining productivity.

It has been speculated that the inhospitable conditions at higher water velocity are due to organic material and fine sediment having been washed away (Nilsson, 1987). Others have observed the negative correlation of water velocity with organic material and fine sediment (Sand-Jenson, 1998; Chambers *et al.*, 1991; Westlake, 1973), but in this study organic content and water velocity both made a significant contribution to model fit. This indicates there are other influences of water velocity beyond its effect on sediment organic content, an observation which has been confirmed by experiment (Chambers *et al.*, 1991). Some causes might be damage from breakage, uprooting or scouring which would prevent vulnerable species from becoming established. The species found at high velocity sites of the Rideau River tended to be flexible species with ribbon like or divided leaves, such as *Vallisneria american*, and *Myriophyllum spp.* This trend was also observed by in the Izica River in Slovania by Germ and Gaberscik (1999). Areas of swift water were mainly limited to non-navigable portions of the Rideau River, and just downstream of dams.

The third best predictor was littoral width which was measured as the distance from shore to depth of 2 metres. Both the cross-sectional slope and the littoral width were used to express the morphology of the littoral area, though littoral width was the better predictor. A larger littoral area means more habitat area is available for aquatic macrophytes. Habitat size has been found to correlate with biodiversity in terrestrial systems (Rosenzweig, 1995), as well as aquatic systems (Rorslett, 1991), though most studies on aquatic systems tend to be comparisons between lakes. In lakes, Duarte and Kalff (1986, 1990) found littoral slope to be a strong predictor of macrophyte biomass, but width of the littoral shelf was not measured. In the Rideau River, large littoral zones also tended to be adjacent to wetlands and areas with few shoreline modifications, so there could be an effect of the adjacent area.

While chlorophyll-*a* did not show a significant relationship with diversity when compared directly, it did show a significant positive relationship when held constant for water velocity, sediment organic content, and littoral width. Usually macrophytes decrease with chlorophyll-*a* due to phytoplankton inhibiting macrophyte growth by competing for nutrients and blocking light (Scheffer *et al.*, 1993). There have, however, been other studies showing chlorophyll-*a* to increase in the presence of macrophytes (Basu *et al.*, 2000; Landers, 1982). In this particular case, the correlation between macrophyte diversity and chlorophyll-*a* may simply be an indirect effect of the overall productivity of the site.

The relationships between diversity, adjacent land use, and shoreline features are complicated by the fact that there were also relationships between adjacent land use and riparian features with some of the other independent variables, namely sediment organic content and littoral width. While there is little doubt that adjacent land use has a strong effect on aquatic ecosystems (Moss, 2000), it appears from this study that macrophyte diversity responds more closely to river morphology than what occurs on the shoreline or the larger catchment. It is possible that a stronger correlation might have been found had a more systematic approach been used to categorise land use and shoreline features (e.g., GIS information) instead of a qualitative survey.

Overall, water nutrient levels show little relationship with species diversity. Most macrophyte species are rooted, and would therefore tend to get their nutrients from the sediment (Carnigan and Kalff, 1990, Chambers et al, 1989). Unlike phytoplankton, nutrient limitation is rare in macrophytes since their structural complexity requires more carbon per unit of growth compared to nitrogen and phosphorus (Kalff, 2002).

Macrophyte biodiversity in the Rideau River appears to be mainly influenced by physical features such as water velocity, littoral width, and sediment organic content rather than water chemistry variables such as pH, dissolved nitrogen and dissolved phosphorus. One reason might be the lack of variation in the data within the river. Studies which had shown effects of nutrients and pH (e.g. Baatrup-Pederson and Riis,1999; Bini *et al.*, 1999; Srivasta *et al.*, 1995; Ali *et al.*, 1995, Lougheed *et al.*, in press) are comparisons between lakes and are therefore examining a larger variation in environmental conditions. For example, Vestergaard and Sand-Jensen (2000) compared lakes with pH ranging from 4.4 to 10.2, and total phosphorus from 0.010 to 0.470 mg/l. By contrast, the pH in the Rideau River ranged between 7.7 and 8.9, while total phosphorus was between 0.017 and 0.052 mg/l.

Duarte and Kalff (1990) upon examining lakes also observed that lake water chemistry and trophic status varied much more between lakes than within an individual lake, whereas site characteristic such as slope, sediment characteristics and wave exposure varied as much within lakes as among them. Their analysis found that determining what regulates macrophyte abundance depended on the scale of analysis. This appears to also apply to macrophyte diversity in rivers.

Chapter 2:

Aquatic macrophyte species composition in the Rideau River

Introduction

The effect of environmental factors on macrophyte species composition in aquatic systemshas been the focus of a limited number of studies, and there does not appear to be a consensus on which factors are most important. Some studies showed trophic status and nutrient availability to have a strong effect on species composition (Roman *et al.*, 2001; Bini, 1999; Srivasta *et al.*, 1995; Seddon, 1971) while others showed no correlation (Jackson and Charles, 1988; Morton and Fraser, 1983; Pip 1979). A similar debate surrounds pH (Srivasta *et al.*, 1995; Toivonen and Huttunen, 1995; Jackson and Charles, 1988; Pip, 1979). Other factors that have been found to influence macrophyte species composition include calcium and magnesium ion concentrations (Ali *et al.*, 1995; Penuelas and Sabater, 1987), alkalinity (Vestergaard and Sand-Jensen, 2000, Srivasta *et al.*, 1995, Morton and Fraser, 1983), conductivity (Toivonen and Huttunen, 1995; Seddon, 1971) sediment composition (Lougheed *et al.*, 2001; Bini, 1999; Baatrup-Pedersen and Riis, 1999) and flood frequency (Barrat-Segretain et al.,1999; Barrat-Segretain and Amoros, 1996)

Most of these studies focus on lakes and reservoirs, with only a fraction on moving waters. Studies on rivers and streams found many of the same factors influencing macrophyte composition in lakes also apply to rivers and streams, but there is the additional influence of flood frequency and intensity (Barrat-Segretain et al, 1999), watercourse size (Demars and Harper, 1998), and water velocity (Nilsson, 1987; Robach *et al.*, 1997).

The purpose of this chapter was to examine the relative importance of physical and chemical habitat characteristics on the distribution of species in the Rideau River, and to secondly to determine if these are the same factors that influence macrophyte diversity.

Methods:

Plant species were observed at 33 sites in belt transects comprised of 6 quadrats spanning a depth gradient of 0.5 to 2.0 metres, as described in Chapter 1. At each quadrat, species were listed and was assigned a percent cover value from 1 to 5 based on the Braun-Blanquet scale (Braun-Blanquet, 1932). It was these values that were used for analyses comparing quadrats. For analyses comparing sites, each species was tallied according to the number of quadrats they were found in, giving a frequency measure between 1 and 6.

Analysis

A number of multivariate techniques were used to examine the patterns in macrophyte species composition and in their relationship to environmental variables.

A cluster analysis connecting sites using Euclidean distances and median linkages was used to examine the patterns in species assemblages.

A Mantel test was used to determine if there was a correlation between sites with similar species composition and sites with similar environmental characteristics. The Mantel test compares two matrices to determine if there is a correlation between the elements of the matrices. In this case, the elements of the first matrix Euclidean distance (a measure of difference) between each pair of sites based on their species composition, and the second matrix is the degree to which each pair of sites is similar in terms of their environmental factors (e.g., sites with similar water velocity, sites with similar amounts of nutrients, etc.). If the sites with a similar environmental condition (e.g., high water velocity) were correlated to the sites with a similar species composition, this would indicate that the environmental condition influences the species composition.

Matrices connecting sites on the basis of, a) species composition, b) diversity (species richness and Shannon diversity), and c) each environmental variable (water velocity, size of littoral zone, substrate organic content, ammonia, TKN, reactive phosphorus, total phosphorus, chlorophyll-*a*, pH) were constructed with Systat 10 (SSPS Inc., 2000) using Euclidean distances. Distance matrices were constructed for each environmental variable separately in order to distinguish the level of influence of each variable. A distance matrix combining all nutrient variables was also constructed. Only species found in more than 5% and less than 90% of the quadrats were included in the species composition calculations. Analysis involving nutrients and pH were only undertaken for the sites sampled during the first field season, since water quality analysis was not conducted during the second field season due to budgetary and equipment constraints. One site from the first field season also had to be excluded since water quality data was not collected that day, for a total of 24 sites.

Mantel 2.0 (Liedloff, 1999) was used to examine whether there was a significant correlation between the elements of the two distance matrices by comparing the test statistic Z with the distribution of Z calculated when the objects in one of the matrices are randomised.

$$Z = \sum_{i=1}^{n}\sum_{j=2}^{i-1} d_{ij}^{(1)} d_{ij}^{(2,R)}$$

where $d_{ij}^{(1)}$ is the element in the ith row and the jth column for the first distance matrix **D**(1), and $d_{ij}^{(2,R)}$ is the element of in the ith row and the jth column for the second distance matrix D(2,R) which was randomised 1000 times to generate the Z distribution. The observed value of Z based on the non-randomised matrix was compared directly to the randomised distribution of Z to calculate p, based on the null hypothesis that the observed Z would not be significantly different from the randomised value of Z. The value of r was calculated based on the correlation between unrandomised matrix values.

The Mantel test only showed effects on overall species composition, but did not indicate which species were affected by which environmental variable and to what extent. There are a number of multivariate techniques that can be used to investigate relationships between environmental variables and species composition, however these techniques require a sample to variable ratio of at least 20, otherwise canonical variates and correlates are unreliable. Because of this limitation, detailed species-environment relationships could only be investigated at the $1m^2$ quadrat scale, that is to say, using each quadrat as a separate data point. The environmental variables that had been measured at each quadrat were: sediment organic content, depth, velocity, slope, and distance from shore. All variables except depth were log-transformed to approximate normal distributions. Only species found in 5% or more of the quadrats were included in the analysis.

It was recognised that the data were not entirely independent since the quadrats were distributed among 33 sites, rather than being randomly placed throughout the river. One effect of this is would be spatial autocorrelation (Appendix 2-1) which results in the real degrees of freedom being somewhat less than the apparent degrees of freedom. Since the CCA was used primarily to generate an ordination diagram that would illustrate relationships between species and environmental variables, and not to test hypotheses, this was not determined to be a problem. The second effect was that there would be equal weight put on within-site relationships as between-site relationships, thus reducing the variation in the distance matrix. As a result, the effects of environmental variables would be under-emphasized and the analysis may be somewhat conservative. This is more likely to be a problem for variables that showed a considerably greater among-site variation than within-site variation. Analysis of variance showed that the F ratios of among-site and within-site variation were highest for sediment organic content (F=23.36) and lowest for depth (F=0.36). The other variables were between 2.97 and 7.23.

Principal components analysis (PCA) was undertaken to determine the extent to which environmental variables were correlated. Since the pair-wise correlations among environmental variables was relatively low, the PCA did not result in much dimensionality reduction. Depth and distance showed similar loadings (as expected) but not to the extent so as to justify excluding one of these variables from the analysis. Thus, all the original variables were retained (Appendix 2-2).

Canonical correspondence analysis (CCA) was used to investigate the relationship between environmental variables and plant community composition. CCA was chosen over redundancy analysis because redundancy analysis assumes a linear response of species to environmental gradients, whereas CCA assumes unimodal response. A detrended correspondence analysis (Appendix 2-3), indicated that gradients in our data ranged from 3.4 to 4.9 in length, and confirming the data were more likely to be unimodal in distribution (Leps and Smilauer, 1999). Visual examination of the data using scatterplots also showed a unimodal relationship. The statistical significance of the relationship between the species data and both the first canonical axis and the entire set of axes were tested using 199 random Monte Carlo permutations. Only species found in more than 5% and less than 90% of the quadrats were included in the analysis.

A correspondence analysis was used to examine the patterns in species composition between quadrats independent of the environmental variables. CANOCO for Windows 4.0 (terBraak and Smilauer, 1998) was used for the above statistical procedures.

Results

The cluster analysis showed a high degree of chaining, with very little clustering of species into groups or communities aside from a few pairs (Figure 2-1). The various species of *Potamogeton* were closely linked, but there were no distinct communities found.

The Mantel tests for the site-level comparisons between species richness and environmental variables, showed that only chlorophyll-*a* had a significant positive relationship to species composition (Table 2-1). This relationship was relatively weak ($r= 0.301$, $p<0.001$). In order to determine whether chlorophyll-*a* would affect submerged species differently from floating and floating leafed species since chlorophyll-*a* attenuates light, two more Mantel tests were done where distance matrices were generated based on floating leafed species composition and submerged plant species composition. Only the submerged species showed a significant relationship with chlorophyll-*a* ($r=.303$, $p<0.001$; for submerged species, $r=0.001$, $p=0.490$ for floating species). There was also a significant but weak negative relationship between sediment organic content and species composition ($r = -0.146$, $p = 0.001$).

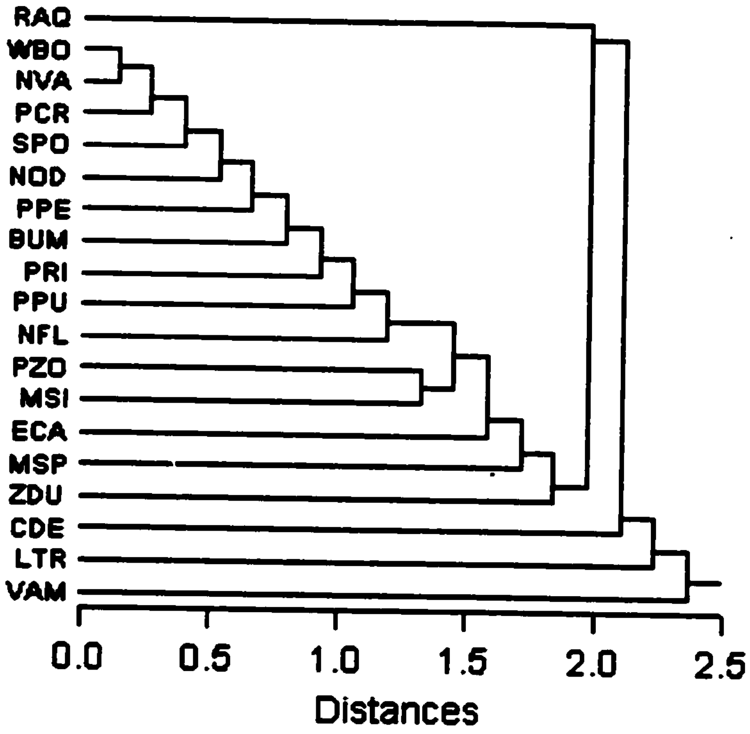
The Mantel tests showed that sites with similar species diversity were correlated most strongly with sites with similar sediment organic content, water velocity, and littoral width. This is corroborates the results found in the previous chapter which showed using regression analysis that species diversity is most strongly predicted by sediment organic content followed by water velocity and the littoral width.

Table 2-1: Results of Mantel tests. Distance matrices connecting sites on the basis of species composition was compared with distance matrices connecting sites on the bases of each environmental variable. Distance matrices were constructed with Systat 10 (SSPS Inc., 2000) using Euclidean distances. Only species found at more than 10 quadrats were included.

Factors	Species composition		Species diversity		Sample size
	p	r	p	r	
chlorophyll a	0.000	0.301	0.452	-0.024	33
littoral width	0.450	-0.006	0.000	0.335	33
organic content	0.002	-0.146	0.000	0.588	33
velocity	0.462	0.004	0.000	0.428	33
pH	0.065	-0.138	0.174	-0.119	24
nutrients	0.416	0.008	0.196	-0.091	24
RP	0.321	-0.060	0.704	0.023	24
TP	0.556	-0.036	0.378	-0.053	24
NH3	0.082	0.124	0.087	-0.128	24
TKN	0.450	-0.046	0.448	-0.046	24

Figure 2-1: Diagram showing results of a cluster analysis connecting sites surveyed on the Rideau River using Euclidean distances and median linkages.

