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Vegetation and hydrologic influences on carbon and nitrogen in subsurface water of a forested riparian wetland

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VEGETATION AND HYDROLOGIC INFLUENCES ON CARBON AND NITROGEN IN SUBSURFACE WATER OF A FORESTED RIPARIAN WETLAND

By

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A Thesis

Submitted in partial fulfillment of the requirements for the degree of

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This thesis, “Vegetation and hydrologic influences on carbon and nitrogen in subsurface water of a forested riparian wetland”, is hereby approved in partial fulfillment of the requirements of for the Degree of MASTER OF SCIENCE IN FOREST ECOLOGY AND MANAGEMENT.

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ABSTRACT

Vegetation communities affect carbon and nitrogen dynamics in the subsurface water of mineral wetlands through the quality of their litter, their uptake of nutrients, root exudation and their effects on redox potential. However, vegetation influence on subsurface nutrient dynamics is often overshadowed by the influences of hydrology, soils and geology on nutrient dynamics. The effects of vegetation communities on carbon and nitrogen dynamics are important to consider when managing land that may change vegetation type or quantity so that wetland ecosystem functions can be retained. This study was established to determine the magnitude of the influences and interaction of vegetation cover and hydrology, in the form of water table fluctuations, on carbon and nitrogen dynamics in a northern forested riparian wetland. Dissolved organic carbon (DOC), dissolved inorganic carbon (DIC), nitrate (NO_3^-) and ammonium (NH_4^+) concentrations were collected from a piezometer network in four different vegetation communities and were found to show complex responses to vegetation cover and water table fluctuations. Dissolved organic carbon, DIC, NO_3^- and NH_4^+ concentrations were influenced by forest vegetation cover. Both NO_3^- and NH_4^+ were also influenced by water table fluctuations. However, for DOC and NH_4^+ concentrations there appeared to be more complex interactions than were measured by this study. The results of canonical correspondence analysis (CCA) and analysis of variance (ANOVA) did not correspond in relationship to the significance of vegetation communities. Dissolved inorganic carbon was influenced by an interaction between vegetation cover and water table fluctuations. More hydrological information is needed to make stronger conclusions about the relationship between vegetation and hydrology in controlling carbon and nitrogen dynamics in a forested riparian wetland.

INTRODUCTION

Wetlands are important ecosystems in the landscape that have unique hydrology, soils and vegetation. Wetlands are important to landscape hydrochemistry by retaining, transforming and transporting nutrients (Groffman et al. 1992, Hill and Devito 1997, Naiman and Decamps 1997). In this way, they influence groundwater and surface water by acting as filters to improve water quality as well as reducing flood pulses through their ability to retain water. One important wetland in the landscape is the forested riparian wetland, which are wetlands adjacent to lakes and rivers. Riparian wetlands are important because they are ecotones between aquatic and upland environments and directly affect the productivity and ecosystem function of stream and lakes systems (Stanford and Ward 1988, Valett et al. 1997, Verry et al. 2000). The individual influences of hydrology and vegetation on hydrochemistry of subsurface water within forested riparian wetlands have been studied throughout North America and in Europe (Peterjohn and Correll 1984, Pinay and Decamps 1988, Ford and Naiman 1989, Phillips et al. 1993, Cirmo and McDonnell 1997, Ohrui et al. 1999, Bischoff et al. 2001, Findlay et al. 2001, Groffman et al. 2002). Yet, interactions between hydrology and vegetation have not well understood in riparian wetlands.

Hydrology influences subsurface biogeochemical processes in forested riparian areas through water table fluctuations and pulses of water flow from rivers that create intermittent aerobic and anaerobic environments where different reactions take place (Regina et al. 1996, Blodau and Moore 2003). Fluctuating water tables and river pulses can also physically transport nutrients vertically and horizontally through the soil profile (Werner and Höhener 2002). Although water table fluctuation regimes for wetlands have been determined (Roulet 1991), the effect of those water table fluctuations on carbon and nitrogen cycling is not well documented in forested riparian wetlands (Hill 1996).

Vegetation also influences carbon and nitrogen cycles through litterfall, decomposition and nutrient content (Aerts et al. 1999). Vegetation influences subsurface water biogeochemical processes by affecting redox status through its contribution of organic matter, oxidizing power, adventitious roots and growth patterns (Havens 1997, Tabacchi et al. 1998). Vegetation can influence nutrient cycling through its control of hydrologic processes and influence water table fluctuations through evapotranspiration processes (Williams and Lipscomb 1981, Verry, Riekerk 1989, Lundin, Bent 2001). The interaction between vegetation, hydrology and nutrient cycling is important in understanding how forested riparian wetland ecosystems function (Likens et al. 1970, Hanson et al. 1994, Stromberg et al. 1996, Bedford et al. 1999, Casey et al. 2004).

Two elements in subsurface water important to biogeochemical cycling are carbon and nitrogen. Carbon and nitrogen are key elements to riparian ecosystem functioning; carbon as a source of energy and nitrogen and a key element to organism functioning. Dissolved inorganic carbon (DIC) can be a source of carbon dioxide (CO_2) to the atmosphere as well as to the stream aquatic environment (Palmer et al. 2001, Jones et al. 2003). Some work in lakes and streams has reported the importance of DIC in surface water and have suggested that groundwater flow influences the amount of DIC in these systems (Amiotte-Suchet et al. 1999, Elder et al. 2000, Palmer et al. 2001, Ortega et al. 2002). It is known that wetlands and riparian areas are important in the aquatic cycling of DIC because of their high primary productivity and respiration rates which influence rivers through subsurface water exchange (Mitsch and Gosselink 2000, Jones et al. 2003). Vegetation can affect DIC by their roots respiring CO_2, and also by producing organic carbon through the decomposition of litter or root exudation which microbes breakdown and thus respire CO_2. However, hydrology can have an effect on DIC by water movement and weathering of soils and bedrock material and breaking down carbonates into their cation and carbonate molecules and leaving carbonates to contribute to subsurface water DIC.

Dissolved organic carbon (DOC), an important component in ecosystem productivity, increases in the subsurface water through microbial break down of organic matter and root exudation. Vegetation influences DOC through the quality and quantity of litter it provides as well as root exudation to the subsurface microbes (Aerts et al. 1999). Hydrology affects DOC through water table depth and flooding from surface waters (McLaughlin et al., Trettin et al. 1996). Vegetation and hydrology can play a role together in controlling DOC concentrations. Hydrology and vegetation influence redox potential which can affect sorption of DOC to iron (Fe) by oxidizing Fe to Fe^{+3} which favors sorption causing DOC to be removed from the subsurface water or creating reduced conditions which reduces Fe^{+3} to the more soluble form, Fe^{+2}, which limits the sorption DOC (Heyes and Moore 1992, Moore et al. 1992, McLaughlin et al. 1994).

Inorganic nitrogen cycling in forested systems has also been reported to be influenced by hydrology (Devito and Dillon 1993, Bechtold et al. 2003) or vegetation (Vitousek et al. 1989, Aerts et al. 1999, Kiernan et al. 2003, Westbrook and Devito 2004). Riparian forests are known to have different inorganic nitrogen cycling processes than upland areas. In non-*Alnus* riparian communities, wetland vegetation can take up nitrogen in amounts that exceed mineralization rates (Bischoff et al. 2001) exerting a significant influence on nitrogen cycling. It has been found that hemlock riparian forests in the northeast have lower net N mineralization and nitrification rates than pine and maple upland areas (Hill and Shackleton 1989, Ohrui et al. 1999, Kiernan et al. 2003). Non-*Alnus* riparian forests tend to take up NO_3^- whereas uplands tend to produce inorganic nitrogen (Ohrui et al. 1999). These studies indicate that non-*Alnus* riparian areas may rely on inorganic nitrogen moving in from other areas of the landscape to meet their nitrogen needs, meaning that different vegetation communities in the landscape can act as a source or sink for inorganic nitrogen.

Riparian forests have been determined to remove nitrogen through uptake from subsurface waters in large amounts (Peterjohn and Correll 1984, Pinay and Decamps 1988, Correll and Weller 1989, Cooper 1990). However, the presence of *Alnus* in riparian forests has also been determined to increase NO_3^- and NH_4^+ concentrations through an association with nitrogen-fixing bacteria (Ohrui et al. 1999, Kiernan et al. 2003). Hydrology controls nitrogen cycling by runoff and leaching NO_3^- into interstitial waters and out of soils (Bechtold et al. 2003) as well as water table depths affecting aeration and thus nitrogen transformations (Devito and Dillon 1993).

While many studies on N and C dynamics in North America and around the world have been done the Northern Lakes States is a unique region containing many riparian areas where information on the controls and interactions between vegetation, hydrology and carbon and nitrogen cycles is not complete. Much has been done in peatlands (Dalva and Moore 1991, Verry and Urban 1992, Blodau 2002) but mineral soils often found in riparian wetlands have yet to be studied in terms of the interactions between vegetation and hydrology controls on carbon and nitrogen cycling.

The Northern Lake States contain many forested mineral and peatland riparian areas which are unique to the area. In northern peatlands carbon mineralization has been found to be influenced by interactions between hydrology and vegetation that are different with different peatlands studies (Blodau 2002). Controls of DOC in peatlands may include runoff, plant release, temperature and evaporation (Blodau 2002). However, the contribution of hydrology and vegetation to the interactive influence on DIC and DOC in mineral riparian wetlands of the Northern Lake States is not well understood.

For nitrogen, vegetation and mineralization have been determined to be the controlling influences of nitrogen cycling in a forested Minnesota bog (Urban and Eisenreich 1988). In a forested conifer peatland in Ontario retention of nitrogen is controlled by hydrological variables and the interactions between hydrology and vegetation (Devito and Dillon 1993). Studies that have investigated the interaction between vegetation, hydrology and nutrient cycling have been focused on peatlands in the Northern Lakes States (Devito and Dillon 1993, Blodau 2002) and are not representative of the interactions seen in the mineral riparian wetlands of the Northern Lakes states because of differences in vegetation, hydrology and geology.

The objectives of this study were to determine the influence and interactions of vegetation and hydrology on DIC, DOC, NO_3^- and NH_4^+ concentrations across different vegetation communities of a Northern Lake States forested wetland complex. The hypotheses were: 1) hydrology, in the form of water table fluctuations and distance from a river, significantly influences DOC, DIC, NO_3^- and NH_4^+ concentrations, 2) vegetation communities significantly affect DOC, DIC, NO_3^- and NH_4^+ concentrations, 3) the influences of vegetation, water table fluctuation and distance from the river interact to control differences in DOC, DIC, NO_3^- and NH_4^+ concentrations.

METHODS

Study Site

The study site is on the West Branch of the Sturgeon River (Figure 1), located in Alger county of the Upper Peninsula of Michigan (46°10’ N, 86°43’W). The 74 km^2

(28.6 mi^2) watershed is part of the Sturgeon River watershed that drains into Lake Michigan. The West Branch subwatershed is a low gradient landscape that ranges from 240 m to 270 m in elevation from northwest to southeast. Bedrock geology of the site is Trenton Limestone and the glacial geology is classified as a peat and muck system (Natural Resources Conservation U.S. Department of Agriculture 1994, Michigan Natural Features Resources 1998). The soil is classified as a Kinross mucky sand which is sandy mixed, frigid and Typic Endoaquod (Trettin 1992, McLaughlin et al. 2000). The soil is acidic and poorly drained fine sand overlain by a 5-15 cm organic layer primarily made of decomposed *Sphagnum* (Trettin 1992, McLaughlin et al. 2000).

The study site is in a managed forested riparian wetland that has three main vegetation communities. The vegetation community closest to the river is a stand dominated by *Alnus incana*. The next vegetation community moving away from the river is a 15 year-old *Pinus banksiana* plantation intermixed with natural *Picea mariana*. The third vegetation community is a mature stand of *Picea mariana*, *Larix laricina* and *Pinus banksiana*. The groundcover is dominated by ericaceous shrubs and *Sphagnum* with other bryophytes being common in both the plantation and mature stands.

The climate of the West Branch subwatershed includes an annual average temperature of 5.4°C (minimum in January at -11.8°C and maximum in July and August at 23.4°C) and average total precipitation of 885 mm annually, with snowfall averaging 3,675 mm annually (National Weather Service 2005). Within the growing season, spring and fall are the wet seasons and summer generally has few precipitation events.