Figure 2-1


RAQ
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PCR
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PPU
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LTR
VAM
0.0
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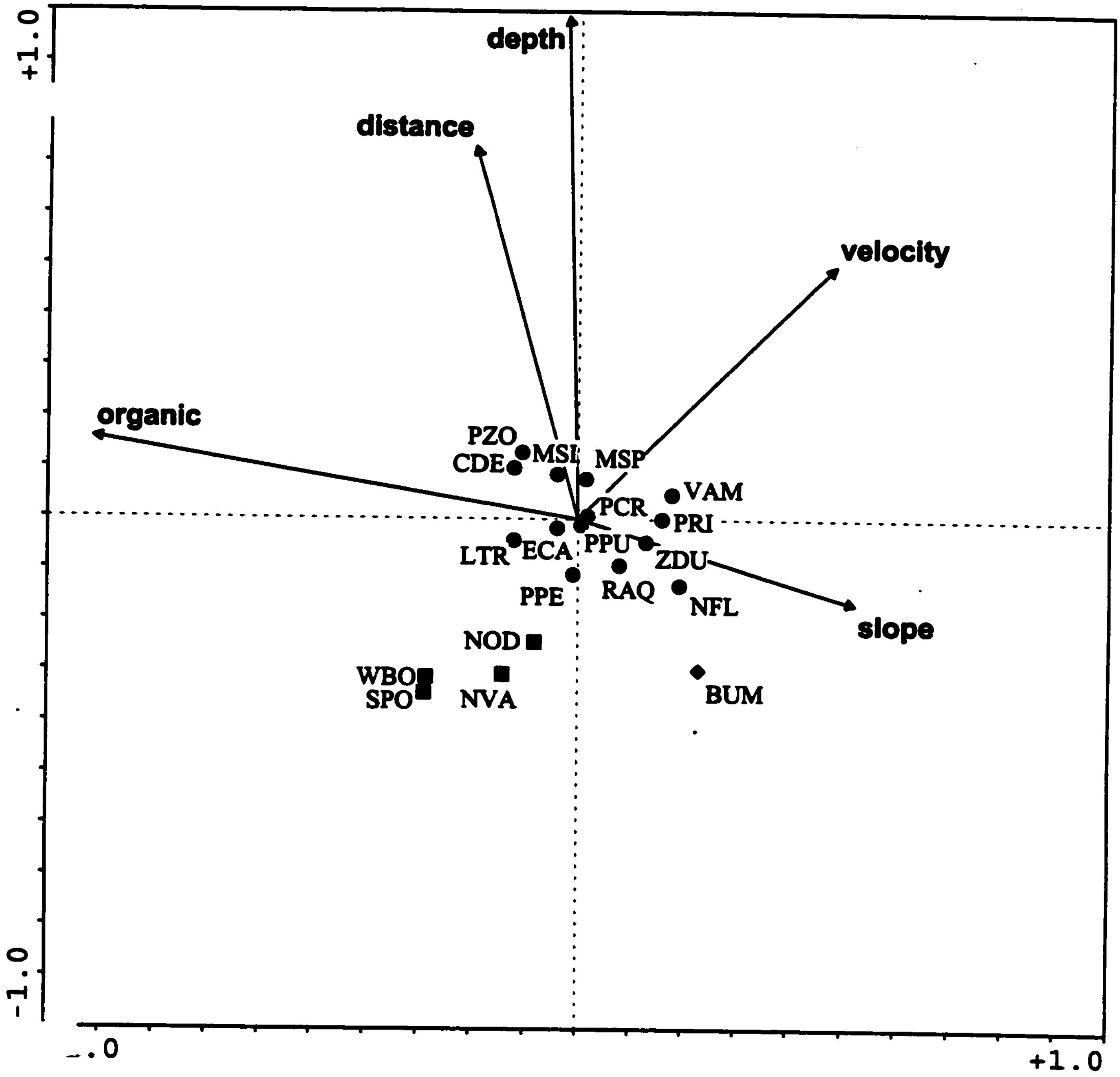
1.5
2.0
2.5
Distances

The results of the CCA are shown in Figure 2-2. The first two axes explained 70% of the species-environment relations. The environmental variables that accounted for most of these species-environment relationships, as indicated by their correlation to the canonical axes, were sediment organic content (r = -0.914 with axis 1), and depth (r =0.994 with axis 2). Unfortunately, these relationships account for a very small proportion for the overall variation in species composition. The first four canonical axes only explained 8% of the variation in species composition, with the first axes explaining only 3.6% (Appendix 2-4). For this reason, the majority of the species were located close to the origin of the biplot which is another indication that very little of the variation in species composition is accounted for by the environmental variables measured.

There was some influence of the environmental variables on the floating and floating-leafed species, *Nymphaea odorata, Nuphar variegatum, Wolffia borealis*, and *Spirodella polyrhyza*, and on the one emergent species that appears in the analysis, *Butomus umbellatus*. The floating species clustered together somewhat opposite the water velocity vector, indicating an association with slow-moving water. *Butomus umbellatus* is shown to be characteristic of shallow water close to shore. The Monte Carlo test with 199 permutations showed that what response of the species to the environmental variables was found, was statistically significant (p=0.005).

Figure 2-2: Canonical correlation analysis biplot illustrating the main pattern of variation in the species assemblage in relation to environmental variables. BUM - Butomus umbellatus, CDE - *Ceratophyllum demersum*, LTR - *Lemna trisulca*, MSI - *Myriophyllum sibiricum*, MSP - *Myriophyllum spicatum*, NFL - *Najas flexilis*, NOD - *Nymphaea odorata*, NVA - *Nuphar variegatum*, PCR - *Potamogeton crispus*, PPE - *Potamogeton pectinatus*, PPU - *Potamogeton pusillis*, PRI - *Potamogeton richardsonii*, PZO - *Potamogeton zosteriformis*, SPO - *Spirodella polyrhyza*, VAM - *Vallisneria americana*, WBO - *Wolffia borealis*, ZDU - *Zosterella dubia*. ● - submerged species, ■ - floating and floating-leaved species ◆ - emergent species.

Figure 2-2



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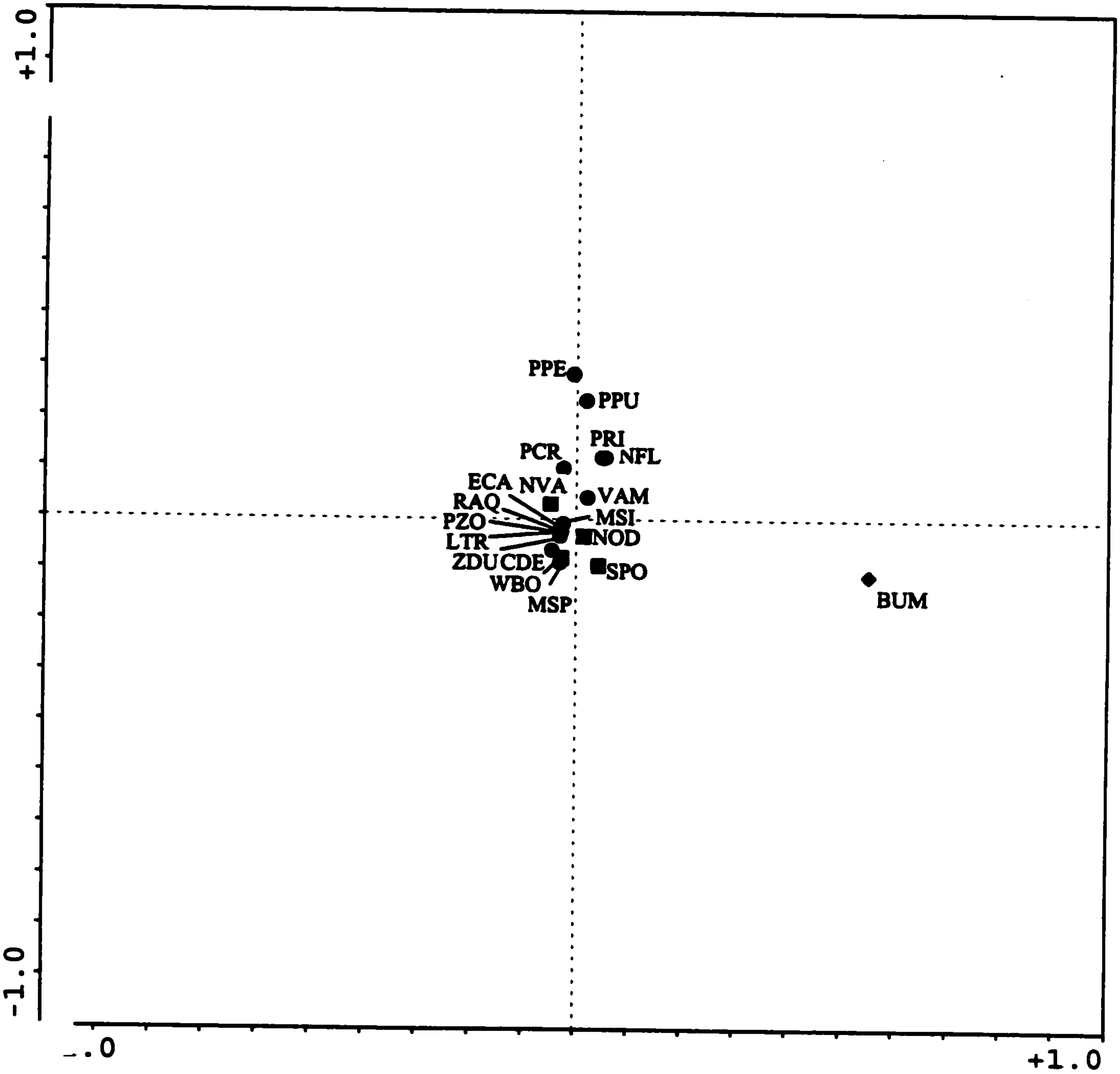
The scatterplot from the correspondence analysis (Figure 2-3) showed most of the species clustered about the origin of the plot, with one group of species (*Elodea canadensis, Lemna trisulca, Myriophyllum sibiricum, Potamogeton zosteriformus, Ranunculus aquatilis*, and *Zosterella dubia*) almost indistinguishable from one another. *Butomus umbellatus* stands apart from the main cluster, indicating that its distribution is independent of the other species. The floating species were not distinguished from the submerged species.

Figure 2-3: Correspondence analysis scatterplot illustrating the main patterns of variation in species composition independent of environmental variables. BUM - Butomus umbellatus, CDE - *Ceratophyllum demersum*, LTR - *Lemna trisulca*, MSI - *Myriophyllum sibiricum*, MSP - *Myriophyllum spicatum*, NFL - *Najas flexilis*, NOD - *Nymphaea odorata*, NVA - *Nuphar variegatum*, PCR - *Potamogeton crispus*, PPE - *Potamogeton pectinatus*, PPU - *Potamogeton pusillis*, PRI - *Potamogeton richardsonii*, PZO - *Potamogeton zosteriformis*, SPO - *Spirodella polyrhyza*, VAM - *Vallisneria americana*, WBO - *Wolffia borealis*, ZDU - *Zosterella dubia*. ● - submerged species, ■ - floating and floating-leaved species ◆ - emergent species.

Figure 2-3



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Discussion

Both the Mantel tests and the canonical correlation analysis show that the environmental variables studied have little impact on community composition, with the possible exception of chlorophyll-*a*. One impact of chlorophyll-*a* is its attenuation of light, which would have a stronger impact on submerged species in deep water. When floating and submerged species were analysed separately, only submerged species appeared to be affected by chlorophyll-*a*, indicating its light attenuation properties are indeed the most likely influence on community composition. There may also be some competition for nutrients between phytoplankton and macrophytes. This would not affect the overall nutrient levels in the water, but could affect certain species more than others. Another possibility is that certain plants facilitate or impede the growth of phytoplankton. There has been some evidence of allelopathic relationships between algae and macrophytes (Scheffer, 1998).

The relationship between sediment organic content and species composition is difficult to interpret. Since relationships between sites are being compared, not the actual sites, the negative correlation means that as the similarity between sites in terms of species composition increased, their similarity in terms of sediment organic content decreased. Precisely what this means in biological terms is uncertain. However, given that the relationship is weak, it is unlikely to be biologically significant, in spite of its statistically significance. In the CCA, sediment organic content accounted for much of the variation in the data, but few species seemed to be heavily influenced by it. This relationship may have been an artifact of the nature of the test. The Mantel test examines the relationships between sites, not sites themselves. Between 24 quadrats there were 276 relationships (elements in the comparison matrix), while for 32 sites there were 496 relationships. As a result, these tests have high power, and even small deviations from the norm would be detected as significant.

The CCA corroborated the results of the Mantel test, that the environmental variable examined in this study has little impact on species composition. In the CCA ordination diagram, species clustered somewhat according to their growth habit, (floating, submerged and emergent) but there was little clustering into defined communities, which has often been observed in other studies on macrophyte species. However, many of these studies (e.g. Baatrup-Pederson and Riis,1999; Bini *et al.*, 1999; Srivasta *et al.*, 1995; Ali *et al.*, 1995, Lougheed *et al.*, 2001), are comparisons between lakes and are therefore examining a larger variation in environmental conditions. For example, Vestergaard and Sand-Jensen (2000) compared lakes with pH ranging from 4.4 to 10.2, and total phosphorus from 0.010 to 0.470 mg/l. In contrast, the pH in the Rideau River ranged between 7.7 and 8.9, while total phosphorus was between 0.017 and 0.052 mg/l.

Few studies examine patterns within one body of water, where there tends to be less variation in water chemistry. One study by Penuelas and Sabater (1987) also examined species composition within one river, but the river exhibited a wide range of habitat types along its course from the headwaters in the Pyrenees mountains to the mouth in the Mediterranean. Ali *et al.* (1995), compared three sites in the Nile river on opposite sides of two dams, but it was difficult to interpret the effect of the 22 variables measured on the 11 species found. Bini *et al.* (1999) examined macrophyte community composition in one reservoir, and was able to find an influence of pH, total phosphorus and euphotic depth, in spite of relatively small gradients.

Another explanation is that there is very little variation in macrophyte species composition independent of the environmental variables, as shown by the cluster analysis and the correspondence analysis. It appears that Rideau River supports one main macrophyte community, that will appear wherever habitat conditions suit macrophyte growth.

Floating and floating-leafed species were the only ones to demonstrate any environmental preference, which was for areas with low water velocity. This was especially pronounced with the non-rooted species *Spirodella polyrhiza* and *Wolffia borealis*, not surprising since even moderate water velocity would wash these tiny floating plants away. The water-lilies (*Nyphaea odorata* and *Nuphar variegata*) are also known for occupying areas of low water velocity (Crow and Hellquist, 2000).

Butomus umbellatus, an alien invasive, stands alone in terms of what determines its presence, both independent of and in response to the environmental variables. The main influence was the distance from shore, and to a lesser extent, the depth. *B. umbellatus* is an emergent species that is also associated with wetlands and wetland species, but can be found in water deeper than usually expected for an emergent species, occasionally appearing at depths of 1 metre or more. The species has been referred to as a transitional species between open water and wetland (Hroudova and Zakravsky, 1994). An informal survey (Gillespie, personal communication) found it common along the shores in the urban parks of Ottawa.

Functionally, it is more of a wetland species than a true aquatic. Since other emergent species rarely appeared in our quadrats it was not possible to determine to what extent *B. umbellatus* would have been associated with these other emergent species.

The Mantel test showed species diversity was highly correlated with sediment organic content, water velocity, and littoral width, which corroborates the patterns found using regression analysis in the previous chapter. It was interesting to find that while species richness could be predicted from site characteristics, these same characteristics were not useful in predicting community composition. It appears that while a particular habitat can support a certain number of species, the particular species which colonise the habitat is determined by a set of factors as of yet undetermined or else by random chance. If indeed species composition is randomly determined, this would imply that the species are functionally similar. Such "neutral models" of community ecology have been recently explored by Hubble (2001) and Bell (2001) This has a number or interesting ecological implications, many of which will need to be investigated in future studies.

General Conclusions

Macrophyte diversity in the Rideau River was primarily affected by physical features, particularly sediment organic content, water velocity, and littoral width. Water chemistry had little effect on macrophyte diversity. One reason for this result is that within the Rideau River there was considerably less variation in water chemistry than there was in physical site characteristics, so any influence of pH or nutrients on macrophyte diversity may not have been detectable. Duarte and Kalff (1990) also commented that determining what regulates macrophyte abundance depends on the scale of analysis since lake water chemistry and trophic status varied much more between lakes than within an individual lake, whereas site characteristic such as slope, sediment characteristics and wave exposure varied as much within as among lakes. Since physical features tend to be more characteristic of a particular site, whereas water chemistry is characteristic of the river in general, it was not surprising that physical features were what determined macrophyte diversity within the Rideau River.

This also explains why species richness was lowest from Manotick downstream to the City of Ottawa. While initially one might expect it be due to the increased phosphorus in the lower portion of the river, it would appear from this study that the lack of species is more due to the physical features of the area. Both sides of the river downstream from Manotick are lined with estate housing, and the kind of shoreline modifications that are typical are those to facilitate boating: infilling, bank reinforcement using rock, rip-rap, and gabians, the addition of sand and gravel, and the establishment of docks and boathouses. The large shallow littoral shelves with organic sediment and slow currents which are ideal macrophyte habitat are not compatible with boating, and over the last several decades have been gradually declining. The upper reaches of the Rideau River have had less developmental pressure.

From a conservation perspective, this study shows that while it would be necessary to prevent any further chemical degradation of the river, in order to manage for plant diversity there must be a focus on the physical features of the littoral zone. Priority should be given to preserving and restoring riverine wetlands and marshes while ensuring nutrients and other pollutants do not exceed present levels. Shoreline modifications should be scrutinised and considered in the context of the whole river.

None of the environmental variables that were examined had much of an influence on macrophyte species composition. Nor was there much variation in macrophyte species composition independent of the environmental variables. Most studies on macrophyte composition showed effects due to water chemistry variables such as alkalinity, pH and nutrient concentrations, (e.g. Baatrup-Pederson and Riis,1999; Bini *et al.*, 1999; Srivasta *et al.*, 1995; Ali *et al.*, 1995, Lougheed *et al.*, in press) and again the variation in water chemistry in the Rideau River was relatively small. Few studies have focussed on physical or site features, though there have been some studies showing effects of sediment characteristics on species composition (e.g. Baatrup-Pederson and Riis, 1999). Overall, there appears to be one community ubiquitous to the river, that inhabits any area suitable for macrophyte growth.

Even the alien species that are considered to be invasive did not show any particular patterns with regard to species composition. *Myriophyllum spicatum* and *Potamogeton crispus* interfere with boating in the Rideau River, but neither of these species was dominant in the littoral zone. *P. crispus* grows vigorously in the early part of the growing season and then dies back by mid June. As a result, it was relatively rare in the quadrats sampled. *M. spicatum*, was commonly observed in the quadrats, but large monocultural expanses of *M. spicatum* were not seen in the littoral areas. Furthermore, the negative impact of this species on overall diversity appeared to be minimal. *M. spicatum* was more common in the lower reaches of the river near Ottawa and *M. sibiricum* more common in the upper reaches, but they often co-existed at a site and did not appear to have a negative impact on each other.

There has also been some concern about the impacts of filamentous algae mats negatively affecting macrophyte development. A regression of species richness and Shannon diversity on average percent algae cover showed that there was no significant impact ($p = 0.435$ and $p = 0.936$ respectively). Filamentous algae reached its peak in late June and early July, but when floating algae were pushed aside, the macrophyte community could be seen growing underneath. Algae died back by August, while macrophytes continued to grow. It is possible, however, that if nutrient concentrations in the Rideau River were to increase, the resulting increase in algae would impede macrophyte growth, possibly resulting in the overall system becoming algae dominated, as has occurred in many shallow lakes world-wide (Scheffer, 1998).

One limitation of the study was the lack of ability to predict where a particular rare species might be found, since they were not found frequently enough to discern a pattern. Unfortunately, these rare species are often the focus of conservation efforts. The species that were rare in the Rideau River (being found in less than 5% of quadrats) were generally found in areas where overall diversity was high, indicating that the best way to protect rare species is to protect these types of habitat. The species that were rare in the Rideau included *Utricularia vulgaris, Potamogeton amplifolius, Potamogeton foliosus, Lemna minor* and *Chara spp.*, though none of these species are rare regionally or provincially. Some are even common elsewhere, but few will tend to be dominant in any kind of habitat. For example, *Utricularia vulgaris* is a typical bog species, and being carnivorous survives well in low-nutrient environments. Since the Rideau River is nutrient-rich, *Utricularia* does not have any particular survival advantage there, so it would not be expected to be common.

It was interesting that while diversity could be predicted, community composition could not. This presents the possibility that while site characteristics determine how many species a habitat can support, exactly which species actually establish themselves is a random process, indicating that many of the species within the Rideau River are functionally similar. This result is consistent with neutral community models (Hubbell, 2001), a concept which has been gaining attention in ecology, and would appear to merit further research.

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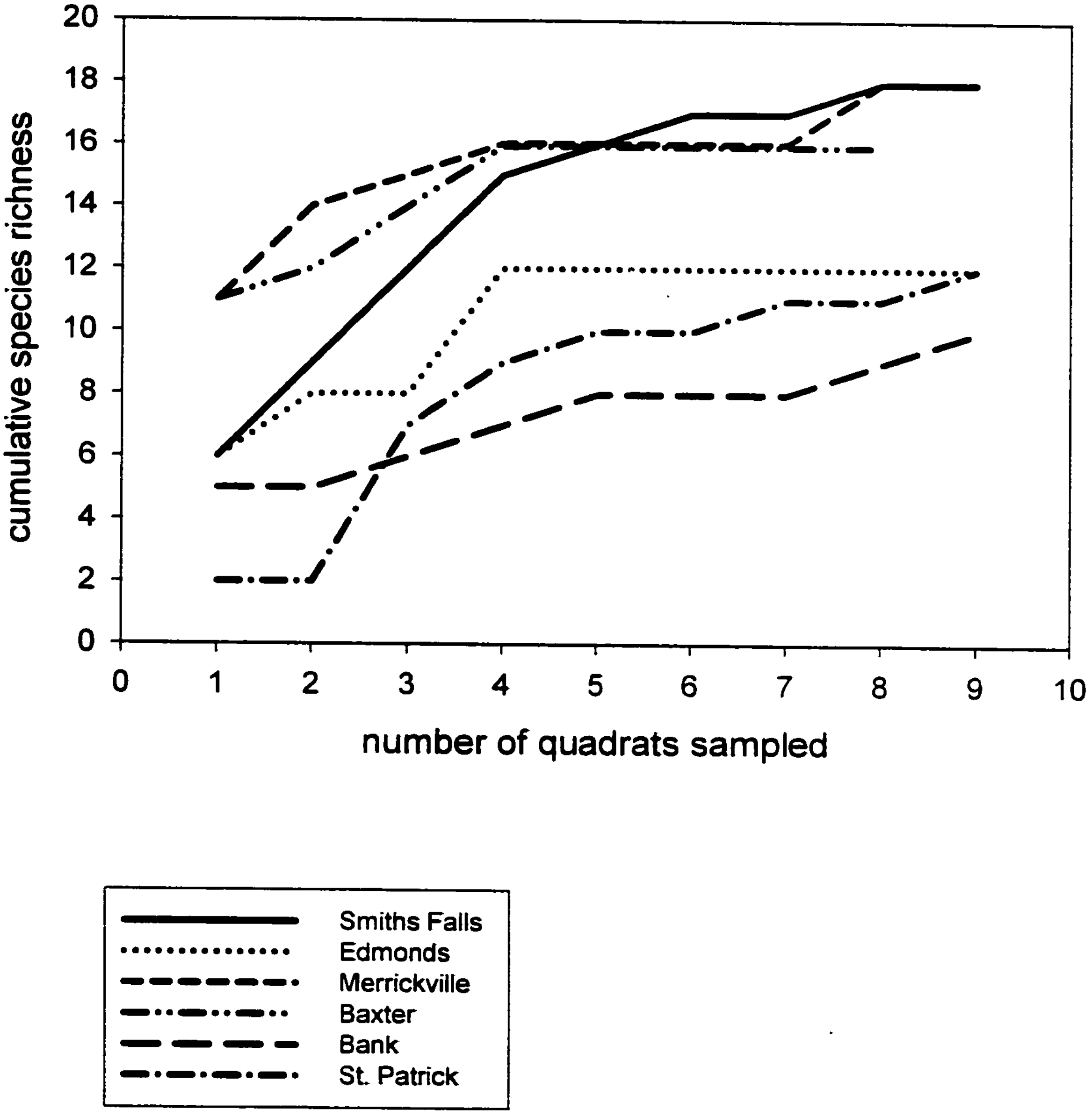
Appendices

Appendix 1-1: Cumulative macrophyte species richness vs. number of quadrats sampled per site in the Rideau River. Unpublished data from Gillespie *et al*. Note that most species were found within six quadrats.

Appendix 1-1



20
18
16
14
12
10
8
6
4
2
0
cumulative species richness
0
1
2
3
4
5
6
7
8
9
10
number of quadrats sampled
Smiths Falls
Edmonds
Merrickville
Baxter
Bank
St. Patrick

Appendix 1-2: Sample calculation for slopes using data from Site 3.

Slope at quadrat 1:
tangent q = (depth at quadrat 2 - depth at shore) / distance at quadrat 2
tangent $\theta = 0.65 - 0.6\ / 8.0)$
$\theta = 0.4$

Slope at quadrat 2:
tangent θ = (depth at quadrat 3 - depth at quadrat 1) / (distance at q.3 - distance at q.1)
tangent $\theta = 0.9 - 0.5 / 9.2 - 7.0)$
$\theta = 10.3$

Slope at quadrat 3:
tangent θ = (depth at q.4 - depth at q.2) / (distance at q. 4 - distance at q. 2)
tangent $\theta = 1.1 - 0.65 / 11.0 - 8.0)$
$\theta = 8.5$

Slope at quadrat 4:
tangent θ = (depth at q.5 - depth at q. 3) / (distance at q. 5 - distance at q. 3)
tangent $\theta = 1.55 - 0.9 / 13.9 - 9.2)$
$\theta = 7.9$

Slope at quadrat 5:
tangent θ = (depth at q. 6 - depth at q. 4) / (distance at q. 6 - distance at q. 4)
tangent $\theta = 2.0 - 1.1 / 15.8 - 11.0)$
$\theta = 10.6$

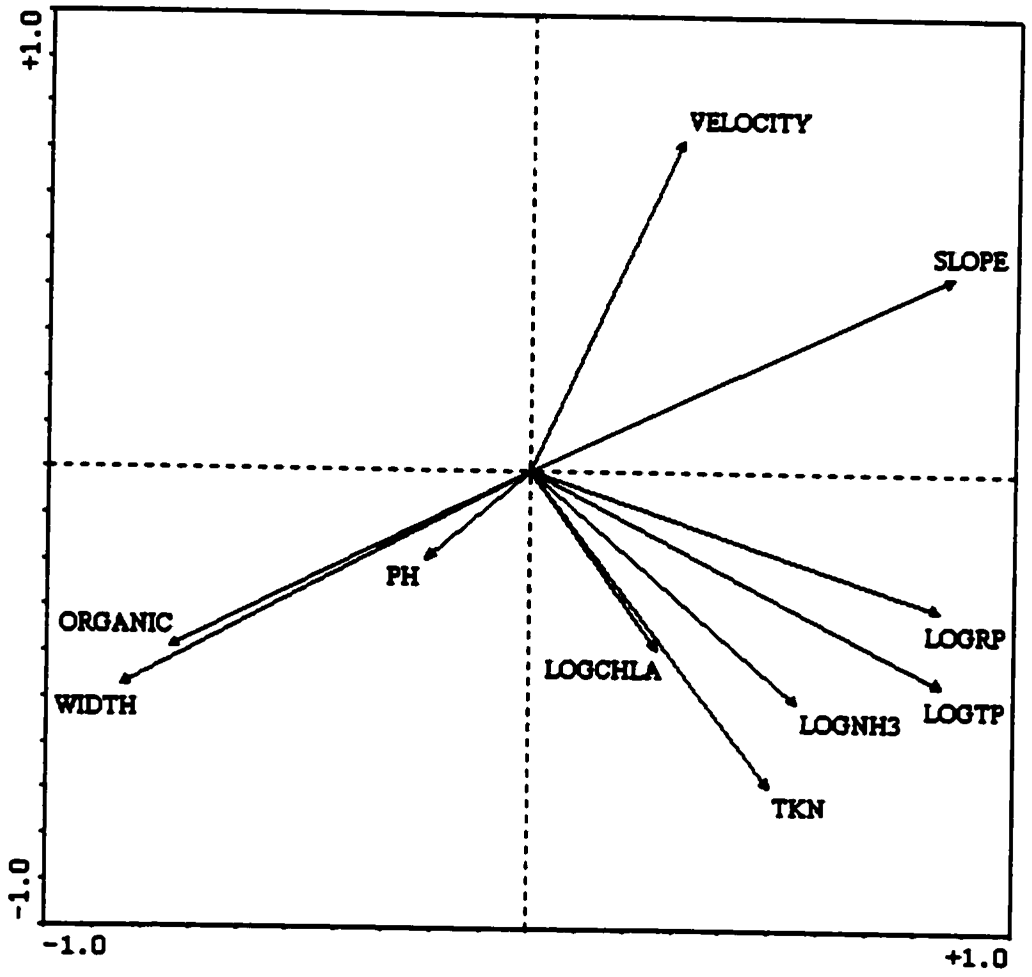
Slope at quadrat 6:
tangent θ = (depth at q. 6 - depth at q. 5) / (distance at q. 6 - distance at q. 5)
tangent $\theta = (2.0 - 1.55) / (15.8 - 13.9)$
$\theta = 13.3$

Average slope for site 3: $(0.4+10.3+8.5+7.9+10.6+13.3) / 6 = 8.5$

Appendix 1-3: Results of Lilliefors probablility test for normalicy on environmental variables, before and after log transformation.

```
Kolmogorov-Smirnov One Sample Test using Normal(0.00,1.00) distribution

  Variable         N-of-Cases       MaxDif  Lilliefors Probability (2-tail)

   VELOCITY            33.000        0.254          0.000
   WIDTH               33.000        0.215          0.000
   ORGANIC             33.000        0.193          0.003
   CHLA                32.000        0.172          0.017
   LOGVELOCITY         33.000        0.082          0.892
   LOGWIDTH            33.000        0.074          1.000
   LOGORGANIC          33.000        0.192          0.003
   NH3                 24.000        0.175          0.055
   RP                  24.000        0.250          0.000
   TKN                 24.000        0.132          0.340
   TP                  24.000        0.139          0.262
   LOGNH3              24.000        0.079          1.000
   LOGTKN              24.000        0.153          0.155
   LOGRP               24.000        0.156          0.132
   LOGTP               24.000        0.099          0.855
   LOGCHLA             32.000        0.085          0.854
```

Appendix 1-4: Principal Components Analysis of continuous environmental variables: a) ordination diagram and b) principal component loadings. Water velocity, slope, and sediment organic content were measured at six quadrats and averaged. Chlorophyll-*a* and water quality data were derived from two samples collected at 1 metre and 2 metres depth and averaged. Littoral width is the distance from shore at 2 metres depth.



Appendix 1-4 b):

```
Latent Roots (Eigenvalues)

                         1          2          3          4          5

                     4.098      2.065      0.935      0.726      0.625

                         6          7          8          9

                     0.310      0.161      0.048      0.032

Component loadings

                         1          2

  LOGTP              0.922      0.293
  LOGRP              0.892      0.122
  LOGSLOPE           0.763     -0.171
  LOGWIDTH          -0.745      0.569
  LOGORGANIC        -0.684      0.577
  TKN                0.622      0.539
  LOGNH3             0.587      0.419
  LOGVELOCITY        0.152     -0.822
  LOGCHLA            0.305      0.370

Variance Explained by Components

                         1          2

                     4.098      2.065

Percent of Total Variance Explained

                         1          2

                    45.534     22.948
```