Three transects were established 75 meters apart and perpendicular to the West Branch River. Through all three vegetation communities, seven stations starting in the river were systematically established, two in the *Alnus incana* stand, two in the *Pinus banksiana* plantation and two in the mature *Picea-Larix-Pinus* stand (Figure 2). Each station (excluding the river station which is surface water) had two piezometers, 3.2 cm in diameter, at depths of 0.5 m and 1 m and a ceramic cup lysimeter at 0.25 m. To test the hypotheses in this study data from all three depths were averaged for each station.

Sample collection

Water samples were collected from each piezometer or lysimeter once a month from August – October in 2001 and June – October in 2002, stored on ice and transported to the lab. The water samples were filtered at 0.45μm and analyzed in the lab for carbon and nitrogen. Dissolved inorganic carbon and DOC from water samples collected in 2001 and 2002 were analyzed with a Shimadzu TOC/TIC 5000A Analyzer. Nitrate and ammonium from water samples collected in 2002 were analyzed with a Braan & Luebbe Traacs 800. Nitrate values are the sum of nitrate and nitrite. However, nitrite concentrations were found to be insignificant.

Water table fluctuations and river influences

Water table measurements were taken at each station from the 100 cm piezometers once a month July through October of 2001 and June through October of 2002. The fluctuation was recorded as the difference between the current month and the previous month. Differences for July 2001 and June 2002 were not calculated since there was no previous month of that year. Distance from the river to each station was measured using GPS coordinates.

Vegetation survey

Vegetation was surveyed in the summer of 2002 at each station of the three transects. Vegetation surveys were done using three categories: overstory, understory and groundcover. Overstory vegetation was surveyed in a 10 m x 10 m plot centered at each sampling station. The species and percent cover of all vegetation over 1 m in height were recorded. Understory vegetation was surveyed in two 5 m x 5 m plots, located in the upper and lower corners within each 10 x 10 m plot. The species and percent cover of all vegetation less than 1 m in height were recorded. Groundcover vegetation was surveyed using a Daubenmire frame (50.5 cm x 20.5 cm) taking three random samples within one of the 5 m x 5 m plots. The species and percent cover of all groundcover within the frame were recorded. Bryophytes, *Carex*, *Dryopteris*, *Potamogeton*, *Solidago* and *Viola* were only recorded to genus because of difficulties in keying them to species at the time of the survey. For statistical analyses, groundcover vegetation was divided further into non-bryophytes (further referred to as groundcover) and bryophytes.

Statistics

The influences of hydrology and vegetation on DIC, DOC, NH_4^+, and NO_3^- concentrations were analyzed individually first, using correlation analysis, detrended correspondence analysis (DCA) and analysis of variance (ANOVA). Then the contribution of hydrology and vegetation as an interactive influence on DIC, DOC, NH_4^+, and NO_3^- concentrations was analyzed using canonical correspondence analysis (CCA).

To determine hydrology influences, correlation analysis was used to look at the relationship between DIC, DOC, NH_4^+, and NO_3^- concentrations versus distance from the river and water table fluctuation. A significant correlation was considered a p-value of 0.05 or less.

To first determine if the three vegetation community types were statistically different in vegetation composition, vegetation cover values were analyzed using DCA (Hill and Gauch 1980). Vegetation cover values for each vegetation category of overstory, understory, groundcover and bryophytes as well as all vegetation cover values together were analyzed using DCA. The vegetation communities determined from DCA were then matched up with their corresponding station to create a new variable, vegetation community, which indicated the vegetation community each point of data was located in.

Mean DIC, DOC, NH_4^+, and NO_3^- concentrations as dependent variables were each compared using one way ANOVA with the independent variable of vegetation community. Nitrate and NH_4^+ dominance in vegetation communities were examined at by taking the difference of the NO_3^- concentration from NH_4^+ concentrations as the dependent variable in an ANOVA where vegetation community was the independent variable. Tukey's multiple comparison test was used for pair-wise comparison of treatments. For analyses, data for corresponding months of 2001 and 2002 were combined to look for seasonal differences. We did not look at annual differences as there were only three months of data in 2001.

To determine the magnitude of vegetation communities and species with hydrologic controls on DIC, DOC, NH_4^+, and NO_3^- concentrations we used CCA (Braak 1986). The influence of individual species and vegetation communities as well as water table fluctuations were independent variables compared to NO_3^-, NH_4^+, DOC and DIC as dependent variables. CCA was performed with and without forward selection; both used 999 permutations for the Monte Carlo permutations test.

RESULTS

Differences in nutrient concentrations with distance from the river and water table fluctuation

Although correlation values (r) were low and negative, DIC and NO_3^- were significantly correlated with distance from the river (Table 1). Dissolved organic carbon and NH_4^+ were not significantly correlated with distance from the river (Table 1). Dissolved inorganic carbon had the strongest relationship with distance from the river with an r value of -0.433 ($p<0.001$). Water table fluctuations were not significantly correlated with any of the concentrations (Table 1).

Differences in nutrients concentrations among vegetation communities

Detrended correspondence analysis revealed four vegetation communities: riparian (station 1), edge (station 2), plantation (stations 3 and 4) and mature stand (stations 5 and 6). As was expected, the overstory vegetation corresponded to the three vegetation communities apparent in the field as well as a fourth intermediate vegetation community: the *Alnus incana* riparian area, the edge between the riparian area and the plantation, the *Pinus banksiana* plantation and the *Picea mariana-Larix laricina-Pinus banksiana* mature stand.

ANOVA indicated that DIC, NO_3^- and DOC were significantly different among vegetation communities ($\alpha=0.05$, $p<0.001$), but there was no difference in $NH4^+$ concentrations. Dissolved inorganic carbon and NO_3^- concentrations were highest in the riparian area (Table 2). The pattern of DOC was not so easily distinguished, but it was higher in the plantation compared to the edge (Table 2). The dominant dissolved inorganic nitrogen form was different ($p<0.001$) among the vegetation communities. Nitrate concentrations were higher than NH_4^+ concentrations in the riparian area (Table 2). Ammonium concentrations were higher than NO_3^- concentrations in the plantation and mature communities.

Vegetation and hydrology influences on nutrient concentrations

The influence of vegetation cover and water table fluctuations on DIC, DOC, NO_3^- and NH_4^+ were analyzed using CCA. The eigenvalues for axes 1 and 2 were low at 0.161 and 0.001, respectively, using forward selection, but axis 1 explained 99.1% and axis 2 explained 0.5% of the species-environmental relation variation. The species-environmental variables correlation for axis 1 was 0.758 and 0.373 for axis 2.

Axis 1 represented mainly differences in vegetation communities. It separated the riparian vegetation community from the plantation and mature stand vegetation communities. There seemed to be a separation of forest vegetation species and more open and riparian vegetation species. The vegetation species that were most correlated to axis 1 were overstory *Acer rubrum* and *Alnus incana*, understory *Cornus foemina* and *Alnus incana*, groundcover *Galium boreale*, *Spartina pectinata* and *Onoclea sensibilis* (Figure 4). Overstory and understory *Alnus incana* was highly correlated with axis 1, which differentiates vegetation communities, indicating the importance of *Alnus incana* in the riparian wetland. Axis 2 represented differences in water table fluctuation. The mature community was most strongly related to water table fluctuations followed by the plantation community, riparian community and edge community.

Dissolved inorganic carbon concentrations were positively correlated to riparian species and not correlated to water table fluctuations (Figure 4). Ammonium concentrations were positively related to plantation and mature species as well as being positively related to water table fluctuations (Figure 4). Dissolved organic carbon concentrations were positively correlated with plantation and mature species not correlated to water table fluctuations. Nitrate concentrations were positively related to the riparian vegetation species and negatively related to water table fluctuations. Dissolved inorganic carbon concentrations had the strongest relationship with vegetation community. Both NO_3^- and NH_4^+ concentrations had strong relationships to water table fluctuation, but DIC and DOC concentrations did not have a relationship with water table fluctuation (Figure 4).

DISCUSSION

Carbon

Dissolved inorganic carbon concentrations were influenced by vegetation communities and not the hydrologic factor of water table fluctuation. Riparian areas have been found to have high productivity (Naiman and Decamps 1997, Mitsch and Gosselink 2000). A high productivity increases decomposition and microbial respiration which increases CO_2 being released into the soil matrix and subsurface water. The CO_2 produced by respiration remains dissolved in the subsurface water and can combine with hydrogen ions in the acidic environment to form bicarbonate and other forms of DIC depending on the carbonate equilibrium (Stumm and Morgan 1981). A number of studies from North America and Europe have shown plant root and microbial respiration are major components of DIC in wetlands and riparian areas (Findlay et al. 1993, Schindler and Krabbenhoft 1998, Amiotte-Suchet et al. 1999). The riparian area in this study contains *Alnus incana* which is known to have a low C:N ratio (Bischoff et al. 2001) increasing decomposition rates (Brady and Weil 2002) and respiration rates also contributing to the increased CO_2 available as a form of DIC. Elder et al. (2000) found DIC concentrations similar to the concentrations in this study in riparian peatlands of northern Wisconsin. However, they did not find a significant decrease in DIC concentrations moving away from the stream through different vegetation communities as this study found. This indicates that the mineral riparian wetland is an important vegetation community to DIC.

The peak in DIC concentration in the riparian area could be attributed to CO_2 from respiration not escaping into the atmosphere as fast as in other areas of the wetland because of the generally shallower water table in the riparian zone. This is due to slow diffusion of CO_2 through water. Carbon dioxide moves through water slower than air, and the water table is higher in the riparian area than in other vegetation communities of the wetland. This theory is supported by Findlay et al. (1993) who found that in near stream flowpaths DIC concentrations increased mainly due to microbial respiration and secondarily to weathering of calcium carbonates.

A peak in calcium (data not shown) was also found in the riparian area which indicates that some of the DIC could be coming from weathered materials. Calcium carbonates from the bedrock geology could be disassociating and moving in the groundwater towards the surface. The glacial geology and sandy soils make groundwater influences likely in the area (Elder et al. 2000). Therefore, the riparian area may have an upwelling of groundwater bringing in DIC from the aquifer below. More information on the riparian community, water table fluctuations, and water movement are required to determine the amount of water saturation and the presence of groundwater upwelling in this area. In particular, deeper wells and piezometers, stable isotopes, dyes and wells and piezometers at different depths are required to determine the DIC movement in groundwater.

Vegetation and not hydrologic influences seem to be affecting DOC (as seen in CCA), however there were not significant differences between the riparian and forest communities (in ANOVA analyses). Different things could be contributing to the DOC concentrations in different vegetation communities. The plantation and mature communities have lower water tables and thus more aerobic environments than the riparian community, which has a consistently high water table. Aerobic environments decompose organic matter more completely (Alexander 1977) leaving less DOC in the subsurface water. However, the DOC left is recalcitrant and not easily broken down.

Dissolved organic carbon concentrations are also known to be associated with metal oxides which bind with DOC and precipitate out of solution (McLaughlin et al. 1994, Carlyle and Hill 2001, Jacinthe et al. 2003). Iron (Fe) is known to bond with DOC in its oxidized form, Fe^{+3}. In wetland areas where anoxic conditions form from consistent high water tables, Fe^{+3} is reduced and can be easily leached out of the soil so sorption of DOC is not as great, leaving greater concentrations of DOC in solution (McLaughlin et al. 1994). In the sandy soils of the West Branch study site Fe^{+2} has been reduced and leached out of the soil by periodic high water tables and thus there is no sorption of DOC out of the subsurface water. Thus the recalcitrant DOC stays in the subsurface water of the plantation and mature stands causing accumulation of DOC. The plantation has the highest mean concentration of DOC which could be due to the mature stand having more *Sphagnum* (data not shown) which can hold water closer to the surface (Halsey et al. 2000) and create less aerobic conditions. The riparian deciduous communities are known to more productive and have higher leaf-litter nutrient concentrations than other conifer communities (Tabacchi et al. 1998, Aerts et al. 1999) as well as having higher litter quality, which leads to increased carbon turnover and more complete decomposition, leaving less carbon in the subsurface water as DOC. The anaerobic conditions of the riparian area create a less complete decomposition than the aerobic plantation and mature communities because electron acceptors other than oxygen are being used (Alexander 1977). However, the increased litter quality and production overcome anaerobic conditions at this site so that the riparian community, even though it had a lower mean DOC concentration, was not significantly different in DOC concentration from the plantation or mature communities.

Dissolved organic carbon concentration was strongly correlated to the first axis in CCA which reflects mainly vegetation differences and not correlated to the second axis which reflects water table fluctuations differences. Increased concentrations of DOC were found in plantation and mature communities with water table fluctuations having no effect. This indicates that DOC is influenced mainly by vegetation and positively influenced by certain types of vegetation communities.