Appendix 1-5 a): Multiple regression models for species richness, using backwards stepwise selection. Similar results were found using forward selection.

```
Dep Var: RICHNESS   N: 32   Multiple R: 0.861   Squared multiple R: 0.741

Adjusted squared multiple R: 0.703   Standard error of estimate: 2.376

Effect            Coefficient     Std Error      Std Coef Tolerance       t   P(2 Tail)

CONSTANT                1.037        4.221         0.000        .       0.246     0.808
LOGVELOCITY            -1.049        0.591        -0.255     0.465     -1.776     0.087
LOGWIDTH                1.354        0.622         0.283     0.566      2.176     0.038
LOGORGANIC              1.156        0.441         0.421     0.372      2.623     0.014
LOGCHLA                 1.339        0.775         0.179     0.893      1.728     0.095


Analysis of Variance
Source               Sum-of-Squares   df  Mean-Square      F-ratio        P

Regression                436.479     4      109.120        19.321       0.000
Residual                  152.489    27        5.648


-------------------------------------------------------------------------------

Durbin-Watson D Statistic          1.865
First Order Autocorrelation        0.004


9 case(s) deleted due to missing data.
Step # 0 R =   0.907 R-Square =   0.823
Effect                 Coefficient   Std Error   Std Coef      Tol.   df        F     'P'

In
___
  1 Constant
  2 LOGVELOCITY            -1.567       0.829     -0.307 0.44812    1    3.570    0.078
  3 LOGWIDTH                1.214       0.893      0.282 0.27367    1    1.849    0.194
  4 LOGORGANIC              1.399       0.727      0.446 0.21998    1    3.705    0.073
  5 LOGNH3                 -0.616       1.305     -0.075 0.46690    1    0.223    0.644
  6 TKN                     7..852     11.267      0.158 0.22864    1    0.486    0.497
  7 LOGRP                   0.941       1.374      0.235 0.09989    1    0.469    0.504
  8 LOGTP                  -2.214       3.708     -0.251 0.06707    1    0.356    0.559
  9 LOGCHLA                 1.567       1.006      0.203 0.69387    1    2.428    0.140

Out                   Part. Corr.
___
    none


-------------------------------------------------------------------------------


Dependent Variable RICHNESS
Minimum tolerance for entry into model = 0.000000

Backward stepwise with Alpha-to-Enter=0.150 and Alpha-to-Remove=0.150
Step # 1 R =  0.906 R-Square =  0.820
Term removed: LOGNH3
```

```
Effect                Coefficient   Std Error  Std Coef     Tol.   df        F      'P'

In
___
  1 Constant
  2 LOGVELOCITY          -1.592       0.807     -0.312  0.44996   1    3.889    0.066
  3 LOGWIDTH              1.296       0.854      0.301  0.28438   1    2.301    0.149
  4 LOGORGANIC            1.255       0.644      0.400  0.26699   1    3.805    0.069
  6 TKN                   7.512      10.967      0.152  0.22958   1    0.469    0.503
  7 LOGRP                 0.673       1.220      0.168  0.12049   1    0.304    0.589
  8 LOGTP                -2.137       3.613     -0.242  0.06720   1    0.350    0.563
  9 LOGCHLA               1.520       0.976      0.197  0.70085   1    2.424    0.139

Out                   Part. Corr.
___
  5 LOGNH3               -0.121         .          .    0.46690   1    0.223    0.644

-------------------------------------------------------------------------------
Step # 2 R =  0.904 R-Square =  0.817
Term removed: LOGRP
Effect                Coefficient   Std Error  Std Coef     Tol.   df        F      'P'

In
___
  1 Constant
  2 LOGVELOCITY          -1.718       0.758     -0.336  0.48955   1    5.141    0.037
  3 LOGWIDTH              1.396       0.818      0.325  0.29772   1    2.913    0.106
  4 LOGORGANIC            1.082       0.550      0.345  0.35026   1    3.869    0.066
  6 TKN                   4.649       9.460      0.094  0.29590   1    0.242    0.629
  8 LOGTP                -0.505       2.028     -0.057  0.20465   1    0.062    0.806
  9 LOGCHLA               1.326       0.892      0.172  0.80476   1    2.211    0.155

Out                   Part. Corr.
___
  5 LOGNH3               -0.053         .          .    0.56319   1    0.044    0.836
  7 LOGRP                 0.137         .          .    0.12049   1    0.304    0.589

-------------------------------------------------------------------------------
Step # 3 R =  0.903 R-Square =  0.816
Term removed: LOGTP
Effect                Coefficient   Std Error  Std Coef     Tol.   df        F      'P'

In
___
  1 Constant
  2 LOGVELOCITY          -1.656       0.696     -0.324  0.55057   1    5.662    0.029
  3 LOGWIDTH              1.501       0.680      0.349  0.40775   1    4.870    0.041
  4 LOGORGANIC            1.108       0.527      0.353  0.36263   1    4.426    0.050
  6 TKN                   2.869       6.025      0.058  0.69157   1    0.227    0.640
  9 LOGCHLA               1.295       0.860      0.168  0.82148   1    2.268    0.149

Out                   Part. Corr.
___
  5 LOGNH3               -0.074         .          .    0.71646   1    0.095    0.762
  7 LOGRP                 0.029         .          .    0.36694   1    0.014    0.907
  8 LOGTP                -0.060         .          .    0.20465   1    0.062    0.806
```

```
--------------------------------------------------------------------------------
Step # 4 R =  0.902 R-Square =  0.814
Term removed: TKN
Effect               Coefficient    Std Error  Std Coef     Tol.   df        F      'P'


In

---
  1 Constant
  2 LOGVELOCITY           -1.783        0.629    -0.349 0.64675    1    8.044    0.011
  3 LOGWIDTH               1.520        0.665     0.354 0.40909    1    5.220    0.034
  4 LOGORGANIC             1.020        0.483     0.325 0.41269    1    4.455    0.048
  9 LOGCHLA                1.447        0.781     0.188 0.95347    1    3.428    0.080

Out                  Part. Corr.

---
  5 LOGNH3                -0.036          .          .  0.79142    1    0.023    0.880
  6 TKN                    0.112          .          .  0.69157    1    0.227    0.640
  7 LOGRP                  0.074          .          .  0.45036    1    0.099    0.757
  8 LOGTP                  0.045          .          .  0.47831    1    0.037    0.850

--------------------------------------------------------------------------------
```

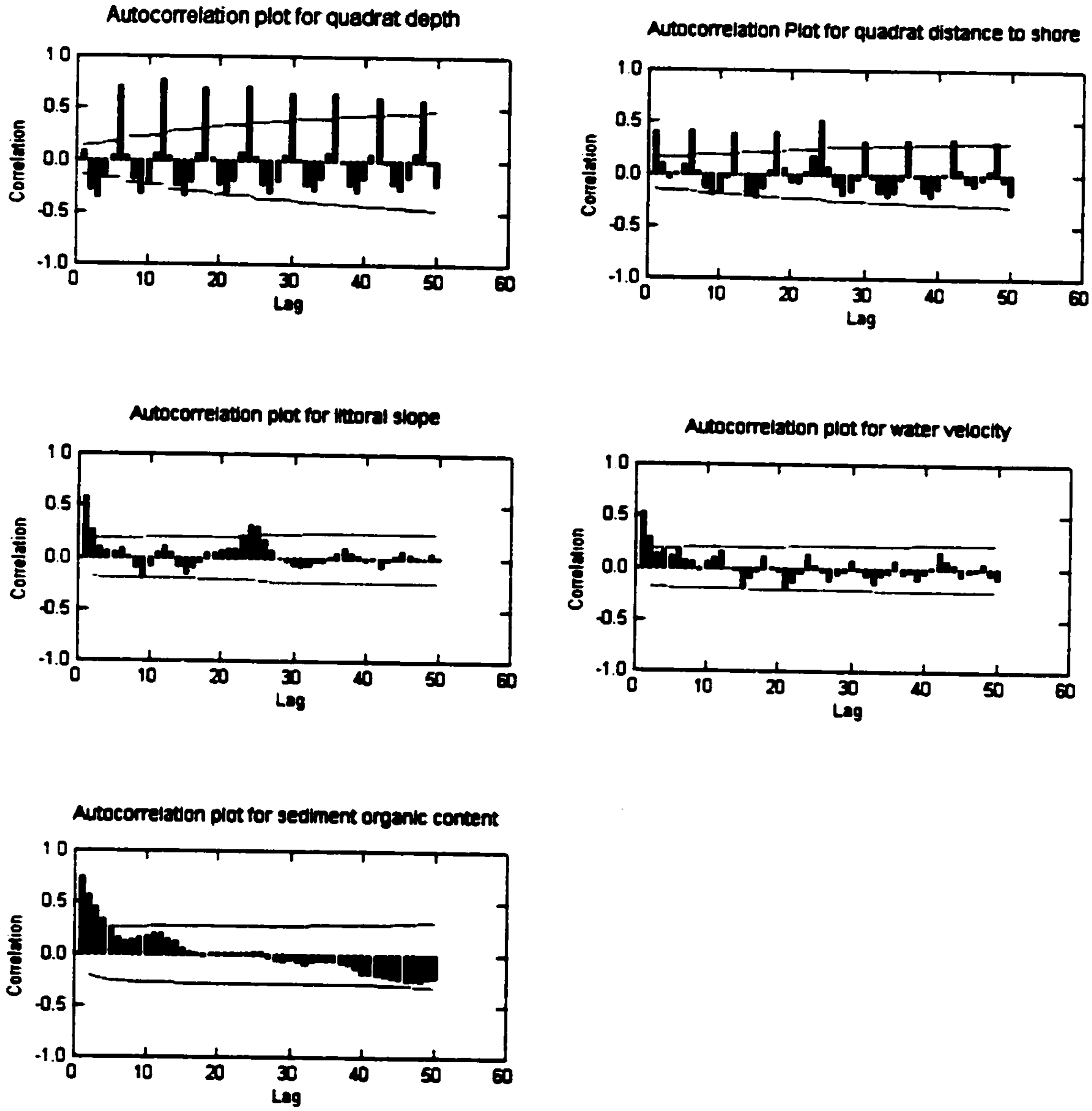
Appendix 1-5 b): Multiple regression models for Shannon diversity, using backwards stepwise selection. Similar results were found using forward selection.

```
Dep Var: SHANNON   N: 33   Multiple R: 0.886   Squared multiple R: 0.784

Adjusted squared multiple R: 0.770   Standard error of estimate: 0.371

Effect           Coefficient    Std Error     Std Coef Tolerance      t   P(2 Tail)

CONSTANT               1.652        0.514        0.000       .       3.213    0.003
LOGVELOCITY           -0.286        0.088       -0.386    0.513     -3.262    0.003
LOGORGANIC             0.283        0.059        0.572    0.513      4.829    0.000


Analysis of Variance
Source              Sum-of-Squares   df  Mean-Square      F-ratio       P

Regression                15.038      2        7.519       54.544       0.000
Residual                   4.135     30        0.138


-------------------------------------------------------------------------------
*** WARNING ***
Case             17 is an outlier          (Studentized Residual =        -3.681)

Durbin-Watson D Statistic           2.126
First Order Autocorrelation        -0.076

Dependent Variable SHANNON
Minimum tolerance for entry into model = 0.000000

Backward stepwise with Alpha-to-Enter=0.150 and Alpha-to-Remove=0.150
Step # 1 R =  0.885 R-Square =  0.784
Term removed: LOGTP
Effect              Coefficient    Std Error   Std Coef     Tol.   df        F     'P'

In
___
 1 Constant
 2 LOGVELOCITY          -0.311        0.146     -0.370 0.44937    1    4.549    0.049
 3 LOGWIDTH              0.074        0.139      0.105 0.34862    1    0.283    0.602
 4 LOGORGANIC            0.298        0.122      0.578 0.24124    1    5.960    0.027
 5 LOGNH3               -0.176        0.229     -0.130 0.46779    1    0.587    0.455
 6 TKN                   0.700        1.264      0.086 0.56219    1    0.307    0.587
 7 LOGRP                 0.095        0.156      0.145 0.23958    1    0.370    0.552
 9 LOGCHLA               0.127        0.164      0.100 0.80596    1    0.595    0.452

Out                 Part. Corr.
___
 8 LOGTP                -0.005          .          .    0.06707    1    0.000    0.986

-------------------------------------------------------------------------------
Step # 2 R =  0.883 R-Square =  0.780
Term removed: LOGWIDTH
Effect              Coefficient    Std Error   Std Coef     Tol.   df        F     'P'
```

```
 In
___
  1 Constant
  2 LOGVELOCITY          -0.334       0.136     -0.398 0.49368    1    6.027    0.025
  4 LOGORGANIC            0.326       0.108      0.631 0.29303    1    9.007    0.008
  5 LOGNH3               -0.200       0.220     -0.148 0.48653    1    0.823    0.377
  6 TKN                   0.833       1.213      0.102 0.58495    1    0.472    0.501
  7 LOGRP                 0.083       0.151      0.126 0.24495    1    0.299    0.591
  9 LOGCHLA               0.109       0.157      0.086 0.84012    1    0.480    0.498

 Out               Part. Corr.
___
  3 LOGWIDTH              0.132         .          .   0.34862    1    0.283    0.602
  8 LOGTP                -0.065         .          .   0.08544    1    0.068    0.797

-------------------------------------------------------------------------------------
Step # 3 R =  0.881 R-Square =  0.776
Term removed: LOGRP
Effect                Coefficient   Std Error  Std Coef    Tol.   df        F     'P'

 In
___
  1 Constant
  2 LOGVELOCITY          -0.360       0.125     -0.429 0.56482    1    8.354    0.010
  4 LOGORGANIC            0.284       0.076      0.550 0.57694    1   14.034    0.001
  5 LOGNH3               -0.123       0.166     -0.091 0.81959    1    0.547    0.469
  6 TKN                   1.032       1.135      0.127 0.64251    1    0.827    0.375
  9 LOGCHLA               0.100       0.153      0.079 0.85052    1    0.421    0.524

 Out               Part. Corr.
___
  3 LOGWIDTH              0.110         .          .   0.35644    1    0.208    0.654
  7 LOGRP                 0.132         .          .   0.24495    1    0.299    0.591
  8 LOGTP                 0.056         .          .   0.19432    1    0.053    0.821

-------------------------------------------------------------------------------------
Step # 4 R =  0.878 R-Square =  0.771
Term removed: LOGCHLA
Effect                Coefficient   Std Error  Std Coef    Tol.   df        F     'P'

 In
___
  1 Constant
  2 LOGVELOCITY          -0.354       0.122     -0.421 0.56863    1    8.358    0.009
  4 LOGORGANIC            0.290       0.074      0.561 0.58482    1   15.269    0.001
  5 LOGNH3               -0.114       0.163     -0.084 0.82545    1    0.487    0.494
  6 TKN                   1.275       1.054      0.156 0.72139    1    1.463    0.241

 Out               Part. Corr.
___
  3 LOGWIDTH              0.079         .          .   0.36909    1    0.112    0.742
  7 LOGRP                 0.112         .          .   0.24798    1    0.231    0.637
  8 LOGTP                 0.087         .          .   0.20399    1    0.136    0.717
  9 LOGCHLA               0.151         .          .   0.85052    1    0.421    0.524

-------------------------------------------------------------------------------------
Step # 5 R =  0.874 R-Square =  0.765
Term removed: LOGNH3
```

```
Effect              Coefficient    Std Error   Std Coef     Tol.   df        F      'P'

In
___
 1 Constant
 2 LOGVELOCITY          -0.343        0.120      -0.408 0.57827    1    8.189    0.010
 4 LOGORGANIC            0.295        0.073       0.572 0.59097    1   16.418    0.001
 6 TKN                   1.041        0.986       0.128 0.80301    1    1.113    0.304

Out                 Part. Corr.
___
 3 LOGWIDTH              0.130         .           .    0.42518    1    0.326    0.575
 5 LOGNH3               -0.158         .           .    0.82545    1    0.487    0.494
 7 LOGRP                -0.014         .           .    0.41307    1    0.004    0.952
 8 LOGTP                -0.017         .           .    0.29552    1    0.005    0.942
 9 LOGCHLA               0.136         .           .    0.85659    1    0.355    0.558

-------------------------------------------------------------------------------------
Step # 6 R =  0.867 R-Square =  0.752
Term removed: TKN
Effect              Coefficient    Std Error   Std Coef     Tol.   df        F      'P'

In
___
 1 Constant
 2 LOGVELOCITY          -0.395        0.110      -0.470 0.69550    1   12.986    0.002
 4 LOGORGANIC            0.265        0.067       0.514 0.69550    1   15.535    0.001

Out                 Part. Corr.
___
 3 LOGWIDTH              0.122         .           .    0.42535    1    0.301    0.590
 5 LOGNH3               -0.073         .           .    0.91885    1    0.106    0.748
 6 TKN                   0.230         .           .    0.80301    1    1.113    0.304
 7 LOGRP                 0.082         .           .    0.49710    1    0.136    0.716
 8 LOGTP                 0.158         .           .    0.65041    1    0.515    0.481
 9 LOGCHLA               0.207         .           .    0.99138    1    0.898    0.355

-------------------------------------------------------------------------------------
```

Appendix 2-1: Autocorrelation plots of environmental variables measured at each quadrat. A total of 198 quadrats were distributed among 33 sites.


Autocorrelation plot for quadrat depth

Autocorrelation Plot for quadrat distance to shore

Autocorrelation plot for littoral slope

Autocorrelation plot for water velocity

Autocorrelation plot for sediment organic content

Appendix 2-2: Pearson correlation matrix of independent environmental variables measured at each $1m^2$ quadrat, and loadings calculated in a principle components analysis.

```
                     DEPTH   LOGDISTANCE  LOGVELOCITY   LOGORGANIC    LOGSLOPE
 DEPTH               1.000
 LOGDISTANCE         0.635      1.000
 LOGVELOCITY         0.279      0.162        1.000
 LOGORGANIC          0.135      0.222       -0.487        1.000
 LOGSLOPE           -0.015     -0.432       -0.003       -0.211         1.000


Latent Roots (Eigenvalues)
                        1            2           3           4           5
                        2.021        1.515       0.853       0.401       0.210

Component loadings
                        1            2
   DEPTH                0.750        0.391
   LOGDISTANCE          0.916        0.127
   LOGSLOPE            -0.602        0.266
   LOGVELOCITY          0.114        0.881
   LOGORGANIC           0.495       -0.706

Variance Explained by Components
                        1            2
                        2.021        1.515

Percent of Total Variance Explained
                        1            2
                      40.428       30.298
```

Appendix 2-3: Log file of detrended correspondence analysis.

```
For explanation of the input/output see the manual or
 Ter Braak, C.J.F. (1995) Ordination. Chapter 5 in:
 Data Analysis in Community and Landscape Ecology
 (Jongman, R.H.G., Ter Braak, C.J.F. and Van Tongeren, O.F.R., Eds)
 Cambridge University Press, Cambridge, UK, 91-173 pp.

 *** Type of analysis ***
  Model                Gradient analysis
                indirect     direct     hybrid
 linear          1=PCA       2= RDA       3
 unimodal        4= CA       5= CCA       6
    ,,           7=DCA       8=DCCA       9
                10=non-standard analysis
 Type analysis number
 Answer =  7


 *** Data files ***
 Species data        : h:\RIVER\CCA\QSPECIES.DAT
 Covariable data     :
 Environmental data  : h:\RIVER\CCA\QENVIRON.DAT
 Initialization file:

 Number of segments                     =   26
 Nonlinear recaling of axes
 Rescaling threshold                    =  .00
 Number of axes in biplot               =    2

 Diagnostics                            =    2

 File    : h:\RIVER\CCA\QSPECIES.DAT
 Title   : WCanoImp produced data file

 Format :   (I5,1X,19F3.0)
 No. of couplets of species number and abundance per line :     0


 No samples omitted
 Number of samples           202
 Number of species            19
 Number of occurrences       709


 File   : h:\RIVER\CCA\QENVIRON.DAT
 Title  : WCanoImp produced data file

 Format :   (I5,1X,4F15.9,1(/6X,(4F15.9)))
 No. of environmental variables :     7

 No interaction terms defined

 No transformation of species data
 No species-weights specified
 No  sample-weights specified
 No downweighting of rare species

 No. of active  samples:    178
 No. of passive samples:      0
```

```
No. of active  species:     19

Total inertia in species data=
Sum of all eigenvalues of CA =    4.29112


****** Check on influence in covariable/environment data ******
The following sample(s) have extreme values
Sample Environmental        Covariable  + Environment space
       variable Influence   influence     influence

   100     4      5.0x
   100                                      3.2x
   137                                      3.1x
   138                                      4.0x
   149     4      6.0x
   149                                      3.5x
   179     4      5.0x
   196                                      3.5x
****** End of check ******

   N  name      (weighted) mean     stand. dev.      inflation factor

   1  SPEC AX1              2.8745              .7243
   2  SPEC AX2              2.7776              .6452
   3  SPEC AX3              1.7031              .5148
   4  SPEC AX4              1.5816              .5370
   5  ENVI AX1              2.8745              .3421
   6  ENVI AX2              2.7776              .3288
   7  ENVI AX3              1.7031              .1219
   8  ENVI AX4              1.5816              .1907
   3  DEPTH                  .0170              .9690          2.3933
   4  distance               .1897             1.0306          2.8522
   5  slope                -.2286              .9607          1.7785
   6  velocity             -.2861              .8089          1.3981
   7  organic                .3842              .8193          1.3114


**** Summary ****

Axes                                      1            2            3            4
      Total inertia

Eigenvalues                      :      .550         .405         .299         .248
            4.291
Lengths of gradient              :     4.475        4.939        3.983        3.455
Species-environment correlations :      .472         .510         .237         .355
Cumulative percentage variance
   of species data               :      12.8         22.3         29.2         35.0
   of species-environment relation:     23.5         49.6           .0           .0

Sum of all unconstrained eigenvalues
        4.291
Sum of all canonical     eigenvalues
         .385
```

Appendix 2-4: Canonical correspondence analysis output file.

```
[Tue Jan 22 11:08:19 2002] Log file created
[Tue Jan 22 11:09:24 2002] Settings changed
[Tue Jan 22 11:09:36 2002] CON file [H:\river\qcca.con] saved
[Tue Jan 22 11:09:41 2002] Running CANOCO:
[Tue Jan 22 11:09:41 2002] CON file [H:\river\qcca.con] saved
 Program CANOCO Version 4.0 April 1998 - written by Cajo J.F. Ter Braak
 Copyright (c) 1988-1998 Centre for Biometry Wageningen, CPRO-DLO
 Box 100, 6700 AC Wageningen, the Netherlands.
 CANOCO performs (partial) (detrended) (canonical) correspondence analysis,
 principal components analysis and redundancy analysis.
 CANOCO is an extension of Cornell Ecology program DECORANA (Hill,1979)

 For explanation of the input/output see the manual or
 Ter Braak, C.J.F. (1995) Ordination. Chapter 5 in:
 Data Analysis in Community and Landscape Ecology
 (Jongman, R.H.G., Ter Braak, C.J.F. and Van Tongeren, O.F.R., Eds)
 Cambridge University Press, Cambridge, UK, 91-173 pp.

 *** Type of analysis ***
  Model              Gradient analysis
               indirect      direct     hybrid
 linear         1=PCA        2= RDA       3
 unimodal       4= CA        5= CCA       6
    ,,          7=DCA        8=DCCA       9
               10=non-standard analysis
 Type analysis number
 Answer =  5


 *** Data files ***
 Species data        : H:\RIVER\QSPECIES.DAT
 Covariable data     :
 Environmental data  : H:\RIVER\QENVIRON.DAT
 Initialization file:

 Forward selection of envi. variables =    0
 Scaling of ordination scores         =    2
 Diagnostics                          =    3

 File    : H:\RIVER\QSPECIES.DAT
 Title   : WCanoImp produced data file

 Format :   (I5,1X,19F3.0)
 No. of couplets of species number and abundance per line :    0

 No samples omitted
 Number of samples            202
 Number of species             19
 Number of occurrences        709


 File   : H:\RIVER\QENVIRON.DAT
 Title  : WCanoImp produced data file

 Format :   (I5,1X,4F15.9,1(/6X,(4F15.9)))
 No. of environmental variables :     7

 No interaction terms defined
```

```
No transformation of species data
No species-weights specified
No  sample-weights specified
No downweighting of rare species

No. of active  samples:    178
No. of passive samples:      0
No. of active  species:     19

Total inertia in species data=
Sum of all eigenvalues of CA =    4.29112

****** Check on influence in covariable/environment data ******
The following sample(s) have extreme values
Sample Environmental        Covariable  + Environment space
       variable Influence   influence     influence

   100     4      5.0x
   100                                      3.2x
   137                                      3.1x
   138                                      4.0x
   149     4      6.0x
   149                                      3.5x
   179     4      5.0x
   196                                      3.5x
****** End of check ******

**** Weighted correlation matrix (weight = sample total) ****

SPEC AX1  1.0000
SPEC AX2  -.0350  1.0000
SPEC AX3  -.0315  -.0821  1.0000
SPEC AX4   .0588   .0496  -.0108  1.0000
ENVI AX1   .6064   .0000   .0000   .0000  1.0000
ENVI AX2   .0000   .5613   .0000   .0000   .0000  1.0000
ENVI AX3   .0000   .0000   .4328   .0000   .0000   .0000  1.0000
ENVI AX4   .0000   .0000   .0000   .4013   .0000   .0000   .0000  1.0000
DEPTH     -.0145   .5559  -.0357  -.0430  -.0239   .9904  -.0825  -.1070
distance  -.1201   .4115   .1968   .1131  -.1980   .7331   .4547   .2818
slope      .3176  -.0939  -.3558   .0372   .5237  -.1673  -.8222   .0927
velocity   .2937   .2804   .0914   .1902   .4843   .4996   .2113   .4741
organic   -.5543   .0890  -.1129   .0714  -.9141   .1585  -.2608   .1779

        SPEC AX1 SPEC AX2 SPEC AX3 SPEC AX4 ENVI AX1 ENVI AX2 ENVI AX3 ENVI AX4

DEPTH         1.0000
distance       .6576     1.0000
slope         -.1220     -.5314     1.0000
velocity       .4224      .3161     -.0168     1.0000
organic        .1843      .1550     -.2972     -.2354     1.0000
           DEPTH       distance    slope      velocity    organic

  N  name      (weighted) mean    stand. dev.      inflation factor

  1  SPEC AX1          .0000               1.6490
  2  SPEC AX2          .0000               1.7816
  3  SPEC AX3          .0000               2.3107
  4  SPEC AX4          .0000               2.4921
  5  ENVI AX1          .0000               1.0000
  6  ENVI AX2          .0000               1.0000
```

```
  7  ENVI AX3               .0000          1.0000
  8  ENVI AX4               .0000          1.0000
  3  DEPTH                  .0170           .9690          2.3933
  4  distance               .1897          1.0306          2.8522
  5  slope                 -.2286           .9607          1.7785
  6  velocity              -.2861           .8089          1.3981
  7  organic                .3842           .8193          1.3114

**** Summary ****

Axes                                  1     2      3     4    Total inertia

Eigenvalues                     :   .156  .114   .051  .038          4.291
Species-environment correlations :  .606  .561   .433  .401
Cumulative percentage variance
   of species data              :    3.6   6.3    7.5   8.4
   of species-environment relation: 40.4  70.2   83.5  93.5

Sum of all unconstrained eigenvalues
        4.291
Sum of all canonical     eigenvalues
         .385

*** Unrestricted permutation ***

Seeds:  23239   945

**** Summary of Monte Carlo test ****

Test of significance of first canonical axis: eigenvalue =      .156
                                              F-ratio    =    6.470
                                              P-value    =     .0050

(  199 permutations under reduced model)

[Tue Jan 22 11:09:43 2002] CANOCO call succeeded
[Tue Jan 22 11:10:49 2002] Running CanoDraw
[Tue Jan 22 11:10:49 2002] CanoDraw call succeeded
```

Appendix 2-5: Correspondence Analysis output file

```
For explanation of the input/output see the manual or
Ter Braak, C.J.F. (1995) Ordination. Chapter 5 in:
Data Analysis in Community and Landscape Ecology
(Jongman, R.H.G., Ter Braak, C.J.F. and Van Tongeren, O.F.R., Eds)
Cambridge University Press, Cambridge, UK, 91-173 pp.

*** Type of analysis ***
 Model             Gradient analysis
              indirect      direct      hybrid
linear         1=PCA        2= RDA        3
unimodal       4= CA        5= CCA        6
   ,,          7=DCA        8=DCCA        9
              10=non-standard analysis
Type analysis number
Answer =  4

*** Data files ***
Species data         : H:\RIVER\CCA\QSPECIES.DAT
Covariable data      :
Environmental data   :
Initialization file:

Scaling of ordination scores          =    2
Diagnostics                           =    3

File    : H:\RIVER\CCA\QSPECIES.DAT
Title   : WCanoImp produced data file

Format :   (I5,1X,19F3.0)
No. of couplets of species number and abundance per line :    0

No samples omitted
Number of samples            202
Number of species             19
Number of occurrences        709

No transformation of species data
No species-weights specified
No  sample-weights specified
No downweighting of rare species

No. of active  samples:    178
No. of passive samples:      0
No. of active  species:     19

Total inertia in species data=
Sum of all eigenvalues of CA =    4.29112

**** Summary ****
Axes                                   1      2      3      4  Total inertia

Eigenvalues                       :  .550   .438   .419   .312          4.291
Cumulative percentage variance
   of species data                :  12.8   23.0   32.8   40.1

Sum of all unconstrained eigenvalues                                    4.291
[Mon Apr 29 10:57:38 2002] CANOCO call succeeded
```

Appendix 3: Raw data

				size of littorial zone										
Site	date	location(kn	sp richness	length r	slope tot	slope avg	velocity m	bank heigh	depth at sh	organic co	pH	pH (sept)	DO	Temp
1	29-Jun	63.4	13	58	1.7	1.9267	0.019	0.85	0.6	13.4706		8.05		
2	4-Jul	61.6	14	124	0.9	1.4921	0.015	n/a	0.1	24.2422		8.2		
3	6-Jul	67.6	12	16	5.0	8.5020	0.018	1	0.6	5.5023		8.15		
4	10-Jul	77.0	14	43	2.7	3.9705	0.031		0	15.5431				
5	11-Jul	53.2	15	96	1.2	1.5762	0.023	n/a	0	13.3967		8.2		
6	13-Jul	26.0	12	58.5	1.7	1.6980	0.03	0.5	0.3	22.5417	8.8	8.61	10	23.3
7	14-Jul	84.7	8	9	12.5	16.3128		2.5	0	3.4290	8.22	8.26	8.7	24
8	14-Jul	82.8	7	15.5	6.4	6.9241	0.019	0.9	0.25	1.7162		8.22	8.6	24.3
9	17-Jul	13.0	9	40	2.9	3.6840	0.042	n/a	0.3	38.0520	7.73	7.55	8.5	23.7
10	19-Jul	14.9	11	125	0.6	0.7351	0.034	n/a	0.7	23.3747	8.7	8.02	8.66	21.6
11	24-Jul	94.8	2	7	15.9	15.2057	0.139	0	0	0.8497	8.27		5.62	23.4
12	25-Jul	100.0	5	46	2.2	2.5007	0.064	n/a	0.1	1.4614	8.13		5.58	23.3
13	26-Jul	75.6	3	20	3.3	3.1946	0.312	25	0.1	0.9716	7.98		5.23	
14	28-Jul	34.4	1	14	5.3	0.5000	0.385	0	0	0.5000	8.3		4.34	24.9
15	28-Jul	34.8	13	41	2.8	3.1486	0.016	n/a	0.5	11.2328	8.57		4.86	25.9
16	31-Jul	50.5	14	259	0.4	1.1316	0.007	n/a	0	15.0405	8.89	8.71	4.73	25.9
17	1-Aug	91.6	0	10.5	10.5	11.1134	0.062	11	0.06	0.9249	8.24		5.69	24.6
18	3-Aug	87.2	9	36	3.2	5.7295	0.011	0.15	0	2.4868	8.03		5.22	24.6
19	8-Aug	80.0	5	20	4.9	5.4786	0.021	0.5	0.3	11.9984	7.74	8.08	2.68	24.3
20	10-Aug	21.3	13	272	0.3	0.3645	0.02	n/a	0.6	38.4480	8.46	8.47	3.18	26
21	11-Aug	2.9	7	43	2.1	1.8973	0.049	n/a	0.45	32.8482	7.76		2.44	23.9
22	14-Aug	2.0	12	80.5	1.2	1.2041	0.026	n/a	0.3	44.0981	8.69		3.31	25.4
23	16-Aug	68.6	10	102	0.9	2.2934	0.029	1	0.4	22.2585	8.12		8.38	24.8
24	17-Aug	50.5	13			0.5226	0.032	0.8	0.1	20.9629	7.13	8.39	1.58	21.3
25	13-Sep	37.2	12	67	1.6	1.6245	0.012	n/a	0.7	31.9927				
26	11-Jul	11.9	9	31.6	3.3	3.1449	0.043	0.4	0.25	4.3690				
27	12-Jul	37.6	2	29	0.8	0.5000	0.088	1.5	0	0.5000				
28	12-Jul	38.1	5	34.6	2.6	0.5000	0.078		0	0.5000				
29	13-Jul	17:2	13	27	2.8	2.9545	0.076		0	4.6749				
30	16-Jul	10.6	13	61	1.8	3.4869	0.005	1	0.2	33.6158				
31	17-Jul	30.4	7	26	2.5	0.5000	0.093		0	0.5000				
32	18-Jul	8.7	14	17	6.9	7.2030	0.005	2	0.1	24.0702				IF(I194
33	18-Jul	7.4	7	18.5	3.1	1.7792	0.165	1.2	0.3	0.8160				(-(SUM