Nitrogen

There was a significant peak of NO_3^- at the riparian community that corresponded to the results in CCA showing a positive relationship to riparian vegetation along with a stronger negative relationship to water table fluctuation. In other studies, *Alnus incana* in New York has been associated with high NO_3^- levels in wetlands (Kiernan et al. 2003). The wetland in this study showed the same pattern of increased NO_3^- concentrations in the riparian area where *Alnus incana* was present. *Alnus incana* was significantly related to riparian vegetation community, where NO_3^- had a peak. *Alnus incana* has two attributes that could have lead to increased NO_3^- concentrations in the subsurface water surrounding it. *Alnus spp.* have nitrogen fixing bacteria associated with their roots. Coupled with high aeration around their roots, this could lead to high rates of nitrification within the rhizosphere soil of the *Alnus spp.* roots (Schröder 1989). Moreover, *Alnus incana* generally has low nitrogen use efficiency, resulting in higher litter nitrogen concentrations that can be mineralized and nitrified to NO_3^- (Bischoff et al. 2001).

The riparian vegetation community lives in a consistently high water table that intuitively would seem to inhibit nitrification due to low availability of oxygen for nitrification (Mitsch and Gosselink 2000). Yet, Westbrook and Devito (2004) have found high gross nitrification rates in saturated soils and Luther and Popp (2002) found that nitrification can occur in the absence of oxygen. These two studies support the possibility that you can have high NO_3^- concentrations under saturated conditions. Another possibility is that NO_3^- concentrations are higher in the riparian community because the movement of the river water that may aerate the subsurface water enough to create conditions for nitrification rates to outweigh denitrification rates. The higher quality of organic matter in the riparian area, due to *Alnus incana*, than the plantation and mature communities could lead to higher nitrification rates in the riparian community than the other vegetation communities. The high NO_3^- concentrations in the riparian zone could also be from groundwater upwelling. In their review, Cirmo and McDonnell (1997) reported that groundwater is relatively high in NO_3^- concentration and may contribute to high NO_3^- concentrations in riparian areas where conductivity and calcium (data not published) indicate the possibility of groundwater influence. More data on hydrologic factors of water table depth and water flow patterns would be needed to make a conclusion on the sources of influence of NO_3^- in this riparian wetland.

Ammonium concentrations were positively related to the plantation and mature stand vegetation communities, but it had a higher positive relationship to water table fluctuations. Analysis from CCA did not correspond to the above findings; NH_4^+ concentrations were not significantly different across vegetation communities using ANOVA. However, NH_4^+ concentrations did increase from the riparian and edge communities to the forest communities. Mineralization of N into NH_4^+ occurs in both aerobic and anaerobic conditions but at different rates due to different microbes initiating the reactions (Gale and Gilmour 1988) thus hydrology can have an effect on the rate of ammonification due to its influence on creating aerobic and anaerobic conditions.

Ammonium concentration means and water table fluctuations were most positively related to the mature vegetation community followed by the plantation, edge and then riparian vegetation communities. The lack of difference in NH_4^+ across vegetation communities in ANOVA and only low relationship to the mature and plantation communities in CCA could due to a number of factors. In the riparian community *Alnus incana* is fixing nitrogen but due to the peak in NO_3^- concentrations it seems that NH_4^+ is rapidly nitrifying. Low NO_3^- concentrations in the mature and plantation communities indicate low nitrification rates in these communities thus leaving more NH_4^+ in the subsurface water. However, without nitrogen fixers like *Alnus incana* the initial NH_4^+ concentrations in the plantation and mature communities were lower than those of the riparian community. Nitrate was negatively related to water table depth supporting that in the West Branch wetland changes in concentrations of NH_4^+ or NO_3^- are due to microbial processing and influenced mainly by water table fluctuations. The lack of differences across vegetation communities could be due to the high variability in NH_4^+ and NO_3^- concentrations and also due to a small sample size.

CONCLUSIONS

In this study, vegetation communities influence DOC, DIC, NO_3^- and NH_4^+ concentrations; however, the magnitude of this influence was strongest in DIC concentrations. Hydrology, in the form of water table fluctuations, interacted, as a stronger contributor, with vegetation to influence NO_3^- and NH_4^+ but did not influence on DOC and DIC. The interaction between hydrology and vegetation would be better understood with more detailed hydrological information. More research should be done to determine subsurface flowpaths and groundwater upwelling and downwelling points in this wetland and how these hydrological factors affect nitrogen and carbon processes. Vegetation is the overriding factor in this study, which may or may not be influenced by hydrology.

REFERENCES

Aerts, R., J. T. A. Verhoeven, and D. F. Whigham. 1999. Plant-mediated controls on nutrients cycling in temperate fens and bogs. Ecology **80**:2170-2181.

Alexander, M. 1977. Introduction to Soil Microbiology, Second edition. Krieger Publishing Company, Malabar, Florida.

Amiotte-Suchet, P., D. Aubert, J. L. Probst, F. Gauthier-Lafaye, A. Probst, F. Andreux, and D. Viville. 1999. delta 13C pattern of dissolved inorganic carbon in a small granitic catchment: the Strengbach case study (Vosges mountains, France). Chemical Geology **159**:129-145.

Bechtold, J. S., R. T. Edwards, and R. J. Naiman. 2003. Biotic versus hydrologic control over seasonal nitrate leaching in a floodplain forest. Biogeochemistry **63**:53-72.

Bedford, B. L., M. R. Walbridge, and A. Aldous. 1999. Patterns in nutrient availability and plant diversity of temperate north American wetlands. Ecology **80**:2151-2169.

Bent, G. C. 2001. Effects of forest-management activities on runoff components and ground-water recharge to Quabbin Reservoir, center al Massachusetts. Forest Ecology and Management **143**:115-129.

Bischoff, J. M., P. Bukaveckas, M. J. Mitchell, and T. Hurd. 2001. N storage and cycling in vegetation of a forested wetlands: implications for watershed processing. Water, Air & Soil Pollution **128**:97-114.

Blodau, C. 2002. Carbon cycling in peatlands - a review of processes and controls. Environmental Reviews **10**:111-134.

Blodau, C., and T. R. Moore. 2003. Experimental response of peatland carbon dynamics to a water table fluctuation. Aquatic Sciences **65**:47-62.

Braak, C. J. F. 1986. Canonical Correspondence Analysis: A New Eigenvector Technique for Multivariate Direct Gradient Analysis. Ecology **67**:1167-1179.

Brady, N. C., and R. R. Weil. 2002. The Nature and Properties of Soils, Thirteenth edition. Prentice Hall, Upper Saddle River, New Jersey.

Carlyle, G. C., and A. R. Hill. 2001. Groundwater phosphate dynamics in a river riparian zone: effects of hydrologic flowpaths, lithology and redox chemistry. Journal of Hydrology **247**:151-168.

Casey, R. E., M. D. Taylor, and S. J. Klaine. 2004. Localization of denitrification activity in macropores of a riparian wetland. Soil Biology & Biochemistry **36**:563-569.

Cirmo, C. P., and J. J. McDonnell. 1997. Linking the hydrologic and biogeochemical controls of nitrogen transport in near-stream zones of temperate-forested catchments: a review. Journal of Hydrology **199**:88-120.

Cooper, A. B. 1990. Nitrate depletion in the riparian zone and stream channel of a small headwater catchment. Hydrobiologia **202**:13-26.

Correll, D. L., and D. E. Weller. 1989. Factors limiting processes in freshwater wetlands: an agricultural primary stream riparian forest. Pages 9-23 *in* R. R. Sharitz and J. W. Gibbons, editors. Freshwater Wetlands and Wildlife. U.S. Department of Energy, Charleston, South Carolina.

Dalva, M., and T. R. Moore. 1991. Sources and sinks of dissolved organic carbon in a forested swamp catchment. Biogeochemistry **15**:1-19.

Devito, K. J., and P. J. Dillon. 1993. The influence of hydrologic conditions and peat oxia on the phosphorus and nitrogen dynamics in a conifer swamp. Water Resources Research **29**:2675-2685.

Elder, J. F., N. B. Rybicki, V. Carter, and V. Weintraub. 2000. Sources and yields of dissolved carbon in northern Wisconsin stream catchments with differing amounts of peatland. Wetlands **20**:113-125.

Findlay, S., J. M. Quinn, C. W. Hickey, G. Burrell, and M. Downes. 2001. Effects of land use and riparian flowpath on delivery of dissolved organic carbon to streams. Limnology and Oceanography:345-355.

Findlay, S., D. Strayer, C. Goumbala, and K. Gould. 1993. Metabolism of streamwater dissolved organic carbon in the shallow hyporheic zone. Limnology and Oceanography **38**:1493-1499.

Ford, T. E., and R. J. Naiman. 1989. Groundwater-surface water relationships in boreal forest watersheds: dissolved organic carbon and inorganic nutrient dynamics. Canadian Journal of Fisheries and Aquatic Science **46**:41-49.

Gale, P. M., and J. T. Gilmour. 1988. Net mineralization of carbon and nitrogen under aerobic and anaerobic conditions. Soil Science Society of America Journal **52**:1006-1010.

Groffman, P. M., N. J. Boulware, W. C. Zipperer, R. V. Pouyat, L. E. Band, and M. F. Colosimo. 2002. Soil Nitrogen Cycle Processes in Urban Riparian Zones. Environmental science & technology **36**:4547 (4546 pages).

Groffman, P. M., A. J. Gold, and R. C. Simmons. 1992. Nitrate Dynamics in Riparian Forests: Microbial Studies. Journal of Environmental Quality **21**:666-671.

Halsey, L. A., D. H. Vitt, and L. D. Gignac. 2000. *Sphagnum*-dominated peatlands in North America Since the last glacial maximum: their occurrence and extent. The Bryologist **103**:334-352.

Hanson, G. C., P. M. Groffman, and A. J. Gold. 1994. Symptoms of nitrogen saturation in a riparian wetland. Ecological Applications **4**:750-756.

Havens, K. J. 1997. The effect of vegetation on soil redox within a seasonally flooded forested system. Wetlands **17**:237.

Heyes, A., and T. R. Moore. 1992. The influence of dissolved organic carbon and anaerobic conditions on mineral weathering. Soil Science **154**:226-236.

Hill, A. R. 1996. Nitrate removal in stream riparian zones. Journal of Environmental Quality **25**:743-755.

Hill, A. R., and K. J. Devito. 1997. Hydrological-chemical interactions in headwater forest wetlands. Pages 213-230 *in* C. C. Trettin, M. F. Jurgensen, D. F. Grigal, M. R. Gale, and J. K. Jeglum, editors. Northern Forested Wetlands: ecology and management. Lewis, New York, New York.

Hill, A. R., and M. Shackleton. 1989. Soil N mineralization and nitrification in relation to nitrogen solution chemistry in a small forested watershed. Biogeochemistry **8**:167-184.

Hill, M. O., and H. G. J. Gauch. 1980. Detrended correspondence analysis: An improved ordination technique. Vegetatio **42**:47-58.

Jacinthe, P. A., P. M. Groffman, and A. J. Gold. 2003. Dissolved organic carbon dynamics in a riparian aquifer: Effects of hydrology and nitrate enrichment. Journal of Environmental Quality **32**:1365-1374.

Jones, J. B. J., E. H. Stanley, and P. J. Mulholland. 2003. Long-term decline in carbon dioxide supersaturation in rivers across the contiguous United States. Geophysical Research Letters **30**:1495.

Kiernan, B. D., T. M. Hurd, and D. J. Raynal. 2003. Abundance of *Alnus incana* ssp. *rugosa* in Adirondack Mountain shrub wetlands and its influence on inorganic nitrogen. Environmental Pollution **123**:347-354.

Likens, G. E., F. H. Bormann, N. M. Johnson, and R. S. Pierce. 1970. Effects of forest cutting and herbicide treatment on nutrient budgets in Hubbard-Brook watershed ecosystem. Ecological Monographs **40**:23-47.

Lundin, L. 1999. Effects on hydrology and surface water chemistry of regeneration cuttings in peatland forests. International Peat Journal **9**:118-126.

Luther, G. W. I., and J. I. Popp. 2002. Kinetics of the Abiotic Reduction of Polymeric Manganese Dioxide by Nitrite: An Anaerobic Nitrification Reaction. Aquatic Geochemistry **8**:15-36.

McLaughlin, J. W., M. R. Gale, M. F. Jurgensen, and C. C. Trettin. 2000. Soil organic matter and nitrogen cycling in response to harvesting, mechanical site preparation, and fertilization in a wet land with mineral substrate. Forest Ecology and Management **129**:7-23.

McLaughlin, J. W., J. C. Lewin, D. D. Reed, C. C. Trettin, M. F. Jurgensen, and M. R. Gale. 1994. Soil factors related to dissolved organic carbon concentrations in a black spruce swamp, Michigan. Soil Science **158**:454-463.

Mitsch, W. J., and J. G. Gosselink. 2000. Wetlands, Third edition. John Wiley & Sons, Inc., New York, NY.

Moore, T. R., W. d. Souza, and J.-F. Koprivnjak. 1992. Controls on the sorption of dissolved organic carbon by soils. Soil Science **154**:120-129.

Naiman, R. J., and H. Decamps. 1997. The ecology of interfaces: riparian zones. Annual review of ecology and systematics **28**:621-658.

National Weather Service, M. M. 2005. Annual and monthly temperature and precipitation normals and records for Munising, MI. *in*. Nation Weather Service, Marquette, MI.

Ohrui, K., M. J. Mitchell, and J. M. Bischoff. 1999. Effect of landscape position on N mineralization and nitrification in a forested watershed in the Adirondak Mountains of New York. Canadian Journal of Forest Research **29**:497-508.

Ortega, T., R. Ponce, J. M. Forja, and A. Gomez-Parra. 2002. Inorganic carbon fluxes at the water-sediment interface in five littoral systems in Spain (southern Europe). Hydrobiologia **469**:109-116.

Palmer, S. M., D. Hope, M. F. Billett, J. J. C. Dawson, and C. L. Bryant. 2001. Sources of organic and inorganic carbon in a headwater stream: Evidence from carbon isotope studies. Biogeochemistry **52**:321-338.

Peterjohn, W. T., and D. L. Correll. 1984. Nutrient dynamics in an agricultural watershed: observations on the role of a riparian forest. Ecology **65**:1466-1475.

Phillips, P. J., J. M. Denver, R. J. Shedlock, and P. A. Hamilton. 1993. Effect of a forested wetlands on nitrate concentrations in ground water and surface water on the Delmarva Peninsula. Wetlands **13**:75-83.

Pinay, G., and H. Decamps. 1988. The role of riparian woods in regulating nitrogen fluxes between the alluvial aquifer and surface water: a conceptual model. Regulated Rivers: Research and Management **2**:507-516.

Regina, K., H. Nykänen, J. Silvola, and P. J. Martikainen. 1996. Fluxes of nitrous oxide from boreal peatlands as affected by peatland type, water table level and nitrification capacity. Biogeochemistry **35**:401-418.

Resources, M. N. F. I. a. M. D. o. N. 1998. Template - Quaternary Geology. Lansing, MI.

Riekerk, H. 1989. Influences of silvicultural practices on hydrology of pine flatwoods in Florida. Water Resources Research **25**:713-719.

Roulet, N. T. 1991. Surface level and water table fluctuations in a subarctic fen. Arctic and Alpine Research **23**:303-310.

Schindler, J. E., and D. P. Krabbenhoft. 1998. The hyporheic zone as a source of dissolved organic carbon and carbon gases to a temperate forested stream. Biogeochemistry **43**:157-174.

Schröder, P. 1989. Characterization of thermo-osmotic gas transport mechanism in *Alnus glutinosa* (L.) Gaertn. Trees - Structure and Function **3**:38-44.

Stanford, J. A., and J. V. Ward. 1988. The hyporheic habitat of river ecosystems. Nature **355**:64-66.

Stromberg, J. C., R. Tiller, and B. Richter. 1996. Effects of groundwater decline on riparian vegetation of semiarid regions: the San Pedro, Arizona. Ecological Applications **6**:113-131.

Stumm, W., and J. J. Morgan. 1981. Aquatic Chemistry. Wiley, New York, New York.

Tabacchi, E., D. L. Correll, R. Hauer, G. Pinay, A.-M. Planty-Tabacchi, and R. C. Wissmar. 1998. Development, maintenance and role of riparian vegetation in the river landscape. Freshwater Biology **40**:497-516.

Trettin, C. C. 1992. Silvicultural effects on functional processes of a boreal forest wetland. Ph.D. North Carolina State University, Raleigh, NC.

Trettin, C. C., M. Davidian, M. F. Jurgensen, and R. Lea. 1996. Organic matter decomposition following harvesting and site preparation of a forested wetland. Soil Science Society America Journal **60**:1994-2003.

U.S. Department of Agriculture, N. R. C. S. 1994. State Soil Geographic (STATSGO) data base for Michigan. Fort Worth, Texas.

Urban, N. R., and S. J. Eisenreich. 1988. Nitrogen cycling in a forested Minnesota bog. Canadian Journal of Botany **66**:435-449.

Valett, H. M., C. N. Dahm, M. E. Campana, J. A. Morrice, M. A. Baker, and C. S. Fellows. 1997. Hydrologic influences on groundwater-surface water ecotones: heterogeneity in nutrient composition and retention. Journal of the North American Benthological Society **16**:239-247.

Verry, E. S. 1986. Forest harvesting and water: the lake states experience. Water Resources Bulletin **22**:1039-1047.

Verry, E. S., J. W. Hornbeck, and C. A. Dolloff, editors. 2000. Riparian Management in Forests of the Continental Eastern United States. Lewis Publishers, Boca Raton, FL.

Verry, E. S., and N. R. Urban. 1992. Nutrient cycling at Marcell Bog, Minnesota. Suo **43**:147-153.

Vitousek, P. M., P. A. Matson, and K. Van Cleve. 1989. Nitrogen availability and nitrification during succession: primary, secondary, and old-field seres. Plant and Soil **115**:229-239.

Werner, D., and P. Höhener. 2002. The influence of water table fluctuations on the volatilization of contaminants from groundwater. Groundwater Quality: Natural and Enhanced Restoration of Groundwater Pollution **IAHS Publ. no. 275**:213-218.

Westbrook, C. J., and K. J. Devito. 2004. Gross nitrogen transformations in soils from uncut and cut boreal upland and peatland conifers forest stands. Biogeochemistry **68**:33-50.

Williams, T. M., and D. J. Lipscomb. 1981. Water table rise after cutting on coastal plain soils. Southern Journal of Applied Forestry **5**:46-48.

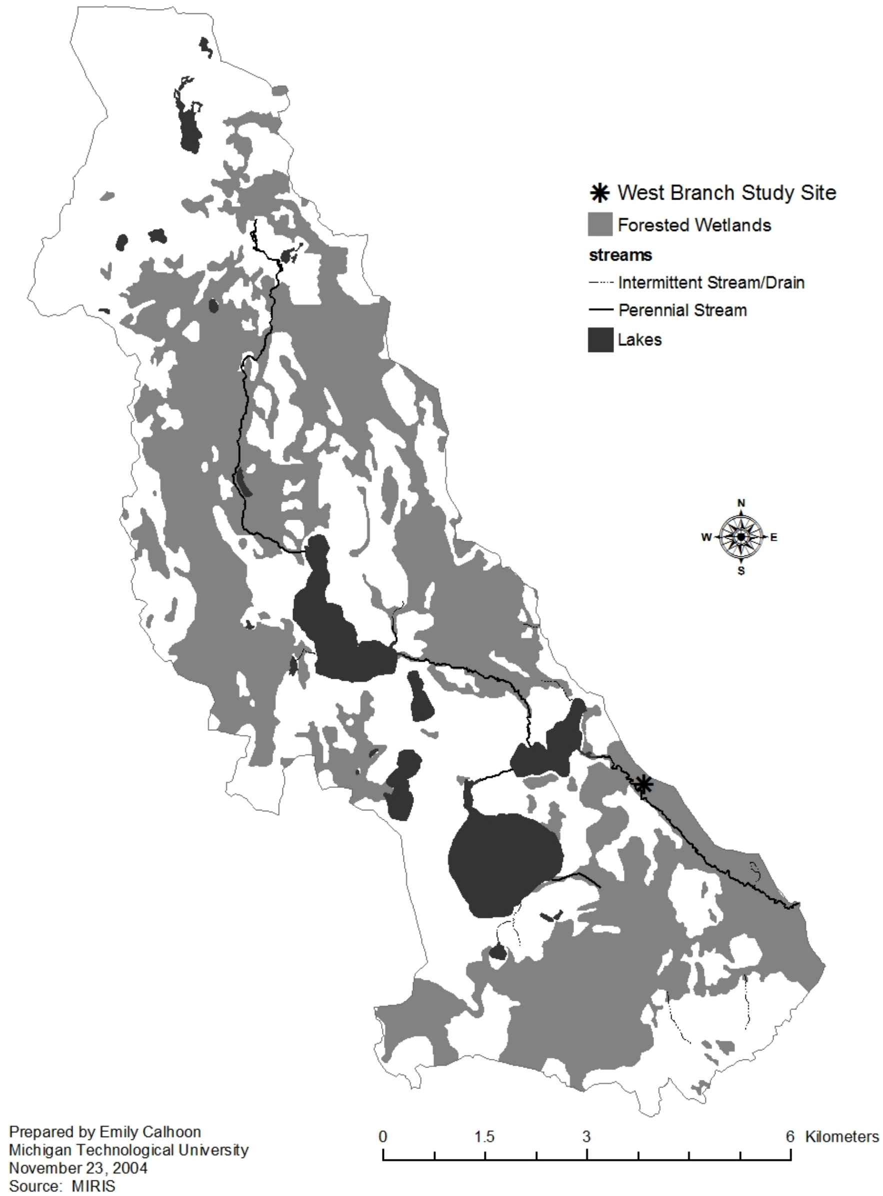

Figure 1. West Branch River subwatershed with the study site indicated by (*).

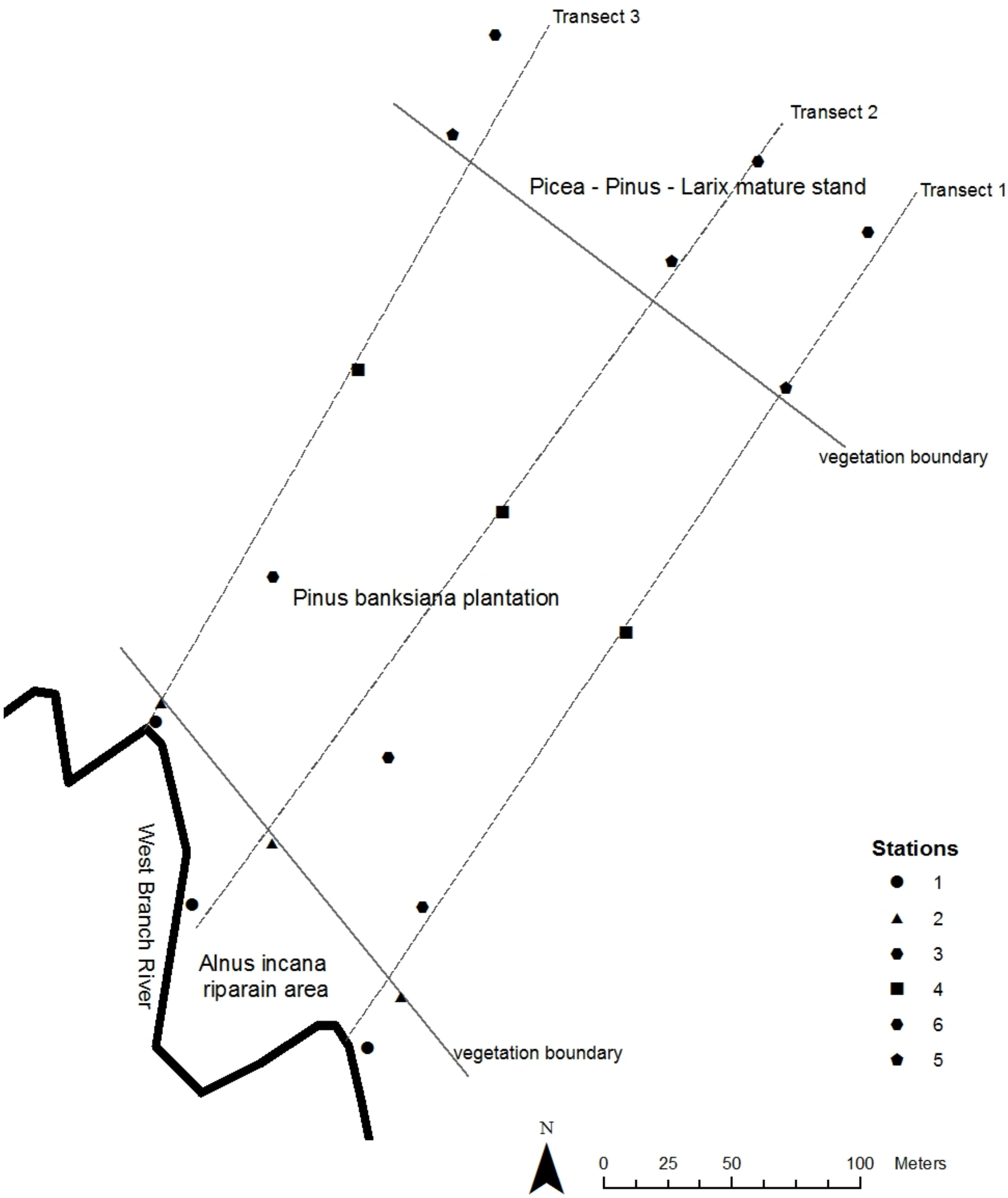

Figure 2. Transect and station layout on the West Branch riparian wetland study site.