											Exotic?	Frequency fo	
Site	NH3 mg/l	RP mg/l	TKN mg/l	TP mg/l	Longitude	Latitude	biomass a	depth a	% algae	Shannon	Richness	Cde	Eca
1	0.070	0.018	0.684	0.031	-75.3856	45.0857	58.25	2.3	2.5	2.484369	13	2	2
2	0.031	0.012	0.689	0.034	-75.3856	45.0768	87.21	1.95	15	2.505847	14	4	3
3	0.047	0.017	0.761	0.050	-75.3807	45.1078	26.4	2	0.41667	2.412388	12	4	2
4	0.024	0.017	0.703	0.039	-75.4142	45.1428	0	2	42.0833	2.382651	14	4	4
5	0.009	0.004	0.749	0.025	-75.3872	45.0381	123.98	2	10.4167	2.359308	15	1	4
6	0.051	0.005	0.706	0.024	-75.526	44.5397	62.31	2	2.5	2.332553	12	2	3
7	0.052	0.046	0.782	0.102	-75.4185	45.1813	22.505	2	6.66667	1.637461	8	0	0
8	0.033	0.027	0.747	0.051	-75.4179	45.17	21.16	2	75	1.632632	7	0	0
9	0.022	0.005	0.601	0.022	-75.5846	44.5227	77.2	2	42.5	1.987694	9	1	3
10	0.028	0.004	0.825	0.034	-75.57	44.5204	115.575	1.9	14.5833	2.322759	11	3	5
11	0.019	0.016	0.616	0.029	-75.4191	45.2285		2	37.9167	1.329662	2	0	0
12	0.025	0.031	0.646	0.041	-75.3992	45.2488		1.85	15.4167	1.468141	5	0	1
13					-75.4103	45.1372		1.25	1.25	0.796312	3	0	0
14	0.021	0.005	0.542	0.019	-75.492	44.5707		1.3	0.41667	0	1	0	0
15	0.017	0.004	0.591	0.021	-75.4899	44.5729		2	0	2.491495	13	3	1
16	0.027	0.006	0.729	0.027	-75.4072	45.0317	185.6	2	2.5	2.53963	14	4	4
17	0.039	0.030	0.724	0.042	-75.4177	45.2146		2	15	0	0	0	0
18	0.044	0.035	0.714	0.051	-75.4196	45.1932		2	40	2.023556	9	5	5
19	0.055	0.027	0.636	0.041	-75.4228	45.1557	5.82	2	62.5	1.468141	5	4	3
20	0.017	0.003	0.553	0.013	-75.537	44.5198	148.68	2	20.8333	2.368433	13	6	2
21	0.024	0.001	0.580	0.017	-76.0285	44.5403		2	35.4167	1.867821	7	5	3
22	0.014	0.001	0.492	0.013	-76.0458	44.5328		2	12.5	2.227399	12	5	3
23	0.021	0.006	0.644	0.028	-75.3815	45.1091		2	17.0833	2.123434	10	6	2
24	0.076	0.021	0.694	0.044	-75.4266	45.0129	160.46	1.8	3	2.43228	13	5	3
25	0.031	0.006	0.532	0.017	-75.4878	44.5851	143.235	1.9	25	2.440134	12	6	4
26								1.8	5.41667	1.798237	9	5	3
27									14.1667	0.187875	2	0	0
28								1.6	21.25	1.088826	5	0	3
29								1.3	0	1.983942	13	1	2
30								1.95	42.9167	2.259928	13	5	3
31	=0,0,((i194/h$194)*(LOG10(i194/h$194))))							1.15	32.9167	0.900557	7	1	1
32	!((I195:AP195)))							2.05	58.3333	2.89693	14	3	5
33								1	38.3333	0.936103	7	0	0
												85	74
												23	25

Site	ind Ltr	Msi	Msp	Nfl	Nod	Nva	Pcr	Pfo	Pfr	Ppe	Ppu	Pri	Pro	Pzo	Raq	Spo	Vam	Wpu (\	Zdu
1	3	0	0	1	0	1	0	2	0	1	1	1	1	0	0	2	2	0	0
2	3	1	0	0	1	1	1	0	0	0	2	0	0	4	0	2	2	4	1
3	3	3	0	0	0	3	2	0	1	0	2	0	0	2	5	0	2	0	3
4	3	0	0	2	1	0	1	0	1	3	1	0	0	2	0	0	6	0	2
5	5	4	0	0	0	0	1	0	1	1	4	6	0	1	3	0	6	0	0
6	5	4	0	4	1	0	1	0	0	3	6	1	0	2	0	0	5	0	0
7	0	0	0	6	0	0	0	0	1	0	0	0	0	0	0	0	6	0	1
8	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	1	1	4
9	6	2	0	0	1	0	0	0	0	0	0	0	0	3	0	1	4	0	0
10	5	3	1	2	0	0	0	0	0	0	3	2	0	4	0	0	4	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
12	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	1	3	0	0
13	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	5	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
15	2	0	4	0	1	0	0	0	1	0	0	0	0	1	1	1	1	1	2
16	2	4	3	1	2	0	0	0	0	2	0	2	0	2	1	0	2	1	2
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	2	4	0	0	0	0	0	0	1	2	0	0	0	0	3	0	1
19	2	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
20	5	3	2	0	1	0	0	0	0	0	0	0	0	2	1	1	2	1	0
21	5	3	0	0	0	0	0	0	0	0	0	0	0	4	0	0	4	0	0
22	6	0	2	0	1	2	0	0	0	0	0	0	1	2	0	0	3	0	2
23	4	1	1	0	2	0	0	0	0	0	0	0	0	0	0	2	4	2	0
24	4	0	2	0	0	1	0	0	0	1	0	1	0	2	0	2	0	2	1
25	3	3	5	0	1	0	1	0	0	0	0	0	0	1	4	0	1	0	2
26	4	3	4	0	0	0	0	0	0	0	0	0	1	0	1	0	6	0	3
27	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	3	0	0	0	0	0	0	0	0	0	0	0	3	0	4	0	5
29	5	2	2	2	2	0	0	0	1	0	0	0	0	2	3	0	4	0	1
30	4	4	4	0	0	0	2	0	0	0	1	0	1	3	4	0	1	0	4
31	4	1	3	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
32	5	5	4	3	2	0	0	0	0	0	2	0	4	5	0	0	4	0	3
33	2	0	1	1	0	0	0	0	3	0	0	0	0	0	1	0	2	0	2
	91	47	47	27	17	8	11	2	9	12	23	17	8	42	27	12	91	12	39
	24	17	17	11	13	5	9	1	7	7	10	8	5	17	11	8	29	7	17

Site	Alisma :	Bbe	Bum	Chglo	Chvul	Chara	Hmo	Lmi	Nitella	Pam	Uvu	Phalar	Scirpus pu	Sparganiur	Sagitaria la	Typha ang	Docodc
1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	1	0	0	1	0	2	0	0	5	0	0	0	0	0	0	0	0
8	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
10	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	2	0	0	0	0	0	0	0	0	1	2	1	0	0	0
12	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0
13	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
21	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
24	0	0	0	0	0	0	3	2	0	0	0	0	0	0	0	0	0
25	0	3	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5	7	14	3	2	2	8	3	6	1	1	1	2	2	2	2	1
	3	4	9	3	2	1	5	2	2	1	1	1	1	2	2	2	1

Site	Drawdown	name	zebra	exposure	shore	adj land use	Chl a	variance v	variance o	sed. phos.
1	0.41	Kars 1		moderate	wetland	agricultural	2.17	0.4539	0.2791	
2	0.41	Kars 2	y	sheltered	wetland	agricultural	4.708989	0.3920	0.0532	
3	0.41	Manotick 1	y	moderate	forest	residential	20.396	0.3581	0.4392	0.727
4	0.41	Manotick 2	y	moderate	riparian strip	residential	6.53	0.1794	0.3428	1.121
5	0.41	Kemptville Creek		moderate	forest	agricultural	2.8	0.3730	0.8025	0.672
6	0.15	Merrickville	n	moderate	forest	forest	4.19	0.5311	0.3396	1.444
7	2.39	Swallow ridge	n	moderate	lawn	residential	6.44	0.0000	0.0000	1.465
8	2.39	Honeygables	n	moderate	lawn	residential	7.47	0.3743	0.1184	0.897
9	0.26	Edmonds	n	sheltered	wetland	agricultural	3.907941	0.4174	0.1144	1.081
10	0.26	Kilmarnock	n	moderate	forest	forest	3.699043	0.1815	0.4592	0.391818
11	n/a	Carleton	y	moderate	riparian strip	urban	2.18161	0.8481	0.2920	
12	n/a	Transitway	y	moderate	riparian strip	urban	2.121427	0.5560	0.4875	0.464
13	0.41	Manotick mill	y	moderate	riparian strip	residential	1.224682	0.1191	0.0761	0.2817
14	0.53	Andrewsville	n	moderate	riparian strip	residential	5.490869	0.5000	0.5000	
15	0.53	Nicholsons	n	sheltered	wetland	forest	2.494513	0.3943	0.3383	0.468
16	0.41	Becketts Landi	n	sheltered	wetland	forest	5.216223	0.2135	0.4450	0.6331
17	2.23	Mooney's Bay	y	moderate	riparian strip	urban	2.309523	0.0359	0.2223	0.627
18	2.23	Black's Rapids		sheltered	riparian strip	agricultural	3.064314	0.3386	0.4268	1.009
19	2.39	Above Jock		sheltered	riparian strip	agricultural	2.54593	0.3955	0.1515	1.161
20	0.15	Big Marsh		sheltered	wetland	forest	2.231161	0.3210	0.1683	
21	0.2	Smith Falls west		moderate	wetland	forest	3.461614	0.4488	0.2856	1.184
22	0.8	Poonamalie		sheltered	wetland	forest	3.300283	0.5266	0.0446	0.925
23	0.41	Jen's site 1		sheltered	lawn	residential	9.480962	0.5568	0.1412	1.287
24	0.41	Jen's site 2		sheltered	riparian strip	agricultural	5.582013	0.5864	0.0463	1.269
25	0.53	Burritts rapids		sheltered	wetland	forest	2.809528	0.3586	0.1328	1.102
26	0.26	Edmonds dam		moderate	riparian strip	residential		0.6562	0.6349	
27	0.41	Burritts rapids dam		moderate	forest	forest	7.594361	0.5000	0.5000	
28	0.41	Burritts rapids site2		moderate	wetland	forest	6.164129	0.5000	0.5000	0.3038
29	0.15	Kilmarnock dam		moderate	wetland	agricultural	6.898255	0.5404	0.6505	0.314
30	0.31	Old Slys		sheltered	riparian strip	agricultural	8.056448	0.0000	0.1294	1.230
31	0.35	Merrickville dam		moderate	riparian strip	residential	6.955653	0.5000	0.5000	
32	0.61	Smith Falls		moderate	riparian strip	urban	7.274064	0.0000	0.2413	0.4152
33	2.12	Smith Falls dam		moderate	lawn	urban	3.29274	0.2874	0.2401	0.413

Label	Site	Quadrat	depth (m)	distance (n	slope	velocity s/1	velocity m/:	logvelocity	organic cor	logorg	cover	richness	cumulative	algae	% algae	cover Cde
1-1	1	1	0.6	9.2	0.8	95	0.011	-1.978	7.092	0.851	2	3	3		0	
1-2	1	2	1	27	1.3	200	0.005	-2.301			1	1	4		0	
1-3	1	3	1.3	40	2.4	66	0.015	-1.820			2	3	7		0	2
1-4	1	4	2.3	58.1	3.2	14	0.071	-1.146			5	3	7		0	5
1-5	1	5	0.6	11.5		200	0.005	-2.301	9.250	0.966	2	5	10		0	
1-6	1	6	1.1	26		200	0.005	-2.301	24.069	1.381	2	5	13	2	15	
site summary			1.150		1.927	129.167	0.019		13.471		2.333	13		1	2.5	2
1-7	1	7	1.4	44.5	0.3	16	0.063	-1.204	22.385	1.350	1	4	14			1
1-8	1	8	2.1			20	0.050	-1.301	20.940	1.321	1	3	14			
							0.026	0.454	9.242	0.279						
2-1	2	1	0.6	7.6	0.7	200	0.005	-2.301	26.000	1.415	4	7	7	2	15	
2-2	2	2	1.05	78	0.5	70	0.014	-1.845	24.759	1.394	5	7	11		0	3
2-3	2	3	1.5	117	1.1	200	0.005	-2.301	24.776	1.394	4	1	11		0	4
2-4	2	4	1.95	124	3.7	30	0.033	-1.477	22.798	1.358	3	4	12		0	2
2-5	2	5	0.6	3.7		200	0.005	-2.301	19.464	1.289	5	6	13	3	37.5	
2-6	2	6	1.05	69		35	0.029	-1.544	27.656	1.442	5	6	14	3	37.5	2
site summary			1.125		1.492	122.500	0.015		24.242		4.333	14		3	15	4
2-7	2	7	1.5			30	0.033	-1.477	22.274	1.348	2	9	16			2
2-8	2	8	2.1			20	0.050	-1.301	21.519	1.333	1	3	16			
							0.013	0.392	2.836	0.053						
3-1	3	1	0.5	7	0.4	45	0.022	-1.653	1.029	0.012	2	2	2	1	2.5	
3-2	3	2	0.65	8	10.3	200	0.005	-2.301	1.455	0.163	2	6	7		0	1
3-3	3	3	0.9	9.2	8.5	200	0.005	-2.301	3.370	0.528	4	10	11		0	2
3-4	3	4	1.1	11	7.9	37	0.027	-1.568	7.268	0.861	5	6	12		0	2
3-5	3	5	1.55	13.9	10.6	35	0.029	-1.544	3.921	0.593	2	5	12		0	
3-6	3	6	2	15.8	13.3	50	0.020	-1.699	15.970	1.203	3	3	12		0	1
site summary			1.117		8.502	94.500	0.018		5.502		3	12		1	0.42	4
							0.011	0.358	5.588	0.439						
4-1	4	1	0.55	6	4.8	40	0.025	-1.602	18.249	1.261	3	3	3	4	62.5	
4-2	4	2	0.8	9.5	3.5	35	0.029	-1.544	15.140	1.180	3	8	8	5	87.5	
4-3	4	3	0.95	12.5	1.1	65	0.015	-1.813	28.426	1.454	4	5	11		0	1
4-4	4	4	1.2		1.1	36	0.028	-1.556	16.142	1.208	4	6	11	5	87.5	3
4-5	4	5	1.5	40	3.8	24	0.042	-1.380	2.837	0.453	5	4	12	2	15	1
4-6	4	6	2	43	9.5	20	0.050	-1.301	12.464	1.096	4	6	12		0	2
site summary			1.167		3.971	36.667	0.031		15.543		3.833	14		4	42.1	4
							0.012	0.179	8.303	0.343						
5-1	5	1	0.6	24	1.4	200	0.005	-2.301	0.589	-0.230	4	7	6	4	62.5	
5-2	5	2	0.8	33.5	1.0	85	0.012	-1.929	0.435	-0.361	4	8	10		0	
5-3	5	3	0.95	45	1.6	22	0.045	-1.342	1.323	0.121	5	6	11		0	
5-4	5	4	1.2	48	3.9	90	0.011	-1.954	2.056	0.313	5	5	11		0	
5-5	5	5	1.5	53	1.0	50	0.020	-1.699	3.868	0.587	5	8	11		0	
5-6	5	6	2	96	0.7	23	0.043	-1.362	72.110	1.858	5	6	13		0	1
site summary			1.175		1.576	78.333	0.023		13.397		4.667	15		1	10.4	1
							0.017	0.373	28.790	0.803						-0.09
6-1	6	1	0.55	6	2.4	200	0.005	-2.301	17.476	1.242	5	6	6		0	1
6-2	6	2	0.85	13.4	1.4	200	0.005	-2.301	22.905	1.360	5	8	10		0	
6-3	6	3	1.05	26.8	0.7	40	0.025	-1.602	6.567	0.817	5	9	11		0	1
6-4	6	4	1.15	37.3	1.7				2.462		5	6	11	2	15	
6-5	6	5	1.55	44.1	2.3	20	0.050	-1.301	32.961	1.518	5	3	11		0	
6-6	6	6	2	58.5	1.8	16	0.063	-1.204	52.879	1.723	5	5	12		0	
site summary			1.192	31.017	1.698	95.200	0.030		22.542		5	12		1	2.5	2
							0.026	0.531	18.510	0.340						
7-1	7	1	0.5	3.5	10.1				3.406		2	2	2		0	
7-2	7	2	0.8	4.5	22.6						2	3	3	1	2.5	
7-3	7	3	1	4.7	21.8				4.053		3	6	4		0	
7-4	7	4	1.2	5.5	21.0						3	4	4		0	
7-5	7	5	1.5	6	12.9						4	5	6		0	
7-6	7	6	2	9	9.5	25	0.040	-1.398	2.828	0.451	2	3	6	3	37.5	
site summary			1.167	5.533	16.31				3.429		2.667	8		2	6.67	0
							0.000	0.000	0.613	0.000						
8-1	8	1	0.5	3.5	5.7	200	0.005	-2.301	1.035	0.015	2	5	3	4	62.5	
8-2	8	2	0.8	5.5	7.1	55	0.018	-1.740	1.824	0.261	2	1	3	4	62.5	
8-3	8	3	1	7.5	6.5	200	0.005	-2.301	1.712	0.233	2	5	6	4	62.5	
8-4	8	4	1.2	9	5.7	53	0.019	-1.724	1.969	0.294	2	1	6	5	87.5	
8-5	8	5	1.5	12.5	7.0	40	0.025	-1.602	2.268	0.356	1	1	6	5	87.5	
8-6	8	6	2	15.5	9.5	25	0.040	-1.398	1.490	0.173	1	1	6	5	87.5	
site summary			1.167	8.917	6.924	95.500	0.019		1.716		1.667	8		6	75	0
							0.013	0.374	0.423	0.118						

9-1	9	1	0.6	2	2.3	200	0.005	-2.301	56.087	1.749	2	3	3			
9-2	9	2	0.75		1.2	32	0.031	-1.505	45.043	1.654	2	4	6	4	62.5	
9-3	9	3	1	21	1.6	23	0.043	-1.362	27.223	1.435	3	2	6	5	87.5	
9-4	9	4	1.2	27.5	2.0	16	0.063	-1.204	31.026	1.492	2	4	8	4	62.5	
9-5	9	5	1.6	38	3.7	23	0.043	-1.362	34.156	1.533	5	4	8		0	
9-6	9	6	2	40	11.3	15	0.067	-1.176	34.777	1.541	5	5	9		0	1
site summary			1.192	25.700	3.684	51.500	0.042		38.052		3.167	9		3	42.5	1
							0.022	0.417	10.646	0.114						
10-1	10	1	0.85	2	1.7	20	0.050	-1.301	54.833	1.739	3	7	7		0	2
10-2	10	2	0.95	8.5	0.9	24	0.042	-1.380	19.835	1.297	3	5	9	5	87.5	2
10-3	10	3	1.05	15	0.4	46	0.022	-1.663	5.621	0.750	5	7	11		0	
10-4	10	4	1.25	48	0.4	27	0.037	-1.431	3.788	0.578	5	6	11		0	
10-5	10	5	1.45	80	0.5	52	0.019	-1.716	13.660	1.135	5	5	11		0	
10-6	10	6	1.9	125	0.6				42.512		5	5	11		0	3
site summary			1.242	46.417	0.735	33.800	0.034		23.375		4.333	11		1	14.6	3
							0.013	0.182	20.792	0.459						
11-1	11	1	0.5	1.5	19.8	200	0.005	-2.301	2.249	0.352	4	4	3	4	62.5	
11-2	11	2	0.9	2.5	16.7	200	0.005	-2.301			2	2	3	4	62.5	
11-3	11	3	1.1	3.5	15.4	30	0.033	-1.477	0.500	-0.301	0	0	3	5	87.5	
11-4	11	4	1.45	4.5	15.6	4.5	0.222	-0.653	0.500	-0.301	1	1	4	2	15	
11-5	11	5	1.8	6	12.4	3.5	0.286	-0.544	0.500	-0.301	0	0	4		0	
11-6	11	6	2	7	11.3	3.5	0.286	-0.544	0.500	-0.301	0	0	4		0	
site summary			1.292	4.167	15.206	73.583	0.139		0.850		1.167	5		4	37.9	0
							0.139	0.848	0.782	0.292						0
12-1	12	1	0.5	2.5	5.5	200	0.005	-2.301	2.658	0.425	4	3	2		0	
12-2	12	2	0.65	5.7	3.0	30	0.033	-1.477	3.735	0.572	5	2	3		0	
12-3	12	3	1	12	1.9				0.971		3	2	4	4	62.5	
12-4	12	4	1.15	20.5	1.3	12	0.063	-1.079	0.272	-0.566	4	2	4	2	15	
12-5	12	5	1.5	34	1.6	10	0.100	-1.000	0.532	-0.274	2	1	4		0	
12-6	12	6	1.85	46	1.7	10	0.100	-1.000	0.601	-0.221	2	2	5	2	15	
site summary			1.108	20.117	2.501	52.400	0.064		1.461		3.333	6		3	15.4	0
							0.043	0.556	1.404	0.488						
13-1	13	1	0.5	5.7	5.9	5	0.200	-0.699	1.040	0.017	2	3	2		0	
13-2	13	2	0.85	7.2	7.9	4	0.250	-0.602	1.152	0.061	3	1	2	1	2.5	
13-3	13	3	1.1	10	1.9	3.5	0.286	-0.544	1.095	0.039	4	1	2	1	2.5	
13-4	13	4	1.05	13.2	0.9	3	0.333	-0.477	0.814	-0.090	5	2	3		0	
13-5	13	5	1.2	16.3	1.7	2.5	0.400	-0.398	0.990	-0.004	2	1	3	1	2.5	
13-6	13	6	1.25	20	0.8	2.5	0.400	-0.398	0.739	-0.131	0	0	3		0	
site summary			0.992	12.067	3.195	3.417	0.312		0.972		2.667	4		3	1.25	0
							0.081	0.119	0.162	0.076						
14-1	14	1	0.5	3	9.5	2	0.500	-0.301	0.500	-0.301	1	1	1		0	
14-2	14	2	0.75	4.5	10.1	2	0.500	-0.301	0.500	-0.301	1	1	1		0	
14-3	14	3	1	5.8	9.5	2.5	0.400	-0.398	0.500	-0.301	0	0	1	1	2.5	
14-4	14	4	1.25	7.5	4.1	2.5	0.400	-0.398	0.500	-0.301	0	0	1		0	
14-5	14	5	1.3	10	0.4	3.5	0.286	-0.544	0.500	-0.301	0	0	1		0	
14-6	14	6	1.3	14	0.0	4.5	0.222	-0.653	0.500	-0.301	0	0	1		0	
site summary			1.017	7.467	5.596	2.833	0.385				0.333	1		1	0.42	0
							0.112	0.140	0.000	0.000						
15-1	15	1	0.5	0.5	2.0	200	0.005	-2.301	26.365	1.421	5	6	6		0	
15-2	15	2	0.8	8.5	2.7	200	0.005	-2.301	8.202	0.914	1	3	9		0	
15-3	15	3	1	11	5.1	200	0.005	-2.301	4.260	0.629	2	3	12		0	
15-4	15	4	1.2	13	4.4	30	0.033	-1.477	7.119	0.852	3	4	14		0	2
15-5	15	5	1.5	17.5	2.5	50	0.020	-1.699	3.679	0.566	4	3	14		0	3
15-6	15	6	2	31	2.1	40	0.025	-1.602	17.771	1.250	5	2	14		0	2
site summary			1.167	13.583	3.149	120.000	0.016		11.233		3.333	14		0	0	3
							0.012	0.394	8.984	0.338						-0.28
16-1	16	1	0.5	13.5	2.1	200	0.005	-2.301	3.171	0.501	3	6	6		0	
16-2	16	2	0.8	21.5	2.0	200	0.005	-2.301	3.397	0.531	4	3	8		0	
16-3	16	3	1.05	29	2.0	60	0.017	-1.778	7.430	0.871	5	8	11		0	3
16-4	16	4	1.2	33	0.2	200	0.005	-2.301	14.066	1.148	5	6	13		0	3
16-5	16	5	1.6	163	0.2	200	0.005	-2.301	37.992	1.580	5	5	14	2	15	3
16-6	16	6	1.95	259	0.2	200	0.005	-2.301	24.187	1.384	5	4	14		0	3
site summary			1.183	86.500	1.132	176.667	0.007		15.040		4.5	14		1	2.5	4
							0.005	0.213	13.753	0.445						
17-1	17	1	0.5	3	10.5	16	0.063	-1.204	1.072	0.030	0	0	0	2	15	
17-2	17	2	0.8	4	14.0	15	0.067	-1.176	1.272	0.104	0	0	0	2	15	
17-3	17	3	1	5	11.3	16	0.063	-1.204	0.523	-0.281	0	0	0	2	15	
17-4	17	4	1.2	6	11.3	18	0.056	-1.255	0.374	-0.427	0	0	0	2	15	
17-5	17	5	1.5	7.5	10.1	18	0.056	-1.255	1.176	0.070	0	0	0	2	15	
17-6	17	6	2	10.5	9.5	15	0.067	-1.176	1.132	0.054	0	0	0	2	15	
site summary			1.167	6.000	11.11	16.333	0.062		0.925		0	0		6	15	0

							0.006	0.036	0.377	0.222							
18-1	18	1	0.5	3.5	9.6	200	0.006	-2.301	0.504	-0.297	1	3	3	3	37.5	1
18-2	18	2	0.85	5	10.1	200	0.005	-2.301	0.902	-0.045	3	5	5	3	37.5	2
18-3	18	3	1	6.3	8.0	200	0.005	-2.301	2.020	0.305	3	4	6	3	37.5	1
18-4	18	4	1.2	7.5	4.1	200	0.005	-2.301	0.937	-0.028	4	6	9	4	62.5	2
18-5	18	5	1.55	14	1.5	35	0.029	-1.544	4.745	0.676	4	4	9	4	62.5	
18-6	18	6	1.95	36	1.0	60	0.017	-1.778	5.813	0.764	3	2	9	1	2.5	2
site summary			1.175	12.050	5.730	149.167	0.011		2.487		3	9		6	40	5
							0.010	0.339	2.246	0.427						
19-1	19	1	0.45	1.7	7.8	200	0.005	-2.301	6.796	0.832	1	1	1	3	37.5	
19-2	19	2	0.75	3.3	7.1	200	0.005	-2.301	9.757	0.989	1	3	4	5	87.5	1
19-3	19	3	1	6.1	5.2	31	0.032	-1.491	19.587	1.292	2	3	5	5	87.5	1
19-4	19	4	1.2	8.2	5.6	32	0.031	-1.505	13.248	1.122	1	2	5	5	87.5	1
19-5	19	5	1.55	11.7	3.9	56	0.018	-1.748	11.520	1.061	1	2	5	3	37.5	1
19-6	19	6	2	19.8	3.2	31	0.032	-1.491	11.083	1.045	0	0	5	3	37.5	
site summary			1.158	8.467	5.479	91.667	0.021		11.998		1	5		6	62.5	4
							0.013	0.395	4.297	0.151						
20-1	20	1	0.6	4	0.6	200	0.005	-2.301	63.696	1.804	5	8	8	3	37.5	3
20-2	20	2	0.9	28	0.4	52	0.019	-1.716	34.545	1.538	1	2	8	5	87.5	1
20-3	20	3	1.1	78	0.3	63	0.016	-1.799	26.957	1.431	5	6	12		0	3
20-4	20	4	1.35	107	0.2	30	0.033	-1.477	24.021	1.381	5	6	12		0	5
20-5	20	5	1.55	214	0.2	37	0.027	-1.568	42.297	1.626	5	5	13		0	1
20-6	20	6	2	272	0.4				39.170		5	2	13		0	5
site summary			1.250		0.365	76.400	0.020		38.448		4.333	13		2	20.8	6
							0.011	0.321	14.201	0.168						
21-1	21	1	0.85	3.7	1.2	200	0.005	-2.301	62.056	1.793	1	1	1	5	87.5	1
21-2	21	2	0.6	7	0.9	15	0.067	-1.176	54.965	1.740	2	3	3	5	87.5	2
21-3	21	3	1.05	17	2.3	18	0.056	-1.255	20.530	1.312	5	5	5	3	37.5	4
21-4	21	4	1.25	23	1.7	30	0.033	-1.477	18.960	1.278	5	6	7		0	3
21-5	21	5	1.6	35.7	2.1	25	0.040	-1.398	29.294	1.467	5	6	7		0	2
21-6	21	6	2	43	3.1	11	0.091	-1.041	11.285	1.053	5	4	7		0	
site summary			1.225	21.567	1.897	49.833	0.049		32.848		3.833	7		3	35.4	5
							0.030	0.449	20.806	0.286						
22-1	22	1	0.6	8.8	2.1	200	0.005	-2.301	48.176	1.683	5	6	6		0	2
22-2	22	2	0.85	15	1.0	200	0.005	-2.301	49.371	1.693	5	4	7		0	1
22-3	22	3	1	31	0.6	200	0.005	-2.301	40.200	1.604	5	5	8	3	37.5	3
22-4	22	4	1.2	46	1.0	40	0.025	-1.602	39.607	1.598	5	7	9	3	37.5	4
22-5	22	5	1.45	56	1.2	40	0.025	-1.602	40.283	1.605	5	4	10		0	
22-6	22	6	1.95	80.5	1.2	11	0.091	-1.041	46.951	1.672	5	3	11		0	5
site summary			1.175	39.550	1.204	115.167	0.026		44.098		5	12		2	12.5	5
							0.033	0.527	4.527	0.045						
23-1	23	1	0.6	3.2	0.7	200	0.005	-2.301	11.340	1.055	3	7	6	5	87.5	2
23-2	23	2	0.85	38.3	0.3	200	0.005	-2.301	28.624	1.457	5	7	7	2	15	2
23-3	23	3	1	70	0.5	200	0.005	-2.301	25.428	1.405	5	2	7		0	4
23-4	23	4	1.2	76	1.0	24	0.042	-1.380	22.466	1.352	5	5	9		0	4
23-5	23	5	1.5	99	1.8	18	0.056	-1.255	22.985	1.361	5	4	10		0	5
23-6	23	6	2	102	9.5	17	0.059	-1.230	22.707	1.356	3	2	10		0	2
site summary			1.192	64.750	2.293	109.833	0.029		22.259		4.333	11		2	17.1	6
							0.026	0.557	5.840	0.141						
24 shore																
24-1	24	1	0.5	3.5	1.0	200	0.005	-2.301	19.874	1.298	3	7	7	3	37.5	1
24-2	24	2	0.75	36.5	0.2	200	0.005	-2.301	21.291	1.328	3	7	8	3	37.5	3
24-3	24	3	0.7	56	0.3	200	0.005	-2.301	22.140	1.345	3	5	10	2	15	2
24-4	24	4	1	80		21	0.048	-1.322	17.620	1.246	1	1	10		0	1
24-5	24	5	1.4			16	0.063	-1.204	20.660	1.315	4	5	12		0	3
24-6	24	6	1.8			15	0.067	-1.176	24.193	1.384	5	4	13		0	
site summary			1.025		0.523	108.667	0.032		20.963		3.167	13		3	3	5
							0.030	0.586	2.208	0.046				0	9.25	-0.3
25-1	25	1	0.7	0.5	1.6	200	0.005	-2.301	50.240	1.701	4	7	7	5	87.5	2
25-2	25	2	0.8	3.5	1.5	200	0.005	-2.301	34.176	1.534	2	6	9	4	62.5	2
25-3	25	3	1.05	14.3	1.6	200	0.005	-2.301	24.601	1.391	5	9	11		0	4
25-4	25	4	1.15	16.4	0.7	33	0.030	-1.519	24.935	1.397	3	6	12		0	2
25-5	25	5	1.45	48.3	1.1	200	0.005	-2.301	26.011	1.415	3	7	14		0	2
25-6	25	6	1.9	56	3.3	52	0.019	-1.716			3	1	14		0	3
site summary			1.175		1.625	147.500	0.012		31.993		3.333	14		2	25	6
							0.011	0.359	10.931	0.133						-0.28
26-1	26	1	0.5	2.3	5.4	200	0.005	-2.301	1.914	0.282	2	4	4	1	2.5	
26-2	26	2	0.75	5.3	3.6	200	0.005	-2.301	6.226	0.794	4	7	8	0	0	1
26-3	26	3	0.95	9.5	3.8	200	0.005	-2.301			5	7	9	2	15	2
26-4	26	4	1.2	12	2.5	26	0.038	-1.415	12.705	1.104	5	5	9	2	15	3