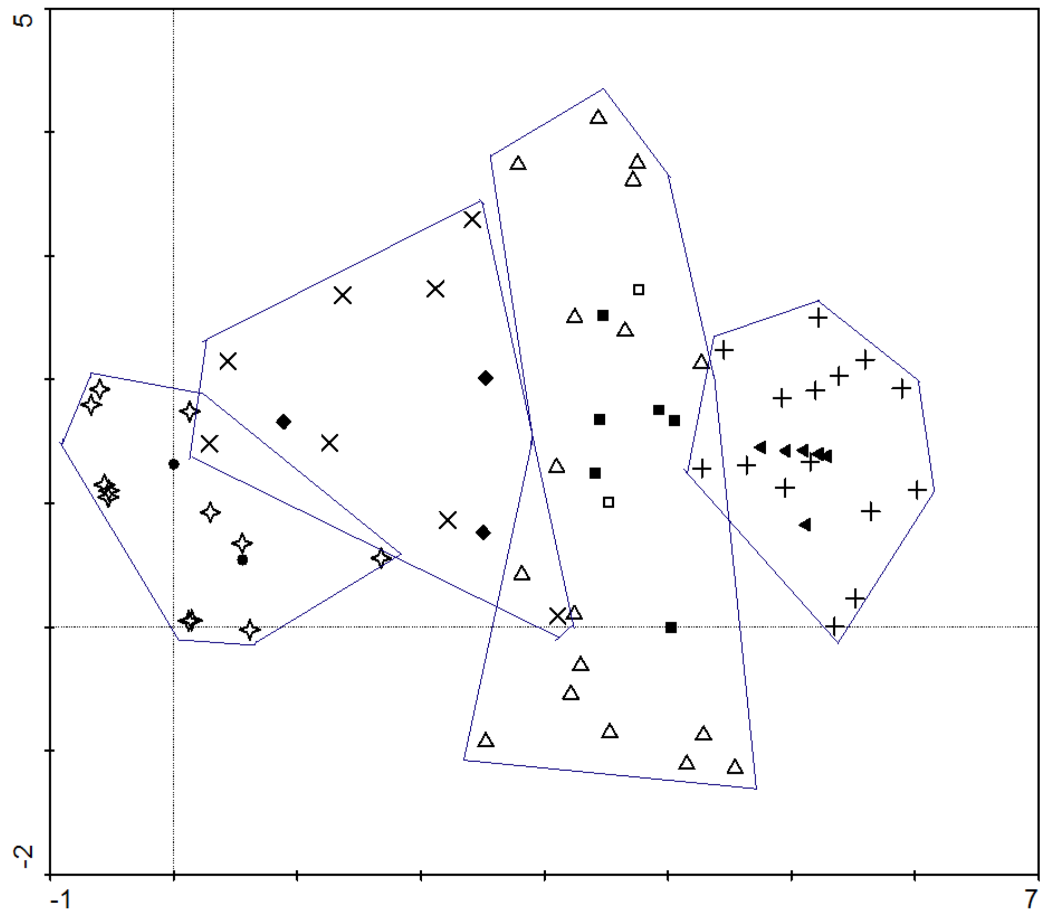

Figure 3. Ordination diagram of detrended correspondence analysis of all vegetation species. Species in the same vegetation community are circled. Species in the four vegetation communities are represented by open symbols: riparian species (star), edge species (X), plantation species (Δ) and mature stand species (+). Species occurring in many vegetation communities are indicated with an open square (□). Stations at the study site are indicated in closed symbols: station 1 (circle), station 2 (diamond), stations 3 and 4 (square) and stations 5 and 6 (triangle).

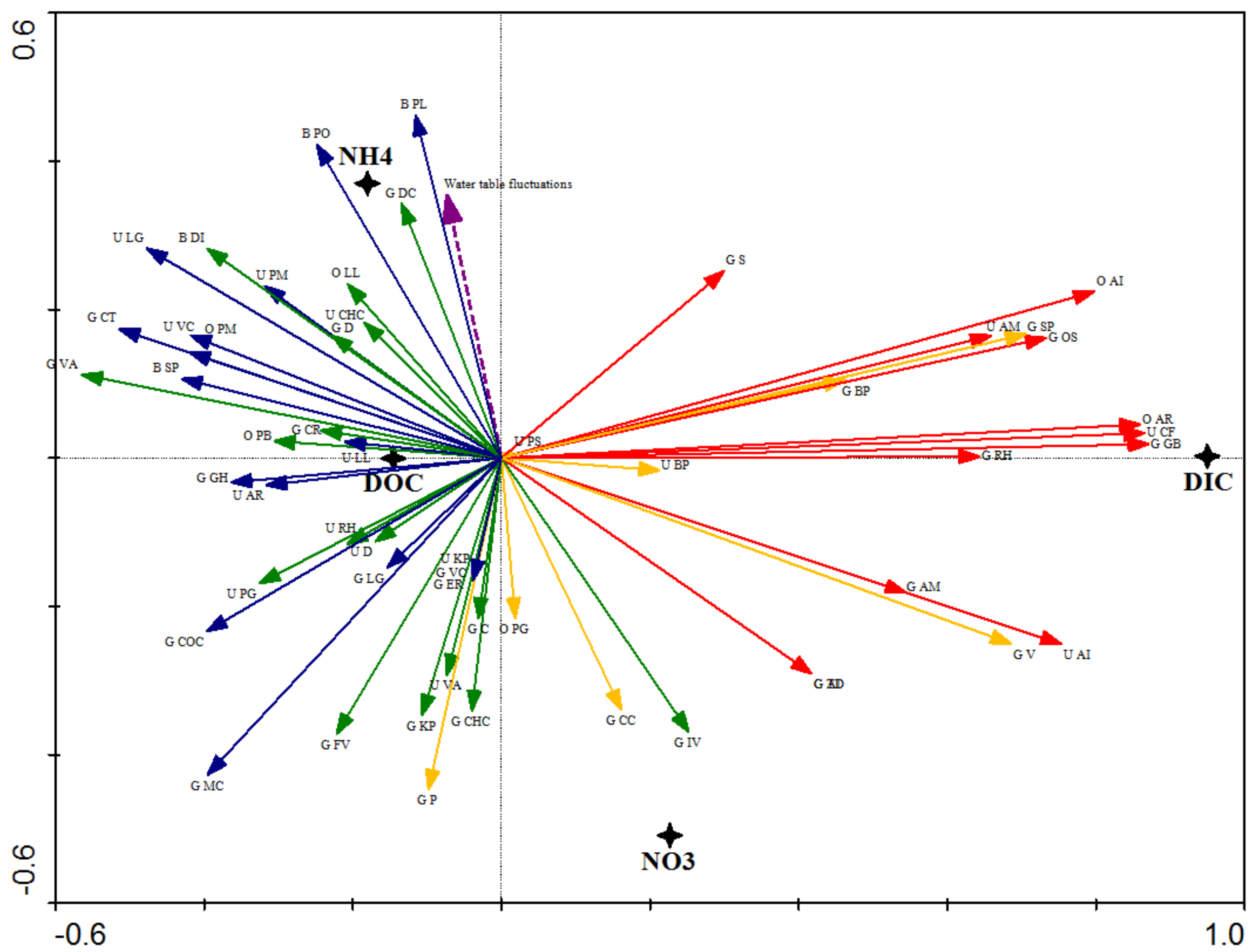

Figure 4. Canonical correspondence analysis between water table fluctuation as well as vegetation species and DOC, DIC, NO_3^-, NH_4^+. Species are divided by vegetation community: riparian vegetation (red), edge vegetation (yellow), plantation vegetation (green), mature stand (blue). Water table fluctuations are represented by a dashed purple line. Vegetation species abbreviation list can be found in Table 4.

Table 1. Distance from the river and water table fluctuation correlation analysis with DIC, DOC, NH_4^+ and NO_3^-.

	Distance from the river		Water table fluctuation	
	r	p-value	r	p-value
DIC	-0.433	<0.001	0.028	NS
DOC	-0.068	NS	-0.050	NS
NH_4^+	0.055	NS	-0.141	NS
NO_3^-	-0.214	0.009	-0.184	NS

Table 2. One-way ANOVA and Tukey test results test results for DIC, DOC, NH_4^+, NO_3^- and NH_4^+ - NO_3^- as the dependent variables and vegetation community. Letters in parentheses represent significant differences from Tukey tests.

vegetation community	p-value	Riparian area	Edge	*Pinus banksiana* plantation	Mature *Picea-Larix-Pinus* stand
DIC (mg/L)	<0.001	13.31 (a)	6.21 (b)	1.96 (c)	1.69 (c)
DOC (mg/L)	<0.001	27.40 (ab)	23.46 (b)	33.85 (a)	27.61 (ab)
NH_4^+ (ppm)	NS	0.11	0.07	0.13	0.14
NO_3^- (ppm)	<0.001	0.21 (a)	0.06 (b)	0.05 (b)	0.07 (b)
NH_4^+ - NO_3^-	<0.001	-0.10 (b)	-0.02 (ab)	0.07 (a)	0.07 (a)

Table 3. Canonical correspondence analysis results – bi-plot scores. Vegetation abbreviations in Table 4.

	Axis 1	Axis 2
DIC	1.026	0.003
DOC	-0.157	0.000
NH4	-0.195	0.400
NO3	0.245	-0.550
WTF	-0.073	0.354
O AR	0.860	0.046
O PB	-0.306	0.023
O PM	-0.419	0.142
O AI	0.797	0.224
O PG	0.019	-0.216
O LL	-0.207	0.234
U AR	-0.316	-0.037
U PM	-0.318	0.232
U AI	0.754	-0.251
U PG	-0.325	-0.169
U LL	-0.211	0.022
U CF	0.866	0.033
U PS	0.015	0.007
U RH	-0.207	-0.116
U VA	-0.073	-0.292
U KP	-0.038	-0.165
U VC	-0.418	0.166
U AM	0.659	0.165
U BP	0.213	-0.017
U CHC	-0.184	0.183
U LG	-0.477	0.283
U D	-0.170	-0.112
G AI	0.418	-0.291
G AM	0.544	-0.182
G BP	0.462	0.106

	Axis 1	Axis 2
G CC	0.161	-0.340
G CHC	-0.040	-0.341
G C	-0.031	-0.216
G CR	-0.243	0.038
G CT	-0.514	0.174
G COC	-0.397	-0.234
G DC	-0.134	0.343
G D	-0.228	0.165
G FV	-0.222	-0.372
G ER	-0.038	-0.165
G GB	0.871	0.019
G GH	-0.364	-0.033
G IV	0.253	-0.369
G KP	-0.107	-0.346
G LG	-0.153	-0.148
G MC	-0.396	-0.428
G OS	0.733	0.162
G P	-0.098	-0.447
G RH	0.643	0.002
G S	0.300	0.252
G SP	0.706	0.167
G TD	0.418	-0.291
G VA	-0.565	0.112
G VC	-0.038	-0.165
G V	0.686	-0.250
B DI	-0.396	0.282
B PL	-0.116	0.462
B PO	-0.248	0.422
B SP	-0.430	0.107

Table 4. Vegetation species abbreviations

Overstory	
O Acer rubrum	O AR
O Alnus incana	O AI
O Larix laricina	O LL
O Pinus banksiana	O PB
O Pinus glauca	O PG
O Pinus mariana	O PM

Understory	
U Acer rubrum	O AR
U Alnus incana	U AI
U Aronia melanocarpa	U AM
U Betula pumila	O BP
U Chamaedaphne calyculata	U CHC
U Cornus foemina	U CF
U Dryopteris spp.	U D
U Kalmia polifolia	U KP
U Larix laricina	U LL
U Ledum groenlandicum	U LG
U Pinus glauca	U PG
U Pinus mariana	U PM
U Prunus serotina	U PS
U Rubus hispidus	U RH
U Vaccinium angustifolium	U VA
U Vibernum cassinoides	U VC

Bryophytes	
B Dicranum spp.	B DI
B Pleurozium spp.	B PL
B Polytrichum spp.	B PO
B Sphagnum spp.	B SP

Groundcover	
G Aronia melanocarpa	G AM
G Alnus incana	G AI
G Betula pumila	G BP
G Calamagrostis canadensis	G CC
G Carex spp.	G C
G Chamaedaphne calyculata	G CHC
G Cladina rangiferina	G CR
G Coptis trifolia	G CT
G Cornus canadensis	G COC
G Deschampsia cespitosa	G DC
G Dryopteris spp.	G D
G Epigaea repens	G ER
G Fragaria virginiana	G FV
G Galium boreale	G GB
G Gaultheria hispidula	G GH
G Iris versicolor	G IV
G Kalmia polifolia	G KP
G Ledum groenlandicum	G LG
G Mianthemum canadensis	G MC
G Onoclea sensibilis	G OS
G Potamogeton spp.	G P
G Rubus hispidus	G RH
G Solidago spp.	G S
G Spartina pectinata	G SP
G Thalictrum dasycarpum	G TD
G Vaccinium angustifolium	G VA
G Vibernum cassinoides	G VC
G Viola spp.	G V

APPENDIX 1: Carbon, nitrogen and water table Data

Month	Year	Transect	Station	Depth	TDC	DIC	DOC	NH4	NO3	Water Table Fluctuations
6	2002	1	1	50	31.44	11.89	19.55	0.07195	0.5921	
6	2002	1	1	100	23.45	1.54	21.91			
6	2002	1	1	25	32.15	5.22	26.93	0.0001	0.0214	
6	2002	1	2	50	26.1	6.381	19.719	0.0001	0.0115	
6	2002	1	2	100	22.42	2.707	19.713	0.0001	0.0379	
6	2002	1	2	25	36.45	9.87	26.58	0.0001	0.0213	
6	2002	1	3	50	27.56	1.32	26.24			
6	2002	1	3	100	25.66	0.65	25.01			
6	2002	1	3	25	28.65	0.24	28.41	0.0001	0.0142	
6	2002	1	4	50	29.13	0.218	28.912	0.0001	0.0082	
6	2002	1	4	100	20.56	1.175	19.385	0.0001	0.3828	
6	2002	1	4	25	32.45	0.22	32.23	0.0001	0.2541	
6	2002	1	5	50	12.29	0.59	11.7	0.0001	0.0831	
6	2002	1	5	100	11.11	1.021	10.089	0.1545	0.093	
6	2002	1	5	25	10.56	0.45	10.11	0.0135	0.5511	
6	2002	1	6	50	16.53	1.777	14.753	0.1216	0.0856	
6	2002	1	6	100	25.1	1.232	23.868	0.0001	0.0149	
6	2002	1	6	25	26.44	0.29	26.15	0.0561	0.0125	
6	2002	2	1	50	33.02	12.55	20.47	0.16595	0.0208	
6	2002	2	1	100	32.78	12.55	20.23	0.0001	0.0911	
6	2002	2	1	25	46.58	18.45	28.13	0.0001	0.0326	
6	2002	2	2	50	16.22	1.553	14.667	0.0001	0.0081	
6	2002	2	2	100	20.83	4.855	15.975	0.03835	0.1074	
6	2002	2	2	25	26.33	7.46	18.87	0.0215	0.0123	
6	2002	2	3	50	49.21	1.304	47.906	0.17975	0.0163	
6	2002	2	3	100	21.38	2.248	19.132	0.69915	0.0246	
6	2002	2	3	25	25.65	1.24	24.41	0.215	0.1241	
6	2002	2	4	50	16	0.787	15.213	0.0001	0.0129	
6	2002	2	5	50	11.53	0.442	11.088	0.01275	0.0233	
6	2002	2	5	100	34.11	1.14	32.97	0.0314	0.012	
6	2002	2	5	25	68.54	1.1	67.44	0.0231	0.547	
6	2002	2	6	50	21.09	1.659	19.431	0.19525	0.0369	
6	2002	2	6	100	16.46	0.69	15.77	0.0001	0.1915	
6	2002	2	6	25	38.44	0.55	37.89	0.321	0.0089	
6	2002	3	1	50	51.35	11.35	40	0.0001	0.9573	
6	2002	3	1	100	32.3	5.738	26.562	0.2963	0.609	
6	2002	3	1	25	34.1	3.34	30.76	0.3254	0.871	
6	2002	3	3	100	19.77	1	18.77	0.125	0.0354	
6	2002	3	3	25	57.35	0.26	57.09	0.0444	0.0129	
6	2002	3	4	50	65.82	0.229	65.591	0.02905	0.012	
6	2002	3	4	100	48.76	0.53	48.23	0.0098	0.0369	
6	2002	3	4	25	61.25	1.29	59.96	0.0001	0.0325	
6	2002	3	5	50	23.22	0.156	23.064	0.1658	0.0994	
6	2002	3	5	100	51.83	0.517	51.313	0.02425	0.0203	
6	2002	3	5	25	51.03	1.05	49.98	0.1243	0.1241	
6	2002	3	6	50	32.7	0.766	31.934	0.24375	0.0236	
6	2002	3	6	100	37.98	0.154	37.826	0.0124	0.0325	
6	2002	3	6	25	44.65	0.248	44.402	0.122	0.0149	
7	2002	1	1	50	48.65	29.56	19.09	0.07195	0.5921	20
7	2002	1	1	100	36.45	13.25	23.2	0.0001	0.2354	20
7	2002	1	1	25	84.65	3.45	81.2	0.1678	0.3489	20

Month	Year	Transect	Station	Depth	TDC	DIC	DOC	NH4	NO3	Water Table Fluctuations
7	2002	1	2	50	22.43	3.21	19.22	0.0001	0.0115	30
7	2002	1	2	100	19.35	1.658	17.692	0.0001	0.0379	30
7	2002	1	2	25	22.89	4.351	18.539	0.0001	0.0264	30
7	2002	1	3	50	48.34	0.659	47.681	0.0235	0.0123	50
7	2002	1	3	100	43.25	0.488	42.762	0.0658	0.0142	50
7	2002	1	3	25	49.65	0.358	49.292	0.0458	0.0245	50
7	2002	1	4	50	29.34	1.375	27.965	0.0001	0.0082	20
7	2002	1	4	100	38.45	0.554	37.896	0.0001	0.3828	20
7	2002	1	4	25	36.45	9.764	26.686	0.0124	0.2415	20
7	2002	1	5	50	16.52	1.004	15.516	0.0001	0.0831	30
7	2002	1	5	100	14.38	2.671	11.709	0.1545	0.093	30
7	2002	1	5	25	12.34	0.356	11.984	0.0248	0.0354	30
7	2002	1	6	50	10.24	1.552	8.688	0.1216	0.0856	25
7	2002	1	6	100	20.64	0.694	19.946	0.0001	0.0149	25
7	2002	1	6	25	35.32	0.287	35.033	0.1687	0.0956	25
7	2002	2	1	50	46.88	23.65	23.23	0.0001	0.1543	27
7	2002	2	1	100	44.66	13.58	31.08	0.0354	0.07458	27
7	2002	2	1	25	70.65	35.66	34.99	0.0001	0.5452	27
7	2002	2	2	50	21.36	5.39	15.97	0.03835	0.1074	20
7	2002	2	2	100	19.87	1.883	17.987	0.0687	0.167	20
7	2002	2	2	25	25.33	4.972	20.358	0.1542	0.0988	20
7	2002	2	3	50	58.64	0.773	57.867	0.7712	0.0354	42
7	2002	2	3	100	28.46	0.348	28.112	0.4591	0.0261	42
7	2002	2	3	25	59.37	1.234	58.136	0.0001	0.02154	42
7	2002	2	4	50	42.63	0.167	42.463	0.6874	0.0351	10
7	2002	2	4	100	40.02	0.394	39.626	0.4581	0.0645	10
7	2002	2	4	25	54.35	0.459	53.891	0.0124	0.0351	10
7	2002	2	5	50	17.38	0.178	17.202	0.4512	0.09871	55
7	2002	2	5	100	15.31	1.591	13.719	0.2354	0.0311	55
7	2002	2	5	25	79.8	1.652	78.148	0.2468	0.0665	55
7	2002	2	6	50	19.87	0.267	19.603	0.0215	0.1354	38
7	2002	2	6	100	18.99	0.189	18.801	0.0874	0.0522	38
7	2002	2	6	25	54.39	1	53.39	0.0111	0.4685	38
7	2002	3	1	50	39.84	5.461	34.379	0.3265	0.1248	50
7	2002	3	1	100	23.67	0.157	23.513	0.3264	0.0325	50
7	2002	3	1	25	53.22	0.502	52.718	0.0321	0.0668	50
7	2002	3	2	50	24.59	3.468	21.122	0.0125	0.3251	31
7	2002	3	2	25	66.45	7.91	58.54	0.1235	0.321	31
7	2002	3	3	50	39.01	0.198	38.812	0.1345	0.2365	25
7	2002	3	3	100	29.68	1.358	28.322	0.0314	0.1292	25
7	2002	3	3	25	55.9	0.975	54.925	0.0325	0.0112	25
7	2002	3	4	50	41.35	0.387	40.963	0.0326	0.0114	20
7	2002	3	4	100	33.41	0.325	33.085	0.0215	0.0214	20
7	2002	3	4	25	72.44	1.384	71.056	0.0356	0.0441	20
7	2002	3	5	50	70.54	0.887	69.653	0.1984	0.1243	43
7	2002	3	5	100	29.78	0.447	29.333	0.0325	0.01	43
7	2002	3	5	25	95.33	0.146	95.184	0.235	0.1132	43
7	2002	3	6	50	39.7	0.11	39.59	0.24375	0.0236	38
7	2002	3	6	100	21.64	0.956	20.684	0.1243	0.0354	38
7	2002	3	6	25	50.65	0.334	50.316	0.3325	0.1246	38
8	2001	1	1	50	29.2	10.29	18.91			5
8	2001	1	1	100	16.22	4.826	11.394			5
8	2002	1	1	50	47.53	26.24	21.29	0.15095	0.2509	0
8	2002	1	1	100	34.86	14.91	19.95	0.0425	0.2923	0

Month	Year	Transect	Station	Depth	TDC	DIC	DOC	NH4	NO3	Water Table Fluctuations
8	2002	1	1	25	85.71	0.37	85.34	0.0683	0.0229	0
8	2001	1	2	50	30.08	11.65	18.43			10
8	2001	1	2	100	15.29	0.628	14.662			10
8	2002	1	2	50	23.57	2.116	21.454	0.0001	0.0061	10
8	2002	1	2	100	25.22	1.624	23.596	0.0001	0.029	10
8	2002	1	2	25	23.49	2.229	21.261	0.0001	0.0203	10
8	2001	1	3	50	31.55	8.43	23.12			15
8	2001	1	3	100	19.99	1.026	18.964			15
8	2002	1	3	50	53.75	1.442	52.308	0.1884	0.0303	5
8	2002	1	3	100	38.79	0.579	38.211	0.0986	0.0314	5
8	2002	1	3	25	50.62	0.472	50.148	0.0032	0.0282	5
8	2001	1	4	50	35.97	8.769	27.201			0
8	2001	1	4	100	22.99	1.45	21.54			0
8	2002	1	4	50	23.57	2.443	21.127	0.0001	0.0336	5
8	2002	1	4	100	41.52	1.579	39.941	0.10245	0.0217	5
8	2002	1	4	25	30.16	13.33	16.83	0.00235	0.0325	5
8	2001	1	5	50	26.29	6.875	19.415			5
8	2001	1	5	100	5.53	0.134	5.396			5
8	2002	1	5	50	15.55	1.525	14.025	0.0001	0.0034	5
8	2002	1	5	100	14.32	3.611	10.709	0.3674	0.1176	5
8	2002	1	5	25	10.35	1.22	9.13	0.0001	0.0054	5
8	2001	1	6	50	41.15	4.18	36.97			5
8	2001	1	6	100	17.79	6.5	11.29			5
8	2002	1	6	50	15.82	1.834	13.986	0.06535	0.0678	5
8	2002	1	6	100	27.8	1.118	26.682	0.1654	0.0163	5
8	2002	1	6	25	29.87	0.358	29.512	0.0354	0.0234	5
8	2001	2	1	50	54.68	22.45	32.23			15
8	2001	2	1	100	40.3	16.99	23.31			15
8	2002	2	1	50	41.76	22.13	19.63	0.1698	0.0808	22
8	2002	2	1	100	46.16	23.37	22.79	0.1292	0.0911	22
8	2002	2	1	25	74.28	31.23	43.05	0.39095	0.0306	22
8	2001	2	2	50	37.68	13.99	23.69			5
8	2001	2	2	100	29.2	10.29	18.91			5
8	2002	2	2	50	18.61	2.382	16.228	0.1744	0.018	5
8	2002	2	2	100	20.16	1.908	18.252	0.2392	0.0496	5
8	2002	2	2	25	24.41	2.022	22.388	0.1006	0.0243	5
8	2001	2	3	50	16.22	4.826	11.394			25
8	2001	2	3	100	30.08	11.65	18.43			25
8	2002	2	3	50	56.83	0.667	56.163	0.0694	0.0118	63
8	2002	2	3	100	26.92	0.625	26.295	0.22165	0.0189	63
8	2002	2	3	25	52.87	0.993	51.877	0.0124	0.0063	63
8	2001	2	4	50	15.29	0.628	14.662			0
8	2001	2	4	100	31.55	8.43	23.12			0
8	2002	2	4	50	41.45	0.893	40.557	0.05365	0.0178	10
8	2002	2	4	100	61.98	4.44	57.54	0.2918	0.0374	10
8	2002	2	4	25	47.2	0.529	46.671	0.05055	0.0239	10
8	2001	2	5	50	19.99	1.026	18.964			20
8	2001	2	5	100	35.97	8.769	27.201			20
8	2002	2	5	50	10.14	0.493	9.647	0.05545	0.0479	30
8	2002	2	5	100	17.09	1.655	15.435	0.001	0.0042	30
8	2002	2	5	25	78.1	1.283	76.817	0.02075	0.0107	30
8	2001	2	6	50	22.99	1.45	21.54			20
8	2001	2	6	100	26.29	6.875	19.415			20
8	2002	2	6	50	17.44	0.504	16.936	0.0001	0.0118	3