26-5	26	5	1.5	22.2	1.8	9	0.111	-0.954	0.500	-0.301	3	3	9	0	0	1
26-6	26	6	1.8	31.6	1.8	11	0.091	-1.041	0.500	-0.301	4	4	9	0	0	1
site summary			1.117		3.145		0.043		4.369			9		3	5.42	5
							0.048	0.656	5.218	0.635						-0.26
27-1	27	1	0.5	5.2	4.8	36	0.026	-1.591	0.500	-0.301	1	1	1	3	37.5	
27-2	27	2	0.8	9.6	3.7	19	0.053	-1.279	0.500	-0.301	1	1	2	2	15	
27-3	27	3	1.05	13.6	1.5	200	0.005	-2.301	0.500	-0.301	0	0	2	0	0	
27-4	27	4	1.05	19.2	-1.9	23	0.043	-1.362	0.500	-0.301	0	0	2	2	15	
27-5	27	5	0.8	21	-2.3	15	0.067	-1.176	0.500	-0.301	0	0	2	1	2.5	
27-6	27	6	0.65	29	-1.1	3	0.333	-0.477	0.500	-0.301	0	0	2	2	15	
site summary			0.806		0.776		0.088		0.500			2			14.2	0
							0.122	0.593	0.000	0.000						0
28-1	28	1	0.5	4.3	5.6	17	0.059	-1.230	0.991	-0.004	2	2	2	0	0	
28-2	28	2	0.85	8.7	4.7	20	0.050	-1.301	0.943	-0.025	4	5	5	0	0	
28-3	28	3	1.05	11	4.4	20	0.050	-1.301	1.566	0.195	5	4	5	4	62.5	
28-4	28	4	1.25	13.9	1.5	20	0.050	-1.301	0.500	-0.301	5	4	5	4	62.5	
28-5	28	5	1.5	28.5	1.0	7.5	0.133	-0.875	0.500	-0.301	3	1	5	0	0	
28-6	28	6	1.6	34.6	0.9	8	0.125	-0.903	0.500	-0.301	4	2	5	1	2.5	
site summary			1.125		3.009		0.078		0.833			5			21.3	0
							0.040	0.206	0.426	0.210						0
29-1	29	1	0.5	6	4.8	200	0.005	-2.301	23.660	1.374	5	7	7		0	
29-2	29	2	0.8	9.5	6.5	27	0.037	-1.431	1.671	0.223	3	9	12		0	
29-3	29	3	1	10.4	4.9	19	0.053	-1.279	1.218	0.086	5	7	14		0	1
29-4	29	4	1.2	14.2	1.1	12	0.083	-1.079	0.500	-0.301	4	4	14		0	
29-5	29	5	1.3	25.5	0.4	9	0.111	-0.954	0.500	-0.301	1	1	14		0	
29-6	29	6	1.3	27.6	0.0	6	0.167	-0.778	0.500	-0.301	1	1	14		0	
site summary			1.017		2.954		0.076		4.675			14			0	1
							0.068	0.540	9.314	0.650						-0.09
30-1	30	1	0.5	2	10.5	200	0.005	-2.301	18.228	1.261	5	8	8	5	87.5	4
30-2	30	2	0.85	3.5	4.8	200	0.005	-2.301	36.859	1.567	4	10	11	3	37.5	3
30-3	30	3	1.05	8.6	2.4	200	0.005	-2.301	36.104	1.558	2	5	11	2	15	1
30-4	30	4	1.15	10.8	1.7	200	0.005	-2.301	37.067	1.569	3	6	12	2	15	
30-5	30	5	1.5	24	0.9	200	0.005	-2.301	41.898	1.622	2	6	12	2	15	1
30-6	30	6	1.95	61	0.7	200	0.005	-2.301	31.539	1.499	3	2	12	5	87.5	2
site summary			1.167		3.467		0.005		33.616			13			42.9	5
							0.000	0.000	8.226	0.129						-0.26
31-1	31	1	0.45	6.5	4.8	200	0.005	-2.301	0.500	-0.301	4	5	5	5	87.5	
31-2	31	2	0.8	9.5	4.9	5	0.200	-0.699	0.500	-0.301	2	3	7	2	15	1
31-3	31	3	1.05	13.5	2.6	200	0.005	-2.301	0.500	-0.301	2	2	7	5	87.5	
31-4	31	4	1.1	16	-1.5	16	0.063	-1.204	0.500	-0.301	2	1	7	1	2.5	
31-5	31	5	0.85	21	0.3	4	0.250	-0.602	0.500	-0.301	1	1	7	1	2.5	
31-6	31	6	1.15	26	3.4	26	0.038	-1.415	0.500	-0.301	0	0	7	1	2.5	
site summary			0.900		2.425		0.093		0.500			7			32.9	1
							0.105	0.747	0.000	0.000						-0.09
32-1	32	1	0.5	2.5	10.6	200	0.005	-2.301	20.392	1.309	2	7	7	5	87.5	
32-2	32	2	0.85	4	10.4	200	0.005	-2.301	20.480	1.311	5	8	10	3	37.5	
32-3	32	3	1.05	5.5	7.5	200	0.005	-2.301	7.678	0.885	5	11	14	3	37.5	1
32-4	32	4	1.3	7.4	5.7	200	0.005	-2.301	31.810	1.503	5	6	14	3	37.5	
32-5	32	5	1.5	10	4.5	200	0.005	-2.301	29.553	1.471	5	9	14	4	62.5	1
32-6	32	6	2.05	17	4.5	200	0.005	-2.301	34.508	1.538	5	7	14	5	87.5	1
site summary			1.208		7.203		0.005		24.070			14			58.3	3
							0.000	0.000	9.940	0.241						-0.19
33-1	33	1	0.55	3.6	6.4	4	0.250	-0.602	0.500	-0.301	1	1	1	5	87.5	
33-2	33	2	1	6.2	1.6	3.5	0.286	-0.544	0.500	-0.301	0	0	1	2	15	
33-3	33	3	0.7	9	0.0	17	0.059	-1.230	1.182	0.073	2	7	7	3	37.5	
33-4	33	4	1	12.5	2.6	8	0.125	-0.903	0.500	-0.301	1	3	7	3	37.5	
33-5	33	5	1	15.5	0.0	14	0.071	-1.146	1.714	0.234	1	1	7	3	37.5	
33-6	33	6	1	18.5	0.0	5	0.200	-0.699	0.500	-0.301	0	0	7	2	15	
site summary			0.875		1.779		0.165		0.816			7			38.3	0
							0.094	0.287	0.518	0.240						0

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Eca	Ltr	Mai	Map	Nfl	Nod	Nva	Pcr	Pfo	Pfr	Ppe	Ppu	Pri	Pro	Pzo	Raq	Spo	Vam	Wpu (\	Wco	Zdu	Agr	Bbe	Bum
1 2 2 1	2 1 1 3 1 1	0 1 1	0	1 1	0	1 1	0	1 1 2 1	0	2 1	2 1	2 1	1 1	0	0	1 1 2	1 1 2	0	0	0	0	0	0
1 3 4 3 1	5 2 3 3 1 1	2 1 1	0	0	1 1	4 1	1 1	0	0	0	3 1 2 1	0 1	0 1	2 1 1 2 4	0	2 1 2 1	1 1 2 2	1 1 1 1 4 1	0 1	2 1	0	0	0
2 1 2	1 1 1 3	1 1 1 3	0	0	0	1 1 3 3	1 2 2	0	1 1	0	1 1 2	0	0	1 4 2	1 1 1 1 1 5	0	1 1 2	0	0	2 1 3 3	0	0	0
1 2 3 1 4	1 1 1 3	0	0	1 1 2	1 1	0	1 1	0	3 1	3 4 1 3	1 1	0	0	2 3 2	0	0	1 2 1 2 4 3 6	0	0	1 1 2	0	0	0
1 1 1 3 4 -0.23	1 1 1 1 1 5 -0.26	2 1 2 2 4 -0.23	0 0	0 0	0 0	0 0	1 1 -0.09	0 0	1 1 -0.09	3 1 -0.09	2 2 2 1 4 -0.23	3 2 3 2 1 2 6 -0.28	0 0	4 1 -0.09	1 1 1 3 -0.19	0 0	1 2 3 5 5 2 6 -0.28	0 0	0 0	0 0	0 0	0 0	1 1 -0.09
2 2 2 3	3 1 2 1 1 5	1 1 1 1 4	0	2 2 1 1 4	1 1	0	2 1	0	0	1 2 2 3	2 2 4 4 5 5 6	1 1	0	2 1 2	0	0	4 2 3 3 1 5	0	0	0	0	0	0
0	0	0	0	2 2 2 2 3 2 6	0	0	0	0	1 1	0	0	0	0	0	0	0	2 1 2 2 2 2 6	0	0	2 1	2 1	0	0
0	0	0	0	0	0	0	0	0	0	1 1	0	2 2 2	0	0	0	0	1 1	1 1	1 1	1 1 1 1 4	2 1 1 3	0	1 1

1 1 1 3	1 1 1 1 1 1 6	1 2 2	0	0	2 1	0	0	0	0	0	0	0	0	1 4 4 3	0	1 1	1 3 2 2 4	0	0	0	0	0	0
1 2 2 1 1 5	1 1 1 1 1 5	1 1 3 3	1 1	2 3 2	0	0	0	0	0	0	1 4 1 3	1 2 2	0	1 1 1 1 4	0	0	2 2 3 5 4	0	0	0	0	0	1 3 1 3
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1 1	0	0	0	0	0	3 2 2
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.37	0	0	0	0	0	-0.27
2 1	0	0	1 2 2 1 4	0	0	0	0	0	0	0	0	0	0	0	0	1 1	2 3 3 3	0	0	0	0	0	4 5 2
0	0	0	0	0	0	0	1 1	0	0	0	0	0	0	0	0	0	1 3 4 5 2 5	0	0	0	0	0	2 1
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1 1 2	0	0	0	0	0	0
1 1	1 1 2	0	2 2 3 4 4	0	2 1	0	0	0	1 1	0	0	0	0	1 1	1 1	1 1	1 1	2 1	0	1 1 2	0	0	0
-0.15	-0.23	0	-0.32	0	-0.15	0	0	0	-0.15	0	0	0	0	-0.15	-0.15	-0.15	-0.15	-0.15	0	-0.23	0	0	0
1 1 2 3 4	1 1 2	4 4 4 2 4	2 3 3 3	1 1	2 2 2	0	0	0	0	2 1 2	0	1 1 2	0	2 4 2	1 1	0	2 4 2	1 1	0	1 1 2	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

1 2 2 2 1			1 1	1 1 2 1							2	1 3					2 3 2			1	3		
5	0	0	2	4	0	0	0	0	0	0	1	2	0	0	0	0	3	0	0	1	1	0	0
1 1 1	1 1			1			1												1?				
3	2	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2 2	5 1 2 4 2	3 2 1	3 3		1									1 1	1	1	3 5	5				1 1	
2	5	3	2	0	1	0	0	0	0	0	0	0	0	2	1	1	2	1	0	0	0	2	0
2 3 1	1 3 2 1 1	4 4 2												1 2 2 3			1 3 3 4					1	
3	5	3	0	0	0	0	0	0	0	0	0	0	0	4	0	0	4	0	0	0	0	1	0
1 3 3	5 4 2 5 2 1		1 2		1	2 1							5	1 1			1 2 1			2 1			
3	6	0	2	0	1	2	0	0	0	0	0	0	1	2	0	0	3	0	0	2	0	0	0
3 1	3 4 4 4	1	2		3 3											1 1	2 1 1 2	2 2	1 1				
2	4	1	1	0	2	0	0	0	0	0	0	0	0	0	0	2	4	2	2	0	0	0	0
1 1 1	1 1 2 1		2 4			2				1		2		1 1		2 2		1 1		1			
3	4	0	2	0	0	1	0	0	0	1	0	1	0	2	0	2	0	2	0	1	0	0	0
-0.23	-0.27	0	-0.18	0	0	-0.12	0	0	0	-0.12	0	-0.12	0	-0.18	0	-0.18	0	-0.18	0	-0.12	0	0	0
2 1 3 1	1 1 1	1 1 1	3 2 1 2 2		1		1							1	1 1 1 1		2			1 1		1 1 2	
4	3	3	5	0	1	0	1	0	0	0	0	0	0	1	4	0	1	0	0	2	0	3	0
-0.23	-0.19	-0.19	-0.26	0	-0.09	0	-0.09	0	0	0	0	0	0	-0.09	-0.23	0	-0.09	0	0	-0.15	0	-0.19	0
1 3 3	1 1 1	1 1	1 1 2										1		1		2 4 3 5			1 2 3			

			1																				
	1	1															3						
																	4						
3	4	3	4	0	0	0	0	0	0	0	0	0	1	0	1	0	6	0	0	3	0	0	0
-0.19	-0.23	-0.19	-0.23	0	0	0	0	0	0	0	0	0	-0.09	0	-0.09	0	-0.28	0	0	-0.19	0	0	0
	1																						
		1																					
0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	-0.09	-0.09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1																							
1																				2			
			1																				
															1		2			3			
1			1																				
															1					5			
			1																				
															1		2			5			
																	3						
																	4			1			
3	0	0	3	0	0	0	0	0	0	0	0	0	0	0	3	0	4	0	0	5	0	0	0
-0.19	0	0	-0.19	0	0	0	0	0	0	0	0	0	0	0	-0.19	0	-0.23	0	0	-0.26	0	0	0
	1		1	1	2																		
1	1	1	1		2				1								1						4
														1	1		3						
	1	1		1																			
															1		5			2			
	1																						
														1	1		4						
	1																						
1																							
2	5	2	2	2	2	0	0	0	1	0	0	0	0	2	3	0	4	0	0	1	0	0	1
-0.15	-0.26	-0.15	-0.15	-0.15	-0.15	0	0	0	-0.09	0	0	0	0	-0.15	-0.19	0	-0.23	0	0	-0.09	0	0	-0.09
3	1	2	2																				
														2	1					1			
2	1	1																					
							1																
														1	1		3			2			1
		2	1																				
															1					1			
	1																						
							1				2		1	1	2								
1	2	2	1																				
																				1			
			3																				
3	4	4	4	0	0	0	2	0	0	0	1	0	1	3	4	0	1	0	0	4	0	0	1
-0.19	-0.23	-0.23	-0.23	0	0	0	-0.15	0	0	0	-0.09	0	-0.09	-0.19	-0.23	0	-0.09	0	0	-0.23	0	0	-0.09
1	1	3			1																		
																	2						
	1		2																				
	1		2																				
			2																				
	1																						
1	4	1	3	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
-0.09	-0.23	-0.09	-0.19	0	-0.09	0	0	0	0	0	0	0	0	0	0	0	-0.09	0	0	0	0	0	0
1	1			1																			
													1	1									
2	1	1	1	1																2			1
																	4						
2	2	2		1	2															2			1
											1			2									
																	3			1		1	
1		1	2		1																		
													1	4									
1	1	1	2																				
											2		4	3			1						
	1	5	2																				
													1	2			1						
5	5	5	4	3	2	0	0	0	0	0	2	0	4	5	0	0	4	0	0	3	0	1	2
-0.26	-0.26	-0.26	-0.23	-0.19	-0.15	0	0	0	0	0	-0.15	0	-0.23	-0.26	0	0	-0.23	0	0	-0.19	0	-0.09	-0.15
	1																						
	1		1	1																			
									1														
															1		1			2			
									1														
																	1			1			
									1														
0	2	0	1	1	0	0	0	0	3	0	0	0	0	0	1	0	2	0	0	2	0	0	0
0	-0.15	0	-0.09	-0.09	0	0	0	0	-0.19	0	0	0	0	0	-0.09	0	-0.15	0	0	-0.15	0	0	0

h$194)*(LOG10(I194/h$194))))

5)))

Chglo	Chvul	Chbr	Hmo	Lmi	Nitella	Pam	Uvu	Grass	Scirpus	Sparga	Sagite	Typha	Docod adj	Shannon
													Nva, Hmo	
				1										
0	0	0	0	1	0	0	0	0	0	0	0	0		
			1											
			1											
0	0	0	2	0	0	0	0	0	0	0	0	0		
													Nod	
													Pri	
0	0	0	0	0	0	0	0	0	0	0	0	0		
1	1												Nva	
													Pri	
1	1	0	0	0	0	0	0	0	0	0	0	0		
1														
	1												Raq	
													Pzo	
1	1	0	0	0	0	0	0	0	0	0	0	0		40
-0.09	-0.09	0	0	0	0	0	0	0	0	0	0	0		2.451888
0	0	0	0	0	0	0	0	0	0	0	0	0		
					2									
1		1			2									
		1			2									
					1									
					2									
1	0	2	0	0	5	0	0	0	0	0	0	0		
													Nfl	
													Vam	
0	0	0	0	0	0	0	0	0	0	0	0	0		

1

Nod
Nod

0 0 0 1 0 0 0 0 0 0 0 0 0

Nod
Pzo
P gramineum

Bum
Map

0 0 0 0 0 0 0 0 0 0 0 0 0

3 2 1
1

0 0 0 0 0 0 0 0 1 2 1 0 0 3
0 0 0 0 0 0 0 0 -0.37 0 0 0.636514

1 Nod, Lmi

0 0 0 0 0 0 0 0 0 0 0 1 0

1

0 0 0 0 0 0 0 0 0 0 1 0 0

Ltr

0 0 0 0 0 0 0 0 0 0 0 0 0

2 3

0 0 0 1 0 0 0 0 0 0 0 0 1 20
0 0 0 -0.15 0 0 0 0 0 0 0 0 -0.15 2.415052

Pri
Vam
Nva

Wolf
Raq

0 0 0 0 0 0 0 0 0 0 0 0 0

0 0 0 0 0 0 0 0 0 0 0 0 0

```
0    0    0    0    0    0    0    0    0    0    0    0    0



0    0    0    0    0    0    0    0    0    0    0    0    0

               1
                                                                  Nod

0    0    0    1    0    0    0    0    0    0    0    0    0



                                                                  Eca
0    0    0    0    0    0    0    0    0    0    0    0    0

                         1
                                                                  Bbe, Nfl
                              2
0    0    0    0    0    1    1    0    0    0    0    0    0


                                   2
0    0    0    0    0    0    0    1    0    0    0    0    0

               2    1
               1    1
               1                                                  Nod

0    0    0    3    2    0    0    0    0    0    0    0    0                  29 IF(I194=0,0,((I124/ap124)*(LOG10(C9/C$42))
0    0    0 -0.23 -0.18 0   0    0    0    0    0    0    0            2.432278
                                                       1    2
                                                                  Nod

0    0    0    0    0    0    0    0    0    0    0    1    1              IF(C9=0,0,((C9/C$42)*(LOG10(C9/C$42)))
0    0    0    0    0    0    0    0    0    0    0 -0.09 -0.09               2.1065
```

```
0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0          1.772269

0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0          0.184444

0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0          1.072999
                                       2

0  0  0  0  0  0  0  0  0  0  0  0  0     1
0  0  0  0  0  0  0  0  0  0  0  0  0 -0.09       1.952066
                                        Nod

                                        Nod
0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0          2.318437
                                       Bum, Sperg

0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0          0.885638

0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0             2.854888
                                       Vam

0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0             0.920296
```