Month	Year	Transect	Station	Depth	TDC	DIC	DOC	NH4	NO3	Water Table Fluctuations
8	2002	2	6	100	19.65	0.553	19.097	0.1068	0.0557	3
8	2002	2	6	25	49.73	1.031	48.699	0.0001	0.0074	3
8	2001	3	1	50	5.53	0.134	5.396			15
8	2001	3	1	100	41.15	4.18	36.97			15
8	2002	3	1	100	26.01	0.494	25.516	0.29735	0.426	12
8	2002	3	1	25	50.76	0.517	50.243	0.0683	0.0436	12
8	2001	3	2	50	17.79	6.5	11.29			5
8	2001	3	2	100	27.06	10.8	16.26			5
8	2002	3	2	50	26.4	1.357	25.043	0.1094	0.0223	8
8	2002	3	2	25	63.21	0.486	62.724	0.2848	0.0332	8
8	2001	3	3	50	24.91	5.34	19.57			0
8	2001	3	3	100	37.11	10.3	26.81			0
8	2002	3	3	50	32.22	0.764	31.456	0.242	0.0277	15
8	2002	3	3	100	23.79	1.874	21.916	0.1048	0.0349	15
8	2002	3	3	25	51.01	0.374	50.636	0.00675	0.0046	15
8	2001	3	4	50	15.28	0.519	14.761			5
8	2001	3	4	100	27.68	5.264	22.416			5
8	2002	3	4	50	39.38	0.27	39.11	0.004	0.0098	5
8	2002	3	4	100	37.97	0.276	37.694	0.0001	0.0138	5
8	2002	3	4	25	69.24	1.245	67.995	0.0001	0.011	5
8	2001	3	5	50	32.77	14.95	17.82			5
8	2001	3	5	100	5.65	0.21	5.44			5
8	2002	3	5	50	69.53	0.341	69.189	0.1114	0.0164	13
8	2002	3	5	100	31.02	1.288	29.732	0.15055	0.0499	13
8	2002	3	5	25	98.48	0.243	98.237		0.0169	13
8	2001	3	6	50	36.7	16.98	19.72			10
8	2001	3	6	100	19.2	2.76	16.44			10
8	2002	3	6	50	41.69	0.146	41.544	0.06935	0.0153	8
8	2002	3	6	100	22	1.144	20.856	0.67835	0.0196	8
8	2002	3	6	25	49.34	0.238	49.102	0.325	0.1224	8
9	2001	1	1	50	22.14	14.65	7.49			30
9	2001	1	1	50	37.87	26.22	11.65			30
9	2001	1	1	100	14.01	3.13	10.88			30
9	2001	1	1	100	18.74	3.64	15.1			30
9	2002	1	1	50	51.38	33.46	17.92	0.1987	0.3541	15
9	2002	1	1	100	39.88	21.45	18.43	0.114	0.3245	15
9	2002	1	1	25	91.33	8.79	82.54	0.0541	0.0354	15
9	2001	1	2	50	15.12	4.65	10.47			25
9	2001	1	2	50	41.58	22.94	18.64			25
9	2001	1	2	100	19.45	2.44	17.01			25
9	2001	1	2	100	17.45	0.65	16.8			25
9	2002	1	2	50	22.77	6.34	16.43	0.0001	0.045	14
9	2002	1	2	100	20.33	0.642	19.688	0.0001	0.0654	14
9	2002	1	2	25	29.88	6.37	23.51	0.0001	0.0325	14
9	2001	1	3	50	8.23	0.34	7.89			50
9	2001	1	3	50	26.66	1.76	24.9			50
9	2001	1	3	100	7.55	0.21	7.34			50
9	2001	1	3	100	28.17	0.61	27.56			50
9	2002	1	3	50	57.99	1.355	56.635	0.1254	0.0125	14
9	2002	1	3	100	39.55	0.441	39.109	0.1036	0.0321	14
9	2002	1	3	25	54.36	2.115	52.245	0.0213	0.0221	14
9	2001	1	4	50	14.41	0.5	13.91			50
9	2001	1	4	50	14.82	0.68	14.14			50
9	2001	1	4	100	15.45	0.41	15.04			50

Month	Year	Transect	Station	Depth	TDC	DIC	DOC	NH4	NO3	Water Table Fluctuations
9	2001	1	4	100	11.35	0.99	10.36			50
9	2002	1	4	50	23.88	3.456	20.424	0.0001	0.0321	31
9	2002	1	4	100	34.52	0.687	33.833	0.125	0.0651	31
9	2002	1	4	25	22.46	8.653	13.807	0.0001	0.0213	31
9	2001	1	5	50	27.4	0.46	26.94			55
9	2001	1	5	50	6.69	0.24	6.45			55
9	2001	1	5	100	4.87	0.2	4.67			55
9	2001	1	5	100	16.37	2.07	14.3			55
9	2002	1	5	50	21.55	1.418	20.132	0.0001	0.0024	25
9	2002	1	5	100	13.55	2.538	11.012	0.3251	0.1546	25
9	2002	1	5	25	14.66	2.154	12.506	0.0001	0.0054	25
9	2001	1	6	50	7.92	0.83	7.09			35
9	2001	1	6	50	10.37	0.11	10.26			35
9	2001	1	6	100	6.33	0.13	6.2			35
9	2001	1	6	100	22.7	2.87	19.83			35
9	2002	1	6	50	13.87	1.946	11.924	0.0365	0.0321	15
9	2002	1	6	100	21.34	0.687	20.653	0.2145	0.0651	15
9	2002	1	6	25	32.66	0.554	32.106	0.0211	0.231	15
9	2001	2	1	50	40.48	27.61	12.87			40
9	2001	2	1	100	37.29	24.74	12.55			40
9	2002	2	1	50	29.67	12.45	17.22	0.0351	0.215	35
9	2002	2	1	100	38.22	17.85	20.37	0.1879	0.1254	35
9	2002	2	1	25	51.34	33.64	17.7	0.1223	0.1252	35
9	2001	2	2	50	15.48	3.44	12.04			30
9	2001	2	2	100	20.83	4.7	16.13			30
9	2002	2	2	50	68.91	38.44	30.47	0.3264	0.1236	20
9	2002	2	2	100	19.65	3.334	16.316	0.1587	0.0325	20
9	2002	2	2	25	26.88	5.647	21.233	0.2135	0.0651	20
9	2001	2	3	50	19.62	0.77	18.85			15
9	2001	2	3	100	15.48	0.87	14.61			15
9	2002	2	3	50	22.44	1.364	21.076	0.1235	0.0154	45
9	2002	2	3	100	41.65	0.534	41.116	0.0455	0.0214	45
9	2002	2	3	25	39.11	0.748	38.362	0.2035	0.0355	45
9	2001	2	4	50	27.54	2.66	24.88			45
9	2001	2	4	100	20.45	0.57	19.88			45
9	2002	2	4	50	55.68	1.354	54.326	0.0245	0.0068	23
9	2002	2	4	100	48.64	0.333	48.307	0.3254	0.0981	23
9	2002	2	4	25	46.51	0.689	45.821	0.0325	0.0145	23
9	2001	2	5	50	21.05	0.56	20.49			50
9	2001	2	5	100	18.66	0.88	17.78			50
9	2002	2	5	50	46.37	0.297	46.073	0.0456	0.0325	36
9	2002	2	5	100	9.87	0.385	9.485	0.0598	0.347	36
9	2002	2	5	25	19.87	1.355	18.515	0.0001	0.0001	36
9	2001	2	6	50	12.62	0.59	12.03			40
9	2001	2	6	100	20.07	2.3	17.77			40
9	2002	2	6	50	64.35	2.384	61.966	0.0211	0.0214	11
9	2002	2	6	100	19.62	1.325	18.295	0.0001	0.0112	11
9	2002	2	6	25	24.33	0.159	24.171	0.124	0.0325	11
9	2002	3	1	50	44.35	0.367	43.983	0.0001	0.0074	17
9	2002	3	1	100	32.48	5.982	26.498	0.1654	0.0211	17
9	2002	3	1	25	22.38	1.386	20.994			17
9	2002	3	2	50	51.22	1.39	49.83			21
9	2002	3	2	100	23.55	2.671	20.879			21
9	2002	3	2	25	71.38	1.665	69.715			21

Month	Year	Transect	Station	Depth	TDC	DIC	DOC	NH4	NO3	Water Table Fluctuations
9	2002	3	3	50	31.88	0.249	31.631			24
9	2002	3	3	100	21.34	0.667	20.673	0.23045	0.0194	24
9	2002	3	3	25	53.28	0.948	52.332	0.01445	0.00855	24
9	2002	3	4	50	41.33	0.198	41.132	0.06545	0.0498	43
9	2002	3	4	100	34.58	0.144	34.436	0.7961	0.03905	43
9	2002	3	4	25	72.64	2.334	70.306		0.20045	43
9	2002	3	5	50	64.25	0.569	63.681	0.83285	0.04995	26
9	2002	3	5	100	35.11	1.652	33.458	0.96635	0.07705	26
9	2002	3	5	25	91.54	0.133	91.407			26
9	2002	3	6	50	40.32	0.548	39.772	0.2315	0.0104	24
9	2002	3	6	100	21.6	1.065	20.535	0.1056	0.0118	24
9	2002	3	6	25	38.44	1.044	37.396	0.7546	0.0325	24
10	2001	1	1	50	27.3	11.77	15.53			40
10	2001	1	1	100	17.33	3.245	14.085			40
10	2002	1	1	50	58.34	39.55	18.79	0.1256	0.2153	25
10	2002	1	1	100	41.23	22.35	18.88	0.0986	0.1986	25
10	2002	1	1	25	87.33	10.65	76.68	0.0354	0.0214	25
10	2001	1	2	50	31.31	9.44	21.87			30
10	2001	1	2	100	14.21	0.294	13.916			30
10	2002	1	2	50	22.67	8.54	14.13	0.0001	0.0124	24
10	2002	1	2	100	19.64	0.225	19.415	0.0001	0.0325	24
10	2002	1	2	25	35.64	14.51	21.13	0.0001	0.0149	24
10	2001	1	3	50	30.67	5.33	25.34			60
10	2001	1	3	100	18.93	0.611	18.319			60
10	2002	1	3	50	55.67	2.65	53.02	0.0215	0.014	26
10	2002	1	3	100	41.36	1.678	39.682	0.0987	0.0369	26
10	2002	1	3	25	50.34	3.335	47.005	0.0125	0.0198	26
10	2001	1	4	50	35.29	6.38	28.91			55
10	2001	1	4	100	24.63	0.55	24.08			55
10	2002	1	4	50	22.68	2.138	20.542	0.0001	0.0001	36
10	2002	1	4	100	30.51	0.157	30.353	0.087	0.0001	36
10	2002	1	4	25	21.65	4.559	17.091	0.0001	0.0123	36
10	2001	1	5	50	24.34	2.11	22.23			50
10	2001	1	5	100	5.61	0.248	5.362			50
10	2002	1	5	50	19.64	0.354	19.286	0.0001	0.0045	35
10	2002	1	5	100	12.59	1.599	10.991	0.1531	0.11	35
10	2002	1	5	25	17.85	1.045	16.805	0.0001	0.0001	35
10	2001	1	6	50	39.21	2.14	37.07			30
10	2001	1	6	100	17.36	4.877	12.483			30
10	2002	1	6	50	15.64	2.254	13.386	0.009	0.0001	20
10	2002	1	6	100	14.65	0.224	14.426	0.1543	0.0452	20
10	2002	1	6	25	30.54	0.458	30.082	0.015	0.1021	20
10	2001	2	1	50	50.13	20.34	29.79			35
10	2001	2	1	100	40.9	13.47	27.43			35
10	2002	2	1	50	31.26	18.64	12.62	0.014	0.188	25
10	2002	2	1	100	44.59	19.65	24.94	0.0897	0.099	25
10	2002	2	1	25	51.33	35.27	16.06	0.114	0.1055	25
10	2001	2	2	50	36.39	10.24	26.15			25
10	2001	2	2	100	27.61	8.539	19.071			25
10	2002	2	2	50	58.98	41.35	17.63	0.235	0.0948	5
10	2002	2	2	100	26.34	6.84	19.5	0.0956	0.0224	5
10	2002	2	2	25	34.55	8.91	25.64	0.2056	0.0455	5
10	2001	2	3	50	15.39	2.14	13.25			40
10	2001	2	3	100	32.53	9.507	23.023			40

Month	Year	Transect	Station	Depth	TDC	DIC	DOC	NH4	NO3	Water Table Fluctuations
10	2002	2	3	50	25.88	0.352	25.528	0.114	0.0092	30
10	2002	2	3	100	40.28	0.331	39.949	0.0142	0.0211	30
10	2002	2	3	25	44.65	0.372	44.278	0.1546	0.0128	30
10	2001	2	4	50	15.13	0.34	14.79			45
10	2001	2	4	100	29.54	3.28	26.26			45
10	2002	2	4	50	50.88	1.592	49.288	0.0001	0.0001	28
10	2002	2	4	100	45.99	0.446	45.544	0.1598	0.102	28
10	2002	2	4	25	49.87	1.658	48.212	0.0095	0.0078	28
10	2001	2	5	50	21.39	0.21	21.18			45
10	2001	2	5	100	31.39	7.341	24.049			45
10	2002	2	5	50	41.65	1.592	40.058	0.056	0.021	36
10	2002	2	5	100	10.47	0.781	9.689	0.0291	0.1143	36
10	2002	2	5	25	23.34	2.215	21.125	0.0001	0.0001	36
10	2001	2	6	50	22.49	0.55	21.94			30
10	2001	2	6	100	24.87	3.388	21.482			30
10	2002	2	6	50	57.66	1.752	55.908	0.0096	0.0087	16
10	2002	2	6	100	21.05	1.059	19.991	0.0001	0.009	16
10	2002	2	6	25	26.44	0.189	26.251	0.0543	0.0125	16
10	2001	3	1	50	4.36	0.09	4.27			50
10	2001	3	1	100	40.14	3.241	36.899			50
10	2002	3	1	50	42.55	0.116	42.434	0.0001	0.0001	35
10	2002	3	1	100	31.22	4.287	26.933	0.1561	0.0133	35
10	2002	3	1	25	24.59	1.064	23.526	0.0001	0.0098	35
10	2001	3	2	50	17.41	4.33	13.08			30
10	2001	3	2	100	26.35	7.436	18.914			30
10	2002	3	2	50	48.57	1.687	46.883	0.0001	0.0125	24
10	2002	3	2	100	22.39	2.416	19.974	0.0561	0.0244	24
10	2002	3	2	25	68.55	1.285	67.265	0.0652	0.0233	24
10	2001	3	3	50	27.49	5.12	22.37			60
10	2001	3	3	100	40.31	12.46	27.85			60
10	2002	3	3	50	30.27	0.148	30.122	0.2456	0.0125	44
10	2002	3	3	100	19.84	0.558	19.282	0.124	0.0086	44
10	2002	3	3	25	51.88	1.54	50.34	0.0001	0.0001	44
10	2001	3	4	50	13.99	0.324	13.666			50
10	2001	3	4	100	26.51	2.358	24.152			50
10	2002	3	4	50	38.41	1.659	36.751	0.0235	0.4411	38
10	2002	3	4	100	30.26	0.248	30.012	0.5463	0.0218	38
10	2002	3	4	25	68.49	2.555	65.935	0.776	0.0986	38
10	2001	3	5	50	32.04	10.534	21.506			50
10	2001	3	5	100	5.39	0.256	5.134			50
10	2002	3	5	50	60.21	0.238	59.972	0.3265	0.0412	41
10	2002	3	5	100	33.47	0.463	33.007	0.154	0.035	41
10	2002	3	5	25	87.02	0.415	86.605	0.321	0.001	41
10	2001	3	6	50	35.66	13.477	22.183			47
10	2002	3	6	50	22.38	0.287	22.093	0.1	0.009	34
10	2002	3	6	50	38.05	0.263	37.787	0.1251	0.0211	34
10	2002	3	6	25	44.35	1.854	42.496	0.5462	0.009	34
10	2001	3	6	100	21.6	1.388	20.212			47

APPENDIX 2: Vegetation Data

Vegetation abbreviations in Table 4.

Percent cover of the overstory vegetation at the West Branch River Subwatershed study site.

Transect	Station	OAR	O PB	O PM	O AI	O PG	O LL
1	1	5	0	0	0	0	0
1	2	0	100	0	0	0	0
1	3	0	60	30	0	0	0
1	4	0	10	5	0	0	0
1	5	0	0	60	0	0	0
1	6	0	0	60	0	0	0
2	1	30	0	0	70	0	0
2	2	0	0	0	10	25	0
2	3	0	50	0	0	0	0
2	4	0	60	0	0	0	0
2	5	0	0	30	0	0	0
2	6	0	0	30	0	0	0
3	1	0	20	0	0	30	0
3	2	0	20	0	0	30	0
3	3	0	50	0	0	20	0
3	4	0	50	0	0	0	0
3	5	0	0	75	0	0	10
3	6	0	0	50	0	0	0

Percent cover of the understory vegetation at the West Branch River Subwatershed study site.

Transect	Station	U AR	U PM	U AI	U PG	U LL	UCF	U PS	U RH	U VA	U KP	U VC	U AM	U BP	U CHC	U LG	U D
1	1	0	0	98	0	0	5	0	0	0	0	0	0	0	0	0	0
1	2	0	0	17.5	10	0	0	10	0	0	0	0	0	0	0	0	0
1	3	12.5	0	0	12.5	0	0	0	0	0	0	0	0	0	0	0	0
1	4	0	0	0	0	0	0	0	5	30	0	0	0	0	0	0	0
1	5	2.5	0	0	15	0	0	2.5	0	0	40	12.5	0	0	0	0	0
1	6	0	12.5	0	0	0	0	0	0	15	0	2.5	0	0	0	7.5	0
2	1	0	0	25	0	0	25	0	0	0	0	0	45	0	0	0	0
2	2	0	0	35	0	0	0	0	0	0	0	0	0	25	0	0	0
2	3	0	0	0	7.5	0	0	0	0	0	0	0	0	0	0	0	25.5
2	4	0	0	0	5	0	0	2.5	0	0	0	15	0	0	10	20	0
2	5	10	25	0	0	0	0	0	0	0	0	37.5	0	0	0	2.5	0
2	6	7.5	5	0	0	0	0	0	0	0	0	25	0	0	0	40	0
3	1	0	0	10	10	0	0	0	0	0	0	0	0	5	0	0	20
3	2	0	0	10	10	0	0	0	0	0	0	0	0	5	0	0	20
3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0
3	4	0	0	0	5	10	0	0	15	0	0	0	5	0	0	2.5	0
3	5	0	7.5	0	0	0	0	0	0	0	0	22.5	0	0	0	10	0
3	6	5	25	0	0	0	0	0	0	0	0	15	0	0	0	17.5	0

Percent cover of the non-bryophyte groundcover vegetation at the West Branch River Subwatershed study site.

Transect	Station	G AI	G AM	G BP	G CC	G CHC	G C	G CR	G CT	G COC	G DC	G D	G FV	G ER	G GB
1	1	16.67	46.66	3.33	0	0	0	0	0	0	0	0	0	0	6.67
1	2	0	10	0	33.33	0	16.67	0	0	0	0	0	5	0	0
1	3	0	0	0	0	0	10	0	5	15	0	10	0	0	0
1	4	0	0	0	0	20	11.67	0	1.67	0	0	0	1.67	0	0
1	5	0	0	0	0	3.33	0	0	6.67	8.33	0	0	0	1.67	0
1	6	0	0	0	0	0	0	0	5	0	0	0	0	0	0
2	1	0	0	0	1.67	0	0	0	0	0	0	0	0	0	26.67
2	2	0	15	21.67	0	0	0	0	0	0	0	0	0	0	0
2	3	0	0	0	0	0	0	0	0	0	15	5	0	0	0
2	4	0	0	0	0	0	0	0	3.33	0	0	0	0	0	0
2	5	0	0	0	0	0	0	0	5	1.67	0	0	0	0	0
2	6	0	0	0	0	0	0	0	5	10	0	0	0	0	0
3	1	0	0	0	20	0	0	0	0	20	0	0	16.67	0	0
3	2	0	0	0	20	0	0	0	0	20	0	0	16.67	0	0
3	3	0	0	0	0	0	0	1.67	3.33	0	0	0	15	0	0
3	4	0	0	0	0	0	0	1.67	3.33	0	0	0	13.33	0	0
3	5	0	0	0	0	0	0	0	40	10	0	0	0	0	0
3	6	0	0	0	0	0	0	0	1.67	6.67	0	0	0	0	0

Transect	Station	G GH	G IV	G KP	G LG	G MC	G OS	G P	G RH	G SU	G SP	G TD	G VA	G VC	G V
1	1	0	3.33	0	0	0	0	0	3.33	0	0	15	0	0	5
1	2	0	11.67	0	0	6.67	0	0	5	0	0	0	0	0	5
1	3	1.67	0	0	0	6.67	0	0	0	0	0	0	20	0	0
1	4	0	13.33	6.67	0	3.33	0	0	0	0	0	0	0	0	0
1	5	3.33	0	0	0	1.67	0	0	0	0	0	0	40	5	0
1	6	3.33	0	0	3.33	1.67	0	0	0	0	0	0	6.67	0	0
2	1	0	0	0	0	0	33.33	0	3.33	0	28.33	0	0	0	3.33
2	2	0	0	0	0	0	0	0	0	33.33	0	0	0	0	10
2	3	6.67	0	0	0	0	0	0	0	0	0	0	18.33	0	0
2	4	0	0	0	0	3.33	0	0	3.33	0	0	0	16.67	0	0
2	5	5	0	0	1.67	1.67	0	0	0	0	0	0	36.67	0	0
2	6	10	0	3.33	0	1.67	0	0	0	0	0	0	16.67	0	0
3	1	0	0	0	0	6.67	0	23.33	0	0	0	0	0	0	6.67
3	2	0	0	0	0	6.67	0	23.33	0	0	0	0	0	0	6.67
3	3	8.33	0	0	0	0	0	0	0	0	1.67	0	45	0	0
3	4	0	0	0	0	0	0	0	0	0	0	0	43.33	0	0
3	5	0	0	0	0	3.33	0	0	0	0	0	0	0	0	0
3	6	0	0	0	0	0	0	0	0	0	0	0	8.33	0	0

Percent cover of the Bryophyte and *Sphagnum* spp. groundcover vegetation at the West Branch River Subwatershed study site.

Transect	Station	B DI	B PL	B PO	B SP
1	1	0	0	0	0
1	2	0	0	0	0
1	3	10	0	0	6.67
1	4	10	0	0	31.67
1	5	0	0	11.67	18.33
1	6	0	0	0	58.33
2	1	0	0	0	0
2	2	0	0	0	0
2	3	55	0	0	0
2	4	63.33	0	0	10
2	5	0	0	0	48.33
2	6	0	0	0	58.33
3	1	0	0	0	0
3	2	0	0	0	0
3	3	3.33	0	0	0
3	4	41.67	0	0	0
3	5	0	0	33.33	26.67
3	6	0	5	26.67	75